European Commission

OELs 6

Study on collecting the most recent information on substances to analyse health, socio-economic and environmental impacts in connection with possible amendments of Directive 2004/37/EC on the protection of workers from the risks related to exposure to carcinogens, mutagens or reprotoxic substances at work

Final Report V3

Welding fumes

November 2024

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Contents

LIST OF ABBREVATIONS AND ACRONYMS

ACSH	Advisory Committee of Safety and Health at Work
AfA	Application for Authorisation
AGS	German Committee on Hazardous Substances
AM	Arithmetic mean
ANSES	The French Agency for Food, Environmental and Occupational Health & Safety
AS	Arc Spraying
ASA	Finnish statutory register of workers exposed to carcinogens
AW	Autogenous Welding (also known as gas fusion welding)
BAT	Best Available Technique
BCR	Benefit Cost Ratio
BGV	Biological guidance value
BK	Recognised occupational diseases
BLV	Biological Limit Value
BOEL	Binding Occupational Exposure Level
BOHS	British Occupational Hygiene Society
BR	Better Regulations
BREF	Best available techniques reference document
BUC	Bottom up costs
C&L	Classification & Labelling (inventory)
CAD	Chemical Agents Directive
CAGR	Compound Annual Growth Rates
CAPEX	Capital Expenditure
CAREX	Carcinogen Exposure (inventory)
CAS	Chemicals Abstracts Service
CBA	Cost Benefit Analysis
CDB	Current Disease Burden
CEA	Cost Effectiveness Analysis
CEN	European Committee of Standardization
CLP	Classification, Labelling and Packaging of substances Regulation

CMR	Carcinogenic, Mutagenic and Reprotoxic chemicals
CMRD	Carcinogens, Mutagens and Reprotoxins Directive
COM	The European Commission
COPD	Chronic Obstructive Pulmonary Disease
CSR	Chemical Safety Report
DALY	Disability Adjusted Life Years
DG	Directorate General
DGUV	Deutsche Gesetzliche Unfallversicherung (German Social Accident Insurance; umbrella association for accident insurance institutions for the industrial and public sectors)
DRR	Dose Response Relationship
DVS	Deutscher Verband für Schweißen und verwandte Verfahren e. V. (German Welding Society)
EB	Electron Beam
ECHA	European Chemicals Agency
EEA	European Economic Area
EMPL	DG for Employment, Social Affairs and Inclusion
ELA	European Labour Authority
ER	Excess Cancer Risk
ERR	Exposure Risk Relationship
ES	Exposure Scenario
ESW	ElectroSlag Welding
ETUI	European Trade Union Institute
EU	European Union
EURES	European Employment Services
EUROFER	European steel association
EWA	European Welding Association
EWE	European Welding Engineer
EWF	European Welding Federation
EWP	European Welding Practitioner
EWS	European Welding Specialist
EWT	European Welding Technologist
EW	European Welder

FCA	Flux-Cored Arc Welding
FCAW	Flux-Cored Arc Welding
FDB	Future Disease Burden
FIOH	Finnish Institute of Occupation Health
FoBiG	Forschungs und Beratungsinstitut Gefahrstoffe
FS	Flame Spraying
FTE	Full time equivalent
GESTIS	Internationale Grenzwerte für chemische Substanzenm (International limits for chemical substances)
GFW	Gas fusion welding
GM	Geometric mean
GMA	Gas Metal Arc welding
GMAW	Gas Metal Arc Welding
GTAW	Gas Tungsten Arc Welding (also known as TIG)
HHI	Herfindahl–Hirschman Index
IA	Impact Assessment
IARC	International Agency for Research of Cancer
IIW	International Institute of Welding
ISCO	International Standard Classification of Occupations
ISO	The International Organization for Standardization
ICC	Joining, Cutting and Coating
JCC	Joining, Cutting and Coating
LBW	Laser Beam Welding
LEV	Local Exhaust Ventilation
LFS	Labour Force Survey
LOAEL	Lowest observed adverse effect level
LOD	Limit of Detection
LOQ	Limit of quantification
MAG	Metal Active Gas welding
MAGC	Metal Active Gas welding with CO2
MAGM	Metal Active Gas welding with gas Mixture
MCA	Multi-criteria analysis

MIG	Metal Inert Gas welding
MMA	Manual Metal Arc welding
MoR	Fatality rates
MS	Member State
MS	Mild Steel
MSA	Member State Authority
NACE	"Nomenclature statistique des activités économiques dans la Communauté européenne" or the Statistical Classification of Economic Activities in the European Community
NHL	Non-Hodgkin lymphomas
NLI	National Labour Inspectors
NSRP	National Shipbuilding Research Program
OEL	Occupational Exposure Limit
OPEX	Operating Expenditure
OR	Odds Ratio
OSH	Occupational Safety and Health
PAH	Polycyclic Aromatic Hydrocarbons
PAF	Population Attributable Fractions
PAPR	Powered Air-Purifying Respirator
PAW	Plasma Arc Welding
PBT	Persistent, bio-accumulative, and toxic
PGS	Process Generated Substances
PC	Plasma Cutting
PNEC	Predicted No Effect Concentrations
PNOS	Particles Not Otherwise Specified
PPE	Personal Protection Equipment
PPM	Parts Per Million
PROC	The process categories
PS	Plasma Spraying
PSP	Poorly soluble particles of low toxicity
PV	Present Value
QALY	Quality-Adjusted Life Year
RADS	Reactive Airways Dysfunction Syndrome

R&D	Research & Development
RAC	Committee for Risk Assessment
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals
RIA	regulatory impact assessment
RMM	Risk Management Measure
ROC	EU roadmap on carcinogens
RPA	Risk & Policy Analysts
RPE	Respiratory Protective Equipment
RIR	Relative incidence risk
RMR	Relative mortality risk
RSW	Resistance Spot Welding
SAW	Submerged Arc Welding
SCOEL	Scientific Committee on Occupational Exposure Limits
SDS	Safety Data Sheets
SDG	Sustainable Development Goal
SIR	Standardized Incidence Ratio
SMR	Standardized Mortality Ratio
SEAC	Committee for Socio-Economic Analysis
SMAW	Shielded Metal Arc Welding
STEL	Short Term Exposure Limit
SME	Small and Medium-sized Enterprise
SML	Small, Medium and Large-sized Enterprise
SS	Stainless Steel
STOP	Substitution, Technological means, Organisational measures and PPE
SU	Sectors of use
SW	Socket Welding for pipeline insertion (also known as stud welding)
SWIP	Steel-Weighted Industrial Production
TC	Torch Cutting
TDC	Top down costs
TIG	Tungsten Inert Gas welding
TRGS	Technical Rules for Hazardous Substances

TWA	Time Weighted Average
UP (schweissen)	'Unter-Pulver' (schweissen) (German translation) = Submerged Arc welding
UN	United Nations
VBMG	The Vereinigung der Metall Berufsgenossenschaften
WCS	Worker Contributing Scenario
WPC	Working Party on Chemicals
WTP	Willingness to Pay: The maximum sum an individual is willing to pay for a service/goods in order to avoid loss, in this case, in terms of health treatment.
YLD	Years lived with disability/disease

ABSTRACT EN-FR-DE

This study supports the European Commission's Impact Assessment of a policy change to the Carcinogens, Mutagens and Reprotoxic substances Directive. It investigates costs and benefits of introducing an entry in Annex I to the Directive for welding fumes that contain carcinogens, mutagens or reprotoxic substances. It also considers the possibility of setting "a generic occupational exposure limit for inhalable and respirable dust specific to welding fumes"; or setting "a non-specific generic dust metric (an inhalable limit and a respirable limit) applicable to all dusts". Evidence was gathered through literature review and stakeholder consultation. The assessment follows the Better Regulation guidelines. Although the results of the cost benefit analysis are highly uncertain, the benefits of the introduction of the Annex I entry are likely to exceed the costs. Achieving the benefits to the full extent requires accompanying the measure with a communication strategy and associated improvements to training programmes, aiming at increasing the awareness of employers and workers of the risks posed by exposure to carcinogens, mutagens and reprotoxic substances in welding fumes.

Cette étude soutient l'évaluation d'impact de la Commission européenne concernant un changement de politique dans la directive sur les substances cancérogènes, mutagènes et toxiques pour la reproduction. Elle examine les coûts et les avantages de l'introduction d'une rubrique à l'annexe I de la directive pour les fumées de soudage qui contiennent des substances cancérogènes, mutagènes ou toxiques pour la reproduction. Elle envisage également la possibilité de fixer "une limite d'exposition professionnelle générique pour les poussières inhalables et respirables spécifique aux fumées de soudage" ou de fixer "une mesure générique non spécifique pour les poussières (une limite pour les poussières inhalables et une limite pour les poussières respirables) applicable à toutes les poussières". Les éléments probants ont été recueillis par le biais d'une analyse documentaire et d'une consultation des parties prenantes. L'évaluation suit les lignes directrices du programme "Mieux légiférer". Bien que les résultats de l'analyse coûts-avantages soient très incertains, les avantages de l'introduction de l'entrée dans l'annexe I sont susceptibles de dépasser les coûts. Pour tirer pleinement parti de ces avantages, il convient d'accompagner la mesure d'une stratégie de communication et d'améliorations connexes des programmes de formation, afin de sensibiliser davantage les employeurs et les travailleurs aux risques liés à l'exposition aux agents cancérigènes, mutagènes et reprotoxiques présents dans les fumées de soudage.

Diese Studie unterstützt die Folgenabschätzung der Europäischen Kommission für eine Änderung der Richtlinie über krebserzeugende, erbgutverändernde und fortpflanzungsgefährdende Stoffe. Sie untersucht die Kosten und den Nutzen der Einführung eines Eintrags in Anhang I der Richtlinie für Schweißrauch, der krebserregende, erbgutverändernde oder fortpflanzungsgefährdende Stoffe enthält. Außerdem wird die Möglichkeit geprüft, "einen allgemeinen Arbeitsplatzgrenzwert für einatembare und lungengängige Stäube speziell für Schweißrauch" oder "einen unspezifischen allgemeinen Staubgrenzwert (einen Grenzwert für einatembare und einen Grenzwert für lungengängige Stäube) für alle Stäube" festzulegen. Einschlägige Informationen wurden durch Literaturrecherche und Konsultation der Interessengruppen gesammelt. Die Bewertung erfolgte gemäß den Leitlinien der EU-Kommission für eine bessere Rechtsetzung. Obwohl die Ergebnisse der Kosten-Nutzen-Analyse mit großer Unsicherheit behaftet sind, dürfte der Nutzen der Aufnahme in Anhang I die Kosten übersteigen. Um den Nutzen in vollem Umfang zu erreichen, muss die Maßnahme mit einer Kommunikationsstrategie und damit verbundenen Verbesserungen der Schulungsprogramme einhergehen, die darauf abzielen, Arbeitgeber und Arbeitnehmer stärker für die Risiken zu sensibilisieren, die von der Exposition gegenüber krebserzeugenden, erbgutverändernden und fortpflanzungsgefährdenden (CMR) Stoffen in Schweißrauch ausgehen.

EXECUTIVE SUMMARY

The Carcinogens, Mutagens and Reprotoxic substances Directive (Directive 2004/37/EC), hereinafter referred to as CMRD, protects workers from exposure to carcinogens, mutagens or reprotoxic substances at work. Article 2 (in paragraph (a)(ii)) of the CMRD defines a 'carcinogen' as:

"*a substance, mixture or process referred to in Annex I to this Directive as well as a substance or mixture released by a process referred to in that Annex*."

IARC (2018) classified welding fumes as a group one human carcinogen, and other studies since have confirmed the carcinogenic nature of welding fumes (9 studies analysed by ANSES, 2022[1]). As welding fumes+ (as defined in section 2.1.1) are Process Generated Substances, the Commission is considering an entry to Annex I in the CMRD for welding fumes+ that contain carcinogenic (or mutagenic or reprotoxic) substances. The study team were asked to "*investigate the costs and benefits in relation to introducing an entry in Annex I to the Directive*", in order to reflect the most recent discussions within the steering committee, in particular the need to bring legal certainty about the scope of the CMRD.

In this study the definition of welding fumes+ by ECHA (2022) was used, which comprises fumes from the following processes:

- Fusion welding: gas welding, arc welding (MIG, MAG, SMAW, FCAW, SAW, ESW, SW), arc welding (TIG, PAW), beam welding;
- Soldering: soft soldering, hard soldering;
- Brazing: greater than 450°C, laser beam brazing, brazing with an electric arc (MIG, TIG, plasma);
- Thermal cutting or gouging;
- Thermal spraying;
- Flame straightening; and
- Additive production processes.

In this study 'welding fumes' is taken to mean the particulate matter (metals and their oxides, including complex structures called spinels), but excludes welding gases produced during welding or used for shielding.

A quantitative assessment of the following two policy options was undertaken:

- Policy option 1 (Baseline scenario): no new measures at EU level (i.e. taking into account existing requirements under OSH legislation, chemicals legislation and other relevant legislation e.g., national legislation, without any entry in Annex I to the CMRD);

- Policy option 2: introducing into Annex I of the CMRD the following processes: "*Work involving exposure to fumes from welding (and similar) processes containing substances*

[1] Honaryar et al. 2019, Michalek, et al . 2019, Barul et al. 2 020, Chen et al. 2021, d'Errico et al. 2020, Michalek, Martinsen, Weiderpass, Hansen, et al.2019, Parent et al. 2017, Pesch et al. 2019, Talibov et al. 2019.

that meet the criteria for carcinogens, mutagens or reprotoxic substances Category 1A or 1B set out in Annex I to the CLP Regulation".

In addition, a qualitative assessment of two possible future options that could be applied to welding fumes+ at a later stage, in addition to an entry in Annex I of the CMRD in a future revision of the CMRD, has been undertaken:

- "Setting a generic occupational exposure limit (OEL) for inhalable and respirable dust specific to welding fumes"*.
- "Setting a non-specific generic dust metric (an inhalable limit and a respirable limit) applicable to all dusts".

*In this study, the study team has taken this to mean an OEL will apply to all welding+ processes.

In this study, an attempt has been made to quantify the effect of exposure to welding fumes on lung cancer only, although other health effects are associated with exposure to welding fumes. This means that the health benefits of reducing exposure to welding fumes may have been underestimated. The extent that welders are exposed to CMRs is difficult to quantify due to uncertainties and gaps in the evidence base.

This study estimates that the excess cancer risk (ER) to lung cancer in welders is 2.7% in the year 2023 (section 2.2 and section 5.1.2). This equates to 27,000 cases of lung cancer in one million exposed workers, or more precisely 32,400 cases of lung cancer in the estimated 1.2 million full time welders across the EU27. The current burden of disease[2] due to past exposure is estimated to be 806 new cases of lung cancer in 2023, with the legacy burden of disease[3] occurring over the next 40 years being estimated at 27,804 cases and the future burden of disease[4] being estimated at 28,821 cases over 40 years with a staff turnover of 5% for all sectors.

There are various difficulties in quantifying the size of the problem, including uncertainties on the numbers of workers in welding+ activities in the EU27, and the number of workers exposed to CMR substances in welding fumes.

This study estimates that there are 1.2 million full time workers in welding+ activities across the EU27, based upon the German Welding Society (DVS: Deutscher Verband für Schweißen und verwandte Verfahren) estimate of 1.2 million full time workers in 'Joining, Cutting and Coating' activities (section 3.4.2.1). Interviews with six key stakeholders agreed that this estimate was reasonable (section 5.1.1).

Welding fumes are highly heterogeneous. The presence of CMR substances in welding fumes depends largely upon the materials being welded. The majority (95%) of the components of welding

[2] Current burden of disease is the estimated number of cases diagnosed in 2023 due to past exposure to welding fumes.

[3] Legacy burden of disease relates to the number of lung cancer cases due to exposure in the last 32 years which will occur in the next 40 years, based on the cancer endpoint having a latency of 30 years and welders having a minimum exposure of two years.

[4] Future burden of disease is the number of cases generated by exposure over the next 40 years; these cases may not actually occur during the next 40 years due to latency – they may occur beyond the 40 year period.

fumes are emitted from the filler or consumables used and only 5% from the base material (ANSES, 2022).

The rate of emissions of welding fumes depends largely upon the welding process being used. Other factors affecting the rate of emissions include the thickness of the sheet being welded, or whether the metal part being welded has been moulded (automotive manufacturer, personal communication, July 2023). The level of experience of the welder (ANSES, 2022), and the angle of the welding (VBMG, 2007) also influence emission rates. The presence of coatings and arc time also affect the composition and rates of emissions respectively (ANSES, 2022).

The toxicity of welding fumes is associated with the size distribution and surface characteristics of particles generated (ANSES, 2022). There is an ongoing argument amongst experts on the need to measure the number of ultrafine particles that workers are exposed to from welding, not just the total mass of particulates. Certain welding+ processes produce a large amount of ultrafine particles, for example thermal spraying (Bémer et al., 2010 in ECHA, 2022).

Exposure levels to welding fumes have been found to be higher from welding mild steel compared with stainless steel for both the inhalable and respirable fractions (Kendzia *et al.*, 2019). However, welding of high alloy steels (for example, those with >5% nickel content) will generate higher emissions of the alloys present (such as nickel).

There is evidence that both welders of mild steel and stainless steel experience an excess risk for lung cancer (Honaryar et al., 2019, Sorensen et al, 2007 in ECHA, 2022). There are also some papers that provide evidence of the mechanistic carcinogenic potency from welding mild steel (Badding et al, 2014; Dierschke et al, 2017; Falcone et al, 2018; Leonard et al, 2019; Zeidler-Erdely et al., 2012 in DGUV, pers comm, July 2023).

Further to the above, exposure levels to welding fumes have been found to vary between countries, industries, and trades (ANSES, 2022) with higher exposure levels measured in Finland and the US, and lower levels in Canada, the UK and New Zealand. The highest exposure levels were found in the manufacturing sector whilst the lowest levels were found in the automotive sector. With regard to trades, the highest exposure levels were found amongst boilermakers and the lowest amongst pipe fitters and welders.

This study focuses on thirteen sectors, which were chosen because they undertake welding+ activities, but also because they cover equivalent sectors identified in other studies as having workers exposed to welding fumes (CAREX and Finnish ASA data).

The literature review found neither data on the number of bystanders that could also be exposed to welding fumes in the workplace nor information allowing an estimate. This means that the benefits of a policy change that results in reduced exposure to welding fumes may have been underestimated, as other workers (bystanders) could also benefit from reduced exposure levels.

The costs and benefits (relative to the baseline) estimated in this report compared to the estimated effects of policy option two (Annex I) are summarised in Table 0-1. The benefits were calculated using two different standardised methods of calculating health benefits (as explained in the separate Methodological note). Method one incorporates the value of statistical life and value of cancer morbidity or statistical morbidity. Method two incorporates disability adjusted life years

(DALYs). The costs are calculated for a top down (market value of RMMs) and bottom up (average estimated cost of additional RMMs per welder) approach. Present values are estimated over 40 years with a static (unchanging) discount rate of 3% and assume a 5% staff turnover. The benefits are between 3.4 and 15.2 times the costs.

The results of the cost benefit analysis are highly uncertain.

The impact that policy option two (the inclusion of welding fumes containing CMR substances in Annex I of the CMRD) would have on employers' and workers' awareness of the risks posed by exposure to welding fumes is unknown. However, the study team estimate of a 1% reduction per year in ER due to improved use of RMMs for five years due to policy option two, before returning to the baseline, was supported based upon consultation with six key stakeholders (section 6.1.3.3.2).

The most important information gaps are: current level of awareness over the risk of being exposed to CMR substances during welding activities; compliance with regulatory requirements; and, more generally, use of risk mitigation measures during welding activities. These factors are likely to vary across the EU27, across sectors, and across small, medium and large enterprises.

Interviews with key EU and national stakeholders and a survey of stakeholders across different Member States indicated that awareness of the possible presence of CMRs in welding fumes is usually good, but awareness of the risks from occupational exposure and understanding of the requirements of the CMRD vary. Most stakeholders claimed that worker protection was good in their countries, with only a minority considering that worker protection may not be optimal in all situations, for example in small enterprises. However, without a comprehensive campaign of unannounced inspections of welding sites across the EU27, it is not possible to fully understand the existing level of worker protection.

Table 0-1 Summary of monetised costs and benefits (3% static discount rate, additional to the baseline) based upon exposed workers (full time welders) and use of RMMs (% of welders needing to purchase additional RMMs = 50%).

Categories of costs and benefits	Results for policy option two (Annex I)
Total benefits M1	€1,000,000,000
Total benefits M2	€530,000,000
Total bottom up costs (BUC)	€160,000,000
Total top down costs (TDC)	€67,000,000
Benefit cost ratio M1 (BUC)	6.5
Benefit cost ratio M1 (TDC)	15
Benefit cost ratio M2 (BUC)	3.4
Benefit cost ratio M2 (TDC)	7.9

Notes: In all cases the increase in RMM expenditure was taken to be 1% and the increase in the rate of change in excess risk per year post year) and benefits from avoided ill health was taken to be 1%.
Notes: Numbers may not sum to total due to rounding.

Source: Study team.

The multi-criteria analysis summarising both the monetised and qualitative impacts of the three policy options that have been evaluated is shown in Table 00-2.

The key issues identified in this study for the decision-making process regarding a policy change include:

- Various consultees pointed to the potential confusion that policy option two (Annex I) may generate in stakeholders' understanding of the legislative requirements, see section 5.4.
- There is a recurrent message from stakeholders that the success of the inclusion of welding fumes in Annex I, the avoidance of confusion, and the reduction of some of the potential risks to research funding, competitiveness, and SMEs in particular depend upon a good communications strategy, communications campaign and associated improvements to training programmes, see section 9.5.2.5.
- The current level of awareness over the risks posed by exposure to welding fumes and in particular related to the presence of CMR substances in welding fumes is difficult to quantify as the opinions of national stakeholders within a Member State sometimes varied widely. The level of compliance with the CMRD both across the EU and within Member States is also difficult to quantify although there is some evidence that compliance is better in western and northern Europe, with larger enterprises more likely than small enterprises to have the resources to have a dedicated health and safety expert or team.

- Welding low alloy steel (mild steel) is <u>not</u> always associated with a low risk of exposure to CMRs, although some stakeholders would like this conclusion to be drawn, see section 5.1.2. A key EU stakeholder concurs with this opinion (*pers comm*, July 2023).

- Throughout the assessment of the current situation and the development of the baseline scenario, there are many sources of information about likely trends that will affect the demand for welding and ways in which the industry will evolve. However, this information is largely qualitative, with few quantitative assessments, and any of these that do exist tend to represent only part of the market. One source provides predictions of market growth (Accuray, 2019) see section 3.4.5 and is used to create a dynamic baseline for the numbers of exposed workers used in calculations of benefits in section 6.1.3.3.1 and to estimate the risk management measure costs in the top down calculation of costs in section 6.2.2.3.

Table 00-2 Multi-criteria analysis (all impacts over 40 years and additional to the baseline) for the different policy options.

Impact	**Stakeholders affected**	**Policy option two (Annex I) Quantitative assessment (PV)**	**In addition to policy option two (Annex I), qualitative assessment only:**	
			OEL (inhalable and respirable dust) specific to welding fumes	**Non-specific generic dust metric (inhalable and respirable)**
Direct costs – compliance				
Risk management measures and discontinuation costs (one-off and recurrent)	Companies	€ 67 - 160 million	Out of scope	Out of scope
Monitoring (sampling and analysis)	Companies	None expected	Out of scope	Out of scope
Direct costs - administrative burdens				
Company cost of administration burden	Companies	N/A	Out of scope	Out of scope
Direct costs - total				
Compliance, monitoring and administration burden costs per company	Companies	€ 67 – 160 million	Out of scope	Out of scope
Direct costs - enforcement costs				
Transposition costs	Public sector	€ 2.7 million	€810,000 - 1,400,000	€810,000 - 1,400,000
Enforcement costs	Public sector	None	Out of scope	Out of scope
Monitoring costs	Public sector	None	Out of scope	Out of scope
Adjudication costs	Public sector	None	Out of scope	Out of scope
Indirect costs - other				
Firms exiting the market - No. of company closures	Companies	None predicted	None predicted	None predicted
Employment – Jobs lost	Workers & families	Not quantified. No legal change, awareness raising.	Not estimated	Not estimated
Employment – Social cost	Workers & families	Not estimated	Not estimated	Not estimated
International competitiveness	Companies	International competition is low for welding as welding often needs to be done *in situ* on site and cannot be exported. See box to right.	Most non-EU competitor countries already regulate welding fumes through dust limit or an OEL (not distinguishable from the available information): AU, CA, CN, IN, NO, KR, US. An exception is JP where employers measure and protect against exposure to Mn as a proxy for welding fumes. The lowest limit is 3 mg/m^3 (R) particles in the US or CA. The highest limit is 10 mg/m^3 (I) particles in the US or CA.	
Consumers	Consumers	None predicted.	Enterprises (especially smaller enterprises) may increase the price of their products to cover the increased costs of compliance.	

Impact	Stakeholders affected	Policy option two (Annex I) Quantitative assessment (PV)	In addition to policy option two (Annex I), qualitative assessment only:	
			OEL (inhalable and respirable dust) specific to welding fumes	Non-specific generic dust metric (inhalable and respirable)
Internal market Lowest to highest OEL	Companies	Not quantified.	Not quantified. The lowest (process-related) OEL for welding fumes is 0.5 mg/m^3 in DK, for 'electrode methods welding stainless steel'. The highest and most common OEL for welding fumes is 5 mg/m^3	Not quantified. The highest generic dust limit is 10 mg/m^3 (I) in Germany It was not possible to identify the full details of the limits for: CZ, IE or ES.
Specific MSs/regions - MSs that would have to change their policy or OELs	Public sector	Less compliance in E and S EU Member States according to anecdotal evidence heard by the study team.	8 Member States already have welding fumes OELs: AT, BE DK, FR, LV, LT, NL, SK.	6 Member States already have generic dust limits: CY, HR, FR, DE, IE, NL. It was not possible to categorise the limits in place in: CZ, IE or ES.
Regulation	Companies	Risk that the policy change creates confusion and company resources are wasted trying to understand what is needed.	OEL would impact on enterprises undertaking welding activities.	Generic dust limit would apply across sectors to all enterprises undertaking activities generating dust.
Direct benefits – improved well-being - health				
Reduced cases of cancer	Workers & families	1,618	Not quantified	Not quantified
Reduced fatalities	Workers & families	1,079	Not quantified.	Not quantified.
Reduced non-fatalities	Workers & families	270	Not quantified.	Not quantified.
Ill health avoided, incl. intangible costs (M1 to M2)	Workers & families	M1: €1 000 million M2: €510 million	Not quantified, but see above qualitative analysis.	Not quantified, but see above qualitative analysis.
Direct benefits – improved well-being - safety				
Avoided costs	Companies	€4.7 million	Not quantified	Not quantified
Avoided costs	Public sector	€16 million	Not quantified	Not quantified
EU policy agenda	All	Increasing the protection of workers health is main social benefit.		
Direct benefits – improved well-being - environmental				
Environmental releases	All	Not quantified	Not quantified	Not quantified
Direct benefits – market efficiency				

Impact	Stakeholders affected	Policy option two (Annex I) Quantitative assessment (PV)	In addition to policy option two (Annex I), qualitative assessment only:	
			OEL (inhalable and respirable dust) specific to welding fumes	Non-specific generic dust metric (inhalable and respirable)
Level playing field	Companies	Awareness raising may lead to an improved level playing field between and within Member States.	Clearer target than policy option two. Would contribute to level playing field across the EU 27.	Clearer target than policy option two. Would contribute to a level playing field across the EU 27.
Indirect benefits				
Administrative simplification	Companies	Not applicable	Not applicable, OEL would be in addition to existing substance specific OELs.	Not applicable, dust limit would be in addition to existing substance specific OELs.
Synergy	Companies			
Corporate Social Responsibility	Companies	Positive minor impact	Positive minor impact	Positive minor impact
Avoided cost of setting OEL (EU27)	Public sector	Not applicable	€1.4 – 2.7 million	€1.4 – 2.7 million
Other impacts				
Recycling – loss of business	Recycling companies	Not applicable. Circular economy principles in EU27 encourage recycling including recycling of metal products which will sometimes involve welding. This is not predicted to be exported, due to the subsidiarity principle - waste management including recycling should be undertaken by local and regional authorities.		
Impacts on fundamental rights	All	Not applicable		
Impacts on digitalisation	Companies	Not applicable		
Contributions to the UN sustainable development goals	All	Positive minor impact towards UN SDG 3: good health and wellbeing and UN SDG 8: Decent work & economic growth		
Notes: Numbers may not sum to total due to rounding.				

Source: Study team.

Résumé Exécutif

La Directive sur les substances cancérigènes, mutagènes et reprotoxiques (Directive 2004/37/CE), ci-après la CMRD, protège les travailleurs contre l'exposition à des substances cancérigènes, mutagènes ou reprotoxiques au travail. L'article 2 (au paragraphe (a)(ii)) du CMRD définit un 'cancérigène' comme:

" *une substance, un mélange ou un procédé visé à l'annexe I de la présente directive ainsi qu'une substance ou un mélange dégagé par un procédé visé à ladite annexe*."

Le CIRC (2018) a classé les fumées de soudage comme cancérogènes pour l'homme du groupe 1, et d'autres études depuis ont confirmé le caractère cancérigène des fumées de soudage (9 études analysées par l'Anses, 2022). Étant donné que les fumées de soudage+ (telles que définies au point 2.1.1) sont des substances générées par les procédés, la Commission envisage d'inscrire à l'annexe I du CMRD les fumées de soudage+ qui contiennent des substances cancérigènes (ou mutagènes ou reprotoxiques). L 'équipe d'étude a été invitée à "*étudier les coûts et les avantages liés à l'introduction d'une entrée dans l'annexe I de la directive*", afin de refléter les discussions les plus récentes au sein du comité directeur, en particulier la nécessité d'apporter une sécurité juridique quant au champ d'application du CMRD.

Dans cette étude, la définition des fumées de soudage+ de l'ECHA (2022) a été utilisée, qui comprend les fumées provenant des processus suivants :

- Soudage par fusion : soudage au gaz, soudage à l'arc (MIG, MAG, SMAW, FCAW, SAW, ESW, SW), soudage à l'arc (TIG, PAW), soudage par poutres;
- Soudage: brasage tendre, brasage dur;
- Brasage: supérieur à 450°C, brasage par faisceau laser, brasage à l'arc électrique (MIG, TIG, plasma);
- Découpe thermique ou gougeage;
- Projection thermique;
- Lissage à la flamme; et
- Processus de production additive.

Dans cette étude, les 'fumées de soudage' désignent les particules (métaux et leurs oxydes, y compris les structures complexes appelées spinelles), mais excluent les gaz de soudage produits pendant le soudage ou utilisés pour le blindage.

Une évaluation quantitative des deux options politiques suivantes a été entreprise:

- Option politique 1 (scénario de référence): aucune nouvelle mesure au niveau de l'UE (c'est-à-dire prenant en compte les exigences existantes en vertu de la législation en matière de SST, de la législation sur les produits chimiques et d'autres législations pertinentes, sans aucune entrée dans l'annexe I du CMRD);
- Option politique 2 : introduire dans l'annexe I du CMRD les processus suivants : "*Travaux impliquant une exposition à des fumées provenant de procédés de soudage (et similaires) contenant des substances qui répondent aux critères des substances cancérigènes, mutagènes ou reprotoxiques de catégorie 1A ou 1B énoncés dans Annexe I du règlement CLP*".

Par ailleurs, une évaluation qualitative de deux possible futures options qui pourraient être appliquées aux fumées de soudage+ plus tard, en complément d'une entrée à l'Annexe I du CMRD dans une future révision du CMRD, a été entreprise:

- "Fixation d'une limite d'exposition professionnelle (VLEP) générique pour les poussières inhalables et respirables spécifiques aux fumées de soudage"*.
- "Définition d'une métrique générique non spécifique pour les poussières (une limite inhalable et une limite respirable) applicable à toutes les poussières".

*Dans cette étude, nous avons interprété cela comme une VLEP à appliquer à tous les procédés de soudage+.

Dans cette étude, on a tenté de quantifier l'effet de l'exposition aux fumées de soudage sur le cancer du poumon uniquement, bien que d'autres effets sur la santé soient associés à l'exposition aux fumées de soudage. Cela signifie que les avantages pour la santé liés à la réduction de l'exposition aux fumées de soudage ont peut-être été sous-estimés. Il est difficile de quantifier dans quelle mesure les soudeurs sont exposés aux CMR en raison des incertitudes et des lacunes des données probantes.

Cette étude estime que l'excès de risque (ER) de cancer du poumon chez les soudeurs est de 2.7% en 2023 (section 2.2 et section 5.1.2). Cela équivaut à 27 000 cas de cancer du poumon chez un million de travailleurs exposés, ou plus précisément à 32 400 cas de cancer du poumon chez les quelque 1.2 million de soudeurs à temps plein dans l'UE 27. La charge de morbidité actuelle due à une exposition passée est estimée à 806 nouveaux cas[5]. De cas de cancer du poumon en 2023, la charge de morbidité héritée[6] au cours des 40 prochaines années étant estimée à 27 804 cas et la charge de morbidité future[7] étant estimée à 28 821 cas sur 40 ans avec un roulement de personnel de 5% pour tous les secteurs.

Il existe diverses difficultés pour quantifier l'ampleur du problème, notamment les incertitudes sur le nombre de travailleurs travaillant dans les activités de soudage+ dans l'UE27 et le nombre de travailleurs exposés aux substances CMR présentes dans les fumées de soudage.

Cette étude estime qu'il y a 1.2 million de travailleurs à temps plein dans les activités de soudage+ dans l'UE27, sur la base d'une estimation de la Société allemande du soudage (DVS: Deutscher Verband für Schweißen und verwandte Verfahren) de 1.2 million de travailleurs à temps plein dans le secteur 'Assemblage, Découpage et Revêtement' activités (section 3.4.2.1). Les entretiens avec six parties prenantes clés ont permis de conclure que cette estimation était raisonnable (section 5.1.1).

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[5] La charge de morbidité actuelle est le nombre estimé de cas diagnostiqués en 2023 en raison d'une exposition passée aux fumées de soudage.

[6] La charge de morbidité héritée du passé correspond au nombre de cas de cancer du poumon dus à une exposition au cours des 32 dernières années et qui se produiront au cours des 40 prochaines années, sur la base d'une latence de 30 ans pour le cancer et d'une exposition minimale de deux ans pour les soudeurs.

[7] La charge de morbidité future est le nombre de cas générés par l'exposition au cours des 40 prochaines années ; ces cas peuvent ne pas se produire au cours des 40 prochaines années en raison de la latence - ils peuvent se produire au-delà de la période de 40 ans.

Les fumées de soudage sont très hétérogènes. La présence de substances CMR dans les fumées de soudage dépend largement des matériaux à souder. La majorité (95%) des composants des fumées de soudage sont émises par l'apport ou les consommables utilisés et seulement 5% par le matériau de base (ANSES, 2022).

Le taux d'émission de fumées de soudage dépend largement du procédé de soudage utilisé. D 'autres facteurs affectant le taux d'émissions comprennent l'épaisseur de la tôle à souder ou le fait que la pièce métallique à souder ait été moulée (constructeur automobile, communication personnelle, juillet 2023). Le niveau d'expérience du soudeur (ANSES, 2022), et l'angle de soudage (VBMG, 2007) influencent également les taux d'émission. La présence de revêtements et la durée de l'arc affectent également respectivement la composition et les taux d'émissions (Anses, 2022).

La toxicité des fumées de soudage est associée à la distribution granulométrique et aux caractéristiques de surface des particules générées (Anses, 2022). Les experts débattent constamment de la nécessité de mesurer le nombre de particules ultrafines auxquelles les travailleurs sont exposés lors du soudage, et non seulement la masse totale des particules. Certains procédés de soudage+ produisent une grande quantité de particules ultrafines, par exemple la projection thermique (Bémer et al., 2010 dans ECHA, 2022).

Il a été constaté que les niveaux d'exposition aux fumées de soudage sont plus élevés lors du soudage de l'acier doux que de l'acier inoxydable, tant pour les fractions inhalables que respirables (Kendzia et al, 2019). Cependant, le soudage d'aciers fortement alliés (par exemple teneur en nickel >5%) générera des émissions plus élevées des alliages présents (tels que le nickel).

Il existe des preuves que les soudeurs d'acier doux et d'acier inoxydable présentent un risque excessif de cancer du poumon (Honaryar et al, 2019, Sorensen et al, 2007 dans ECHA, 2022). Certains articles fournissent également des preuves du pouvoir cancérigène mécaniste du soudage de l'acier doux (Badding et al, 2014 ; Dierschke et al, 2017 ; Falcone et al, 2018 ; Leonard et al, 2019 ; Zeidler-Erdely et al, 2012 dans DGUV, communication personnelle, juillet 2023).

Par ailleurs, les niveaux d’exposition aux fumées de soudage varient selon les pays, les industries et les métiers (Anses, 2022). Les niveaux d'exposition les plus élevés ont été mesurés en Finlande et aux États-Unis, et les plus faibles au Canada, au Royaume-Uni et en Nouvelle-Zélande. Les niveaux d'exposition les plus élevés ont été relevés dans le secteur manufacturier, tandis que les niveaux les plus faibles ont été observés dans le secteur automobile. En ce qui concerne les métiers, les niveaux d'exposition les plus élevés ont été relevés chez les chaudronniers et les plus faibles chez les tuyauteurs et les soudeurs.

Cette étude se concentre sur treize secteurs, qui ont été choisis parce qu'ils exercent des activités de soudage+, mais aussi parce qu'ils couvrent des secteurs équivalents identifiés dans d'autres études comme ayant des travailleurs exposés aux fumées de soudage (données CAREX et ASA finlandaise).

La revue de la littérature n’a trouvé ni données sur le nombre de personnes présentes qui pourraient également être exposées aux fumées de soudage sur le lieu de travail, ni informations permettant une estimation. C ela signifie que les avantages d’un changement de politique entraînant une réduction de l’exposition aux fumées de soudage ont peut-être été sous-estimés, dans la mesure où d'autres travailleurs (les spectateurs) pourraient également bénéficier de niveaux d'exposition réduits.

Les coûts et avantages (par rapport à la ligne de base) estimés dans ce rapport par rapport aux effets estimés de la deuxième option politique (Annexe I) sont résumés dans le tableau 0-1. Les avantages ont été calculés à l'aide de deux méthodes standardisées différentes de calcul des avantages pour la santé (comme expliqué dans la note méthodologique séparée). La première méthode intègre la valeur statistique de la vie et la valeur de la morbidité cancéreuse ou de la morbidité statistique. La deuxième méthode intègre les années de vie ajustées sur l'incapacité (DALY). Les coûts sont calculés selon une approche descendante (valeur marchande des RMM) et ascendante (coût moyen estimé des RMM supplémentaires par soudeur). Les valeurs actuelles sont estimées sur 40 ans avec un taux d'actualisation statique (invariable) de 3% et supposent un turnover du personnel de 5%. Les bénéfices sont compris entre 3,4 et 15,2 fois les coûts.

Les résultats de l'analyse coûts-avantages sont très incertains.

l'impact qu'aurait la deuxième option politique (l'inclusion des fumées de soudage contenant des substances CMR dans l'Annexe I du CMRD) sur la sensibilisation des employeurs et des travailleurs aux risques posés par l'exposition aux fumées de soudage est inconnu. Cependant, l'estimation de l'équipe d'étude d'une réduction de 1 % par an du RE due à l'amélioration de l'utilisation des mesures de gestion des risques pendant cinq ans grâce à l'option politique 2, avant de revenir à la situation de référence, a été soutenue sur la base de la consultation de six parties prenantes clés (section 6.1.3.3.2).

Les lacunes d'information les plus importantes sont: le niveau actuel de sensibilisation au risque d'être exposé aux substances CMR lors des activités de soudage; le respect des exigences réglementaires; et, plus généralement, l'utilisation de mesures d'atténuation des risques lors des activités de soudage. Ces facteurs sont susceptibles de varier au sein de l'UE27, selon les secteurs et selon les petites, moyennes et grandes entreprises.

Des entretiens avec les principales parties prenantes européennes et nationales ainsi qu'une enquête auprès des parties prenantes dans différents États membres ont indiqué que la connaissance de la présence possible de CMR dans les fumées de soudage est généralement bonne, mais que la connaissance des risques liés à l'exposition professionnelle et la compréhension des exigences du CMRD varient. La plupart des parties prenantes ont affirmé que la protection des travailleurs était bonne dans leur pays, seule une minorité estimant que la protection des travailleurs n'était peut-être pas optimale dans toutes les situations, par exemple dans les petites entreprises. Cependant, sans une campagne complète d'inspections inopinées des sites de soudage dans l'UE27, il n'est pas possible de totalement comprendre le niveau actuel de protection des travailleurs.

Tableau 0-1 Résumé des coûts et avantages monétisés (taux d'actualisation statique de 3 %, en plus du niveau de référence) basés sur les travailleurs exposés (soudeurs à temps plein) et l'utilisation de RMM (% de soudeurs devant acheter des RMM supplémentaires = 50 %).

Option politique	Deuxième option politique (Annexe I)
Avantages totaux M1	€1 000 000 000
Avantages totaux M2	€530 000 000
Coûts totaux ascendants (BUC)	€160 000 000
Coûts descendants totaux (TDC)	€67 000 000

Option politique	Deuxième option politique (Annexe I)
Rapport avantages-coûts M1 (BUC)	6,5
Rapport avantages-coûts M1 (TDC)	15
Rapport avantages-coûts M2 (BUC)	3,4
Rapport avantages-coûts M2 (TDC)	7,9
Remarques: *Dans tous les cas, l'augmentation des dépenses RMM a été estimée à 1% et l'augmentation du taux de variation du risque excédentaire par an après l'année) et les avantages liés à une mauvaise santé évitée ont été estimés à 1%.* Les chiffres ayant été arrondis, il est possible que leur somme ne corresponde pas exactement au total indiqué	

Source: Equipe d'étude.

L'analyse multicritère résumant à la fois les impacts monétaires et qualitatifs des trois options politiques qui ont été évaluées est présentée dans le tableau 0-2.

Les questions clés identifiées dans cette étude pour le processus décisionnel concernant un changement de politique comprennent:

- Diverses personnes consultées ont souligné la confusion potentielle que la deuxième option politique (Annexe I) pourrait générer dans la compréhension des parties prenantes des exigences législatives, voir la section 5.4.
- Les parties prenantes transmettent un message récurrent selon lequel le succès de l'inclusion des fumées de soudage à l'annexe I, la nécessité d'éviter toute confusion et la réduction de certains des risques potentiels pour le financement de la recherche, la compétitivité et les PME dépendent d'une bonne stratégie de communication, de communications campagne et les améliorations associées aux programmes de formation, voir section 9.6.2.1.
- Le niveau actuel de sensibilisation aux risques posés par l'exposition aux fumées de soudage et en particulier liés à la présence de substances CMR dans les fumées de soudage est difficile à quantifier, car les opinions des parties prenantes nationales au sein d'un État membre varient parfois considérablement. Le niveau de conformité au CMRD, tant au sein de l'UE qu'au sein des États membres, est également est difficile à quantifier, bien que certains éléments indiquent que le respect est meilleur en Europe occidentale et septentrionale, les grandes entreprises étant plus susceptibles que les petites entreprises de disposer des ressources nécessaires pour disposer d'un système dédié expert ou équipe en matière de santé et de sécurité.
- Le soudage d'aciers faiblement alliés (aciers doux) n'est pas toujours associé à un faible risque d'exposition aux CMR, même si certains acteurs souhaiteraient que cette conclusion soit tirée, voir section 5.1.2. U n acteur clé de l'UE partage cet avis (comm. pers, juillet 2023).
- Tout au long de l'évaluation de la situation actuelle et de l'élaboration du scénario de référence, il existe de nombreuses sources d'informations sur les tendances probables qui affecteront la demande de soudage et la manière dont l'industrie évoluera. Cependant, ces informations sont en grande partie qualitatives, avec peu d'évaluations quantitatives, et celles qui existent ne représentent généralement qu'une partie du marché. U ne source fournit des prévisions de croissance du marché (2019 Accuray), voir la section 3.4.5 et est utilisée pour créer une référence dynamique pour le nombre de travailleurs exposés utilisé dans les calculs des avantages dans la section 6.1.3.3.1 et pour estimer les coûts des mesures de gestion des risques. d ans le calcul descendant des coûts à la section 6.2.2.3.

- Fixer une limite de poussière (qu'elle soit spécifique aux fumées de soudage ou non) aurait une valeur supplémentaire limitée pour protéger les travailleurs contre les substances CMR par rapport à l'utilisation des VLEP existantes pour les substances CMR, précisément parce qu'une limite de poussière protégerait les travailleurs des effets sanitaires de la poussière et non des substances CMR, qui nécessitent des valeurs limites beaucoup plus strictes que celles généralement observées pour les limites de poussières.

Tableau 0-2 Analyse multicritère (tous les impacts sur 40 ans et en plus par rapport à la référence) pour les différentes options politiques.

Impact	Parties prenantes concernées	Deuxième option politique (Annexe I) Évaluation quantitative (VP)	En plus de la deuxième option politique (Annexe I), évaluation qualitative uniquement:	
			VLEP (poussières inhalables et respirables) spécifiques aux fumées de soudage	Mesure générique non spécifique des poussières (inhalables et respirables)
Coûts directs – ajustement				
Mesures de gestion des risques et coûts d'arrêt (ponctuels et récurrents)	Entreprises	€ 67 - 160 million	Hors de portée	Hors de portée
Surveillance (échantillonnage et analyse)	Entreprises	Aucun attendu	Hors de portée	Hors de portée
Coûts directs - charges administratives				
Coût de la charge administrative de l'entreprise	Entreprises	Non applicable	Hors de portée	Hors de portée
Coûts directs – total				
Coûts de conformité, de surveillance et d'administration par entreprise	Entreprises	€ 67 – 160 million	Hors de portée	Hors de portée
Coûts directs - coûts d'application				
Frais de transposition	Secteur public	€ 2.7 million	€810,000 – 1,400,000	€810,000 – 1,400,000
Coûts d'application	Secteur public	None	Hors de portée	Hors de portée
Coûts de surveillance	Secteur public	None	Hors de portée	Hors de portée
Frais d'arbitrage	Secteur public	None	Hors de portée	Hors de portée
Coûts indirects - autres				
Entreprises sorties du marché - Nombre de fermetures d'entreprises	Entreprises	Non prévu	Non prévu	Non prévu
Emploi – Emplois perdus	Travailleurs et familles	Non quantifié. Pas de changement juridique, sensibilisation.	Non estimé	Non estimé
Emploi – Coût social	Travailleurs et familles	Not estimated	Non estimé	Non estimé
Compétitivité internationale	Entreprises	La concurrence internationale est faible pour le soudage, car le soudage doit souvent être effectué sur place et ne peut pas être exporté. Voir l'encadré à droite.	La plupart des pays concurrents non européens réglementent déjà les fumées de soudage via une limite de poussière a ou une VLEP (ne pouvant être distinguée des informations disponibles): AU, CA, CN, IN, NO, KR, US. Une exception est le Japon, où les employeurs mesurent et protègent contre l'exposition au Mn comme indicateur des fumées de soudage. La limite la plus basse est de 3 mg/m^3 (R) de particules aux États-Unis ou en Californie. La limite la plus élevée est de 10 mg/m^3 (I) de particules aux États-Unis ou en Californie.	

Impact	Parties prenantes concernées	Deuxième option politique (Annexe I) Évaluation quantitative (VP)	En plus de la deuxième option politique (Annexe I), évaluation qualitative uniquement:	
			VLEP (poussières inhalables et respirables) spécifiques aux fumées de soudage	Mesure générique non spécifique des poussières (inhalables et respirables)
Consommateurs	Consommateurs	Aucun n'a été prédit.	Les entreprises (en particulier les petites entreprises) peuvent augmenter le prix de leurs produits pour couvrir l'augmentation des coûts de mise en conformité.	
Marché interne VLEP la plus basse à la plus élevée	Entreprises	Non quantifié.	Non quantifié. La VLEP la plus basse (liée au procédé) pour les fumées de soudage est de 0,5 mg/m³ en DK, pour les "méthodes de soudage de l'acier inoxydable à l'électrode". La VLEP la plus élevée et la plus courante pour les fumées de soudage est de 5 mg/m³.	Non quantifié. La limite générique de poussière la plus élevée est de 10 mg/m³ (I) en Allemagne Il n'a pas été possible d'identifier tous les détails des limites pour: CZ, IE ou ES.
EM/régions spécifiques – EM qui devraient modifier leur politique ou leurs VLEP	Secteur public	Moins de conformité dans les États membres E et S de l'UE, selon des preuves anecdotiques entendues par l'équipe d'étude.	Huit États membres disposent déjà de VLEP pour les fumées de soudage : AT, BE DK, FR, LV, LT, NL, SK.	Six États membres disposent déjà de limites génériques de poussières: CY, HR, FR, DE, IE, NL. Il n'a pas été possible de catégoriser les limites en vigueur en CZ, IE ou ES.
Régulation	Entreprises	Le risque que le changement de politique crée de la confusion et que les ressources de l'entreprise soient gaspillées à essayer de comprendre ce qui est nécessaire.	Les VLEP auraient un impact sur les entreprises entreprenant des activités de soudage.	Une limite générique de poussière s'appliquerait dans tous les secteurs à toutes les entreprises entreprenant des activités générant de la poussière.
Bénéfices directs – amélioration du bien-être – santé				
Réduction des cas de cancer	Travailleurs et familles	1 618	Non quantifié.	Non quantifié.
Réduction des décès	Travailleurs et familles	1 079	Non quantifié.	Non quantifié.
Non-décès réduits	Travailleurs et familles	270	Non quantifié.	Non quantifié.
Mauvaise santé évitée, incl. c oûts immatériels (M1 à M2)	Travailleurs et familles	M1: €1 000 million M2: €510 million	Non quantifié, mais voir ci-dessus l'analyse qualitative.	Non quantifié, mais voir ci-dessus l'analyse qualitative.
Bénéfices directs – bien-être amélioré – sécurité				
Coûts évités	Entreprises	€4.7 million	Non quantifié.	Non quantifié.
Coûts évités	Secteur public	€16 million	Non quantifié.	Non quantifié.

Impact	Parties prenantes concernées	Deuxième option politique (Annexe I) Évaluation quantitative (VP)	En plus de la deuxième option politique (Annexe I), évaluation qualitative uniquement:	
			VLEP (poussières inhalables et respirables) spécifiques aux fumées de soudage	Mesure générique non spécifique des poussières (inhalables et respirables)
Agenda politique de l'UE	All	L'augmentation de la protection de la santé des travailleurs constitue le principal avantage social.		
Bénéfices directs – bien-être amélioré – environnemental				
Rejets dans l'environnement	All	Non quantifié.	Non quantifié.	Non quantifié.
Bénéfices directs – efficacité du marché				
Des règles du jeu équitables	Entreprises	La sensibilisation peut conduire à des conditions de concurrence plus équitables entre les États membres et au sein de ceux-ci.	Cible plus claire que la deuxième option politique. C ontribuerait à des conditions de concurrence équitables dans l'ensemble de l'UE des 27.	Cible plus claire que la deuxième option politique. C ontribuerait à des conditions de concurrence équitables dans l'ensemble de l'UE des 27.
Bénéfices indirects				
Simplification administrative	Entreprises	Non applicable	Sans objet, la VLEP s'ajouterait aux VLEP spécifiques aux substances existantes.	Sans objet, la limite de poussière s'ajouterait aux VLEP spécifiques aux substances existantes.
Synergie	Entreprises			
Responsabilité sociale des entreprises	Entreprises	Impact mineur positif	Impact mineur positif	Impact mineur positif
Coût évité de fixation des VLEP (UE27)	Secteur public	Non applicable	€1.4 – 2.7 million	€1.4 – 2.7 million
Autres impacts				
Recyclage – perte d'activité	Entreprises de recyclage	N'est pas applicable. L es principes de l'économie circulaire dans l'UE27 encouragent le recyclage, y compris le recyclage des produits métalliques qui implique parfois du soudage. O n ne s'attend pas à ce que cela soit exporté, en raison du principe de subsidiarité : la gestion des déchets, y compris le recyclage, devrait être prise en charge par les autorités locales et régionales.		
Impacts sur les droits fondamentaux	Tous	Non applicable		
Impacts sur la numérisation	Entreprises	Non applicable		
Contributions aux objectifs de développement durable des Nations Unies	Tous	Impact positif mineur sur l'ODD 3 de l'ONU : bonne santé et bien-être et sur l'ODD 8 de l'ONU: Travail décent et croissance économique.		
Remarques: Les chiffres ayant été arrondis, il est possible que leur somme ne corresponde pas exactement au total indiqué.				

Source: équipe d'étude.

Kurzfassung

Die Richtlinie über krebserzeugende, erbgutverändernde und fortpflanzungsgefährdende Stoffe (Richtlinie 2004/37/EG), im Folgenden CMRD genannt, schützt Arbeitnehmer vor der Exposition gegenüber krebserzeugenden, erbgutverändernden oder fortpflanzungsgefährdenden Stoffen bei der Arbeit. I n Artikel 2 (in Absatz (a)(ii)) der CMRD wird ein "Karzinogen" definiert als:

„einen Stoff, ein Gemisch oder ein Verfahren, der bzw. das in Anhang I dieser Richtlinie aufgeführt ist, sowie einen Stoff oder ein Gemisch, der bzw. das durch ein in diesem Anhang genanntes Verfahren freigesetzt wird."

Die IARC (2018) stufte Schweißrauch als Karzinogen der Gruppe 1 für den Menschen ein, und andere Studien haben seitdem den karzinogenen Charakter von Schweißrauch bestätigt (9 von der ANSES analysierte Studien, 2022). Da Schweißrauch+ (wie in 2.1.1 definiert) prozessbedingte Stoffe sind, erwägt die Kommission einen Eintrag in Anhang I der CMRD für Schweißrauch+, der krebserregende (oder mutagene oder reproduktionstoxische) Stoffe enthält. Das Studienteam wurde damit beauftragt, „die Kosten und den Nutzen in Bezug auf die Einführung eines Eintrags in Anhang I der Richtlinie zu untersuchen", um den jüngsten Diskussionen im Lenkungsausschuss Rechnung zu tragen, insbesondere der Notwendigkeit, Rechtssicherheit über den Anwendungsbereich der CMRD zu schaffen.

In dieser Studie wurde die Definition von Schweißrauch+ der ECHA (2022) verwendet, die Rauch aus den folgenden Verfahren umfasst:

- Schmelzschweißen: Gasschweißen, Lichtbogenschweißen (MIG, MAG, SMAW, FCAW, SAW, ESW, SW), Lichtbogenschweißen (TIG, PAW), Strahlschweißen;
- Löten: Weichlöten, Hartlöten;
- Hartlöten: über 450°C, Laserstrahlhartlöten, Hartlöten mit Lichtbogen (MIG, WIG, Plasma);
- Thermisches Schneiden oder Fugenhobeln;
- Thermisches Spritzen;
- Flammrichten; und
- Additive Fertigungsverfahren.

In dieser Studie wird unter „Schweißrauch" die partikelförmige Substanz (Metalle und ihre Oxide, einschließlich komplexer Strukturen, die als Spinelle bezeichnet werden) verstanden, nicht jedoch die Schweißgase, die beim Schweißen entstehen oder als Schutzgas verwendet werden.

Es wurde eine quantitative Bewertung der folgenden politischen Optionen vorgenommen:

- Option 1 (Basisszenario): keine neuen Maßnahmen auf EU-Ebene (d. h. Berücksichtigung der bestehenden Anforderungen im Rahmen der Rechtsvorschriften über Sicherheit und Gesundheitsschutz bei der Arbeit, der Rechtsvorschriften über chemische Stoffe und anderer einschlägiger Rechtsvorschriften, ohne Aufnahme in Anhang I der CMRD);

- Option 2: Aufnahme der folgenden Verfahren in Anhang I der CMRD: „Arbeiten mit einer Exposition gegenüber bei Schweißvorgängen (und ähnlichen Verfahren) erzeugtem Rauch, der Stoffe enthält, die die Kriterien für eine Einstufung als krebserzeugend, erbgutverändernd oder fortpflanzungsgefährdend (CMR) der Kategorie 1A oder 1B gemäß Anhang I der CLP-Verordnung erfüllen."

Darüber hinaus wurde eine qualitative Bewertung zweier möglicher künftiger Optionen vorgenommen, die zusätzlich zu einem Eintrag in Anhang I der CMRD bei einer künftigen Überarbeitung der CMRD auf Schweißrauch+ zu einem späteren Zeitpunkt angewendet werden könnten:

- „Festlegung eines allgemeinen Arbeitsplatzgrenzwertes (AGW) für einatembaren und lungengängigen Staub speziell für Schweißrauch"*.

- „Festlegung eines unspezifischen allgemeinen Staubgrenzwertes (ein inhalierbarer Grenzwert und ein lungengängiger Grenzwert), der für alle Stäube gilt."

*In dieser Studie wird dies so verstanden, dass ein AGW für alle Schweiß+ verfahren gilt.

In dieser Studie wurde versucht, nur die Auswirkungen der Schweißrauchexposition auf Lungenkrebs zu quantifizieren, obwohl auch andere gesundheitliche Auswirkungen mit der Schweißrauchexposition in Verbindung gebracht werden. Dies bedeutet, dass der gesundheitliche Nutzen einer Verringerung der Exposition gegenüber Schweißrauch möglicherweise unterschätzt wurde. Das Ausmaß der Exposition von Schweißern gegenüber CMR ist aufgrund von Unsicherheiten und Lücken in der Evidenzbasis schwer zu quantifizieren.

Diese Studie schätzt, dass das zusätzliche Risiko (Excess Risk, ER) für Lungenkrebs bei Schweißern im Jahr 2023 bei 2,7 % liegt (Abschnitt 2.2 und Abschnitt 5.1.2). Dies entspricht 27.000 Fällen von Lungenkrebs bei einer Million exponierter Arbeitnehmer oder genauer gesagt 32.400 Fällen von Lungenkrebs bei den geschätzten 1,2 Millionen Vollzeitschweißern in der EU-27. Die derzeitige Krankheitslast[8] aufgrund früherer Exposition wird für das Jahr 2023 auf 806 neue Fälle von Lungenkrebs geschätzt, wobei die frühere Krankheitslast[9] in den nächsten 40 Jahren auf 27.804 Fälle und die künftige Krankheitslast[10] bei einer Personalfluktuation von 5 % für alle Sektoren auf 28.821 Fälle über 40 Jahre geschätzt wird.

Es gibt Schwierigkeiten bei der Quantifizierung des Ausmaßes des Problems, einschließlich der Unsicherheiten bezüglich der Anzahl der Arbeitnehmer, die in der EU27 im Bereich Schweißen+ tätig sind, und der Anzahl der Arbeitnehmer, die CMR-Stoffen im Schweißrauch ausgesetzt sind.

[8] Die derzeitige Krankheitslast ist die geschätzte Zahl der im Jahr 2023 diagnostizierten Fälle, die auf eine frühere Exposition gegenüber Schweißrauch zurückzuführen sind.

[9] Die frühere Krankheitslast bezieht sich auf die Anzahl der Lungenkrebsfälle, die in den letzten 32 Jahren aufgrund der Exposition aufgetreten sind und in den nächsten 40 Jahren auftreten werden, wobei eine Latenzzeit von 30 Jahren für den Endpunkt Krebs und eine Mindestexposition von zwei Jahren für Schweißer zugrunde gelegt wird.

[10] Die künftige Krankheitslast ist die Anzahl der Fälle, die durch die Exposition in den nächsten 40 Jahren verursacht werden; diese Fälle treten aufgrund der Latenzzeit möglicherweise nicht in den nächsten 40 Jahren auf, sondern erst nach dem 40-Jahres-Zeitraum.

Diese Studie schätzt, dass es in der EU27 1,2 Millionen Vollzeitbeschäftigte im Bereich Schweißen+ gibt, basierend auf der Schätzung des Deutschen Verbandes für Schweißen und verwandte Verfahren (DVS) von 1,2 Millionen Vollzeitbeschäftigten im Bereich "Fügen, Trennen und Beschichten" (Abschnitt 3.4.2.1). Die Befragung von sechs wichtigen Interessengruppen ergab, dass diese Schätzung angemessen ist (Abschnitt 5.1.1).

Schweißrauche sind sehr heterogen. Das Vorhandensein von CMR-Stoffen im Schweißrauch hängt weitgehend von den zu schweißenden Materialien ab. Der Großteil (95 %) der Bestandteile des Schweißrauchs stammt aus dem verwendeten Schweißzusatz und nur 5 % aus dem Grundwerkstoff (ANSES, 2022).

Die Menge der Schweißrauchemissionen hängt weitgehend von dem verwendeten Schweißverfahren ab. Weitere Faktoren, die die Emissionsrate beeinflussen, sind die Dicke des geschweißten Blechs oder ob das geschweißte Metallteil geformt wurde (Automobilhersteller, persönliche Mitteilung, Juli 2023). Auch der Erfahrungsgrad des Schweißers (ANSES, 2022) und der Schweißwinkel (VBMG, 2007) beeinflussen die Emissionsraten. Das Vorhandensein von Beschichtungen und die Lichtbogenzeit wirken sich ebenfalls auf die Zusammensetzung bzw. die Emissionsraten aus (ANSES, 2022).

Die Toxizität von Schweißrauch hängt mit der Größenverteilung und den Oberflächeneigenschaften der erzeugten Partikel zusammen (ANSES, 2022). Unter den Experten gibt es eine anhaltende Diskussion über die Notwendigkeit, die Anzahl der ultrafeinen Partikel zu messen, denen die Arbeitnehmer beim Schweißen ausgesetzt sind, und nicht nur die Gesamtmasse der Partikel. Bestimmte Schweiß+ verfahren erzeugen eine große Menge an ultrafeinen Partikeln, zum Beispiel das thermische Spritzen (Bémer et al., 2010 in ECHA, 2022).

Es wurde festgestellt, dass die Exposition gegenüber Schweißrauch beim Schweißen von unlegiertem Stahl höher ist als beim Schweißen von rostfreiem Stahl, und zwar sowohl für die inhalierbare als auch für die lungengängige Fraktion (Kendzia et al., 2019). Beim Schweißen von hochlegierten Stählen (z. B mit einem Nickelgehalt von mehr als 5 %) werden jedoch höhere Emissionen der vorhandenen Legierungen (wie Nickel) erzeugt.

Es gibt Hinweise darauf, dass sowohl Schweißer von Baustahl als auch von nichtrostendem Stahl ein erhöhtes Risiko für Lungenkrebs haben (Honaryar et al, 2019, Sorensen et al, 2007 in ECHA, 2022). Es gibt auch einige Arbeiten, die die mechanistische karzinogene Potenz des Schweißens von Baustahl belegen (Badding et al, 2014; Dierschke et al, 2017; Falcone et al, 2018; Leonard et al, 2019; Zeidler-Erdely et al, 2012 in DGUV, pers comm, Juli 2023).

Darüber hinaus wurde festgestellt, dass die Exposition gegenüber Schweißrauch je nach Land, Branche und Beruf variiert (ANSES, 2022), wobei in Finnland und den USA höhere Expositionswerte und in Kanada, dem Vereinigten Königreich und Neuseeland niedrigere Werte gemessen wurden. Die höchsten Expositionswerte wurden im verarbeitenden Gewerbe festgestellt, während die niedrigsten Werte im Automobilsektor gemessen wurden. In Bezug auf die Berufe wurden die höchsten Expositionswerte bei Kesselbauern und die niedrigsten bei Rohrschlossern und Schweißern festgestellt.

Diese Studie konzentriert sich auf dreizehn Sektoren, die ausgewählt wurden, weil in ihnen Schweißarbeiten+ durchgeführt werden, aber auch, weil sie entsprechende Sektoren abdecken, die in anderen Studien identifiziert wurden, in denen Arbeitnehmer Schweißrauch ausgesetzt sind (CAREX und finnische ASA-Daten).

Bei der Literaturrecherche wurden weder Daten über die Anzahl der umstehenden Personen, die ebenfalls Schweißrauch am Arbeitsplatz ausgesetzt sein könnten, noch Informationen gefunden, die eine Schätzung ermöglichen. Dies bedeutet, dass der Nutzen einer Änderung der Politik, die zu einer geringeren Exposition gegenüber Schweißrauch führt, möglicherweise unterschätzt wurde, da auch andere Arbeitnehmer (Umstehende) von einer geringeren Exposition profitieren könnten.

Die in diesem Bericht geschätzten Kosten und Nutzen (im Vergleich zur Ausgangslage) im Vergleich zu den geschätzten Auswirkungen der Option 2 (Aufnahme in Anhang I) sind in Tabelle 0 1 zusammengefasst. Der Nutzen wurde anhand von zwei verschiedenen standardisierten Methoden zur Berechnung des gesundheitlichen Nutzens berechnet (wie im separaten Methodenbericht erläutert). Methode 1 berücksichtigt den Wert des statistischen Lebens und den Wert der Krebsmorbidität oder der statistischen Morbidität. Bei Methode 2 werden behinderungsbereinigte Lebensjahre (Disability Adjusted Life Years, DALYs) berücksichtigt. Die Kosten werden nach einem Top-down-Ansatz (Marktwert der RMMs) und einem Bottom-up-Ansatz (geschätzte Durchschnittskosten für zusätzliche RMMs pro Schweißer) berechnet. Die Gegenwartswerte werden über einen Zeitraum von 40 Jahren mit einem statischen (unveränderlichen) Abzinsungssatz von 3 % geschätzt, wobei von einer Personalfluktuation von 5 % ausgegangen wird. Der Nutzen liegt zwischen dem 3,4- und 15,2-fachen der Kosten.

Die Ergebnisse der Kosten-Nutzen-Analyse sind höchst unsicher. Es ist nicht bekannt, welche Auswirkungen die zweite Option (die Aufnahme von Schweißrauch, der CMR-Stoffe enthält, in Anhang I der CMR-Richtlinie) auf das Bewusstsein der Arbeitgeber und Arbeitnehmer für die mit der Exposition gegenüber Schweißrauch verbundenen Risiken haben würde. Die Schätzung des Studienteams, dass die ER aufgrund der verbesserten Nutzung von Risikomanagementmaßnahmen fünf Jahre lang um 1 % pro Jahr abnimmt, bevor sie zum Ausgangswert zurückkehrt, wurde jedoch auf der Grundlage von Konsultationen mit sechs wichtigen Interessengruppen unterstützt (Abschnitt 6.1.3.3.2).

Die wichtigsten Informationslücken sind: der derzeitige Grad des Bewusstseins über das Risiko, bei Schweißarbeiten CMR-Stoffen ausgesetzt zu sein, die Einhaltung gesetzlicher Vorschriften und, allgemeiner, das Ausmaß der Anwendung von Risikominderungsmaßnahmen bei Schweißarbeiten. Diese Faktoren dürften in der EU27, in den einzelnen Sektoren und in kleinen, mittleren und großen Unternehmen unterschiedlich sein.

Interviews mit EU- und nationalen Interessenvertretern und eine Umfrage unter Interessenvertretern in verschiedenen Mitgliedstaaten ergaben, dass das Bewusstsein für das mögliche Vorhandensein von CMR in Schweißdämpfen in der Regel gut ist, dass aber das Bewusstsein für die Risiken der beruflichen Exposition und das Verständnis für die Anforderungen der CMR-Richtlinie unterschiedlich sind. Die meisten Interessenvertreter gaben an, dass der Schutz der Arbeitnehmer in ihren Ländern gut sei, und nur eine Minderheit war der Ansicht, dass der Schutz der Arbeitnehmer nicht in allen Situationen optimal sei, beispielsweise in kleinen Unternehmen. Ohne eine umfassende Kampagne mit unangekündigten Inspektionen von Schweißanlagen in der gesamten EU-27 ist es jedoch nicht möglich, das bestehende Niveau des Arbeitnehmerschutzes vollständig zu verstehen.

Tabelle 0-1 Zusammenfassung der monetarisierten Kosten und des Nutzens (statischer Abzinsungssatz von 3%, zusätzlich zum Basisszenario) auf der Grundlage der exponierten Arbeitnehmer (Vollzeitschweißer) und der Verwendung von RMMs (% der Schweißer, die zusätzliche RMMs kaufen müssen = 50 %).

Kategorien der Kosten und Nutzen	Ergebnis für Option 2 (Anhang I)
Gesamtnutzen M1	€1 000 000 000
Gesamtnutzen M2	€530 000 000
Gesamte Bottom-up-Kosten (BUC)	€160 000 000
Gesamte Top-Down-Kosten (TDC)	€67 000 000
Nutzen-Kosten-Verhältnis M1 (BUC)	6,5
Nutzen-Kosten-Verhältnis M1 (TDC)	15
Nutzen-Kosten-Verhältnis M2 (BUC)	3,4
Nutzen-Kosten-Verhältnis M2 (TDC)	7,9
Anmerkungen: In allen Fällen wurde der Anstieg der Ausgaben für Risikomanagement mit 1 % und der Anstieg der Änderungsrate des Überschussrisikos pro Jahr nach dem Jahr) und des Nutzens durch vermiedene Krankheiten mit 1 % angenommen. Die Summe kann sich aufgrund von Auf- bzw. Abrunden von der Gesamtsumme unterscheiden.	

Quelle: Studienteam.

Die Multikriterienanalyse, die sowohl die monetären als auch die qualitativen Auswirkungen der drei bewerteten politischen Optionen zusammenfasst, ist in Tabelle 0 2 dargestellt.

Zu den wichtigsten Ergebnissen, die in dieser Studie als wichtig für den Entscheidungsfindungsprozess für eine Änderung der Politik ermittelt wurden, gehören:

- Mehrere Konsultationsteilnehmer wiesen auf die mögliche Verwirrung hin, die die zweite Option (Anhang I) beim Verständnis der rechtlichen Anforderungen durch die Beteiligten hervorrufen könnte (siehe Abschnitt 5.4).
- Die Beteiligten wiesen immer wieder darauf hin, dass der Erfolg der Aufnahme von Schweißrauch in Anhang I, die Vermeidung von Verwirrung und die Verringerung einiger potenzieller Risiken für die Forschungsfinanzierung, die Wettbewerbsfähigkeit und die KMU von einer guten Kommunikationsstrategie, einer Kommunikationskampagne und damit verbundenen Verbesserungen der Ausbildungsprogramme abhängen, siehe Abschnitt 9.6.2.1.
- Der derzeitige Stand des Bewusstseins über die Risiken, die von der Exposition gegenüber Schweißrauch ausgehen, und insbesondere in Bezug auf das Vorhandensein von CMR-Stoffen in Schweißrauch, ist schwer zu quantifizieren, da die Meinungen der nationalen Interessengruppen innerhalb eines Mitgliedstaates manchmal stark voneinander abweichen. Der Grad der Einhaltung der CMR-Richtlinie sowohl in der gesamten EU als auch innerhalb der Mitgliedstaaten lässt sich ebenfalls nur schwer quantifizieren, obwohl es einige Hinweise darauf gibt, dass die Einhaltung in West- und Nordeuropa besser ist, wobei größere Unternehmen eher als kleine Unternehmen über die Ressourcen verfügen, um einen speziellen Experten oder ein Team für das Thema Gesundheit und Sicherheit zu beschäftigen.
- Das Schweißen von niedrig legiertem Stahl (Baustahl) ist nicht immer mit einem geringen Risiko der Exposition gegenüber CMR verbunden, auch wenn einige Interessenvertreter diese Schlussfolgerung gerne gezogen hätten (siehe Abschnitt 5.1.2). Ein wichtiger EU-Stakeholder schließt sich dieser Meinung an (pers. Mitteilung, Juli 2023).

- Für die Bewertung der aktuellen Situation und die Entwicklung des Basisszenarios gibt es viele Informationsquellen über wahrscheinliche Trends, die sich auf die Nachfrage nach Schweißarbeiten auswirken werden, und über die Art und Weise, wie sich die Branche entwickeln wird. Bei diesen Informationen handelt es sich jedoch größtenteils um qualitative Informationen mit wenigen quantitativen Einschätzungen, und die vorhandenen Informationen repräsentieren meist nur einen Teil des Marktes. Eine Quelle liefert Vorhersagen zum Marktwachstum (2019 Accuray), siehe Abschnitt 3.4.5, und wird verwendet, um eine dynamische Basislinie für die Anzahl der exponierten Arbeitnehmer zu erstellen, die in den Berechnungen des Nutzens in Abschnitt 6.1.3.3.1 verwendet wird, und um die Kosten der Risikomanagementmaßnahmen in der Top-Down-Berechnung der Kosten in Abschnitt 6.2.2.3 zu schätzen.
- Die Festlegung eines Staubgrenzwerts (unabhängig davon, ob er speziell für Schweißrauch gilt oder nicht) hätte nur einen begrenzten zusätzlichen Nutzen für den Schutz der Arbeitnehmer vor CMR-Stoffen im Vergleich zur Verwendung der bestehenden AGW für CMR-Stoffe, und zwar genau deshalb, weil ein Staubgrenzwert die Arbeitnehmer vor den gesundheitlichen Auswirkungen von Staub und nicht von CMR-Stoffen schützen würde, die viel strengere Grenzwerte erfordern, als sie üblicherweise für Staubgrenzwerte gelten.

Tabelle 0-2 Multikriterienanalyse (alle Auswirkungen über 40 Jahre und zusätzlich zum Ausgangswert) per Option

Auswirkungen	**Betroffene Stakeholders**	**Option 2 (Anhang I)** **Quantitative Bewertung** **(Gegenwartswert, PV)**	**Zusätzlich zu Option 2 (Anhang I), nur qualitative Bewertung:**	
			AGW (einatembarer und lungengängiger Staub) speziell für Schweißrauch	**Unspezifische allgemeine Staubmetrik (einatembar und lungengängig)**
Direkte Kosten – Anpassung				
Kosten, die Risikomanagementmaßnahmen und Unterbrechungen enstehen (einmaling und wiederkehrend)	Unternehmen	67 - 160 Millionen €	Nicht im Rahmen der Studie	Nicht im Rahmen der Studie
Überwachung (Probenahmen und Analysen)	Unternehmen	Keine Auswirkungen werden erwartet	Nicht im Rahmen der Studie	Nicht im Rahmen der Studie
Direkte Kosten - Verwaltung				
Verwaltungsaufwand für Unternehmen	Unternehmen	K.A.	Nicht im Rahmen der Studie	Nicht im Rahmen der Studie
Direkte Kosten – gesamt				
Kosten für die Einhaltung der Vorschriften, die Überwachung und den Verwaltungsaufwand pro Unternehmen	Unternehmen	67 – 160 Millionen €	Nicht im Rahmen der Studie	Nicht im Rahmen der Studie
Direkte Kosten - Durchsetzungskosten (enforcement)				
Umsetzungskosten	Öffentlicher Sektor	2,7 Millionen €	810,000 – 1,400,000 €	810,000 – 1,400,000 €
Durchsetzungskosten außer Umsetzung	Öffentlicher Sektor	Keine	Nicht im Rahmen der Studie	Nicht im Rahmen der Studie
Kosten für Überwachung	Öffentlicher Sektor	Keine	Nicht im Rahmen der Studie	Nicht im Rahmen der Studie
Gerichtskosten	Öffentlicher Sektor	Keine	Nicht im Rahmen der Studie	Nicht im Rahmen der Studie
Indirekte Kosten - Sonstige				
Firmen, die den Markt verlassen - Anzahl der Unternehmensschließungen	Unternehmen	Es werden keine Auswirkungen vorhergesagt.	Es werden keine Auswirkungen vorhergesagt.	Es werden keine Auswirkungen vorhergesagt.
Beschäftigung - verlorene Arbeitsplätze	Arbeitnehmer & Familien	Nicht quantifiziert.	Nicht geschätzt	Nicht geschätzt

Auswirkungen	**Betroffene Stakeholders**	**Option 2 (Anhang I)** **Quantitative Bewertung** **(Gegenwartswert, PV)**	**Zusätzlich zu Option 2 (Anhang I), nur qualitative Bewertung:**	
			AGW (einatembarer und lungengängiger Staub) speziell für Schweißrauch	**Unspezifische allgemeine Staubmetrik (einatembar und lungengängig)**
		Keine Gesetzesänderung, Bewusstseinsbildung.		
Beschäftigung - Soziale Kosten	Arbeitnehmer & Familien	Nicht geschätzt	Nicht geschätzt	Nicht geschätzt
Internationale Wettbewerbsfähigkeit	Unternehmen	Der internationale Wettbewerb beim Schweißen ist gering, da die Schweißarbeiten oft vor Ort durchgeführt werden müssen und nicht exportiert werden können. Siehe Kasten auf der rechten Seite.	Die meisten Nicht-EU-Wettbewerbsländer regeln Schweißrauch bereits durch Staubgrenzwerte oder einen AGW (aus den verfügbaren Informationen nicht zu erkennen): AU, CA, CN, IN, NO, KR, US. Eine Ausnahme ist JP, wo Arbeitgeber die Exposition gegenüber Mn als Ersatz für Schweißrauch messen und sich dagegen schützen. Der niedrigste Grenzwert beträgt 3 mg/m^3 (R) Partikel in den USA oder CA. Der höchste Grenzwert liegt bei 10 mg/m^3 (I) Partikel in den USA und CA.	
Verbraucher	Verbraucher	Es werden keine Auswirkungen vorhergesagt.	Unternehmen (insbesondere kleinere Unternehmen) könnten die Preise ihrer Produkte erhöhen, um die höheren Kosten der Einhaltung der Vorschriften zu decken.	
Binnenmarkt Niedrigster bis höchster AGW	Unternehmen	Nicht quantifiziert.	Nicht quantifiziert. Der niedrigste (verfahrensbedingte) AGW für Schweißrauch beträgt 0,5 mg/m^3 in DK, für "Elektrodenverfahren zum Schweißen von rostfreiem Stahl". Der höchste und gebräuchlichste OEL für Schweißrauch beträgt 5 mg/m^3	Nicht quantifiziert. Der höchste allgemeine Staubgrenzwert liegt in Deutschland bei 10 mg/m^3 (I). Es war nicht möglich, die vollständigen Einzelheiten der Grenzwerte für: CZ, IE oder ES.

Auswirkungen	Betroffene Stakeholders	Option 2 (Anhang I) Quantitative Bewertung (Gegenwartswert, PV)	Zusätzlich zu Option 2 (Anhang I), nur qualitative Bewertung:	
			AGW (einatembarer und lungengängiger Staub) speziell für Schweißrauch	Unspezifische allgemeine Staubmetrik (einatembar und lungengängig)
Spezifische Mitgliedstaaten/Regionen – Mitgliedstaaten, die AGWs ändern müssten	Öffentlicher Sektor	Geringere Einhaltung in den östlichen und südlichen EU-Mitgliedstaaten, wie das Studienteam aus eigener Anschauung erfuhr.	8 Mitgliedstaaten haben bereits AGWs für Schweißrauch: AT, BE, DK, FR, LV, LT, NL, SK.	6 Mitgliedstaaten haben bereits allgemeine Staubgrenzwerte: CY, HR, FR, DE, IE, NL. Es war nicht möglich, die geltenden Grenzwerte zu kategorisieren in: CZ, IE oder ES.
Verordnung	Unternehmen	Risiko, dass die Änderung der Politik Verwirrung stiftet und Unternehmensressourcen verschwendet werden, um zu verstehen, was erforderlich ist.	AGW würde sich auf Unternehmen auswirken, die Schweißarbeiten durchführen.	Der allgemeine Staubgrenzwert würde branchenübergreifend für alle Unternehmen gelten, die staubverursachende Tätigkeiten durchführen.
Direkte Nutzen – verbessertes Wohlbefinden - Gesundheit				
Geringere Krebsinzidenz	Arbeitnehmer & Familien	1 618	Nicht quantifiziert	Nicht quantifiziert
Geringere Sterblichkeit	Arbeitnehmer & Familien	1 079	Nicht quantifiziert.	Nicht quantifiziert.
Geringere Morbidität	Arbeitnehmer & Familien	270	Nicht quantifiziert.	Nicht quantifiziert.
Krankheitsfälle vermieden, einschließlich immaterieller Kosten (M1 bis M2)	Arbeitnehmer & Familien	M1: 1 000 Millionen € M2: 510 Millionen €	Nicht quantifiziert, siehe obige qualitative Analyse.	Nicht quantifiziert, siehe obige qualitative Analyse.
Direkte Nutzen – verbessertes Wohlbefinden - Sicherheit				
Vermiedene Kosten	Unternehmen	4,7 Millionen €	Nicht quantifiziert	Nicht quantifiziert
Vermiedene Kosten	Öffentlicher Sektor	16 Millionen €	Nicht quantifiziert	Nicht quantifiziert
Politische Agenda der EU	Alle	Die Verbesserung des Gesundheitsschutzes der Arbeitnehmer ist der wichtigste soziale Nutzen.		

Auswirkungen	Betroffene Stakeholders	Option 2 (Anhang I) Quantitative Bewertung (Gegenwartswert, PV)	Zusätzlich zu Option 2 (Anhang I), nur qualitative Bewertung:	
			AGW (einatembarer und lungengängiger Staub) speziell für Schweißrauch	Unspezifische allgemeine Staubmetrik (einatembar und lungengängig)
Direkte Vorteile - verbessertes Wohlbefinden - Umwelt				
Freisetzungen in die Umwelt	Alle	Nicht quantifiziert	Nicht quantifiziert	Nicht quantifiziert
Direkte Vorteile - Markteffizienz				
Gleiche Ausgangsbedingungen	Unternehmen	Die Sensibilisierung kann zu einer Verbesserung der Wettbewerbsbedingungen zwischen und innerhalb der Mitgliedstaaten führen.	Eindeutigeres Ziel als Option 2. Würde zu gleichen Wettbewerbsbedingungen in der EU-27 beitragen.	Eindeutigeres Ziel als Option 2. Würde zu gleichen Wettbewerbsbedingungen in der EU-27 beitragen.
Indirekte Nutzen				
Vereinfachung der Verwaltung	Unternehmen	Nicht zutreffend	Nicht zutreffend, der AGW würde zusätzlich zu den bestehenden stoffspezifischen AGWs gelten.	Nicht zutreffend, der Staubgrenzwert würde zusätzlich zu den bestehenden stoffspezifischen AGW gelten.
Synergie	Unternehmen			
Soziale Verantwortung der Unternehmen	Unternehmen	Geringe positive Auswirkungen	Geringe positive Auswirkungen	Geringe positive Auswirkungen
Vermiedene Kosten der Festlegung eines AGW (EU-27)	Öffentlicher Sektor	Nicht zutreffend	1,4 - 2,7 Millionen €	1,4 - 2,7 Millionen €
Andere Auswirkungen				
Auswirkungen auf die Grundrechte	Recycling-Unternehmen	Nicht zutreffend. Die Grundsätze der Kreislaufwirtschaft in der EU27 fördern das Recycling, einschließlich des Recyclings von Metallprodukten, was manchmal das Schweißen beinhaltet. Aufgrund des Subsidiaritätsprinzips - die Abfallbewirtschaftung, einschließlich des Recyclings, sollte von den lokalen und regionalen Gebietskörperschaften durchgeführt werden - wird nicht damit gerechnet, dass dies exportiert wird.		

Auswirkungen	**Betroffene Stakeholders**	**Option 2 (Anhang I)** **Quantitative Bewertung** **(Gegenwartswert, PV)**	**Zusätzlich zu Option 2 (Anhang I), nur qualitative Bewertung:**	
			AGW (einatembarer und lungengängiger Staub) speziell für Schweißrauch	**Unspezifische allgemeine Staubmetrik (einatembar und lungengängig)**
Auswirkungen auf die Digitalisierung	Alle	Nicht zutreffend		
Beiträge zu den UN-Zielen für nachhaltige Entwicklung	Unternehmen	Nicht zutreffend		
Auswirkungen auf die Grundrechte	Alle	Geringe positive Auswirkungen auf UN SDG 3: Gesundheit und Wohlbefinden und UN SDG 8: Menschenwürdige Arbeit und Wirtschaftswachstum		

Anmerkungen: Die Summe kann sich aufgrund von Auf- bzw. Abrunden von der Gesamtsumme unterscheiden.

Quelle: Studienteam.

1 INTRODUCTION

This chapter comprises the following sections:

- Section 1.1: Political and legal context;
- Section 1.2: Background; and
- Section 1.3: The study.

1.1 Political and legal context

Welding fumes are Process Generated Substances (PGS) generated during welding processes. The constituents of welding fumes are complex and highly heterogenous. In 2018 welding fumes were classified as carcinogenic to humans (Group 1) by IARC, after an evaluation of their carcinogenicity. However, IARC based their conclusion on welding fumes in general without specifying to which types of welding processes or to which base metals their conclusions would apply (ECHA, 2022). Importantly, despite existing requirements for worker protection, there is still a concern that welders are at high risk from various diseases (including cancers), and therefore ECHA (2022) identified a policy need for more to be done to ensure that the required control measures are in place to minimise worker exposure to welding fumes+.

ECHA (2022) define welding fumes+ as fumes from the following processes which typically involve working with metals or metal compounds at high temperatures for joining, cutting or coating purposes:

- Fusion welding (gas welding, arc welding (MIG, MAG, SMAW, FCAW, SAW, ESW, SW), arc welding (TIG, PAW), beam welding;
- Soldering (soft soldering, hard soldering);
- Brazing (>450°C, Laser beam brazing, Brazing with an electric arc (MIG, TIG, plasma));
- Thermal cutting or gouging;
- Thermal spraying;
- Flame straightening; and
- Additive production processes.

The Commission (COM) is preparing proposals for the amendment of the Carcinogens, Mutagens and Reprotoxic substances Directive (Directive 2004/37/EC), following the 2021 Commission commitment to promote a 'Vision Zero' approach to work-related deaths by undertaking various activities including launching a social partner consultation (this study) on reduced limit values for welding fumes, polycyclic aromatic hydrocarbons, isoprene and 1,4-dioxane under the CMRD in 2023 (EC, 2021). ECHA prepared a scoping study for the Commission to identify the extent, range and nature of the key welding processes and substances involved that lead to the exposure of workers from welding fumes+, to determine the value of setting an occupational exposure limit and to propose different potential policy options.

A consortium led by RPA Ltd was commissioned to undertake a study collecting the most recent information on welding fumes to analyse health, socio-economic and environmental impacts associated with possible amendments of the CMRD. The main purpose of this study is to assess the impacts related to the introduction of welding fumes (containing CMR substances) into Annex I to the CMRD. Substances in welding fumes that meet the criteria for classification as category 1A or 1B carcinogen, mutagen or reproductive (C, M or R or CMR) toxicant are already covered by the CMRD. However, the European Commission has identified a need to provide legal clarity to the situation regarding regulation of welding fumes, and it believes that one way to do this is through an Annex I entry for welding fumes containing CMR substances.

1.1.1 The Carcinogens, Mutagens and Reprotoxic substances Directive

The Carcinogens, Mutagens and Reprotoxic substances Directive (Directive 2004/37/EC), hereinafter referred to as CMRD, protects workers from exposure to carcinogens, mutagens or reprotoxic substances at work.

Article 2 (in paragraph (a)(ii)) of the CMRD defines a 'carcinogen' as:

"*a substance, mixture or process referred to in Annex I to this Directive as well as a substance or mixture released by a process referred to in that Annex*."

Since welding fumes+ are Process Generated Substances, the Commission is considering an entry to Annex I for welding fumes+ that contain carcinogenic, mutagenic or reprotoxic substances as explained below.

Employers have a number of obligations related to CMR substances (category 1A or 1B) present in welding fumes within the scope of the CMRD which include:

- The employer shall reduce the use of the CMR substances (in welding fume) at the place of work by replacing them, in so far as is technically possible, with substances, mixtures or process(es) which, under their conditions of use, are not dangerous or are less dangerous to workers' health or safety, as the case maybe;

- Where it is not technically possible to replace the CMR substances, the employer shall ensure that the substances are, in so far as is technically possible, contained in a closed system;

- Where a closed system is not technically possible, the employer shall ensure that the level of exposure of workers to the CMR[11] substances is reduced to as low a level as is technically possible; and

[11] This only applies to reprotoxins without a threshold value.

- Where it is not technically possible to use or manufacture a threshold reprotoxic substance in a closed system, the employer shall ensure that the risk related to the exposure of workers to that threshold reprotoxic substance is reduced to a minimum.

More detailed European guidance on how to apply the Hierarchy of Controls to welding fumes is included in Table 3-50 in section 3.8.1.

The minimum requirements for protecting workers that are exposed to carcinogens and mutagens are — for some substances — expressed by Occupational Exposure Limit (OELs). For each OEL, Member States (MS) are required to establish a corresponding national limit value (OEL), from which they can only deviate to a lower but not to a higher value. An OEL expresses the concentration for substances within the scope of the CMRD of the relevant substance in the air within the breathing zone of a worker in relation to a specified reference period as set out in Annex III to the CMRD. However, there are no legal proposals to set limit values for welding fumes.

Of importance for the current assessment, in the case of any activity likely to involve a risk of exposure to CMR substances in welding fume that are within the scope of the Directive, the nature, degree and duration of workers' exposure shall be determined in order to make it possible to assess any risk to the workers' health or safety and to lay down the measures to be taken. The assessment shall be renewed regularly and, in any event, when any change occurs in the conditions which may affect workers' exposure to the substances.

In order to determine the degree of exposure, it would typically be necessary to measure the workplace concentrations of CMR substances in welding fumes. However, measurements of workplace concentrations are not specifically linked to the assessment of compliance with an OEL. The assessment shall be renewed regularly, but the CMRD does not require regular monitoring if changes in the conditions which may affect workers' exposure to the substances do not occur.

1.1.2 REACH

The substances in welding fumes+ are process generated, produced during the welding process. There is no requirement for process generated substances to be registered under REACH. According to ECHA (2022) the base metals can be considered to be part of an article whilst the filler materials could be either articles or mixtures (alloys are special mixtures), and although covered by REACH are not subject to REACH registration. Some substances present in welding fumes+ may be registered for other uses, but the tonnage information has not been included in this report because it is not useful to this study. For instance, while it is possible to estimate the total registration tonnage of a substance like nickel, it is not possible to determine how much of this nickel is used for solders since information on specific uses is not provided in registration data.

1.1.2.1 Restrictions

Not applicable to welding fumes.

1.1.2.2 Authorisation

Not applicable to welding fumes.

1.1.2.3 Possible REACH revisions (optional)

Not applicable to welding fumes.

1.1.2.4 Risk management option analysis

Not applicable to welding fumes.

1.1.3 Other relevant legislation

'Welding fumes+' as a group of Process Generated Substances, with highly complex and variable composition, do not have a harmonised classification and labelling for CMR effects under the CLP Regulation (ECHA, 2022). However, some of the constituents of welding fumes+ have a harmonised classification in Annex VI to the CLP Regulation (No 1272/2008) as carcinogenic, mutagenic or reprotoxic 1A or 1B and are therefore in the scope of the CMRD, as defined by Article 2 paragraph a(i).

Some of the metals used in welding+ processes (such as chromium or nickel in steel) may be classified as carcinogenic under the CLP Regulation, and their exposure needs to be controlled under the CMRD. Other metals (such as aluminium and copper) do not have such hazard classifications under the CLP, but exposure needs to be controlled under the Chemical Agents Directive (CAD) (98/24/EC). Employers have requirements, under the hierarchy of controls, to minimise worker exposure (as set out in 1.1.1).

Occupational Safety and Health (OSH) is also covered under the UN Sustainable Development Goal number 8 with the objective "*Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all*" (UN, 2023a). Under this goal, Target 8.8 calls for the protection of labour rights and the promotion of "*safe and secure working environments for all workers, including migrant workers, in particular women migrants, and those in precarious employment"*.

1.1.4 Summary of legal context

Different constituents of welding fumes are classified under the Chemical Agents Directive (CAD) (98/24/EC), Classification, Labelling and Packaging Regulation (CLP) (1272/2008) and CMRD (2004/37/EC), as summarised in Table 1-1. These three pieces of secondary European legislation have been chosen as being most relevant to controlling worker's occupational exposure to the constituents of welding fumes as they are process generated substances rather than intentionally used substances. The CLP is critical in the classification of substances properties that lead to a hazardous classification and ensuring adequate risk management throughout the EU, CAD and CMRD are recognised as being the most pertinent pieces of legislation affecting exposure to chemical agents. REACH was not included here as welding fumes are process-generated substances rather than manufactured or imported substances. REACH includes regulatory obligations that the users of the substances used in welding processes would be required to implement including use of restricted substances (REACH Annex XVII) and those on the authorisation list (REACH Annex XIV).

Table 1-1 below provides an overview of the metals and their compounds which may be present in welding fumes, it is not intended to be a definitive list. Not all metals or metal compounds require exposure control, for example some copper and zinc related compounds are not hazardous agents and do not have binding Biological Limit Values (BLVs). Also note that some metals or metal compounds will be listed in legislation due to being present in combination with other hazardous metals or metal compounds, not necessarily due to their own hazardous properties. For example, iron and zinc are present in several lead alloys and compounds.

Table 1-1 Metals and metal compounds in welding fumes+ and associated secondary (European) legislation.

Metals and metal compounds	CAD[1]	CLP	CMRD
Aluminium and oxides	Exposure must be controlled	Many variations, most do not have CMR properties	Article 2[2]
Antimony (soldering fumes)	Exposure must be controlled	Carc. and Repr. depending upon the compound	
Barium and barium compounds (e.g.BaCO3)	Exposure must be controlled	Carc. Muta. and/or Repr. depending upon the compound	Article 2[2]
Beryllium oxide	Exposure must be controlled	Carc. 1B	Annex III limit values
Cadmium oxide	Exposure must be controlled	Carc. 1B	Annex III limit values
Cobalt and oxides (e.g. CoO, Co2O3)	Exposure must be controlled (see binding BLVs in CAD Annex II)	Carc. and Repr. classification Cat. 1 depending upon compound. Some forms are Muta. Cat. 2	Article 2[2]
Copper and oxide	Exposure must be controlled (see binding BLVs in CAD Annex II)	(Check copper compounds - but formic acid, copper nickel salt might be the most relevant to consider)	Check copper compounds: some have BLVs under Annex IIIa; some are covered by Article 2[2]
Chromium and Chromium (III) compounds	Exposure must be controlled (see binding BLVS in CAD Annex II)	Carc.,1 Muta. 1 and Repr. 1 classifications depending upon compound	Annex IIIa - BLVs
Hexavalent Chromium (Cr(VI)) compounds (e.g.Na2CrO4)	Exposure must be controlled	Carc., 1 Muta. 1 and Repr. 2 classifications depending upon compound	Annex III limit values
Gold (soldering fumes)	See binding BLVs in Annex II		Annex IIIa- BLVs
Indium (soldering fumes)	Exposure must be controlled		Annex IIIa - BLVs
Lead (inorganic) and its compounds (soldering fumes)	Exposure must be controlled, OEL in Annex I, Annex II - Binding BLVs	Carc. and/or Repro. classification depending upon compound.	Annex III limit values and Annex IIIa - BLVs
Magnesium and oxide			
Manganese and oxides (e.g. MnO, Mn3O4)	Consider compounds	Carc. and/or Repro. classification depending upon compound.	Annex IIIa – BLVs for manganese compounds
Nickel and oxides (e.g. NiO)	Exposure must be controlled	Carc. classification	Annex III limit values
Silver (soldering fumes)	See binding BLVs in Annex II		Annex IIIa - BLVs

Metals and metal compounds	CAD[1]	CLP	CMRD
Tin (soldering fumes)	Exposure must be controlled		Annex IIIa - BLVs
Titanium dioxide	Exposure must be controlled	Labelling requirement	
Vanadium and oxides (Vanadium pentoxide)	Exposure must be controlled (see binding BLVs in Annex II)	Carc. depending upon the compound.	Check vanadium compounds, some are Article 2[2]
Zinc and oxide	Exposure must be controlled		Zinc may be captured in the CMRD due to its presence in other compounds

Notes:

Note 1: CAD obligations cover CMR substances (in combination with the CMRD) as well as substances with explosive, oxidising, flammable, toxic, harmful, corrosive, irritant, sensitising properties.

Note 2: "Article 2" means that some compounds are prescribed by the CLP as category 1A or category 1B carcinogens or mutagens or reprotoxins and are therefore covered by article 2 of the CMRD.

Key:

BLVs = Biological Limit Values

Carc. = Carcinogenic

Muta. = Mutagenic

Repr. = Reprotoxic

Sources: ECHA, 2022, Chemical Agents Directive (CAD) (98/24/EC), Classification, Labelling and Packaging Regulation (CLP) (No. 1 272/2008), ECHA classification and labelling online database (https://echa.europa.eu/information-on-chemicals/cl-inventory-database) and CMRD (2004/37/EC)

1.2 Background

1.2.1 Initiatives by the European Commission

The Commission is one of the signatories to the 'EU roadmap on carcinogens' covenant (RoC). Pillar four of the RoC on 'targeting innovation' includes 'challenges' or work programmes including process-generated carcinogens such as welding. An expert seminar on strategies to control PGSs was held in November 2021 (Fransman *et al.*, 2021). A follow up seminar was held in April 2022 to take forward the findings of the first workshop, and to develop a strategy for PGSs (Meima *et al.*, 2023). A simple factsheet on welding has been developed to summarise the cancer risk from welding (EU, 2018a).

The EU roadmap on carcinogens initiative also developed guidance for National Labour Inspectors of welding (see section 3.8.1 'Best Practice').

1.2.2 Opinion of the Committee of Risk Assessment (RAC)

At the time of writing there has not yet been an opinion by RAC on welding fumes, only a scoping study published by ECHA in December 2022.

1.2.3 Scientific Committee on Occupational Exposure Limits (SCOEL)

Not relevant to welding fumes.

1.2.4 Advisory Committee on Safety and Health at Work (ACSH)

The ACSH has in its opinion on priority chemicals for new or revised occupational exposure limit values under EU OSH legislation from 2021 listed welding fumes as a priority carcinogen under the CMRD (immediate priorities) (ACSH, 2021). The ACSH opinion on welding fumes was adopted on 22 September 2023 (ACSH, 2023). The three Interest Groups of the ACSH recognised that the exposure of workers to welding fumes in the European

Union remains a concern. They agreed that this issue should be tackled at the EU level, and agreed the following points concerning the inclusion of welding fumes into Annex I of the CMRD:

- There is a need for an Annex I entry regarding welding fumes;
- There is a need to develop a guidance to specify in more detail what is meant with the Annex I entry;
- Further measures to reduce health effects of exposure to particulates coming from welding fumes or other sources is needed. This includes specifically - but not exclusively - the establishment of a general dust limit under the CAD; and
- All Interests Groups agree that the welding fume entry in annex I should be complemented with a reminder to substance specific BOELVs in annex III. These limit values need to be complied with anyway and most of the relevant hazardous substances for welding processes are already listed there (or are on the way to be listed).

The ACSH strongly recommended the Commission to adopt as soon as possible the below new entry into Annex I under Directive 2004/37/EC:

"*Work involving exposure to fumes from welding processes containing substances that meet the criteria for CMR category 1A/1B set out in Annex I to the CLP regulation*."

The ACSH also strongly recommended developing guidance to provide more detail on the Annex I entry. They suggested that guidance should be prepared over a period of at least 2 years, under the responsibility of the DG EMPL with support from the WPC.

The ACSH encouraged the Commission to clarify within Annex I or in the proposed entry for welding fumes the fact that currently Annex I contains only a list of carcinogenic substances, mixtures and processes and that reprotoxic substances, mixtures and processes need to be included in order to be consistent with the proposed welding fumes entry. They also identified the need to distinguish between the requirements applying to carcinogens versus those for reprotoxicants.

1.3 The study

This report is one of six reports elaborated within the framework of a study undertaken for the European Commission by a consortium comprising (RPA) Risk & Policy Analysts (United Kingdom), RPA Europe Prague (Czech Republic), RPA Europe (Italy), COWI A/S (Denmark), FoBiG Forschungs- und Beratungsinstitut Gefahrstoffe (Germany), Forcetechnology (Denmark) and EPRD Office for Economic Policy and Regional Development (Poland). The six reports are:

- Methodological note;
- Report for 1,4-dioxane;

- Report for isoprene;
- Report for polycyclic aromatic hydrocarbons (PAH);
- Report for welding fumes; and
- Report for cobalt and inorganic cobalt compounds.

One of the key aims of the study is to provide the Commission with the most recent, updated and robust information on a number of substances with the view to support the European Commission in the preparation of an Impact Assessment report to accompany a potential proposal to amend Directive 2004/37/EC.

The specific objective of this report is to assess the impacts of introducing "*work involving exposure to fumes from welding (and similar) processes containing substances that meet the criteria for CMR Category 1A or 1B set out in Annex I to the CLP Regulation*" into Annex I to the CMRD.

Details on the methodology used across all substances are included in the Methodological note. The note also includes an initial screening of potential impacts for all impact categories.

1.3.1 Study objectives

The general objectives with regard to these substances (except for welding fumes) include a detailed assessment of the baseline scenario (past, current, and future), as well as the assessment of the impacts of introducing a new Occupational Exposure Limit (OEL) and, where appropriate, a Short-Term Exposure Limits (STEL) a skin notation and a respiratory notation.

The specific objective of this report is to assess the impacts of introducing "*work involving exposure to fumes from welding (and similar) processes containing substances that meet the criteria for CMR Category 1A or 1B set out in Annex I to the CLP Regulation*" into Annex I to the CMRD. This is 'policy option two (Annex I)' throughout this report, with the existing baseline being policy option one.

A qualitative analysis of future options that could be applied to welding fumes in a future revision of the CMRD has also been undertaken, in response to a request by DG Employment. The future options (complementary to policy option two (Annex I) above) discussed are based on the ECHA scoping study (ECHA, 2022):

- "Setting a generic occupational exposure limit (OEL) for inhalable and respirable dust specific to welding fumes"*; and
- "Setting a non-specific generic dust metric (an inhalable limit and a respirable limit) applicable to all dusts".

*In this study, the study team has taken this to mean an OEL will apply to all welding+ processes.

For clarification, this OEL or dust metric would be applied in addition to existing substance specific OELs.

In this study, the definition of welding fumes+ by ECHA (2022) was used, which comprises fumes from the following processes:

- Fusion welding: gas welding, arc welding (MIG, MAG, SMAW, FCAW, SAW, ESW, SW), arc welding (TIG, PAW), beam welding;
- Soldering: soft soldering, hard soldering;
- Brazing: greater than 450°C, laser beam brazing, brazing with an electric arc (MIG, TIG, plasma);
- Thermal cutting or gouging;
- Thermal spraying;
- Flame straightening; and
- Additive production processes.

1.3.2 Limit values assessed

This report does not include an assessment of proposed limit values since there are no European limit values currently proposed specifically for welding fumes. However, existing national limit values on welding fumes and national and EU limit values on specific substances within welding fumes are discussed.

Throughout this document the term 'Limit Values' is used to refer to the group of measures being proposed. This includes OELs, STELs, BLVs and notations.

OELs are 8-hour time weighted average (TWA) exposures and define a threshold beyond which workers must not be exposed. OELs are set by the European Commission. For each OEL, Member States are required to establish a corresponding national limit value, from which they can only deviate to a lower but not a higher value.

In addition to setting/reviewing OELs, the European Chemicals Agency (ECHA) has also been mandated to adopt, as appropriate, scientific opinions on the establishment of:

- Biological limit values; and
- Notations.

A 'biological limit value' (BLV) is 'the limit of the concentration in the appropriate biological medium of the relevant agent, its metabolite, or an indicator of effect'.

A 'notation' is a means of alerting employers that air sampling alone is insufficient to accurately quantitate exposure and that other measures may need to be taken. For example, a 'skin notation' would indicate that measures need to be taken to prevent significant absorption through the skin.

Furthermore, in cases where adverse health effects are not adequately controlled by compliance with an 8-hour TWA OEL, short-term exposure limit (STEL) values, which are usually based on a 15-minute reference period, can also be established.

1.3.3 Existing limit values at EU level

In terms of existing limit values at EU level, there are currently no limit values specifically for welding fumes. However, nine of the 27 EU Member States (MS) already have OELs for welding fumes or total dust (particulates): Austria, Belgium, France, Denmark, Germany, Ireland, Latvia, Lithuania, The Netherlands, Slovakia, Spain (see section 3.1.1).

At the EU level, OELs exist for substances commonly present in welding fumes, for example the following metals (and oxides): barium, chromium metal and chromium II/III, hexavalent chromium VI (Cr VI), manganese, nickel (Ni) (see section 3.1.2). It is worth noting that depending on the composition of the welding materials, the EU OEL for a non-CMR substance such as manganese may be harder to achieve than an OEL for a CMR substance (Cr VI, Ni, Cd, Co) (see Table 11-17 in Annex 1). Therefore, the presence of manganese may be the driver for introducing RMMs to reduce worker exposure, and, as exposure levels of manganese are controlled, the presence of other substances, including CMRs, substances may also be reduced concurrently. (The hazardous substances which are expected to be present in different welding processes, depending on base and filler materials are listed in Table 2-1.)

Currently no EU BLVs have been established for welding fumes+ at European level, however some Member States (MS) have occupational BLVs or reference values for the general population (not occupationally exposed) for the possible components of welding fumes+. BLVs have been set for the following metal compound in urine: aluminium (3 MS), barium (1 MS), cobalt (5 MS), hexavalent chromium (4 MS), nickel (3 MS).

1.3.4 Future limit values at EU level which impact welding

New OELs for chromium VI and nickel are due to come into force in January 2025 across the EU, after the current transition period. As these OELs will be introduced, they have been considered as part of the baseline of this study. These new tighter OELs could impact upon welding of stainless steel (an alloy) which contains chromium VI and nickel, where extra RMMs may be required to achieve the new OELs. However, as the majority (93% by weight of metal welded) of welding in Europe is joining mild steel (according to the EWA, 2019 & EWA, March 2023, *Pers Comm*) (no alloy or low alloy steel) which either does not contain chromium VI or only contains small quantities of chromium VI or nickel, the new OELs are unlikely to have a big impact on welding.

There is a risk that quantifying the amount of welding based on the weight of metal being welded could distort the assessment of worker exposure. By focusing solely on the weight of metal being welded, rather than the numbers of welders undertaking the activities, this could place too much emphasis on the sectors undertaking large scale welding; for example, where a relatively small number of welders are welding large pieces of metal such as steel beams in the construction sector. In the meantime, the 7% of remaining metals (stainless steel, cast iron, nickel-based metals, aluminium and aluminium alloys) could be worked on by a large number of workers exposed to welding fumes containing a range of CMR substances including chromium VI and nickel. Sometimes simplifications and assumptions are necessary, especially if there is a lack of detail on the total numbers of welders and the number of welders per sector (section 3.4).

Nickel and cobalt are handled in a similar way and the RMMs for each of them are similar (Voestalpine, *pers comm,* April 2023). Therefore, in workplaces where both substances are present, the introduction of RMMs to achieve the OEL for nickel will have the co-benefit of also helping to achieve a future cobalt OEL if one is introduced. Some Member States such as Germany already have national OELs for cobalt (more information provided in the separate impact assessment on cobalt).

Cobalt steel is a specialist material, which is rarely welded in Europe (the EWA estimate that only ~0.1% of welding activities are of cobalt alloys, *pers comm*, April 2023). The DVS also said that cobalt is rarely used in the EU because it is expensive; but note that cobalt alloys are used in welding fumes consumables for hard casing (DVS, *pers comm*, April 2023). Therefore, if an OEL is introduced for cobalt the impact will be limited to the relatively small number of applications and sectors using cobalt steel (this is covered in a separate impact assessment report). Cobalt steel is used for applications (and sectors) specific to its properties (Advanced Refractory Metals, 2023 unless otherwise stated) including:

- High performance magnetic materials, as magnetic steel remains magnetic after a single magnetisation and retains this magnetism up to a high temperature (1150°C);
- Tool steel due to being resistant to wear and good cutting performance;
- Engines and steam turbines as cobalt steel retains its hardness even if heated to 1000°C and is resistant to oxidation without using any protective coating, widely used in the aerospace and modern military sectors; and
- Thermal spraying for surface coating to improve wear and corrosion resistance and hardness for example (*pers comm*, DVS, April 2023).

1.3.5 Existing limit values at national level which impact welding

-Certain MSs have their own national OELs (or tolerable levels) for other metals (and oxides) such as: aluminium, cobalt, copper, iron, magnesium, manganese and vanadium. OELs for individual metals (and oxides) are typically set at the level of µg/m^3, whereas OELs for welding fumes are usually set at the level of mg/m^3, a magnitude greater than for individual components of welding fumes. A national OEL for manganese, which is present in stainless steel (the most commonly welded metal in Europe), can be a driver for companies to introduce RMMs to protect their workers. Austria, Denmark, Germany and Hungary all have their own national OEL for manganese (Table 11-17). Although welding fumes contains hazardous gases, they are excluded from the ECHA definition of welding fumes and have not been considered in this study (see section 1.3.6).

Whilst no EU BLVs have been established for welding fumes+, certain MS have occupational BLVs or reference values for the general population (not occupationally exposed) for the possible components of welding fumes+. BLVs have been set for the following metal compound in urine: aluminium (3 MS), barium (1 MS), cobalt (5 MS), hexavalent chromium (4 MS), nickel (3 MS).

1.3.6 Substances within the scope of the study

Welding fumes are formed when metals (base and/or filler) are heated above their boiling point (vapourised) and their vapours rapidly condense into fine particles (solid particulates or dust) (ECHA, 2022). This particulate matter contains metals and their oxides, including 'spinels' which are complex compounds containing metals, oxygen, silicon and/or fluorine. The focus of this study is on the particulate matter (dust) in welding fumes.

ECHA (2022) proposed that welding gases which are either produced during welding (such as nitrogen oxides, carbon monoxide and ozone) or used as shielding gases during welding (such as argon, helium, nitrogen) should be excluded from the definition of welding fumes. The Commission services decided to follow ECHA's scientific recommendation for the purposes of this study.

The focus of this study is on welding fumes+ that would be covered by the CMRD due to the parent and/or filler material containing a CMR substance as established in Annex VI to the CLP Regulation. Welding fumes+ containing substances that lead to health effects other than CMR would be regulated under the CAD. Table 1-1 above summarises the substances in welding fumes regulated under the CAD, CLP and CMRD.

If in future the decision is made to include "*work involving exposure to fumes from welding (and similar) processes containing substances that meet the criteria for CMR Category 1A or 1B set out in Annex I to the CLP Regulation*" into Annex I to the CMRD, then companies would be able to look at the datasheets accompanying the material and consumables being welded to see which hazardous substances are present. The substances present can be looked up in the ECHA Classification and Labelling database (https://echa.europa.eu/information-on-chemicals/cl-inventory-database). Under the CL Inventory, the substance name is added, then in the discriminator field 'harmonised C&L' is selected and for classification details under 'Health', 'Carc 1A', 'Carc 1B', 'Muta 1A', 'Muta 1B', 'Repr 1A' and 'Repr 1B' must all be ticked, and then the query is run. A summary of CMR (category 1A/1B) substances that are generated from different welding processes, depending upon the base and filler materials are listed in Table 2-1.

For welding filler materials, safety data sheets (SDS) will contain harmonised classifications of substances so can be used to check for the classification 1A or 1B for carcinogenicity, mutagenicity or reproductive effects. However, the threshold for notification of substances that are CMR (category 1A or 1B under the CLP) and present in a mixture for inclusion in SDS is greater than or equal to 0.1% concentration (ECHA, 2020). If a substance is present below this threshold there is no obligation for the producer to list it on the SDS, and the user (welder) will not know it is present, but the situation may arise where such a substance may be picked up in occupational monitoring for a CMR substance with an established OEL.

2 BACKGROUND FOR ANALYSING THE HEALTH IMPACTS

This chapter comprises the following sections:

- Section 2.1: Summary of epidemiological and experimental data;
- Section 2.2: Deriving an Exposure Risk Relationship (carcinogenic effects) and a Dose Response Relationship (non-carcinogenic effects);
- Section 2.3: Groups at extra risk; and
- Section 2.4: Summary of background for analysing health impacts.

2.1 Summary of epidemiological and experimental data

2.1.1 Identity and classification

As noted in section 1.3.6, welding fumes are a mixture of particulate matter (dust) containing metals and their oxides, 'spinels' or complex compounds formed after the fumes are released, and gases (either produced by or used during welding). However, the focus of this study is on the particulate matter (dust) in welding fumes+, and in particular, the components that would be covered by the CMRD due to the parent and/or filler material containing a CMR substance as established in Annex I to the CLP Regulation. Welding fumes+ containing substances that lead to health effects other than CMR would be regulated under the CAD.

As noted above, IARC (2018) reclassified welding fumes from the previous classification as a 'potential human carcinogen' to the current classification of a group I 'human carcinogen'. The IARC scientific review concluded that exposure to mild steel welding fumes can cause lung cancer and possibly kidney cancer in humans.

2.1.1.1 Identity

During welding, metal pieces are fused through coalescence by using heat (energy) and filler material (also containing metals). Welding methods can be classified according to their heat source: gas welding (fuel gas), arc welding (electricity), and beam welding (laser/electron beams). There are other techniques producing fumes like soldering (lower temperature and only the filler melts), thermal cutting, thermal spraying, or flame straightening (ECHA, 2022). These processes are further explained below. In this report welding fumes and fumes from other processes are termed "welding fumes+" in accordance with ECHA (2022).

During the heating process metals vaporise and condense rapidly afterwards into fine particles (particulate matter/fumes). The fumes contain metals, their oxides, and spinals (complex structures of metals). Depending on the base metals, the used filler material, and the heat source the composition of the fumes can vary widely (ECHA, 2022). Next to the particulate matter (welding fumes), gases (molecules in a gaseous state) are present as well and might also play a role in hazard evaluation (ECHA, 2022). It has to be noted that IARC (2018) and AGS (2020) define fumes as particular matter. The ECHA scoping report (2022) mainly refers to the categories of AGS (2020) (see Table 2-1), which are based on application techniques such as thermal spraying. Additionally, the information on heat (energy) sources from an ANSES expert report are considered (ANSES, 2022).

Fusion melting is an umbrella term for welding processes and stands for processes that use sources like gas, electrical arc, laser or plasma for melting the base metal material before joining it. Gas welding combusts gases e.g. oxygen and acetylene to produce high temperature gases with up to 3200°C. The flame can be adjusted depending on the desired reaction (soft, harsh or violent). Arc welding (gas metal arc welding, GMAW) applies an electrical arc that forms between an electrode (consumable or non-consumable) and the base material as heat source to reach temperatures between 3000°C to above 20000°C. At those temperatures metal reacts chemically with oxygen and nitrogen in the air, therefore protective shielding gas or slag is used to reduce the chemical reaction. This technique includes two methods:

- Consumable electrode method: consuming the electrode as filler material (Metal Inert/Active Gas Welding (MIG/MAG); Shielded Metal Arc Welding (SMAW); Flux Cored Arc Welding (FCAW); Submerged Arc Welding (SAW); Electro-Slag Welding (ESW); Arc Stud Welding (SW)) and Metal Active Gas Welding (MAG)); and

- Non-consumable electrode method: leaving the electrode as it is (Tungsten Inert Gas Welding (TIG), Plasma Arc Welding (PAW)).

ECHA (2022) describes MAG as one of the most widely used welding processes. The difference between MIG and MAG lies in the used shielding gas, which is inert in MIG and is used for welding of non-ferrous metals like aluminium. For MAG active shielding gases are used that can react with filler metal, affect the chemistry and/or resulting in specific mechanical properties.

Beam welding uses laser energy to join metals and form a join. This process is used in applications using automation e.g. in the automotive industry. Two different methods are applicable with conduction limited welding (laser power up to 500 watts; metal is heated up to melting point, but not until evaporation) and keyhole welding (high power laser 105W/cm²; plasma-like stages are created with evaporation of the contact surface and penetration deep into the metal). Electron beam (EB) welding is a fusion welding process using an electron beam gun which is highly automated, and computer controlled, since it is a vacuum process.

Another source of fumes is soldering, which is a process that joins two pieces by melted metal filler (solder) material (permanent but reversible connections) and is applied in electronics, metalwork (e.g. musical instruments) and plumbing. The solder material has a lower melting point compared to the base material, which is not melted in contrast to welding. There are three main categories of solders: lead-based solder (60/40 tin/lead ration; melting point app. 180-190°C; increasingly replaced by lead-free solder), lead-free solder (tin whiskery/incorporating SnAgCu alloy as a solder; higher melting point than conventional solder), flux core solder (rosin used in electronics; acid cores used in metal mending and plumbing). Soldering processes are categorised into soft soldering (90°C - 450°C, mostly used with lead free solders in electronic industry), hard (silver) soldering (>450°C, copper-zinc alloys are used containing silver additives), and brazing (>450°C, mainly wire-shaped copper-based alloys are used, restrictions exist for cadmium containing brazing fillers).

Thermal cutting or gouging describes a welding process to cut a shape or remove unwanted metal and has a wide range of use for the repair and maintenance of structures. Cutting processes are also classified according to their sources: flame cutting, arc-air gouging (electric arc cutting), plasma cutting, laser cutting. Depending on the base material exposure to toxic agents can cause problems. Thermal cutting or gouging can produce fumes with a high level of metal vapour, carbon dust as well as metallic by-products. ECHA (2022) describes that the air carbon-arc gouging can produce high fumes levels. Plasma gouging (a variation of plasma cutting) use is softer compared to air carbon-arc gouging and therefore less metal vapour can be expected (ECHA, 2022).

Thermal spraying is a method of surface treatment (improvement or restorage of a surface) to e.g. resistance to wear, erosion, cavitation, corrosion etc. Multiple thermal spray processes exist depending on energy sources (e.g. molten liquid, combustion of gases, kinetic energy, beam and electric discharge). Ideally operations take place automatically in enclosures specially designed to extract fumes (ECHA, 2022).

Flame straightening uses a physical principle of temperature related expansion and construction of metals to create plastic deformations. All metals, which are worked on by welding can also be flame straightened. Consequently, hazardous fumes depend on the base material and the fuel gas applied (e.g. acetylene and oxygen).

The different welding fumes+ processes, process related substances and indication of CMR presence are summarised in Table 2-1.

Table 2-1 Summary of welding fumes+ processes, generated substances and indication of CMR substances adapted from ECHA (2022)

Welding process	Heat source	Generated substances	CMRs (1A/1B)	Presence of the hazardous substances is known/proven, possible or exceptional
Fusion welding	Gas welding	Metal oxides from the base and filler materials, nitrogen oxides	Yes, depending on the base and filler materials	Base and filler materials: mild steel (Fe, Mn), copper alloys (Cu, Ni, Zn), aluminium (fluorides from the flux)
	Arc welding - consumable electrode (filler) (MIG, MAG, SMAW, FCAW, SAW, ESW, SW)	Metal oxides mostly from the filler material, nitrogen oxides, carbon monoxide (MAG), ozone (aluminium alloys)	Yes, depending on the filler material, carbon monoxide (MAG)	Base and filler materials: mild steel (Fe, Mn, fluorides), stainless steel (Fe, Mn, Cr(III), Cr(VI), Ni, Co, V, fluorides), cast iron (Fe, Mn, Cr(VI), Ni), nickel-based alloys (Ni, Cr(VI), Fe), copper alloys (Cu, Ni), aluminium alloys (Al, Mg, Mn, Zn, Cu
	Arc welding - non-consumable electrode (TIG; PAW)	Metal oxides mostly from the filler material, ozone	Yes, depending on the filler material	Base and filler materials: mild steel (Fe, Mn), stainless steel (Fe, Mn, Cr(III), Cr(VI), Ni, Co, V), cast iron (Fe, Mn, Cr(VI), Ni), nickel-based alloys (Ni, Cr(VI), Fe), copper alloys (Cu, Ni), aluminium alloys (Al, Mg, Mn, Zn, Cu), titanium alloys (Ti, Al, V), zirconium alloys (Zr)
	Beam welding	Metal oxides from the base material	Yes, depending on the base material	Base materials: mild steel (Fe, Mn), stainless steel (Fe, Mn, Cr(III), Cr(VI), Ni, Co, V), cast iron (Fe, Mn, Cr(VI), Ni), nickel-based alloys (Ni, Cr(VI), Fe), copper alloys (Cu, Ni), aluminium alloys (Al, Mg, Mn, Zn, Cu), titanium alloys (Ti, Al, V), zirconium alloys (Zr)
Soldering	Soft soldering (90°C- 450°C)	Mainly tin and tin oxides (from filler material), aldehydes (from rosin) and hydrogen chloride, evaporating solvents	No, as long as lead-free due to restriction	Filler materials: mainly tin-based solders (e.g. Sn99Cu1 or Sn95Ag4Cu1) Fluxes: natural resins (e.g. rosin), organic acids (e.g. adipic acid) and chlorides (e.g. zinc chloride or ammonium chloride)

Welding process	Heat source	Generated substances	CMRs (1A/1B)	Presence of the hazardous substances is known/proven, possible or exceptional
		(isopropanol) from fluxes.		
	Hard (silver) soldering	Copper oxide, zinc oxide, silver oxide, chlorides and fluorides (hydrogen chloride and hydrogen fluoride)	No	Filler materials: brazing solders made of copper-zinc alloys with additives of silver
	Brazing	Copper oxide Exceptionally cadmium oxide	No, with specific exceptions	Filler materials: copper-based alloys (e.g. CuSi3, CuAl8 or CuSn6) Exceptionally in defence and aerospace applications and when used for safety reasons (brazing fillers with cadmium)
Thermal cutting or gouging		Metal oxides from the base material, nitrogen oxides, ozone	Yes, depending on base materials (e.g. Cr(VI) and Ni)	Base materials: mild steel (Fe, Mn), stainless steel (Fe, Mn, Cr(III), Cr(VI), Ni, Co, V), cast iron (Fe, Mn, Cr(VI), Ni), nickel-based alloys (Ni, Cr(VI), Fe), copper alloys (Cu, Ni), aluminium alloys (Al, Mg, Mn, Zn, Cu), titanium alloys (Ti, Al, V), zirconium alloys (Zr)
Thermal spraying		Metal oxides from the spray additive, nitrogen oxides	Yes, depending on the spray additives (e.g. Cr(VI), Ni, Co)	Spray additives: boron, cobalt, molybdenum, nickel, chromium, silicon, plastics, copper, carbides (WC-12Co, WC-27NiCr, WC-14CoCr, WC/Ti-C-17-Ni, Cr3C2-25NiCr etc.), steel, aluminium, zinc, bronze (Cu, Sn), tin, Monel (Ni, Cu, Fe), oxide ceramics (Al2O3, Cr2O3, TiO2, Y2O3, ZrO2), tantalum
Flame straightening		Nitrogen oxides	No	Nitrogen oxides occur
Additive production processes		Metal powders	No, the substrates do not contain carcinogenic substances. Carcinogenic substances can be formed in the closed installation space (e.g. nickel oxide).	Metal powders, especially iron, titanium, nickel, chromium and aluminium alloys

Source: ECHA, 2022.

Note: Metals: Aluminium (Al), Cadmium (Cd), Cobalt (Co), Trivalent Chromium (Cr (III)), Hexavalent Chromium (Cr (VI)), Copper (Cu), Iron (Fe), Magnesium (Mg), Manganese (Mn), Nickel (Ni), Titanium (Ti), Vanadium (V), Zinc (Zn), Zirconium alloys (Zr).

Welding process/heat source: Metal Inert/Active Gas Welding (MIG/MAG), Shielded Metal Arc Welding (SMAW), Flux Cored Arc Welding (FCAW); Submerged Arc Welding (SAW), Electro-Slag Welding (ESW), Arc Stud Welding (SW) and Metal Active Gas Welding (MAG), Tungsten Inert Gas Welding (TIG), Plasma Arc Welding (PAW).

2.1.1.2 Classification

There is no harmonised classification or labelling for carcinogenic or other hazards under the CLP Regulation (Regulation (EC) 1272/2008) for welding fumes+ as a whole. However, single metals present in welding fumes+ have an existing EU harmonised classification and labelling. This includes the metal compounds beryllium oxide, Chromium VI compounds and nickel compounds. For carcinogenic metals and its compounds, including Chromium VI compounds, nickel compounds, cadmium with its inorganic compounds, beryllium with it inorganic compounds, the Carcinogens, Mutagens or Reprotoxic Directive (CMRD, Directive 2004/37/EC) provides Binding Occupational Exposure Level (BOEL) (ECHA, 2022). Although gases are out of scope of this assessment, carbon monoxide, which also occurs during welding is regulated by the CMRD.

Other substances including aluminium, and copper are monitored under the Chemical Agents Directive (CAD, Directive 98/24/EC).

It has to be noted that IARC (2018) based its risk assessment on human and animal studies with exposure to (stainless) steel welding fumes. Human data on solder workers were not included in the evaluation from IARC (2018) (ECHA, 2022).

2.1.2 General toxicity profile, critical endpoints and mode of action

The nature of the health effects after welding fumes+ inhalation depends on the used base material, filling material and the applied process. Several short-term (acute) and long-term (chronic) effects are described for the respiratory tract, but also other organ systems are targeted (see section 2.1.5) (ECHA, 2022). IARC (2018) classified welding fumes as carcinogenic to humans Group 1 (see section 0).

An overview of hazardous substances arising during welding work according to their harmful effect on health is shown in Table 2-2 (adapted from the German Technical Rules for Hazardous Substances, TRGS 528 (AGS, 2020)). An overview of the main carcinogenic compounds identified in welding fumes is shown in Table 2-3(adapted from Health reference values - Work involving exposure to welding fumes to be included in the list of carcinogenic substances, mixtures and processes (ANSES, 2022)).

Table 2-2 Overview of hazardous substances arising during welding work according to their harmful effect on health adopted from AGS (2021).

Hazardous substance	**Effect**			
Particular matter	**Respiratory tract effecting**[1)]	**Toxic**[2)]	**Carcinogenic**	**Reproductive toxic**
Aluminium oxide	X			
Iron oxides e.g. Fe_3O_4	X			
Magnesium oxide	X			
Barium compounds (e.g. $BaCO_3$)		X		
Lead (II) oxide		X		X[5)]
Fluorides		X		
Copper oxide		X		
Manganese oxides		X		
Molybdenum (VI) oxide		X	X[4)]	

Hazardous substance	Effect			
Particular matter	**Respiratory tract effecting[1)]**	**Toxic[2)]**	**Carcinogenic**	**Reproductive toxic**
Vanadium pentoxide		X		
Chromium (III) compounds		X		
Zinc oxide		X		
Titanium dioxide	X			
Chromium(VI) compounds		X	X[3)]	
Nickel oxides		X	X[3)]	
Cobalt metal			X[6)]	
Cobalt oxide		X	X[7)]	
Cadmium oxide		X	X[3)]	
Beryllium oxide		X	X[3)]	

Source: AGS, 2021.

1) Respiratory and pulmonary stress in this situation is defined as chronic inflammation (chronic bronchitis) due to particle overload e.g. chronic obstructive pulmonary disease (COPD). These substances are regulated via general dust limit values in Germany.

2) Toxic covers acute or chronic toxic effects described in the literature and usually includes a classification according to the CLP Regulation. These hazardous substances are not sufficiently covered by the general dust limit value (A fraction), which are limited to respirable and inhalable substances.

3) Classified according to the CLP Regulation in hazard class Carcinogenic, categories 1A or 1B.

4) Classified under the CLP Regulation in hazard class Carcinogenic, category 2.

5) Classified under the CLP Regulation as having the hazard class Reproductive toxicity, category 1A.

6) Classified according to TRGS 905 (AGS, 2010) as carcinogenic, category 1B.

7) Classified according to TRGS 905 (AGS, 2010) as carcinogenic, category 2.

Table 2-3 Overview of main carcinogenic compounds identified in welding fumes adapted from (ANSES, 2022)

Compounds	Classification according to the CLP Regulation
Arsenic and its oxides	Arsenic trioxide and arsenic pentoxide: category 1A carcinogens
Beryllium and its oxides	Category 1B carcinogen
Cadmium and its oxides	Non-pyrophoric cadmium and its oxides: Carcinogen category 1B
Chromium VI compounds	Chromium trioxide: category 1A carcinogen Chromium VI compounds: category 1B carcinogens
Formaldehyde	Category 1B carcinogen
Nickel and nickel oxides	Nickel: category 2 carcinogen

Compounds	Classification according to the CLP Regulation
	Nickel oxides: category 1A carcinogens
Iron oxides	No carcinogenicity classification at the date of the expert appraisal
Silica dust or crystalline silica including quartz and cristobalite	No harmonized carcinogenicity classification; Work involving exposure to work involving exposure to respirable crystalline silica dust resulting from work processes are processes classified as carcinogenic according to Directive (EU) 2017/2398
Inorganic lead compounds	Some lead compounds are classified as carcinogens. For example: lead hydrogen arsenate: C1A; lead sulfochromate yellow: C1B; chromate, molybdate and lead sulphate red: C1B; lead chromate C1B
Vanadium pentoxide	Classified by ECHA's RAC as a category 1B carcinogen under CLP in September 2020

Source: ANSES, 2022.

In addition to whether hazardous substances are present, it is important to note that emission rates vary depending upon the welding process being used (Table 2-4). The The Vereinigung der Metall Berufsgenossenschaften (VBMG) have classified these emission classes according health hazard classes (I low health hazard to IV high health hazard) for health effects on the respiratory tract and lung; toxic or toxic irritating substances; and of particular interest to this study - presence of carcinogenic substances (discussed in section 3.6.1).

Table 2-4 Assessment of the processes based on emission rates. Allocation to emission groups adopted from AGS (2020).

Procedures	Emission rate (milligrammes per second)	Emission group
Submerged arc welding	< 1	Low
Gas welding (Oxyacetylene process)	< 1	Low
TIG	< 1	Low
Laser welding without filler metal	1 to 2	Medium
MIG/MAG (low-energy gas-shielded welding)	1 to 4	Medium to high
Laser welding with filler metal	2 to 5	High
MIG (solid wire, nickel, nickel-based alloys)	2 to 6	High
MIG (aluminium materials)	0.8 to 29	Low to very high
MAG (solid wire)	2 to 12	High
LBH	2 to 22	High
MAG (flux-cored welding with shielding gas)	6 to > 25	High to very high
MAG (flux-cored welding without shielding gas)	> 25	Very high
Soft soldering	< 1	Low

Procedures	Emission rate (milligrammes per second)	Emission group
Brazing	1 to 4	Medium to high
MIG brazing	1 to 9	Medium to high
Laser cutting	9 to 25	High to very high
Autogenous flame cutting	> 25	Very high
Plasma cutting	> 25	Very high
Arc spraying	> 25	Very high
Flame spraying	> 25	Very high

Source: AGS, 2020 (TRGS, 528).

The below carcinogenic and non carcinogenic endpoints of exposure to welding fumes (Table 2-5) have been discussed in the rest of section 2.1.

Table 2-5 Relevant carcinogenic and non carcinogenic endpoints of welding fumes exposure.-

Endpoint	Assessment
Lung cancer	Considered for tentative risk estimate
Kidney cancer (weak evidence)	Discussed qualitatively
Acute respiratory tract toxicity (including airway irritation and metal fumes fever), increased risk for acute pneumonia	Discussed qualitatively
Chronic respiratory tract toxicity: occupational asthma, chronic bronchitis, siderosis	Discussed qualitatively

Source: Study team list.

2.1.3 Cancer endpoints – toxicological and epidemiological key studies (existing assessments)

In 2018 the WHO International Agency for the Research on Cancer (IARC) assessed the potential carcinogenicity of exposures at welding workplaces. IARC (2018) concluded that welding fumes are carcinogenic to humans (sufficient evidence in humans, Group 1). The highest weight of evidence exists for lung cancer. However, other cancer types including cancer of the brain cancer, head and neck cancer, haematopoietic cancer, kidney cancer, mesothelioma, urinary bladder, ocular melanoma and other sites were identified as well. But due to limitations of the available data the weight of evidence is weaker for those locations. Table 2-6 provides a summary of cancer endpoints from toxicological and epidemiological key studies.

In the evaluated epidemiological studies evaluated by IARC (2018) identification of exposed workers mainly occurred based on job descriptions (as welders). It is not possible to clearly differentiate between various welding techniques as explained in section 2.1.1). It can be assumed that the majority of workers included were steel welders.

It is difficult to link the cancer risk to a specific group of welders reading the reviewed cohort and case-control studies. During lifetime welders most probably work with different welding processes. Cohort studies included works from different industry types and welding material and processes such as shipyard, MS or SS welders. Mortality analysis of a big international cohort study showed increased standardized mortality ratio (SMR) for lung cancer in MS welders, ever SS welders and predominantly SS welders. For lung cancer it has been indicated that exposure duration (employment as welder) is a critical factor especially for MS and SS welders.

No dose-response relationship for ever SS welders and predominantly SS welders was determined.

Animal studies focused on the exposure with gas metal arc - stainless steel (GMA-SS), manual metal arc – stainless steel (MMA-SS) or gas metal arc - gas metal arc – mild steel (GMA-MS), no other methods like flux core arc welding were included.

In the following Table 2-6 the evidence per tumour localisation as described by IARC (2018) is summarised.

Table 2-6 Summary of cancer endpoints of welding fumes exposure.

Endpoint	Increased risk identified	Cohort/ case- control studies	Limitations
Lung cancer	Yes	Cohort studies (>20) Case-control studies (>20)	Confounders like smoking and asbestos were partly excluded from the studies.
Kidney cancer	Weak evidence	Cohort studies (6) Case-control studies (8)	Lack of statistical significance, confounding factors cannot be excluded.
Bladder cancer	Inconclusive	Cohort studies (>10) Case-control studies (>18)	Confounders can not be excluded.
Leukaemia	Inconclusive	Cohort studies (limited number) Case-control studies (limited number)	Confounding factors such as benzene or radiation exposure.
Non-Hodgkin lymphomas (NHL)	Inconclusive	Cohort studies (not reported) Case-control studies (limited number)	Limited availability of data. Therefore, no evaluation possible at the moment.
Brain cancer	Weak evidence	Cohort studies (several) Case-control studies (2) Large international study	Insufficient study quality, confounded by ionizing radiation.
Head and neck cancer	Inconclusive	Case-control studies (12)	Low incidence and confounding factors such as smoking and alcohol drinking.
Ocular melanoma	Yes*	-	Dichotomous variables are present, and the welding processes are not described.
Mesothelioma	Yes**	-	-
Other cancer: -Gastrointestinal -Prostate -Testis -Offspring***	Inconclusive	-	No conclusion can be drawn.

Source: IARC, 2018
*Notes: * Increased risk associated with UV light exposure rather than a substance in the welding fumes; ** Asbestos was the likely causative agent; ***Prenatal exposure*

2.1.3.1 Lung cancer

The majority of cohort (> 20) and case-control (> 20) studies showed an increased risk of lung cancer associated with an occupation as welder (especially for arc and gas welding). Lung cancer is numerically the best occupied and robust cancer type studied in welders. Several exposure-effect relationships (e.g. duration of employment, intensity, probability and/or frequency of exposure) were evaluated. Associations between employment time (risk increase due to cumulative exposure and duration), dose-effect relationship, and lung cancer were identified. Although confounders namely smoking and asbestos were partly not excluded in the studies, they cannot explain the high number of lung cancer cases in welders, according to IARC (2018). The increased risk of lung cancer was independent of the welding method and material (IARC, 2018).

2.1.3.2 Kidney cancer

IARC (2018) screened over 35 cohort studies (industrial and population-based). All 6 studies that investigated the relationship between welding (including shipyard welders using electrical and arc gas welding, boiler welders, stainless steel (SS) welders, and blue-collar welders) and kidney cancer showed a significantly elevated risk ranging from 1.2 to 3.8. However, in none of the studies confounder effects can be excluded.

Out of 8 evaluated case-control studies five showed odds ratios (OR) from 1.10 to 1.76 (not statistically significant) for kidney cancer and occupational welding fumes exposure. However, also here confounders cannot be excluded. Moreover, one cited case-control study reported an odds ratio of 0.8 (95%CI, 0.5-1.3) for arc welding and gas welding fumes exposure. However, the limitation of this study lies in the small size as well as in the control group (using other cancer types).

Taken together, in the majority of IARC (2018) reviewed studies, elevated risks were reported. Nevertheless, the evidence is limited due to the lack of statistical significance and confounders factors that cannot be excluded (IARC, 2018).

2.1.3.3 Bladder cancer

Multiple cohort (>10) and case-control studies (>18) were reviewed by IARC (2018). The risk estimates ranged widely from <0.6 to >2 in the cohort studies. Furthermore, in the cohort studies confounding factors such as smoking cannot be excluded. There is a relatively large number of case-control studies available. However, most of these studies indicated no increased risk (relative risk close to unity). IARC (2018) also cited a meta-analysis (Reulen et al., 2008) which analysed numerous cohort and case-control studies which were available via EMBASE and Medline until May 2008. The meta estimate for the case-control studies was 1.04 (95% CI, 0.88-1.23). Taken together, the collected information does not allow for a clear conclusion.

2.1.3.4 Leukaemia

For the evaluation of the leukaemia (multiple forms) risk after welding fumes exposure only limited information from cohort and case-control studies is available. Studies, which showed statistical significance could not exclude other risk factors like benzene or radiation exposure (IARC, 2018).

2.1.3.5 Non-Hodgkin lymphomas (NHL)

The difficulty for the assessment of the estimate risk between NHL and welding fumes lies among other things in the altered NHL classification over the past 20 years. A few case-control studies provide evidence for an increased risk of welding fumes exposure and NHL subtype of diffuse B-cell lymphoma. In summary, an increased risk for specific NHL subtypes and welding fumes exposure might exist, however due to limited availability of data this cannot be evaluated at the moment (IARC, 2018).

2.1.3.6 Brain cancer

Several cohort and case-control studies exist, which describe the relationship between welding fumes exposure and the diagnosis of brain cancer. Overall, the case-control studies indicate a rather small elevated risk and the results of the cohort studies are inconsistent or have a weak informative power due to quality deficiencies (IARC, 2018).

There are two case-control studies (small study (9 case reports) and large international study (94 cases)) indicating a positive association between welders (women and men) and the occurrence of meningiomas (IARC, 2018).

2.1.3.7 Head and neck cancer

No increased risk for the presence of sinonasal cancer was detected in welders in a pooled analysis of 12 case-control studies (IARC, 2018).

Due to low incidence of head and neck cancer and the presence of confounder factors such as smoking and alcohol drinking in the available data does not allow a proper assessment (IARC, 2018).

2.1.3.8 Ocular melanoma

The risk of developing ocular melanoma is associated with the acute overexposure of the eye to UV radiation emerging from electrical arc welding (i.e. the carcinogenic effect is expected to be caused by the UV light exposure rather than a substance in the welding fumes (IARC, 2018). IARC (2018) discussed in their assessment that the evidence is mainly based on case control studies in which dichotomous exposure variables are present and the exact welding processes performed are not described.

2.1.3.9 Mesothelioma

Investigations that evaluated the risk of mesothelioma in welders indicated asbestos to be the likely causative agent (IARC, 2018).

2.1.3.10 Other sites

For cancer of the gastrointestinal tract (pancreas, colorectum, stomach, oesophagus), prostate, testis and cancer in offspring due to parental exposure no conclusion can be drawn (IARC, 2018).

2.1.3.11 Animal studies

IARC (2018) reported that for their assessment of welding fumes no long-term inhalation exposure animal studies were available. Different short-term experiments were conducted with gas metal arc - stainless steel (GMA-SS), manual metal arc – stainless steel (MMA-SS) or gas metal arc - gas metal arc – mild steel (GMA-MS) via inhalation in mice, oropharyngeal aspiration in mice, intratracheal installation in hamster, or intratracheal installation in mice showing either no effect or are inconclusive. There were two inhalation studies in mice, which indicated a tumour-promoting effect of GMA-SS after lung tumour initiation with 3-methylcholanthrene.

2.1.3.12 Evaluations questioning IARC's conclusions

In 2019, the US National Shipbuilding Research Program (NSRP) published an evaluation of the IARC report (NSRP, 2019). The report discusses consequences for the US shipyard welding situation and found it difficult to assess the consequences for the US situation, as IARC did not propose occupational exposure limits and as international studies were included which may not be representative for the US situation. The only major methodological critique focussed on the difficulties to separate exposure from welding from confounding variables such as smoking, asbestos exposure and other factors.

The consultancy Ramboll on behalf of the American Welding Society also reviewed IARC's evaluation (Ramboll, 2020). They concluded that the evidence for an association between welding and lung cancer "remains inconsistent" and that confounding by smoking, asbestos exposure and other variables could not be completely excluded even in the studies of highest quality. Exposure assessment (or the lack of detailed and individual exposure levels) was considered a major limitation. The authors recommend updating hazard communication to better inform workers of IARC's classification, improve the documentation of exposure to welding fumes and to identify areas where exposure control could be improved.

IARC (2018) in their assessment of the evidence carefully evaluated the role of confounders. Furthermore, these confounders were taken into account in recent meta-analyses by Honaryar et al. (2019) and Loomis et al. (2022), who nevertheless concluded that occupational welding is associated with an increased risk of lung cancer.

2.1.3.13 New epidemiological evidence not included in IARC's evaluation

In a case-control study Parent et al. (2017) investigated the relationship between exposure to metals and welding fumes and brain cancer (**glioma**). The analysis included 1800 glioma patients from seven countries and more than 5000 controls. No evidence for an association between welding fumes exposure and an elevated risk for glioma was found.

Michalek et al. (2019a) evaluated the relationship between exposure to metals, welding fumes and other occupational exposures and the risk for kidney cancer. Close to 60,000 kidney cancer cases from Nordic European countries and 300,000 controls were compared. In general, no association with occupational exposures were found. Only in certain age groups with high exposure significant increases were found (age group 59-74, high exposure to welding fumes: odds ratio (OR) 1.43, 95% CI 1.09-1.89).

The same group published results from a large cohort study in European Nordic countries, which evaluated a possible association of tumours of the renal pelvis and occupational exposures (Michalek et al., 2019b). Information on occupation for the 1.59 Mio individuals included came from national censuses. For welders, a standardized incidence ratio (SIR) of 1.37 (95% CI 1.03-1.78) was found.

In a small case-control study in Hong Kong (352 cases, 410 controls) a high risk was found for the association between exposure to welding fumes and nasopharyngeal carcinoma (OR adjusted for confounders 9.18 (95% CI 1.05 – 80.35, based on 7 cases). Other occupational exposures with significant associations were cotton dust, chemical fumes and disinfectants (Xie et al., 2017).

Using a newly developed exposure matrix Pesch et al. (2019) analysed 3418 lung cancer cases and 3488 controls from two German case-control studies. The authors adjusted for confounders and other exposure variables. Highly exposed welders had an OR for lung cancer of 1.55 (95%

CI 1.17-2.05). ORs for exposure to Cr(VI) and nickel compounds were also significantly increased (independent risk factors for lung cancer).

Chung et al. (2021) performed a cohort study with 6326 workers of a shipyard in Korea. Workers were examined radiologically (lung tumour screening) (diagnosed between 2010 and 2018). Male shipyard workers with high welding exposure had significantly more often radiological findings of category 3 (likelihood of malignancy >1%) or higher (hazard ratio 1.7). However, asbestos exposure as a confounder cannot be ruled out.

2.1.3.14 Recent meta-analyses

Honaryar et al. (2019) performed a meta-analysis of epidemiological studies (case-control and cohort studies) on the association of welding and **lung cancer**. In a literature search they identified 45 studies which qualified for inclusion (reduced to 37 after eliminating overlapping studies). These studies included > 16 Mio participants from cohort studies and 137 624 cases and 364 555 controls from case-control studies. The authors obtained the following results for individuals classified as welders or being exposed to welding fumes (mRR: meta relative risks, CI: confidence interval):

- Cohort studies (n=22): mRR 1.29 (95%CI 1.2-1.39);
- Case-control studies (n=15): mRR 1.87(95% CI 1.53-2.29);
- With an overall mRR of 1.43 (95% CI 1.31-1.55); and
- Case-control studies adjusted for smoking and asbestos exposure (n=8): mRR 1.17 (95% CI 1.04-1.38).

Slightly higher risks were obtained for mild steel versus stainless steel workers and gas welders versus arc welders. Risks increased with increasing duration of employment. The authors saw the statistically significantly elevated lung cancer risks as confirmation of the conclusions drawn by IARC (2018).

Based on a detailed study protocol for systematic review and meta-analysis (Pega et al., 2020) a recently published meta-analysis of Loomis et al. (2022) included 40 analytical epidemiological occupational studies (29 case-control and 11 cohort studies) with publication dates from 1954 to 2017. The systematic review focussed on studies with occupational exposure. These studies included more than 1.2 Mio participants in 21 countries. Inclusion criteria for participants in the individual studies varied but most considered workers with the job title of "welder", with a minimum occupation duration (e.g. one year).

Loomis et al. (2022) considered tumours of the **lung**, **trachea** and **bronchus**. Adjustment to confounders such as smoking and co-exposures were carefully evaluated for each study. Based on the pooled evidence from 23 studies with 57931 participants a significant relative incidence risk (RIR) of 1.48 (increase of risk to contract trachea, bronchus or lung cancer by 48%) was determined. The respective mortality relative risk (RMR) based on the findings of only three studies was lower (1.27) but still significant. No differences by region or sex were found. The authors consider the available evidence for an increased incidence of cancer of the lung, trachea and bronchus as "sufficient" among the exposed workers ("limited evidence" for dying from these cancers).

2.1.4 Genotoxicity

IARC (2018) concluded that there is moderate evidence for genotoxic effects of welding fumes. Observations (chromosomal aberration and sister-chromatid exchange rates in lymphocytes) in humans are contradictory. Micronucleus formation in lymphocytes and exfoliated cells after welding fumes exposure show methodological weaknesses. DNA damage measurements showed positive results (increase in 8-hydroxy-2'-deoxyguanosine (8-OHdG) in blood plasma and urine after welding exposure. 8-OHdG serves as surrogate maker for DNA damages associated with oxidative stress. Oxidative stress itself is also a described effect after welding fumes exposure. The DNA damage findings are supported by studies performed in rats and bacteria (IARC, 2018).

Additional potential modes of action are induction of inflammation, immunosuppression, cell proliferation, apoptosis, nutrition supply and receptor-mediated effects. Respective observations were made after exposure to SS or MS welding fumes (based on human and experimental animal information) (IARC, 2018).

2.1.5 Non-cancer endpoints – toxicological and epidemiological key studies (existing assessments)

The main non-cancer endpoints for welders exposed to welding fumes+ during their occupational career are acute (short-term) or chronic (long-term) effects in the respiratory tract. A summary of non-cancer endpoints from toxicological and epidemiological key studies is provided below (Table 2-7).

Table 2-7 Summary of non-cancer endpoints of welding fumes exposure.

Endpoint	Presumed causative agent	Effects/symptoms	Limitations	Sources
Acute respiratory effects	Ozone, NOx, particles Metal oxides Immune suppressive components of welding fumes	Irritation to throat and larger airways Metal fumes fever Acute pneumonia	-	ECHA, 2022
Occupational asthma	Chromium VI, cobalt or nickel in welding fumes	Asthma	Weak evidence of components other than nickel sulphate	ECHA, 2018a ECHA, 2022
Chronic bronchitis	Welding fumes in general	Cough, mucus in bronchiolar airways	Confounding by smoking	Antonini (2003) IARC (2018)
Lung function changes and COPD	Welding fumes in general	Constricted airways and inflammatory reactions	Weak evidence	ECHA (2022) Antonini, 2003
Welder's lung (siderosis)	Metal particles in welding fumes	Benign pneumoconiosis	No clear correlation with decreased lung function	ECHA (2022) Antonini, 2003
Other effects	Manganese Cadmium Nickel, cadmium, manganese, CO	Neurological disorders Nephrotoxicity Reprotoxic effects	Results are partly inconclusive.	IARC (2018) ECHA (2022)

Source: Study team list.

2.1.5.1 Acute effects

Acute respiratory health effects include irritation to the throat and larger airways in the lungs, acute irritation-induced asthma, metal fumes fever, and acute pneumonia (ECHA, 2022). Acute irritation to the throat and larger airways in the lungs is thought to be mainly caused by gases (ozone or nitrous oxides) and fine particles in the welding fumes+. For oxyacetylene welding some cases of toxic pulmonary oedema have been described (ECHA, 2022). Acute irritation-induced asthma (previously also known as reactive airways dysfunction syndrome (RADS)) is rather unlikely since high concentrations of irritants are necessary. Metal fumes fever symptoms are associated with welding or hot work on galvanised metals, mainly linked to the inhalation of zinc oxide fumes but also other metal oxides like copper or mild steel weld (ECHA, 2022). Welders show a higher risk to develop acute pneumonia (pneumococcal pneumonia). The higher risk for infections is suspected to be related with an immunosuppressive effect of welding fumes+. It has been estimated that two welders per year die due to acute pneumonia. Further, acute health effects which may result from exposure to welding gases are headache, dizziness, nausea (association with carbon monoxide) and asphyxiation (from high exposure to shielding gases) (ECHA, 2022).

2.1.5.2 Chronic effects

The following effects are associated with long-term exposure to welding fumes.

2.1.5.3 Occupational asthma

Occupational asthma (including sensitisation reactions) can be caused by Cr(VI), nickel compounds and cobalt containing welding fumes e.g. stainless steel welding or MMA. Occupational asthma due to nickel is rare and to date only established for nickel sulphate (ECHA, 2018a). For Cr(VI) epidemiological data are missing for a proper assessment. High level short-term or low level long-term exposure may play a role (ECHA, 2022).

2.1.5.4 Bronchitis

According to Antonini (2003) and IARC (2018) chronic bronchitis (airway inflammation) is a frequently observed health condition among welders. Symptoms are cough and mucus on the epithelial lining of the bronchiolar airways. Bronchitis is also caused by smoking (smoking is therefore an important confounder), however, increased rates of bronchitis were also reported among non-smoking welders (Antonini, 2003).

2.1.5.5 Lung function changes and COPD

ECHA (2022) discusses chronic obstructive pulmonary disease (COPD) as a possible consequence of exposure to welding fumes. However, the evidence is considered weak. It is characterised by constricted airways and inflammatory reactions, leading to reduced lung function. However, clear deterioration of lung function was not consistently observed among welders but only in smaller groups of heavily exposed welders (Antonini, 2003).

2.1.5.6 Welder's lung (siderosis)

ECHA (2022) describes respiratory toxicity caused by welding fumes as occupational asthma, chronic obstructive pulmonary disease (COPD), and a condition called "welder's lung". Welder's lung (also known as siderosis) is a Fe-particle induced benign pneumoconiosis, which is unlikely to proceed to interstitial fibrosis. It is characterised by deposition of metal particles in the lung, with no clear correlation to a decrease in lung function (Antonini, 2003). Only in single cases steel welding over a long period of time and high exposure was related to lung fibrosis. Similar effects have been described for aluminium exposure (ECHA, 2022).

2.1.5.7 Other effects

In addition to the respiratory effects described above, IARC (2018) links welding fumes exposure to neurological disorders, possibly caused by manganese (for example manganism which has similar symptoms to Parkinson's disease), and to nephrotoxicity (tubular dysfunction), due to the presence of cadmium in welding fumes. IARC (2018) further mentions an increased risk for cardiovascular disease among welders.

According to ECHA (2022) reprotoxic effects are described in several epidemiological studies. Mechanistically, a decrease of testosterone levels is linked to sperm parameters including decreased motility and number of spermatozoids. Suspected welding fumes+ metals are nickel, cadmium, manganese, and the gas carbon monoxide. However, the results are inconclusive (ECHA, 2022).

2.1.6 Biological monitoring – toxicological and epidemiological key studies (existing assessments)

There are no biomonitoring methods to assess exposure towards particulate matter such as welding fumes. However, biomonitoring methods are established for individual components such as nickel and chromium (RAC, 2018) (Finnish occupational hygienist, *pers comm*, May 2023). This is useful for measuring employee exposure to stainless steel welding fumes, but not for unalloyed steel welding fumes since biomonitoring of manganese is problematic and may only be useful at a group level analysis of exposure (Finnish occupational hygienist, *pers comm*, May 2023).

2.2 Deriving an Exposure Risk Relationship (carcinogenic effects) and a Dose Response Relationship (non-carcinogenic effects)

2.2.1 Starting point

In contrast to the other substances under discussion in this project, no RAC opinion on setting an occupational exposure limit (OEL) is available for welding fumes and setting of an OEL is not included in the policy options under discussion. ECHA's scoping report on welding fumes discusses the options for putting welding fumes and similar process-generated mixtures, summarised as welding fumes+, in Annex 1 of the CMRD and the scope of such an activity (ECHA, 2022). Analysing the consequences of setting an OEL at various exposure levels is not in the scope of this project and is not considered in the policy options for welding fumes+. Consequently, developing Exposure Risk Relationship (ERRs) and Dose Responsible Relationships (DRRs) is not intended here and would face serious problems, due to the lack of reliable exposure-effect data. Instead, it is attempted to provide an indication of the size of the health problems by characterising the cancer risks from welding fumes under exposure conditions of the previous years.

2.2.2 Tentative cancer risk estimate

2.2.2.1 Approach

Despite the carcinogenicity confirmed by IARC (2018), developing an Exposure Risk Relationship (ERR) for welding fumes is especially challenging. Welding fumes are a complex mixture of various hazardous substances, both in gaseous and particulate form. No single substance was identified as the main or only cause of cancer and no adequate indicator was determined so far for measuring exposure to carcinogenic welding fumes.

Therefore, in the context of this project, a tentative characterisation of lung cancer risk only has been performed by the study team. This tentative risk estimate represents occupational situations covered by the epidemiological studies in the meta-analysis of Loomis et al. (2022). This risk estimate does not express excess cancer risks per unit of measured exposure, as exposure is not quantifiable. Instead, the tentative cancer risk estimate expresses risks as they probably existed at the workplaces included in the meta-analysis.

Loomis et al. (2022) is a highly qualified starting point due to the following properties:

- It is up-to-date and based on systematic review principles; and
- It includes 40 analytical epidemiological studies (29 case-control and 11 cohort studies) with more than one million individuals.

Compared to Honaryar et al. (2019), a similar meta-analysis, Loomis et al. (2022) applies a stricter systematic review method.

The epidemiological studies included by Loomis et al. (2022) were published between 1954 and 2017, with the main body of data belonging to exposure periods from the 1980s to the early years of the new millennium and to studies from North America and Europe (also see 2.1.3.14). Inclusion criteria for participants of the individual studies varied. Mainly workers with the job title "welder" were considered, with a minimum occupation duration of e.g. one year. Loomis et al. (2022) considered tumours of the lung, trachea, and bronchus. Adjustment to confounders such as smoking and co-exposures were carefully evaluated for each study. Based on the pooled evidence from 23 studies which includes 57,931 participants, a statistically significant relative incidence risk (RIR) of 1.48 (increase of risk to contract trachea, bronchus or lung cancer by 48%) was determined. The respective relative mortality risk (RMR) was lower (1.27) but still significant, based on only three studies. The RIR of 1.48 is used in the following calculations to provide a rough, tentative extra cancer risk estimate.

According to the ECHA Guidance Document on Information Requirements and Chemical Safety Assessment R.8 a direct, linear method can be used to derive cancer risk estimates from epidemiological data (ECHA, 2012):

- Excess cancer risk (ER) = background risk * (RIR-1);
- Background risk = lifetime background risk in the relevant population (incidence or mortality risk); and
- RIR = the relative risk observed in epidemiological studies.

The background lung cancer risk was recently assessed by RAC for deriving an ER for polycyclic aromatic hydrocarbons in coal-tar pitch, high-temperature (ECHA, 2018b). The committee concluded that the lifetime risk to contract lung cancer for the male EU population was 7%. As men form the larger part of the workforce exposed to welding fumes and show higher background risks for lung cancer, this value is also used here.

Excess cancer risks for lung cancer associated with occupational exposures as welders are calculated as follows:

- Excess cancer risk (ER) = background risk * (RIR-1)
    - = 0.07 * (1.48-1)

- = 0.034 (equating to 34,000 cases in one million exposed workers).

2.2.2.2 Conclusion

A tentative extra cancer risk of 0.034 as estimated, based on the recent meta-analysis of Loomis et al. (2022). This risk adheres to exposure of welders under the occupational conditions of the past decades, as covered in the epidemiological studies forming part of the meta-analysis of Loomis et al. (2022).

2.2.2.3 Discussion

It is to be noted that the main body of information on health effects adhere to exposure to welding fumes. For additional processes, summarised under welding fumes+ (soldering, thermal cutting or gouging, thermal spraying, flame straightening, additive production processes, see section 1.3.1 for full details) health risks cannot be adequately described. This is due to a lack of epidemiological studies on these other related processes, as noted by ANSES (2022). Following a review of the literature, ANSES (2022) recommended that these other related processes be classified as carcinogenic, due to the exposure of workers to metal fumes from these processes but did not calculate any excess risk values for them. For the purposes of this study, and due to the lack of epidemiological studies, the assumption is that the ER for welding would also apply to these other processes.

Various uncertainties are associated with tentative excess cancer risk estimate developed above:

- The studies include occupational situations with varying conditions; however, it can be assumed that all participants had jobs which qualify them as "welders";
- Depending on processes and techniques, welding fumes vary in concentration and composition;
- Many studies included had minimum exposure durations of 1 year or even less; it can be assumed that a relevant fraction of the participants was not exposed over a full work life (40 years); therefore, the extra cancer risk estimate is not a lifetime risk;
- On the other hand, the risk adheres to the occupational situation as covered in the included epidemiological studies (e.g., the situation having been existent decades ago); occupational exposure at welding workplaces are expected to have improved (Olsson and Kromhout (2021) assumed a reduction of exposure of 2-3% per year). However, the studies included by Loomis et al. (2022) with study periods after 2000 do not show clear differences compared to studies with periods before 2000; and
- Also, recent epidemiological studies further supported the suspicion of elevated lung cancer risks due to welding fumes (Chung et al., 2021, Pesch et al., 2019).

An alternative possibility to come to a rough estimate of the cancer burden caused by a certain occupational situation is to use "population attributable fractions" (PAF). A PAF is "the estimated proportion of cases that would not have occurred if the exposure had not been present" (Olsson and Kromhout, 2021). Inputs for estimating PAFs are relative risks from epidemiological studies and the proportion of the total population exposed to the substance under consideration.

These authors estimated that occupational exposure is responsible for 18 to 25% (PAF) of all lung cancer cases, based on data from Canada, France and the UK. In a recent overview on the contributions of process-generated substances at the workplace, including welding fumes, they cite two studies (from the UK and Canada), which estimate the PAF of welding fumes for causing lung cancer at 0.7 (UK) and 2.4% (Canada) for men and 0.08 (UK) and 0.1% (Canada) for women. In the UK study (Rushton et al., 2007) cited by Olsson and Kromhout (2021) the authors used the results from an older meta-analysis (Ambroise et al., 2006), which concluded on an RIR of 1.26 for lung cancer among welders. Further, Rushton et al., (2007) estimated the proportion of the population in the UK exposed to welding fumes and gases to be 0.028 for men and 0.0039 for women. With approximately 20,000 and 12,000 lung cancer cases per year for men and women, respectively, they estimated 139 and 13 new cancer cases among men and women in the UK in the year 2004. In the report from Canada by Labrèche et al., (2019) the study of Kendzia et al., (2013) was used as a starting point, who reported odds ratios (OR) for lung cancer of 1.44 and 1.19 for welders and occasional welding, respectively. Their calculation resulted in estimated 305 (men) and 8 (women) lung cancer cases per year attributable to welding exposure, based on approx. 829,000 ever welders and 222,000 occasional welders.

On behalf of the European Trade Union Institute (ETUI) Vencovsky et al., (2017) also estimated PAFs for various occupational hazards. Calculations for a "central estimate" were based on the study of Mannetje et al., (2012, in Vencoksky et al, 2017) with an OR of 1.36 and an assumed exposed population in the EU28[12] of 4.2 million An attributable fraction of 1.5% was calculated for occupation as welder.

With approximately 205,000 new lung cancer cases among men and 113,000 cases among women in the EU-27 in the year 2020, the PAF ranges given above (Canada: 2.4%, UK: 0.8%; EU28 (ETUI 2017 study): 1.5%) would result in the following estimate of lung cancer cases due to welding exposure in the EU.

Men: 0.7 – 2.4% of 205,000: 1,435 – 4,920 cases per year

Women: 0.08 to 0.1% of 113,000: 90 – 113 cases per year.

In order to compare these figures with the excess cancer risk derived from Loomis et al., (2022) information on the number of exposed workers is required:

- The European Labour Authority (ELA) states that there were 678,000 people employed in the occupation 'welders and flame cutters' in 2020 (ELA, 2021);
- DVS (Deutscher Verband für Schweißtechnik) estimated that there were 1.2 million full time workers in joining, cutting and coating technologies sector in 2019 (DVS, 2021); and
- The European Welding Association (EWA) estimated the number of professional and part time welders is approximately 2 million people(Guy Missiaen, EWA, personal communication, 4 April 2023).

With the range for the number of workers exposed to welding fumes between 0.678 to 2 million a simplified assumption is that this workforce consists to 100% of men. The excess cancer risk

[12] The EU28 includes the UK prior to its exit from the EU.

developed from Loomis et al., (2022) above would lead to a range of 23,000 to 68,000 lung cancer cases in male workers exposed under the conditions of the studies included by Loomis et al., (2022). To facilitate the comparison, it is further assumed that the exposure duration in these studies was on average 20 years.

Although the methodology is not exactly comparable (yearly number of lung cancer cases times compared to cancer cases in a work force exposed over prolonged periods) it can be stated that the two approaches lead to similar figures for estimated cancer cases:

PAF-based:1,435 – 4,920 cases in men per year x 20 years: 28,700 – 98,400 lung cancer cases.

RIR-based: 23,000 – 68,000 lung cancer cases.

2.2.3 DRR for non-carcinogenic effects

Non-carcinogenic effects of exposure to welding fumes consist of irritative effects in the respiratory tract, asthma, bronchitis and an increased risk for pulmonary infections among others (see section 2.1.5). In addition, adverse effects are also discussed for other organ system classes e.g. reproductive system and nervous system. However, no reliable dose-response data are available or have been discussed in ECHA's scoping report (ECHA, 2022). Consequently, no dose-response relationship is derived.

2.3 Groups at extra risk

No specific groups at extra risk were described in ECHA's scoping report (ECHA, 2022) or were identified in the literature. During this study, the study team has heard anecdotal evidence from the stakeholders interviewed (*personal communication,* June – July 2023) that the following groups of workers are at extra risk from exposure to CMRs in welding fumes, usually from lack of training and/or access to RMMs:

- Non-professional welders;
- Part time or occasional welders;
- Welders in SMEs; and
- Migrant workers.

2.4 Summary of background for analysing health impacts

2.4.1 Summary of exposure, uptake and health effects

2.4.1.1 Routes of exposure and uptake

During welding, metal pieces are fused through coalescence by using heat (energy) and filler material (also containing metals). During the heating process metals vaporise and condense rapidly afterwards into fine particles (particulate matter/fumes). Depending on the base metals, the used filler material, and the heat source the composition of the fumes can vary widely. In addition to the particulate matter (welding fumes), gases such as carbon monoxide are present and might impact observed health effects. Inhalation is the most important route of exposure. Process-generated fumes from welding and similar processes ((soldering, thermal cutting or gouging, thermal spraying, flame straightening, additive production processes) are summarised by ECHA (2022) as welding fumes+.

2.4.1.2 Adverse health effects

A critical health effect is carcinogenicity. IARC (2018) concluded that there is sufficient evidence for increased lung cancer risks in humans due to exposure to welding fumes. Also, a weaker association was observed with kidney tumours.

Apart from carcinogenicity, welding fumes may cause several types of respiratory tract toxicity, after short-term as well as long-term exposure. Acute effects comprise acute irritation to the throat and larger airways in the lungs. Metal fumes fever is a (transient) flu-like condition. Further, welders show a higher risk to develop acute pneumonia (pneumococcal pneumonia).

Chronic effects consist of occupational asthma, chronic bronchitis (airway inflammation, with symptoms like coughing and mucus in the bronchiolar airways) and welder's lung (also known as siderosis). Welder's lung is an iron-particle induced benign pneumoconiosis, which is unlikely to proceed to interstitial fibrosis. It is characterised by deposition of metal particles in the lung, with no clear correlation to a decrease in lung function. The evidence for welding fumes deteriorating lung function and causing chronic obstructive pulmonary disease (COPD) is discussed, but the evidence so far is weak.

In addition to the respiratory effects, it is discussed that welding fumes exposure may lead to neurological disorders, possibly caused by manganese and nephrotoxicity (tubular dysfunction), due to the presence of cadmium in welding fumes. Further, reproductive toxicity caused by welding fumes is under discussion.

2.4.2 Summary of ERR and DRR

There is no agreement yet as to how to measure and quantify exposure to welding fumes+. Further, the composition of welding fumes+ is variable, and depends on materials and techniques used. Most available human studies did not quantify exposure by measurements. Therefore, no ERR or DRR can be derived. Analysing the consequences of setting an OEL at various exposure levels is not in the scope of this project. However, in order to indicate the order of magnitude of the health concern a tentative estimate of the lung cancer risk is performed. Please note that the below ER is an underestimate of the total health effects from exposure to welding fumes (other health effects are discussed in section 2.1 and summarised above in section 2.4.1).

This tentative risk estimate uses the relative risks calculated in the recent meta-analysis of Loomis et al. (2022). This risk estimate represents the occupational situations covered by the analysed epidemiological studies included in the meta-analysis. It does not express excess cancer risks per unit of measured exposure, as exposure is not quantifiable.

It is to be noted that the main body of information on health effects adhere to exposure to welding fumes. For additional processes, summarised under welding fumes+ (soldering, thermal cutting or gouging, thermal spraying, flame straightening, additive production processes) health risks cannot be estimated as published epidemiological data is lacking. F or the purposes of this study and in the absence of epidemiology studies, these other processes are assumed to have the same ER to lung cancer as welding.

Excess cancer risks for lung cancer associated with occupational exposures as welders are calculated as follows:

- ER = background risk * (RIR-1)

- = 0.07 * (1.48-1)

- = 0.034 (equating to 34,000 cases in one million exposed workers).

An alternative approach using "population attributable fractions" (PAF) is estimated by Olsson and Kromhout (2021). These authors estimated that welding fumes are responsible for causing lung cancer at 0.7 – 2.4% for men. This would account for 7,000 to 24,000 lung cancer cases in a population of one million exposed male workers.

3 CURRENT SITUATION

This chapter comprises the following sections:

- Section 3.1: Existing national limits;
- Section 3.2: Relevant sectors, processes and uses;
- Section 3.3: Exposure concentrations;
- Section 3.4: Exposed workforce;
- Section 3.5: Current risk management measures;
- Section 3.6: Voluntary industry initiatives;
- Section 3.7: Examples of good/best practice;
- Section 3.8: Standard monitoring methods/tools;
- Section 3.9: Intermediate uses not covered by certain REACH procedures;
- Section 3.10: Market analysis;
- Section 3.11: Alternatives;
- Section 3.12: Current disease burden (CDB); and
- Section 3.13: Summary of the current situation.

3.1 Existing national limits

3.1.1 OELs in Member States

Existing limit values for welding fumes and dust limit values are summarised in Table 11-16 in Annex 1. There are no STELs for welding fumes.

3.1.2 OELs and STELs for metals in welding fumes in Member States

As welding fumes contain different constituents depending upon the metals being welded, OELs and STELs for the metal constituents are summarised in Table 11-17.

A summary of the number of Member States with an OEL for metals (and metal oxides) is below in Table 3-1.

Table 3-1 Summary of Member States with an OEL for metals (and metal oxides) common in welding.

Metal	Number of Member States with an OEL
Aluminium	12
Barium	EU27
Cobalt	6
Chromium metal and Cr (II)/(III)	EU27

Metal	Number of Member States with an OEL
Hexavalent Chromium (Cr(VI))	EU27
Copper	10
Iron	9
Magnesium	9
Manganese	EU27
Nickel compounds	EU27
Vanadium	11

Source: Study team, based on Table 11-17 in Annex I.

3.1.3 BLVs in Member States

There are no BLVs established for welding fumes (EHCA, 2022). However, there are national BLVs or reference values for some of the components of welding fumes. The below list the BLVs established for some of the metals common in welding fumes (tables extracted from ECHA, 2022):

- Metal compounds in urine in the general population (Table 11-18); and
- Metal compounds in blood in the general population (Table 11-19).

3.1.4 Minimum, maximum and average national OELs

Separate indicative tables have been prepared for OELs specific to welding fumes (Table 3-2) and for generic dust limit values (Table 3-3), based upon the information in Table 11-16.

The existing OELs for welding fumes in EU27 Member States range from 0.7 – 5mg/m^3.

The existing limit values for generic dust in EU27 Member States range from 1.25 – 10mg/m^3. Please note that from July 2023 new non-specific dust limits are being introduced in France of 4 mg/m^3 for inhalable and 0.9 mg/m^3 respirable welding fumes; this will make 0.9 mg/m^3 the lowest national non-specific dust limit in the EU.

Table 3-2 Maximum, minimum and average of OELs in mg/m^3 for welding fumes in those EU Member States where an OEL exists.

Maximum, minimum and averages	Welding fumes OELs	Compounds or welding processes covered
Maximum	5 mg/m^3 [1,2]	[1] Austria (R) all welding types. Belgium (I) welding fumes (not specified). Cyprus (T). Ireland. Lithuania (I) welding aerosol. Slovakia welding aerosol, applies to solid aerosol particles. Spain. [2] Granular bio-resistant dusts with a mean density of 2.5 g/cm^3 in Germany
Minimum	0.5-1.7 mg/m^3	Process-related limit values for several welding processes in Denmark
Median	5 mg/m^3	

Maximum, minimum and averages	Welding fumes OELs	Compounds or welding processes covered
Mode	5 mg/m^3	
Mean	4.625 mg/m^3	An average across all welding fumes OELs (Respirable and inhalable).

Source: Study team on basis of information presented in this section.

Notes: R = Respirable fraction; I = Inhalable fraction; T = Total

Table 3-3 Maximum, minimum and average of dust limit values in mg/m^3 for welding fumes in those EU Member States where a dust limit value exists.

Maximum, minimum and averages	Generic dust limit values	Compounds or welding processes covered
Maximum	10 mg/m^3 (I) general limit value	Granular bio-resistant dusts with a mean density of 2.5 g/cm^3 in Germany
Minimum	1 mg/m^3 (I)	Generic dust limit value implemented across sectors in the Netherlands. From July 2023 new non specific dust limits in France of 0.9 mg/m3 respirable dust and 4 mg/m3 for inhalable dust.
Median	4.25 mg/m^3	
Mode	N/A	There was no commonly occurring dust limit value.
Mean	4.625 mg/m^3	An average across all dust limit values.

Source: Study team.

Notes: I = Inhalable fraction

3.1.5 Member States already defining welding fume as a process generated substance

DG Employment asked the study team:

"*Would it be possible to also include a table with all Member States having classified welding fumes as PGS in their national legislations, together with the wording used*?"

The study team undertook an investigation to answer this question. The methodology for this investigation is included in Annex 14.

3.1.5.1 Results

Ten MSAs replied to the request for information and the study team's conclusions based upon their responses and the findings of the study team, are in Table 3-4.

Table 3-4 Welding fumes mentioned as a process generated substance in Member State legislation relating to the CMRD

MS	MSA replied	Conclusion
AT	None	No mention The study team cannot find any definition of welding fumes specifically as a process generated substance, as carcinogen or equivalent to the definition in Annex I of the CMRD. The relevant document is the Austrian Order Grenzwerteverordnung 2021 - GVK https://www.ris.bka.gv.at/GeltendeFassung.wxe?Abfrage=Bundesnormen&Gesetzesnummer=20001418 Annex I of the CMRD seems to have been transposed on a state-by-state basis. For example, in the Styrian state (second largest state in Austria) Annex I is transposed in the State law gazette, dated 13 October 2005, p414: https://www.ris.bka.gv.at/Dokumente/Lgbl/LGBL_ST_20051013_100/LGBL_ST_20051013_100.pdf
BE	Yes	No mention The study team cannot find any definition of welding fumes specifically as a process generated substance, as carcinogen or equivalent to Annex I, despite Belgium having a specific OEL for welding fumes on 5 mg/m^3. Annex I of the CMRD is transposed into Annex VI.2-2 of the 2017 Codex on well-being at work: https://werk.belgie.be/sites/default/files/content/documents/Welzijn op het werk/Regelgeving/codex2017.pdf
BG	Yes	No mention The MSA says there is no specific legislation for welding fume, other than the OEL for Chromium VI. The relevant document is the Regulation No 10 of September 26, 2003 on the Protection of Workers from Risks Related to Exposure to Carcinogens and Mutagens at work: https://www.lex.bg/bg/mobile/ldoc/2135473243 The study team cannot find any definition of welding fumes specifically as a process generated substance, as carcinogen or equivalent to Annex I. Annex I of the CMRD is transposed in Appendix 3 of the above Regulation.
HR	None	No mention The study team cannot find any definition of welding fumes specifically as a process generated substance, as carcinogen or equivalent to Annex I. The relevant documents are the original bylaw from 2018 on the protection of workers against exposure to dangerous chemicals at work, exposure limit values and biological limit value: https://narodne-novine.nn.hr/clanci/sluzbeni/2018_10_91_1774.html and updates to the 2018 bylaw are in this bylaw https://narodne-novine.nn.hr/clanci/sluzbeni/2021_01_1_10.html The transposition of Annex I is done as a separate update with each by-law only listing the updates to the original by-law. The list of substances in the Annex I of the CMRD do not appear to be listed together in one place.
CY	None	Unclear The study team cannot find any definition of welding fumes specifically as a process generated substance, as carcinogen or equivalent to Annex I. The relevant document is the Safety and Health at work laws of 1996 to (No. 2) of 2015: https://www.mlsi.gov.cy/mlsi/dli/dliup.nsf/all/D74ACEE6A814B7EAC2257E03002A76C9/$file/KDP_282-2020.pdf According to the MSA response for the main consultation, Cyprus has an OEL for welding fumes. But the study team cannot find this. Neither can any documents be found that mention items from Annex I of the CMRD. All documents are difficult to search, either because they cannot be searched, or they cannot be copied.
CZ	None	No mention The study team cannot find any definition of welding fumes specifically as a process generated substance, as carcinogen or equivalent to Annex I. Annex I of the CMRD is transposed into Government Regulation No. 361/2007 Coll: https://www.tzb-info.cz/pravni-predpisy/narizeni-vlady-c-361-2007-sb-kterym-se-stanovi-podminky-ochrany-zdravi-pri-praci

MS	MSA replied	Conclusion
DK	Yes	Yes, mentioned, process-related limit values for several welding+ processes Study team interpretation: Denmark effectively defines welding fumes as process generated substances because there are process-related limit values for several welding+ processes. Also, there is a legal requirement to use a ventilation system to remove welding fumes. Requirements for welding are included in the AT guide 'Welding, cutting, etc. in metal': https://at.dk/regler/at-vejledninger/svejsning-skaering-metal-d-2-16/ Section C of nation legislation BEK nr 1054 af 28/06/2022: https://www.retsinformation.dk/eli/lta/2022/1054 includes the list of Danish process-related limit values for welding processes. Substance specific limit values for metal fumes are included in Section A. There are many mentions of dust, including limit values for metal dusts. Annex I of the CMRD is transposed into Appendix 2 of BEK nr 1795 af 18/12/2015: https://www.retsinformation.dk/eli/lta/2015/1795.
EE	None	No mention Study team interpretation: there is no definition of welding fumes as process generated substances or carcinogen or equivalent in Annex I. The relevant document is the 2019: Occupational health and safety requirements for the handling of carcinogenic and mutagenic chemicals, Number 305 of 15 December 2005, revised 21 February 2021: https://www.riigiteataja.ee/akt/117102019004 and the current list of limit values are in this legislation: Use of hazardous chemicals and materials containing them occupational health and safety requirements and limit values of chemical hazard factors in the working environment, Number 105 of 20 March 2001: https://www.riigiteataja.ee/aktilisa/1211/2202/2014/VV_132m_lisa.pdf Paragraph 2 covers Annex I. There is an additional item which would include welding, but is not specific: "*other activities in which there is a risk of workers being exposed to carcinogens or mutagens*". No other reference to welding. Annex I of the CMRD is transposed in the 2021 update of the Occupational health and safety requirements for the use of hazardous chemicals and materials containing them and limit values for chemical hazard factors in the working environment, Number 105, of 17 January 2020: https://www.riigiteataja.ee/akt/121122022014 with no further relevant information.
FI	Yes	Yes, mentioned, already in transposition of Annex 1 of the CMRD MSA says, and study team confirms, that welding and thermal cutting of stainless steel has already been added to the Finnish equivalent of Annex I of the CMRD. The decree is the following: https://www.finlex.fi/fi/laki/alkup/2019/20191267 on page 4 is Annex I, in Finnish "Liite I", which includes carcinogenic work processes. Annex I includes: "*10. Ruostumattoman teräksen hitsaus ja polttoleikkaus*." This translates to: "Welding and thermal cutting of stainless steel". The relevant document is the Decree of the Government addressing the risk of work-related cancer, 1267/2019, of 12 December 2019: https://www.finlex.fi/fi/laki/alkup/2019/20191267
FR	None	No mention The study team cannot find any definition of welding fumes specifically as a process generated substance, as carcinogen or equivalent to Annex I. There are non-specific generic dust limits (for inhalable and respirable dust respectively) which apply to welding fumes, but the study team was unable to find any mention of welding relating to generic dust. Annex I of the CMRD was transposed in Article 1 of the Order of October 26, 2020 establishing the list of carcinogenic substances, mixtures and processes within the meaning of the labour code, (Version in force since July 1, 2021, Article 1 was modified by an Order dated 3 May 2021): https://www.legifrance.gouv.fr/loda/article_lc/LEGIARTI000043483855/2021-07-01 A brochure on how to use OELs, called 'Methods of prevention: measurement and evaluation devices': https://www.inrs.fr/dms/inrs/CataloguePapier/ED/TI-ED-6443/ed6443.pdf contains no reference to welding, or welding fumes, and only 2 references to fumes (fumées) in relation to the definition of an aerosol, and the definition of fumes.

MS	MSA replied	Conclusion
		The definition of fumes is given as: " dispersions in the air of very fine solid particles, possibly accompanied by gases and vapours, generated by thermal processes, either by condensation from the gas phase (sometimes accompanied by chemical reactions such as oxidation), or by incomplete combustion".
DE	Yes	Yes, mentioned, through OEL for dust and regulations for carcinogens in welding fumes The study team interpretation of MSA comments and their findings: Germany does not specifically define welding fume as a process generated substance but effectively it does because of its OEL for dust and the extensive regulations (TRGS 528) around carcinogens in welding fumes. Annex I of the CMRD is directly transposed in section 2 of TRGS 906: https://www.baua.de/DE/Angebote/Regelwerk/TRGS/TRGS-906.html The relevant documents are TRGS 906, TRGS 910 which lists carcinogenic substances: https://www.baua.de/DE/Angebote/Regelwerk/TRGS/TRGS-910.html, TRGS 402 which covers risk assessments for welding fumes: https://www.baua.de/DE/Angebote/Regelwerk/TRGS/TRGS-402.html, TRGS 900 providing workplace limit values:https://www.baua.de/DE/Angebote/Regelwerk/TRGS/TRGS-900.html, and TRGS 528: https://www.baua.de/DE/Angebote/Regelwerk/TRGS/pdf/TRGS-528.pdf?__blob=publicationFile&v=1 providing detailed technical rules for hazardous substances for welding work specifically. The definition of welding fumes according to TRGS 528, Article 2 Definitions is "[fumes] *from welding work resulting in particulate substances*". 32 references to the carcinogenicity of aspects of welding fumes or how carcinogenicity is taken into account are made in TRGS 528, so the carcinogenic nature of welding fumes is definitely recognised in Germany. However, exposure to welding fumes is regulated in a risk-based way, rather than a blanket regulation of all welding fumes. Figure 1 illustrates the fact that the size of particles in fumes depends upon the process. The processes included in this diagram include welding, soldering, thermal cutting and gouging.
EL	None	Unclear The study team cannot find any definition of welding fumes specifically as a process generated substance, as carcinogen or equivalent to Annex I (but it is hard to be sure.) The Government Gazette 50A 2020 https://elinyae.gr/sites/default/files/2020-03/50a_2020.pdf harmonises Greek legislation with the CMRD, and exposure limit values for chemical & biological agents 2019 (Greek legislation) https://www.elinyae.gr/sites/default/files/2019-10/oriakes%20times%202019_L_0.pdf is an older version of similar legislation, with many terms in English. Both documents are difficult to search, either because some or all of the documents cannot be searched, or because some or all of the documents cannot be copied. Annex I of the CMRD is directly transposed on page 2 of the Government Gazette 50A 2020 and does not mention welding.
HU	None	No mention The study team cannot find any definition of welding fumes specifically as a process generated substance, as carcinogen or equivalent to Annex I. The relevant document is the ITM decree on the protection of the health and safety of workers exposed to chemical pathogenic factors, 5/2020 (II.6): https://net.jogtar.hu/jogszabaly?docid=a2000005.itm Annex I of the CMRD is transposed in EüM decree on protection against occupational carcinogens and the prevention of health damage caused by them, 26/2000 (IX 30): https://net.jogtar.hu/jogszabaly?docid=a0000026.eum, with no item relating to welding.
IE	None	No mention The study team cannot find any definition of welding fumes specifically as a process generated substance, as carcinogen or equivalent to Annex I. The relevant document is the Irish 2021 Code of Practice for the Safety, Health and Welfare at Work (Chemical Agents) Regulations (2001-2021) and the Safety, Health and Welfare at Work (Carcinogens) Regulations (2001-2019:

MS	MSA replied	Conclusion
		https://www.hsa.ie/eng/publications_and_forms/publications/chemical_and_hazardous_substances/2021-code-of-practice-for-the-chemical-agents-and-carcinogens-regulations.pdf There are substance specific limit values for metal fumes and metal dusts that may be relevant to welding. Annex I of the CMRD is transposed in Schedule 4 of the 2021 Code of Practice.
IT	None	No mention The study team cannot find any definition of welding fumes specifically as a process generated substance, as carcinogen or equivalent to Annex I. The relevant document is the Legislative Decree no. 9 of 2008 April 81 amended November 2023 includes the transposition of the CMRD. https://www.ispettorato.gov.it/files/2023/11/TU-81-08-Ed.-Novembre-2023.pdf Annex XLII of the above covers Annex 1 on page 439 and there is no mention of welding.
LV	None	No mention The study team cannot find any definition of welding fumes specifically as a process generated substance, as carcinogen or equivalent to Annex I. The relevant document is Regulations of the Cabinet of Ministers No. 325: https://likumi.lv/doc.php?id=157382&from=off on the Labour protection requirements in contact with chemical substances in workplaces. Annex I of the CMRD is transposed into Appendix 2 of the Cabinet of Ministers Regulations No. 803 of September 29, 2008: https://likumi.lv/ta/id/181871-darba-aizsardzibas-prasibas-saskaroties-ar-kancerogenam-vielam-darba-vietas
LT	Yes	Yes, mentioned, OEL for welding aerosols Study team interpretation: the definition of welding aerosol provided by the MSA implies that aerosol is process generated and the toxicity of the substances present (with associated limit values) in the aerosol will depend upon the materials being welded and welding process being used. This provision was established before Lithuania joined the EU (not as a transposition of CMRD) The study team found that in Order HN 23:2011 https://www.e-tar.lt/portal/lt/legalAct/TAR.8012ED3EA143/asr on Lithuanian Hygiene Standards Occupational Exposure Limits for Chemicals., item 692 of Annex I of the Lithuanian Hygiene Standard HN 23:2011 referenced by the MSA was provides the definition and an OEL for welding aerosols. There is no other reference to welding fumes. The translation of the definition of welding aerosol is "the **entire respirable fraction** of a **suspension of solid, liquid or solid and liquid particles** in a gaseous medium. Depending on the composition of the welding alloy, the electrodes used and the welding process, ozone may be released into the environment (e.g. when welding aluminium, titanium and their alloys with an electric arc in a protective argon atmosphere), carbon monoxide (e.g. when welding alloy steel with an electric arc), metals (iron, manganese, chromium, nickel), fluorides (flux-coated and hollow electrodes are prepared with fluorides). Therefore, first of all, it is necessary to determine whether the individual limit values of the aerosol components are not exceeded. If there are no toxic substances in the welding electrode, the metal to be welded or its coating, and no toxic gases are formed during welding, it is sufficient to determine the total concentration of the welding aerosol." Annex 1 of the CMRD is transposed in https://www.e-tar.lt/portal/lt/legalAct/TAR.313208361D5D under Section VII Final provisions.
LU	None	No mention The study team cannot find any definition of welding fumes specifically as a process generated substance, as carcinogen or equivalent to Annex I. The relevant documents are Regulation 37 of the 30 January 2020 and Regulation 684 of the 16 August 2018 Annex I of the CMRD is transposed into Annex I of the Grand-ducal regulation of November 14, 2016 concerning the protection of employees against the risks linked to exposure to carcinogens or mutagens at work: https://legilux.public.lu/eli/etat/leg/rgd/2016/11/14/n3/jo
MT	None	Unclear

MS	MSA replied	Conclusion
		The study team was unable to find any mention of welding fumes, despite undertaking extensive searches but there may be other legislation which was not identified. The relevant documents were in a database of Maltese legislation https://legislation.mt/. The Maltese Legal Notice (LN) 227 of 2003 https://legislation.mt/eli/sl/424.24/eng/pdf , which contains the OELs, has since been amended by LN 198 of 2015, LN 57 of 2018 and LN 356 of 2021: these three Legal Notices were also searched. Annex I of the CMRD: the study team is unable to establish where this is transposed into Maltese legislation.
NL	None	No mention The study team cannot find any definition of welding fumes specifically as a process generated substance, as carcinogen or equivalent to Annex I. The relevant documents were reproductively toxic substances, Ministry of Social Affairs and Employment" published on 3 January 2022 in the Government Gazette of the Kingdom of the Netherlands: https://zoek.officielebekendmakingen.nl/stcrt-2022-51.html The Netherlands Working Conditions Regulations (https://wetten.overheid.nl/BWBR0008587/2022-07-01#BijlageXIII) contain the generic dust limit value for welding fume for the Netherlands, but no other references to welding fume, welding and no reference to welding as a process generated substance. Annex I of the CMRD is transposed into a list of carcinogenic substances and processes which was published in Gazette entry mentioned above published on 3 January 2022.
PL	Yes	No mention MSA says there is no definition of welding fumes as a process generated substance. The study team cannot find any definition of welding fumes specifically as a process generated substance, as carcinogen or equivalent and to Annex I. The relevant documents are the list of limit values of 12 June 2018:https://sip.lex.pl/akty-prawne/dzu-dziennik-ustaw/najwyzsze-dopuszczalne-stezenia-i-natezenia-czynnikow-szkodliwych-dla-18733965 and 3 December 2021, Poz. 2235 https://isap.sejm.gov.pl/isap.nsf/download.xsp/WDU20210002235/O/D20212235.pdf Annex 1 of the CMRD is transposed on page 6 of Poz. 2235 the regulation on chemical substances.
PT	None	No mention The study team cannot find any definition of welding fumes specifically as a process generated substance, as carcinogen or equivalent to Annex I. The relevant documents are the Decree-Law number 24/2012 of the 6 February 2012: https://dre.pt/dre/legislacao-consolidada/decreto-lei/2012-115495237 which lists limit values. Annex I of the CMRD is transposed into Article 3 of Decree-Law No. 35/2020, of July 13 2020: https://diariodarepublica.pt/dr/detalhe/decreto-lei/35-2020-137703603
RO	Yes	No mention MSA says there is no specific legislation for welding fume. The study team cannot find any definition of welding fumes specifically as a process generated substance, as carcinogen or equivalent to Annex I. The relevant documents are the Decision no. 1,218 of September 6, 2006 regarding the establishment of the minimum safety and health requirements at work to ensure the protection of workers against risks related to the presence of chemical agents: http://www.monitoruljuridic.ro/act/hot-r-re-nr-1-218-din-6-septembrie-2006-privind-stabilirea-cerin-elor-minime-de-securitate-i-s-n-tate-n-munc-pentru-asigurarea-protec-iei-lucr-torilor-mpotriva-riscurilor-legate-de-prezen-a-agen-ilor-245021.html or the Romanian Legislation Portal: HG 1218 06/09/2006 - Portal Legislativ (just.ro). Annex I of the CMRD: the study team is unable to establish where this is transposed into Romanian legislation.
SK	Yes	Yes, mentioned, OEL for welding solid aerosols MSA indicates that there is specific legislation for welding fumes, with an OEL. Welding solid aerosols have an OEL of 5mg/m^3. The relevant documents are the Slovak regulation 355/2006 or "Temporary version of the Regulation protecting the health of employees from risks related to exposure to carcinogenic and mutagenic factors at work, of 10

MS	MSA replied	Conclusion
		May 2006, effective from 01.10.2020": https://www.slov-lex.sk/pravne-predpisy/SK/ZZ/2006/356/ Annex 1 of the CMRD is directly transposed in Annex 1 of the above regulation.
SI	None	No mention The study team cannot find any definition of welding fumes specifically as a process generated substance, as carcinogen or equivalent to Annex I. The relevant document are the online legal information service: http://www.pisrs.si/Pis.web/pregledPredpisa?id=PRAV14252# under the Ministry of Labour, Family and Social Affairs (2006) Annex I of the CMRD is transposed on page 26 of Practical guidelines for limit values for hazardous chemical substances, : https://vzd.mddsz.gov.si/document-download/prakticne-smernice-za-mejne-vrednosti-za-nevarne-kemicne-snovi-2022-01-14-429.
ES	Yes	No mention The MSA says there is no specific legislation for welding fume and no definition of welding fume as a process generated substance. The study team cannot find any definition of welding fumes specifically as a process generated substance, as carcinogen or equivalent to Annex I. The relevant document is the Royal Decree 665/1997, of May 12, 1997, on the protection of workers against risks related to exposure to carcinogens at work BOE-A-1997-11145 Royal Decree 665/1997 of 12 May <> on the protection of workers against the risks related to exposure to carcinogens at work. Annex I of the CMRD is transposed in Annex I of the above Royal Decree 665/1997 of 12 May 1997.
SE	None	No mention The study team cannot find any definition of welding fumes specifically as a process generated substance, as carcinogen or equivalent to Annex I. The relevant document is 2018:1 The Swedish Work Environment Authority's regulations and general advice on hygiene limit values in relation to the inhalable and respirable fractions of welding fume particles: https://www.av.se/arbetsmiljoarbete-och-inspektioner/publikationer/foreskrifter/hygieniska-gransvarden-afs-20181-foreskrifter/ This legislation contains many dust limit values for different substances, but not welding specifically. There is advice on the measurement of workplace dust and references to Swedish standards and a Swedish OSH method. Annex I of the CMRD is transposed into the Swedish Provisions and General Recommendations on Chemical Hazards in the Working Environment (AFS 2011:19): https://www.av.se/globalassets/filer/publikationer/foreskrifter/engelska/chemical-hazards-in-the-working-environment-provisions-afs2011-19.pdf and amended by general advice on chemical work environment risks (AFS 2022:4) https://www.av.se/globalassets/filer/publikationer/foreskrifter/andringsforeskrift/afs-2022-4.pdf

Sources: Study team and links as indicated

3.1.5.2 Conclusions

The study team were unable to find mention of welding fumes as process generated substances or as carcinogenic in the majority (20, 74%) of Member States' legislation. It is possible that the relevant legislation was not found by the study team; it was particularly difficult to search the legislation for Cyprus, Greece and Malta. In most cases there was no reply from the Member State Authority (16, 59%), so these conclusions are largely drawn from the research undertaken by the study team.

Welding was usually only mentioned in Member States's legislation in relation to the OEL for chromium VI. Only a minority of Member States (3, 11%) have defined welding fumes as process generated substances and/or the equivalent to Annex I as outlined below. The study team were able to identify the national legislation which transposed Annex I of the CMRD for the majority of

Member States (24, 89%), but occasionally the list of processes was not fully transposed, or subsets of the list were transposed across different legislation rather than in one piece of legislation.

Three Member States have defined welding fumes as process generated substances or the equivalent to Annex I processes: Denmark, Germany, and Finland. Denmark effectively defines welding fumes as process generated substances because there are evidence based, process-related limit values for several[13] welding+ processes (see Table 3-1); there is also a legal requirement to use a ventilation system to remove welding fumes. The carcinogenic nature of welding fumes is well-established in German technical guidance, and exposure to welding fumes is regulated through a detailed risk-based system (the German Technische Regeln für Gefahrstoffe TRGS or Technical Rules for Hazardous Substances are referred to throughout the welding report, in particular TRGS 528). Finland is most unusual as it is the only Member State which has included '*welding and thermal cutting of stainless steel'* in the Finnish version of Annex I in the Decree of the Government addressing the risk of work-related cancer, 1267/2019 of 12 December 2019.

Three Member States have defined OELs for welding aerosols, which are effectively process generated substances: Latvia, Lithuania and Slovakia. See Table 3-1 for more details about these OELs.

The study team was unable to find the national legislation that includes the transposition of Annex I of the CMRD for Cyprus, Malta, Romania. It could be that the relevant legislation exists, but the study team did not find it, or that the Annex I or the CMRD has not been transposed in those Member States.

3.2 Relevant uses, processes and sectors

3.2.1 Summary of REACH registration data

The substances within the scope of the study are not subject to the requirements for registrations under REACH.

The substances that are covered by welding fumes+ are not liable to REACH registration as they are process generated, or by-products. Base metals and filler materials are covered by REACH but are not liable to REACH registration. Registration of some substances in welding fumes+ can occur in some cases where there are other uses. Chromium VI is the sole substance used in welding activities, as plating and surface treatment, that is under Annex XIV of REACH's Authorisation List. Surfaces that have been treated do not contain chromium trioxide, but there is occupational exposure through the plating to Chromium VI that can be carcinogenic. Chromium VI is not used as a starting, base or additional material in welding activities, but Chromium VI compounds are created through some welding activities (ECHA, 2022).

Although welding fumes and gases are not intended to be used by consumers or workers, the occupational exposure to these substances can be of a magnitude that matches substances that are covered by REACH. Due to this consideration, REACH methodology has been applied by the European Welding Association to welding fumes and gases to assess hazards and risks and implement control measures to support health and safety (EWA, 2021).

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[13] Although it should be noted that the welding processes for which there are Danish process-related limit values does not match the full list of welding+ processes as defined in the ECHA scoping report (2022).

3.2.2 Generation of welding fumes

Welding fumes+ are process generated substances. Welding is a process in which metals are joined together to form a secure joint (IARC, 2018). A filler material is added to the joint during welding to create a pool of molten material that becomes stronger when it cools. Welding can be performed using different techniques such as arc welding using electricity, gas welding using fuel gases, laser welding, or plasma welding. Another method of joining metals is soldering, where two or more items are joined by melting and adding a filler metal (solder) into the joint. The filler has a lower melting point than the adjoining metal, and the workpieces do not need to be melted. Soft soldering is used in the electronics industry for making good electrical connections, while brazing, a type of high-temperature soldering, creates a strong joint between the same or different metals.

Welders may use various welding methods in their work and may be full-time or part-time welders. Besides joining metals, they may also carry out tasks such as cutting shapes, gouging, flame straightening, and thermal spraying. The German Technical regulations for hazardous substances consider additive manufacturing, such as 3D printing with metal powder, as part of welding activities (BAUA, 2021).

The welding+ activities (or welding+ processes) defined by ECHA are summarised in Table 3-5 and described in more detail in section 3.2.3.

Table 3-5 The list of welding+ activities as defined by ECHA.

Welding+ activity	Definition
Fusion welding	Gas welding, arc welding (MIG, MAG, SMAW, FCAW, SAW, ESW, SW), arc welding (TIG, PAW), beam welding
Soldering[1]	Soft soldering, hard soldering
Brazing[1]	Temperatures greater than 450°C, laser beam brazing, brazing with an electric arc (MIG, TIG, plasma brazing)
Thermal cutting or gouging[1]	
Thermal spraying[2]	
Flame straightening[2]	
Additive production processes[3] (3D printing using metal powder)	

Notes:

[1] These activities were previously not considered to be welding, but were allied with welding (Force Technology, Pers comm, February 2023).

[2]These activities were not previously considered to be welding (Force Technology, Pers comm, February 2023). However, thermal spraying was considered to be an allied process by the German "Vereinigung der MetallBerufsgenossenschaften" (Association of Metalworkers' Liability Insurance Associations) (VBMG, 2007).

[3]This is a relatively new process, and was not previously considered to be welding (ECHA, 2022).

Source: ECHA, 2022.

Based upon sales figures from the European Welding Association (EWA) members, which represent more than 80% of European welding activities, the key metals that are used across Europe are (*pers comm by email March 2023*):

- Steel (unalloyed and low-medium alloyed): 93% of metal welded;
- Stainless steel, cast iron and nickel base: 5%;
- Aluminium and aluminium alloys: 2%; and
- Copper and copper alloys: negligible amounts.

This list of metals can be cross referenced with the list of metals and their oxides that are covered by the CAD, CLP and CMRD (Table 1-1). The simplest steel contains iron and carbon, otherwise known as 'carbon steel' or 'mild steel'. Alloy steels commonly contain manganese, nickel, chromium, molybdenum, vanadium, silicon and boron. Less commonly used alloyants include aluminium, cobalt, copper, titanium, tin, zinc and lead.

According to the EWA arc welding consumables market data, the top four welding processes in 2018 by value were: MIG/MAG, then TIG and MMA, followed by plasma cutting and then other processes including submerged arc welding and others (EWA, 2019). The EWA estimate that around 50% of welding in Europe is MIG/MAG (pers comm, February 2023). According to 2020 arc welding consumables market data, MIG/MAG/TIG made up 52% of the product value sold, followed by covered stick electrodes (used in SMAW) at 23%, then SAW wires and fluxes (16%) and flux-cored welding (used in MAG) at 9%. The EWA were asked to put arc welding into the overall picture of other types of welding used in the European context, based upon global welding consumables market data. The EWA have provided the following estimates of the breakdown of different welding processes in Europe, based on the welding consumables market data (with additional comments from the EWA provided in brackets):

- 70% electric arc welding:
  - MIG-MAG 34%;
  - SMAW (MMA) 14%;
  - SAW 11% (very few fumes);
  - FCAW 6%;
  - TIG 5% (few fumes);
- 30% other technologies:
  - Plasma cutting (8% of the overall total);
  - Resistance welding (8%) (very few fumes);
  - Oxyfuel cutting (5%);
  - Laser beam welding and cutting (5%) (very few fumes);
  - Oxyfuel welding – brazing (3%) (few fumes); and
  - Ultrasonic welding (1%) (very few fumes).

The value of the welding consumables market in 2021 was estimated by the EWA to be 1.7 million Euro for the EU28 (EWA *pers comm*, February 2023). However, 2021 may not have been a typical year for the industries undertaking welding activities, as working practices may have been different due to the Covid 19 pandemic. Therefore 2018 data seems more reliable as a baseline, as this was before the pandemic hit.

3.2.3 Overview of key intentional uses

The annexes of this report contain further information on welding processes. A diagram to classify the types of welding processes is included in 11.9 (Annex 12). A description of the different types of welding+ activities is included in section 11.10 (Annex 13), to provide useful background information. The 'estimated category of risk for worker exposure' (in Annex 4) is based upon likelihood of worker exposure based upon a combination of:

- Emission rates from that process (extracted from BAUA, 2021);
- How commonly the process is used (various sources);
- Whether the process is automated and in a closed system therefore reducing worker exposure (ECHA, 2022); and
- Whether workers are likely to be using Respiratory Protective Equipment (RPE).

Table 3-6 below lists hazardous substances that are generated by different welding processes depending upon the materials being welded, and whether EU or national OELs exist for these substances. Table 3-7 provides a list of welding processes with shortened names that will be used during this study.

Table 3-6 Hazardous substances generated from different welding processes, depending upon base and filler materials welded and whether there are OELs in place at European or National level in Member States for these hazardous substances.

Welding process	Base and filler materials	Hazardous substances generated		
		EU OELs	National OELs	No OELs in place
Gas welding	Mild Steel	Mn	Fe	
	Copper alloys	Ni	Cu	Zn
	Aluminium			Fluorides from the flux
Arc welding - consumable electrode (filler) (MIG, MAG, SMAW, FCAW, SAW, ESW, SW)	Mild steel	Mn	Fe	Fluorides
	Stainless Steel	Mn, Cr(III), Cr(VI), Ni	Fe, Co, V	Fluorides
	Cast Iron	Mn, Cr(VI)	Fe	
	Nickel-based alloys	Ni, Cr(VI)	Fe	
	Copper alloys	Ni	Cu	
	Aluminium alloys	Mn	Al, Mg, Cu	Zn
Arc welding - non-consumable electrode (TIG; PAW)	Mild Steel	Mn	Fe	
	Stainless Steel	Mn, Cr(III), Cr(VI), Ni	Fe, Co, V	
	Cast Iron	Mn, Cr(VI), Ni	Fe	
	Nickel-based alloys	Ni, Cr(VI)	Fe	
	Copper alloys	Ni	Cu	

Welding process	Base and filler materials	Hazardous substances generated		
		EU OELs	National OELs	No OELs in place
	aluminium alloys	Mn	Al, Mg, Cu	Zn
	Titanium alloys		Al, V	Ti
	Zirconium alloys			Zr
Beam welding	Mild Steel	Mn	Fe	
	Stainless Steel	Mn, Cr(III), Cr(VI), Ni	Fe, Co, V	
	Cast Iron	Mn, Cr(VI), Ni	Fe	
	Nickel-based alloys	Ni, Cr(VI)	Fe	
	Copper alloys	Ni	Cu	
	aluminium alloys	Mn	Al, Mg, Cu	Zn
	Titanium alloys		Al, V	Ti
	Zirconium alloys			Zr
Soft soldering (90°C- 450°C)	Fluxes			Natural resins (e.g. rosin), organic acids (e.g. adipic acid) and chlorides (e.g. zinc chloride or ammonium chloride)
Hard (silver) soldering (> 450°C, flame brazing)	Brazing solders		Copper-zinc alloys	with additives of silver
Brazing (>450°C, Laser beam brazing, Brazing with an electric arc (MIG, TIG, plasma)	Copper based alloys		CuSi3, CuAl8 or CuSn6	
	Brazing fillers			Cadmium (1)
Thermal cutting or gouging	Mild steel	Mn	Fe	
	Stainless Steel	Mn, Cr(III), Cr(VI), Ni	Fe, Co, V	
	Cast Iron	Mn, Cr(VI), Ni	Fe	
	Nickel-based alloys	Ni, Cr(VI)	Fe	
	Copper alloys	Ni	Cu	
	aluminium alloys	Mn	Al, Mg, Cu	Zn
	Titanium alloys		Al, V	Ti
	Zirconium alloys			Zr
Thermal spraying	Spray Additives		Cobalt, copper	Boron, molybdenum, silicon, plastics, carbides (WC-12Co, WC-27NiCr, WC-14CoCr, WC/Ti-C-17-Ni, Cr3C2-25NiCr etc.), steel, zinc, tin, tantalum

Welding process	Base and filler materials	Hazardous substances generated		
		EU OELs	National OELs	No OELs in place
	Bronze		Cu	Sn,
	Monel	Ni	Cu, Fe	
	Oxide ceramics	Cr_2O_3	Al_2O_3	TiO_2, Y_2O_3, ZrO_2
Additive production processes	Metal powders	Nickel, Chromium	Iron, Aluminium alloys	Titanium

Source documents: Adapted from ECHA, 2022 (Table 3)

Note 1 Exceptionally in defence and aerospace applications and when used for safety reasons.

Table 3-7 Welding processes with shortened names.

Welding process	Short name
Additive production: 3D printing, using metal dust	3D printing
Arc spraying	AS
Autogenous flame cutting	Auto flame cutting
Brazing	Brazing
Flame spraying	F Spray
Flame straightening	F Straight
Gas fusion welding	GFW
Laser beam cutting (without additional materials)	LB cutting
MAG (solid wire)	MAG (solid wire)
MAG (flux-cored arc welding with shielding gas)	MAG (flux, shielding gas)
MAG (flux cored arc welding without shielding gas)	MAG (flux)
MIG/MAG (low-energy protective gas welding)	MIG/MAG
MIG (solid wire, nickel, nickel-based alloys)	MIG (solid wire, Ni)
MIG (aluminium materials)	MIG (Al)
MIG Soldering	MIG Solder
MMA	MMA
Plasma cutting	PC

Welding process	Short name
Soft soldering	Soft solder
Submerged Arc Welding	SAW
Tungsten Inert Welding	TIG

Source: Study team.

3.2.4 Processes unintentionally generating welding fumes

Not applicable to welding fumes

3.2.5 Presence of welding fumes as impurity

Not applicable to welding fumes.

3.2.6 Overview of sectors

Welding+ activities are undertaken across a broad range of sectors, where metal products are manufactured, installed, repaired or maintained (Section 3.2.3). Besides these key sectors identified by ECHA and the guidance in TRGS 528, electronics manufacturing and repair and more minor sectors also undertake welding+ activities such as craftsmen, plumbers, hobbyists (e.g. jewellery making). Within each sector, different types of welding activities are undertaken using different base materials. These all play a part in terms of the types and rate of welding emissions generated. Soldering consumables such as solder and flux also affect the welding emissions generated.

The European Welding Association (EWA, 2019) point out that welding is closely correlated with the consumption of steel. EWA members, that represent more than 80% of the welding community in Europe, mainly weld mild steel or low alloys (93% of metal welded). In the absence of data on the remaining 20% of the European welding community, the study team assumes that this has a similar make up to the EWA members. The EWA say (EWA, 2019 and EWA, *pers comm*, February 2023) that consumption of steel per sector can be used as a surrogate to estimate the amount of welding in each sector.

Table 3-8 shows that the sectors likely to be undertaking the most welding work are construction (34%), followed by automotive (20%), then mechanical engineering (15%), then metalware (14%) and (manufacture of steel) tubes (11%), with domestic appliances, other transport and miscellaneous following (2% respectively) (percentages are given for steel consumption in 2020).

The EWA say (*pers comm,* March 2023) that the remaining 7% of the total metal welded (deposited) in Europe is:

- Stainless steel + Cast iron + Ni Base: 5%; and
- Aluminium + Aluminium alloys: 2%.

These proportions of metals being welded in Europe are important, as previously noted, the substances in welding fumes depend largely on the metals being welded. This will be explored further in section 3.3 below.

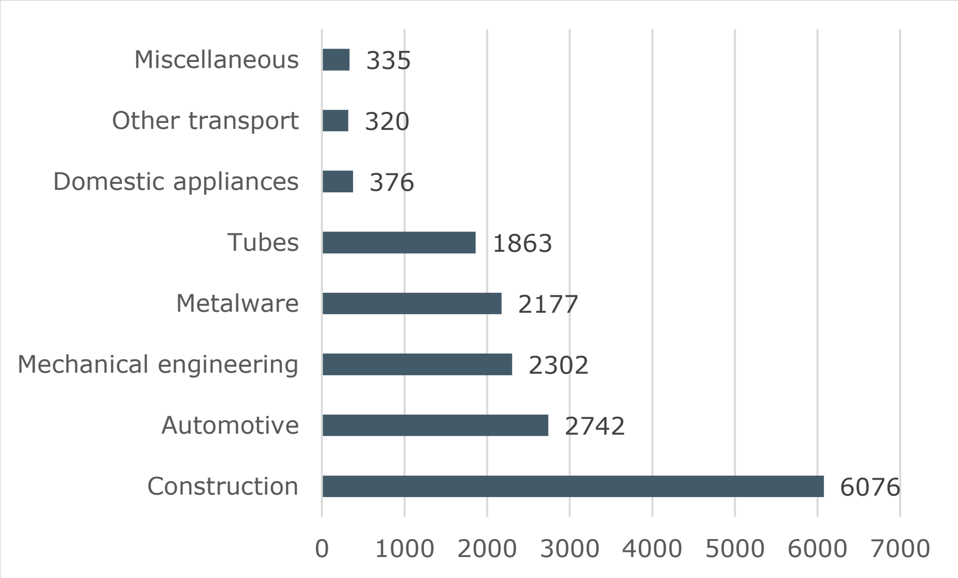

Table 3-8: Steel consumption per steel-using sector (in thousands of metric tonnes) in 2020.

Source: EUROFER, 2022.

Note: Consumption by steel-using sector is calculated using the Steel-Weighted Industrial Production (SWIP) index.

The sectors undertaking the most welding are likely to also correlate with the sectors with the most welders, except for tasks that are automated such as body shell construction in the automotive industry (see section 3.2.3). However, this is a simplified assumption which does not take into account the fact that some sectors will be welding large pieces of metal, such as the construction industry welding steel construction beams, whilst some sectors will be welding relatively smaller pieces of metal such as repair of motor vehicles by resistance spot welding.

Table 3-9: Key sectors undertaking welding activities and base materials

Sector	Description of welding activities	Base materials
Shipbuilding	Joint welding: • MIG/MAG • MMA • Submerged arc • TIG cutting • Flame cutting • Plasma cutting	Mainly non alloy steels (5-30 mm). Aluminium (3-20 mm) Chrome-nickel steels and copper alloys on a case by cases basis.
Automotive engineering – body shell construction	Body shell construction using robots. Pre-assembled components joined by robots using: • Body adhesive • Resistance spot welding • Inert gas welding • 'Emergency strategy' • Manual resistance spot welding • MAG welding	Galvanised, non alloy steel for body panels (0.6-0.8mm) Body reinforcement sheets (2mm) Aluminium alloys for outer skin sheets (1.5mm)

Sector	Description of welding activities	Base materials
	• Special areas (closed systems with direct extraction) • Laser beam welding processes • Laser beam brazing	
Plant, container and pipeline construction	Machining processes Conventional and automatic fusion welding processes (submerged arc, MIG/MAG, partly TIG welding) MAG welding of non alloy and high alloy steels. Flame & plasma cutting	Non alloy or high strength structural steels Pressure vessel steels High alloy steels
Steel construction (e.g. road or railway bridges)	Joint welding on steel materials: • MIG/MAG • TIG	Non alloy steels Chrome-nickel steels (<200mm)
Metal construction (e.g. stairs, railings, canopies, balconies, gates, grilles or fences – may be constructed on site or before installation)	Machining processes Conventional fusion welding: • MMA for assembly (10%) • MIG/MAG for manufacturing (5%) • TIG for manufacturing (5%) • MAG welding for manufacturing of non alloy steels (80%)	(Corresponding to processes to the left): • Non alloy steel, Cr-Ni steel • Al, Cr-Ni steel • Al, Cr-Ni steel • Non alloy steel
Manual commercial vehicle production & repair	Machining processes Conventional fusion welding: • MIG/MAG • TIG • MAG welding of non alloy steels	
Electrical and electronics – manufacturing, installation and repair	Soldering to achieve electrical connections	Often uses copper for example on printed circuit boards
Plumbing	Soldering to achieve watertight joints.	Copper pipes
Crafts, hobbyists, jewellery making, musical instruments	Soldering to join together jewellery, sculptures, musical instruments etc.	Various solders used: alloy containing lead or lead-free such as antimony, bismuth, brass, copper, indium, tin or silver. Flux used: rosin Various base metals can be solded such as: silver, gold,

Sector	Description of welding activities	Base materials
Blacksmiths	Brazing to repair cast-iron objects & wrought iron furniture	Iron

Source documents:

BAUA (2021) Technical Rules for Hazardous Substances (TRGS) 528 - Welding work. Committee on hazardous substances. Germany, August 2021.

ECHA (2022) ECHA Scoping Study report for evaluation of limit values for welding fumes and fumes from other processes that generate fumes in a similar way at the workplace, European Chemical Agency, Helsinki, Finland, November 2022.

TWI (2022) What is soldering? A full guide (meaning, and types). Available from https://www.twi-global.com/technical-knowledge/faqs/what-is-soldering#WhatMetalsareUsed

3.2.6.1 Sources of information about sectors generating welding fumes

The key sources of information that have been used to understand the sectors generating welding fumes are:

- ECHA (2022) ECHA Scoping Study report for evaluation of limit values for welding fumes and fumes from other processes that generate fumes in a similar way at the workplace, European Chemical Agency, Helsinki, Finland, November 2022;
- BAUA (2021) Technical Rules for Hazardous Substances (TRGS) 528 - Welding work. Committee on hazardous substances. Germany, August 2021; and
- TWI (2022) What is soldering? A full guide (meaning, and types). Available from https://www.twi-global.com/technical-knowledge/faqs/what-is-soldering#WhatMetalsareUsed.

3.2.6.2 Sectors of use (SU) in REACH registration dossiers

Not applicable to welding fumes.

3.2.6.3 Summary of sector data sources

Not required for welding fumes.

3.2.7 Consideration of exclusion of sectors from further analysis

A discussion of the factors that could lead to exclusion of sectors from further analysis are follows:

- If 93% of metal being welded in Europe is mild steel (no alloy or low alloy steel) (EWA, 2019), the welding fumes will contain only **low concentrations of hexavalent chromium or nickel**, or other CMR substances at low concentrations, although a high emission welding process welding low alloy steel can produce measurable levels of chromium VI or nickel (section 5.1.2);
- The five main sectors (which consume 94% of steel in Europe) are construction, automotive, manufacture of machinery and equipment, metal product manufacturing and tubes (Table 3-8, based on data from EUROFER, 2022);
- Table 3-8. This list ranks 'domestic appliances' and 'other transport' (which would include shipbuilding, aerospace and the rail industry) as much smaller users of steel;

- The remaining 7% of metals that are welded in Europe comprise stainless steel, cast iron, nickel-based metals, aluminium and aluminium alloys (EWA, *pers comm*, March 2023) – these metals produce welding fumes with higher concentrations of CMR substances (Table 2-1). Welding of these alloys will be affected by the new OELs for Cr(VI) and nickel compounds in 2025;

- In terms of welding processes, processes with higher emission rates (plasma cutting, arc spraying, flame spraying, laser cutting, laser welding, MAG) are of more concern than processes with **lower emission rates such as TIG, SAW and gas welding** (Table 2-4). However, as welding processes are used across different sectors (3.2.6) this does not enable exclusion of any sectors from analysis, but simply focuses the study on the processes with higher emissions which could result in higher worker exposure;

- In terms of sectors which undertake welding+ processes with low emission rates, **soft soldering has a low emission rate** (as the temperature for soldering is low and the emission rate is higher at higher temperatures) and is used by: the electrical and electronics sector; and for plumbing;

- Indeed, for 'electrical and electronics – manufacturing, repair and installation' the only welding+ process is assumed to be soft soldering which does not contain any CMR substances so can be excluded from the impact assessment;

- For 'electrical, plumbing and other construction installation activities' the welding+ processes are likely to be largely soft soldering but could contain other types of welding so are included but with the caveat that overall total exposure levels are likely to be low. Whether CMR substances are present in the fumes will also depend upon the materials being welded. So welding fumes from soldering copper pipes could contain copper;

- Whether CMR substances are present in welding fumes can also be used to exclude certain welding processes, using certain materials, for certain sectors. This could be done with reference to Table 2-2;

- Regarding the working environment, confined spaces will result in higher worker exposure (unless measures are taken to extract welding fumes);

- In terms of automation, if **processes are automated and enclosed**, or automated and the operator is working at a distance or in a cab, then the likelihood for worker exposure is reduced due to isolation from the fumes. This is largely the case for body shell construction in the automotive industry, where welding (resistance spot welding and inert gas welding) is undertaken by robots, and where laser beam welding and laser beam brazing are undertaken in closed systems with direct extraction (section 3.2.6). However, manual welding is undertaken for the repair and maintenance of automotive vehicles, using resistance spot welding (low emission rate) or MAG welding (high to very high emission rate) so the latter is still of concern to this study;

- Since manganese is present in welding fumes from mild steel, which is the majority of metal being welded in Europe, the assumption could be made that companies in countries with low national OELs for manganese that are tighter than the European OELs for manganese (i.e. stricter than 0.2 for inhalable and 0.05 mg/m^3 for respirable manganese and inorganic compounds). They are also more likely than other countries to be applying good practice measures to protect workers from exposure to welding fumes more generally (Table 11-17); and

- National OELs for manganese range from 1.6 – 20 mg/m^3 for 15 minute STELs for inhalable manganese and inorganic compounds (in Austria, Denmark, Germany, Hungary).

3.2.8 *Identified sectors with risk of exposure to welding fumes*

The study team identified the key sectors with risk of exposure to welding fumes based upon sectors listed in ECHA (2022), supplemented with sectors from their own judgement. In the below table (Table 3-10) please note that higher level NACE codes have been given to shorten the list; where sub codes that have been grouped under each NACE code the subcodes included were as follows:

- C24 Manufacture of basic metals:
  - C24.1 Manufacture of basic iron and steel and of ferro-alloys;
  - C24.2 Manufacture of tubes, pipes, hollow profiles and related fittings, of steel;
  - C24.41 Precious metals production; and
  - C24.42 Aluminium production.
- C25 Manufacture of fabricated metal products (excl. machinery & equipment):
  - C25.1 Manufacture of structural metal products;
  - C25.2 Manufacture of tanks, reservoirs, and containers of metal;
  - C25.3 Manufacture of steam generators, except central heating hot water boilers;
  - C25.4 Manufacture of weapons and ammunition;
  - C25.5 Forging, pressing, stamping, and roll-forming of metal; powder metallurgy;
  - C25.6 Treatment and coating of metals; machining;
  - C25.73 Manufacture of tools;
  - C25.93 Manufacture of wire products, chain and springs; and
  - C25.99 Manufacture of other fabricated metal products n.e.c.
- C26 Manufacture of computer, electronic & optical products:
  - C26.1 Manufacture of electronic components and boards;

  - C26.11 Manufacture of electronic components;
  - C26.3 Manufacture of communication equipment;
  - C26.4 Manufacture of consumer electronics;
  - C26.51 Manufacture of instruments and appliances for measuring, testing and navigation; and
  - C26.7 Manufacture of optical instruments and photographic equipment.
- C28 Manufacture of machinery & equipment:
  - C28.1 Manufacture of general-purpose machinery.
- C32: Other manufacturing:
  - C32.12 Manufacture of jewellery and related articles; and
  - C32.13 Manufacture of imitation jewellery and related articles;
  - C32.2 Manufacture of musical instruments;
  - C32.3 Manufacture of sports goods;
  - C32.4 Manufacture of games and toys;
  - C32.5 Manufacture of medical and dental instruments and supplies; and
  - C32.99 Other manufacturing not elsewhere classified (n.e.c.)
- E38 Waste collection, treatment & disposal, materials recovery:
  - E38.32 Recovery of sorted materials.
- F42 Civil engineering:
  - F42.1 Construction of roads and railways.
- F43 Specialised construction activities:
  - F43.2 Electrical, plumbing and other construction installation activities;
  - F43.3 Building completion and finishing; and
  - F43.91 Roofing activities.
- G45 Wholesale & retail trade & repair of motor vehicles & motorcycles:
  - G45.2 Maintenance and repair of motor vehicles; and
  - G45.4 Sale, maintenance and repair of motorcycles and related parts and accessories.

Table 3-10 Gross list of identified sectors with potential risk of exposure to welding fumes

Sector (NACE Code)	NACE description	Specific activity
C24	Manufacture of basic metals	Cutting e.g. laser/flame/plasma/thermal cutting or gouging, thermal spraying
C25	Manufacture of fabricated metal products (excl. machinery & equipment)	Welding processes, cutting, coating (spraying)
C26	Manufacture of computer, electronic & optical products	Welding processes, soldering
C27	Manufacture of electrical equipment	Soldering
C28	Manufacture of machinery & equipment	Welding, cutting, coating (spraying)
C29	Manufacture of motor vehicles, trailers & semi-trailers	Welding, cutting, coating (spraying)
C30	Manufacture of other transport equipment	Welding, cutting, coating (spraying)
C31	Manufacture of furniture	Welding, cutting, coating (spraying)
C32	Other manufacturing	Welding, cutting, coating (spraying)
C33	Repair & installation of machinery & equipment	Welding, soldering
E38	Waste collection, treatment & disposal, materials recovery	Cutting up metal products for materials recovery.
F41	Construction of buildings	Welding processes
F42	Civil engineering	Welding processes
F43	Specialised construction activities	Welding processes, soldering electronics or soldering pipework.
G45	Wholesale & retail trade & repair of motor vehicles & motorcycles	Welding processes: resistance spot welding
J61	Telecommunications	Soldering
S95	Repair of computers & personal & household goods	Soldering

Source: Study team building upon sectors listed in ECHA, 2022, BAUA, 2021

3.2.9 Uses of sectors excluded from analysis

In most sectors a range of different welding+ processes are undertaken. This makes it difficult to exclude sectors from the analysis since almost all welding processes can result in exposure to CMR substances, see Table 3-11; the clear exception to this is soft soldering.

Table 3-11 Uses and sectors excluded from analysis

Use or sector	Source of information on use or sector	Reasons for exclusion
C27 Manufacture of electrical equipment	ECHA, 2022	Soft soldering (for electrics) does not contain CMR substances as lead is restricted from use in solder.
J61 Telecommunications	ECHA, 2022	As above for soft soldering.
S95 Repair of computers & personal & household goods	ECHA, 2022	As above for soft soldering.

Use or sector	Source of information on use or sector	Reasons for exclusion
C25.50 powder metallurgy: Additive production (3D printing using metal powders e.g. iron, titanium, nickel, chromium and aluminium alloys)	ECHA, 2022	Production is enclosed inside machines, so exposure during operation is not possible. However, worker exposure to the metal powders is possible when the powder is loaded into the machine, or during cleaning. The assumption is that PPE would be worn by workers during maintenance activities.

Source: Study team.

3.2.10 Sectors taken forward for analysis

The sectors that have been taken forward for analysis are summarised in Table 3-12 which also includes a description of the activities with exposure to welding fumes containing CMR substances for each sector. Table 3-13 lists the shortened names of the sectors taken forward for analysis.

Table 3-12 Analysed sectors with risk of exposure to welding fumes

NACE code	Short name for sector	Description of activities with exposure to welding fumes containing CMR substances
C24	Manufacture of basic metals	Welding processes, cutting during manufacture of steel tubes, pipes etc.
C25	Manufacture of fabricated metal products (excl. machinery & equipment)	Welding processes, cutting, coating (spraying)
C26	Manufacture of computer, electronic & optical products	Welding processes, soldering
C28	Manufacture of machinery & equipment	Welding, cutting, coating (spraying)
C29	Manufacture of motor vehicles, trailers & semi-trailers	Welding, cutting, coating (spraying)
C30	Manufacture of other transport equipment	Welding, cutting, coating (spraying)
C31	Manufacture of furniture	Welding, cutting, coating (spraying)
C32	Other manufacturing	Welding, cutting, coating (spraying)
C33	Repair & installation of machinery & equipment	Welding, soldering
E38	Waste collection, treatment & disposal, materials recovery	Cutting up metal products for materials recovery.
F41	Construction of buildings	Welding processes
F42	Civil engineering	Welding processes
F43	Specialised construction activities	Welding processes, soldering electronics or soldering pipework.
G45	Motor trade & repair	Welding processes: resistance spot welding

Source: Study team.

Table 3-13 Sectors identified and shortened names.

NACE	Sector	Short name
C24	Manufacture of basic metals	C24 Basic metals
C25	Manufacture of fabricated metal products	C25 Metal products
C28	Manufacture of machinery and equipment n.e.c.	C28 Machinery & equipment
C29	Manufacture of motor vehicles, trailers, and semi-trailers	C29 Motor vehicles
C30	Manufacture of other transport equipment	C30 Transport equipment
C31	Manufacture of furniture	C31 Furniture
C32	Other manufacturing	C32 Other
C33	Repair and installation of machinery and equipment	C33 Equipment repair & installation
E38	Waste collection, treatment & disposal, materials recovery	E38 Waste
F41	Construction of buildings	F41 Construction
F42	Civil engineering	F42 Civil engineering
F43	Specialised construction activities	F43 Specialist construction
G45	Wholesale & retail trade & repair of motor vehicles & motor-cycles	G45 Motor trade & repair

Source: Study team

3.3 Exposure concentrations

Measured exposure concentrations for welding fumes have not been used in the cost benefit analysis for an entry into Annex I of the CMRD. This is due to the paucity of exposure data available, with insufficient data to be able to compare exposure levels from a particular welding process undertaken in a particular sector. However, German exposure measurements are briefly discussed during the qualitative assessment of policy options for an OEL for dust limit values (section 7.3).

3.3.1 Data sources

A scientific literature review of meta-analyses and of individual scientific papers was undertaken to gather data on welding fumes exposure concentrations, across sectors and across welding processes. However, some of the descriptors for the data (location, welding process, base material, sector, Risk Management Measures (RMMs) in place) are often incomplete, making it hard to compare and contrast data. The years of exposure ranged from 1997 to 2016. Due to the paucity of the data gathered, it will have limited uses but will be used for reference when considering the exposure levels associated with different processes.

3.3.2 Inhalable vs. respirable fraction

The stakeholder consultation 2023 did not ask for exposure measurements in terms of the inhalable and respirable fraction of welding fumes.

Table 3-14 in section 3.3.4 below includes exposure measurements divided into respirable versus inhalable fractions for different welding processes, with and without fumes extraction in place. This provides an indication of the types of exposure that are observed in German workplaces but is not a random sample as explained below.

3.3.3 Combinations of substances in welding fumes

The effects of a combination of substances present in welding fumes+ were considered and the following issues found:

- There is no agreed way of addressing worker exposure to a combination of substances in welding fumes+;
- The ISO formula (from ISO 15011-4) for calculating an additive welding fumes limit value for a combination of different substances in welding fumes discussed by ECHA (2022) is itself contentious as it should not be used for complex mixtures (like welding fumes+);
- The ISO (15011-4) formula is not currently a recommended method for calculating an additive welding fumes limit value for an Annex I entry; and
- In a discussion about another additive formula used in Canada (ECHA, 2022), it is pointed out that they should not be used for:
    - substances with toxicological effects that are not additive (welding fumes may contain diverse metal compounds with complex interactions; some compounds can inhibit each other's effects or have synergistic effects); and
    - carcinogens.

Further to the above, ECHA (2022) point out that in Germany there is no assessment index for a mixture of carcinogenic substances. The reasoning for this is that the lack of knowledge about the combined effects of carcinogenic substances and the possibility of additive, synergistic and antagonistic effects make it currently impossible to assess a mixture of carcinogenic substances. Therefore, in Germany carcinogenic substances are assessed individually. ECHA concludes that while there might be scope to consider combined exposure in some limited circumstances for welding fumes, this would not be possible in the majority of cases.

3.3.4 Exposure data from national databases

Welding fumes exposure data has been extracted from the German MEGA database[14] to compare exposure by process and exposure with and without fumes extraction, for the purpose of a paper on welding fumes exposure in Germany and evaluation of the harmful effects on health by Koppisch *et al*, 2023 (Table 3-14). However, when reviewing this exposure data, it is worth noting that exposure measurements in the German MEGA database are undertaken for three main reasons: for routine inspections, general surveillance or for investigations of suspected exceedance of OELs (DGUV, 2023b, *pers comm*). Therefore, the MEGA database is not a random, representative sample of workplace exposures in Germany. Also, the exposure measurements in

[14] The Institut für Arbeitsschutz der Deutschen Gestzlichen Unfallversitcherung's (IFA's) exposure database: Measurement data relating to workplace exposure to hazardous substances (in German "Messdaten zur Exposition gegenüber Gefahrstoffen am Arbeitsplatz") https://www.dguv.de/ifa/gestis/expositionsdatenbank-mega/index-2.jsp

MEGA are specific to Germany and are not representative of other countries across the EU, where the working conditions could be quite different.

The DGUV stress that from 2000 until 2022, for exposure assessment, the sampling system was placed behind the protective equipment (normally only a visor for protection against UV radiation) (DGUV, 2023b, *pers comm*). In a few cases sampling was performed under a powered air-purifying respirator (PAPR), which protects against welding fumes and UV radiation. The measurement data in the Table below come from both measurement procedures. The DGUV say that ideally a more detailed explanation regarding measurement processes, type of welding work and welding material, etc. would be needed, to be able to analyse the data properly.

Table 3-14 German welding fumes exposure data by process, from 1999 to 2019.

	No of measurements	No of workplaces	No of values <LoD*	Highest LoD*	Concentration (mg/m³)	
					50th percentile*	90th percentile*
Metal active gas welding (MAG): A fraction (respirable fraction)						
With fumes extraction	622	358	132	1.25	0.84	2.8
Without fumes extraction	150	111	15	1.25	2.1	6.8
Metal active gas welding (MAG): E fraction (inhalable fraction)						
With fumes extraction	1,424	674	239	0.72	1.9	8.1
Without fumes extraction	580	345	21	0.72	5.5	15
Metal cored wire welding with shielding gas: A fraction (respirable fraction)						
(2004 – 2019)	11	10	1	0.25	0.93	3.2
Metal cored wire welding with shielding gas: E fraction (inhalable fraction)						
(2004 – 2019)	45	24	7	0.71	3.6	17
Metal inert gas welding (MIG): A fraction (respirable fraction)						
With fumes extraction	76	43	24	1.25	0.63	2.7
Without fumes extraction	19	15	3	1.25	1.5	2.7
Metal inert gas welding (MIG): E fraction (inhalable fraction)						
With fumes extraction	227	133	47	0.71	1.6	8.2
Without fumes extraction	85	57	8	0.71	4.1	13
Tungsten inert gas welding (TIG): A fraction (respirable fraction)						
With fumes extraction	171	129	121	1.25	<LoD	0.58
Without fumes extraction	113	94	51	1.25	0.34	0.89+
Tungsten inert gas welding (TIG): E fraction (inhalable fraction)						
With fumes extraction	453	312	269	0.76	<LoD	1.2

	No of measurements	No of workplaces	No of values <LoD*	Highest LoD*	Concentration (mg/m³)	
					50th percentile*	90th percentile*
Without fumes extraction	363	238	169	0.81	0.36	1.6
Manual metal arc welding (MMA): A fraction (respirable fraction)						
With fumes extraction	66	55	14	1.25	0.75	3.1
Manual metal arc welding (MMA): E fraction (inhalable fraction)						
With fumes extraction	195	127	42	0.72	1.3	7.2
Without fumes extraction	24	20	4	0.71	3.7	9.8
Submerged arc welding (SAW): A fraction (respirable fraction)						
	31	20	3	1.25	0.64	1.3
Submerged arc welding (SAW): E fraction (inhalable fraction)						
	34	23	4	0.71	1.9	8.1
Resistance spot welding: A fraction (respirable fraction)						
	141	74	111	1.25	<LoD	0.6
Resistance spot welding: E fraction (inhalable fraction)						
	162	83	121	0.71	<LoD	0.81

Source: MEGA data published in Koppisch et al, 2023
Notes:
If analysis results are below the LoD i.e. r espective measurement method in this case, then the value of half the LoD is included in the statistics. The LoD varies depending on for example: the sampling duration and the volume flow during sampling, therefore the highest LoD is given in the table.
<LoD: More than 50% of the measured values are below the LoD. Therefore, no concentration is given for this percentile.
E fraction: The data was determined using measuring systems that record the inhalable dust fraction (E dust).
A fraction: the data was determined using measuring systems that record the respirable dust fraction (A dust)

3.3.5 Exposure data by sector

A simplified model has been developed to make some general assumptions about the proportion of companies across the EU27 that:

- Need to invest in improved extraction (extraction at source rather than general ventilation) to achieve optimal protection of workers;
- Need to invest in helmets (to replace masks) to achieve optimal protection of workers;
- Already have optimal RMMs but need to use them[15]; and

[15] There are various reasons that enterprises may have RMMs, but workers may choose not to use them. For example general ventilation may not be used on a cold day as it lowers the temperature of the room beyond what is comfortable to work in. Workers may choose not to wear RPE on offer if they consider it cumbersome and that it may make their work more difficult to accomplish. Supervisors may choose not to enforce recommended RMMs that are available on site. All of these examples are anecdotal experiences from the study team.

- Already have optimal RMMs and already use them.

The first two categories incur associated costs which can be estimated and discounted for 40 years. It can be argued that the last two categories incur no Capital Expenditure (CAPEX) costs, but category 3 incurs Operating Expenditure (OPEX) costs (running costs such as electricity for extraction and consumables e.g. filters) and benefits.

3.3.6 Summary of exposure data by sector

Respondents to the stakeholder consultation 2023 were asked to tick which substances they monitor for in air concentrations or biomonitoring for welding+ activities. The below tables have been created for parameters monitored in air concentrations for welding+ activities by welding fumes and dust (Table 3-15), gases (Table 3-16) and metal compounds (Table 3-17) respectively. The lowest and highest airborne concentrations of welding fumes as measured by the respondents to the consultation 2023 are summarised in Table 3-18.

The respondents to the consultation were not representative of all sectors undertaking welding. No responses were received from the construction sector, and this is one of the largest sectors undertaking welding. There were also some anomalies; the manufacture of paper and paperboard (C17.12) and manufacture of glass and glass products (C23.1) would not be expected to include welding of metals. It is surmised that these sectors may be hiring welders to install and maintain equipment. Therefore, the responses cannot be taken to be representative, but only indicative of the situation. The range of welding fumes exposure levels reported was wide, but the full details of sampling regime are not available: whether the fraction being measured was inhalable (‘E’ fraction) or respirable (‘A’ fraction); whether sampling was behind a visor or under a powered air-purifying respirator for example; and whether fumes extraction was in place or not. For these reasons it is not possible to compare the exposure levels reported here (Table 3-18). More reliable exposure levels have been obtained from the German MEGA database (Table 3-14).

Table 3-15 Number of companies monitoring parameters of welding fumes monitored in air concentrations for welding+ activities, by sector.

Row Labels	Inhalable welding fumes	Respirable welding fumes	Welding fumes (generic)	Particulate matter (dust)
C21 Manufacture of basic pharmaceutical products (1)				1
C23.1 Manufacture of glass and glass products (1)	1	1		
C24.2 Manufacture of tubes, pipes, hollow profiles and related fittings, of steel (1)	1	1		1
C24.51 Casting of iron (2)				2
C25 Manufacture of fabricated metal products (26)	8	6	8	7
C25.99 Manufacture of other fabricated metal products (1)	1	1		
C28 Manufacture of machinery and equipment n.e.c. (7)			1	
C29 Manufacture of motor vehicles, trailers and semi-trailers (6)	4	4	2	3
C30.3 Manufacture of air and spacecraft and related machinery (1)	1			1
C33 Repair and installation of machinery and equipment (6)			1	1
G45.2 Repair of motor vehicles and motorcycles (1)				1
Total	17	13	13	16

Source: Stakeholder consultation 2023.

Notes: The numbers in brackets are the total number of companies who responded.

Table 3-16 Number of companies monitoring gases in air concentrations for welding+ activities, by sector.

Sector	Carbon monoxide	Nitrogen mon-oxide (NO)	Nitrogen dioxide (NO2)	Nitrogen oxides (NOx)	Ozone
C17.12 Manufacture of paper and paperboard (0)	1			1	
C23.1 Manufacture of glass and glass products (1)					1
C24.51 Casting of iron (2)	3	2	3	2	2
C25.2 Manufacture of other general-purpose machinery (1)	1	1	1		
C28 Manufacture of machinery and equipment n.e.c. (7)				1	3
Total	4	3	4	3	6

Source: Stakeholder consultation 2023.

Notes: The numbers in brackets are the number of companies who responded.

Table 3-17 Number of companies monitoring metal compounds in air concentrations for welding+ activities, by sector.

Sector	Aluminium compounds (Al)	Barium compounds (Ba)	Cobalt compounds (Co)	Chromium II or III compounds (Cr II/III)	Chromium VI compounds (CrVI)	Total chromium (Cr)	Copper compounds (Cu)	Iron compounds (Fe)	Magnesium compounds (Mg)	Manganese compounds (Mn)	Nickel compounds (Ni)	Vanadium compounds (V)	Other, please specify:
C17.12 Manufacture of paper and paperboard (0)			1	1	1		1			1	1		
C21 Manufacture of basic pharmaceutical products (1)			1			1	1	1			1		
C23.1 Manufacture of glass and glass products (1)	1	1	1			1	1	1	1	1	1	1	
C24.51 Casting of iron (2)	1	1	1	2	6	5	4	4	2	6	8	2	
C25.2 Manufacture of other general-purpose machinery (1)										1			
C25.99 Manufacture of other fabricated metal products (1)				1	1					1			
C28 Manufacture of machinery and equipment n.e.c. (7)			2	2	5	3	1			4	5		
C29 Manufacture of motor vehicles, trailers and semi-trailers (6)			1		1	1				1	1		
C30.3 Manufacture of air and spacecraft and related machinery (1)			1	1	2	3	1	1		1	3		
Total	2	2	7	6	15	14	8	7	3	15	19	3	0

Source: Stakeholder consultation 2023.

Notes: The numbers in brackets are the number of companies that responded.

Table 3-18 Minimum and maximum exposure concentrations for welding fumes (mg/m^3) by welding process, including the sector and sampling method. Where cells are empty there was no data collected from the stakeholder consultation 2023-.

Welding process	Min (mg/m3)	Sampling method	Sector	Max	Sampling method	Sector
Additive manufacturing						
Autogenous flame cutting						
Brazing						
Flame spraying	<0.04	stationary sampling	C23.1 Manufacture of glass & glass products	0.21	stationary sampling	C23.1 Manufacture of glass & glass products
Gas fusion welding	0	stationary sampling	C29 Manufacture of motor vehicles, trailers and semi-trailers	14.7	stationary sampling	C29 Manufacture of motor vehicles, trailers and semi-trailers
Laser beam cutting	2.61	stationary sampling	C29 Manufacture of motor vehicles, trailers and semi-trailers	18.7	stationary sampling	C29 Manufacture of motor vehicles, trailers and semi-trailers
Laser beam cutting (with additional materials)						
Laser beam cutting (without additional materials)	<0.35	stationary sampling	C25.99 Manufacture of other fabricated metal products			
MAG (flux-cored arc welding with shielding gas)	<0.21	personal sampling	C25 Manufacture of fabricated metal products	2.9	personal sampling	C25 Manufacture of fabricated metal products
MAG (flux-cored arc welding without shielding gas)						
MAG (solid wire)	<0.03	personal sampling	C25 Manufacture of fabricated metal products	0.136	personal sampling	C25 Manufacture of fabricated metal products

Welding process	Min (mg/m3)	Sampling method	Sector	Max	Sampling method	Sector
MIG (aluminium materials)	1.36	personal sampling	C29 Manufacture of motor vehicles, trailers and semi-trailers	2.5	personal sampling	C29 Manufacture of motor vehicles, trailers and semi-trailers
MIG (solid wire, nickel, nickel-based alloys)				0.7	personal sampling	C24.2 Manufacture of tubes, pipes, hollow profiles and related fittings, of steel
MIG soldering	0.001	stationary sampling	C21 Manufacture of basic pharmaceutical products	1	stationary sampling	C21 Manufacture of basic pharmaceutical products
MIG/MAG (low-energy protective gas welding)	4.8	stationary sampling	C29 Manufacture of motor vehicles, trailers and semi-trailers	9.14	stationary sampling	C29 Manufacture of motor vehicles, trailers and semi-trailers
MMA	0.001	stationary sampling	C21 Manufacture of basic pharmaceutical products	1.86	stationary sampling	C33 Repair and installation of machinery and equipment
Plasma cutting	2.44	stationary sampling	C29 Manufacture of motor vehicles, trailers and semi-trailers	2.44	stationary sampling	C29 Manufacture of motor vehicles, trailers and semi-trailers
Soft soldering						
Submerged arc welding	0.14	personal sampling	C29 Manufacture of motor vehicles, trailers and semi-trailers	5.09	stationary sampling	C25 Manufacture of fabricated metal products
TIG	0	stationary sampling	C33 Repair and installation of machinery and equipment	3.64	personal sampling	C33 Repair and installation of machinery and equipment

Source: Stakeholder consultation 2023.

3.3.7 Exposure levels with and without respiratory protective equipment (RPE)

There was insufficient data reported in the stakeholder consultation 2023 to make a meaningful comparison as to exposure levels with and without RPE. To do so, the sample size for each type of welding process would need to be much larger, with examples of exposure levels with and without RPE for each. As there were only 57 responses from companies, and an uneven distribution of exposure measurements across different types of welding process this was not possible.

The Netherlands 5xbeter modelling study (discussed further in section 3.7), includes the results of using different RPE on welding fumes exposure levels (Table 3-64). Modelling exposure data showed that a simple face mask (FFP2/FFP3) reduced exposure levels by 50%; whereas a welding helmet with fresh air (TH2/TH3) reduced exposure levels by 76%; and a welding helmet with fresh air and a wide folding window reduced exposure levels by 88%.

3.3.8 Trends in exposure concentrations

Olssum and Kromhout (2021) report a trend in workplace exposure to welding fumes concentrations decreasing on average by 2-3% per year from a 20-year study in the Netherlands, due to increased implementation of RMMs. Peters *et al* (2016) modelled overall exposure to chromium VI and found an average downward trend of -2.7% per year from 1979 to 1996 and note that exposure to welding fumes is one of the major activities for exposure to chromium VI. Peters *et al* (2016) only found a small decrease in nickel compounds exposure of -1.2% per year, of which welding is an important activity for exposure. Peters *et al* (2016) note that trends vary between industries and countries. They were unable to estimate industry or region-specific trends due to data limitations. A decreasing trend in exposure of -4% per year was reported for welding fumes (Creely *et al,* 2007 in Peters *et al,* 2016). Peters *et al* (2016) estimate that more than 20,000 exposure measurements are needed for each determinant to model realistic estimates of occupational exposure. A summary of these identified trends is provided in Table 3-19.

Exposure trends vary between countries and industries (Peters *et al*, 2016). The status of implementation of best practice RMMs varies between countries; feedback indicates that the implementation of RMMs may be plateauing in some countries such as Germany and the Netherlands (interviews with key stakeholders, June-July, 2023, *personal communication*; see section 5.1.4 and Table 5-4 for a summary). Therefore, the previous rate of improvement in RMMs (in the early 2000s) may no longer be achievable in some countries, but still achievable in others. The study team therefore took a conservative baseline estimate of continuing 1% annual reduction in exposure to welding fumes applied across the EU27 over the next 40 years.

Table 3-19 Summary of trends in welding fumes, Chromium VI and nickel exposure as identified in the literature.

Exposure concentration	Trend	Period trend was observed	Remarks	Reference(s)
Workplace exposure to welding fumes	-2-3% per year	20 years total Mid 1980s-mid 1990s (ECRHS I) then 1998 – 2007 (ECRHS II)	Due to increase in use of RMMs. Study of Netherlands data	Olsson & Kromhout, 2021

Exposure concentration	Trend	Period trend was observed	Remarks	Reference(s)
CrVI exposure, including in welding fumes	-2.7% per year	1977 - 2009	Trends vary between industries & countries, but not able to draw conclusions at this level of granularity due to data limitations.	Peters *et al*, 2016
Nickel compounds exposure, including in welding fumes	-1.2% per year	1977 - 2009	See above note.	Peters *et al*, 2016
Welding fumes	-4% per year	1983 - 2003	16 year old study, so may be out of date if improvements have plateaued now.	Creely *et al*, 2007 in Peters *et al*, 2016

A previous impact assessment for the new OEL for chromium VI (reducing by 80% from 0.025 mg/m^3 inhalable to 0.005 mg/m^3 inhalable over a transition period ending on 17 January 2025) noted that additional risk management measures introduced for this new OEL could result in exposure levels for nickel compounds and associated cases of ill-health to decrease, regardless of the introduction of a new OEL for nickel (EC, 2019). Lehnert (2014, part of the German WELDOX study, in EC, 2019) found that a reduction in exposure to Chromium VI corresponded with a reduction in nickel exposure, achieved by introducing welding helmets with a purified air supply. As a results of the improved RPE, there was a reduction of 96.6% of chromium VI air exposure and a corresponding 96.3% reduction in nickel air exposure.

The IIW corroborated the previous study team's assumption that nickel exposure would decrease alongside chromium VI exposure, and that there would be no issues in meeting the proposed OEL for nickel compounds once the OEL for chromium VI is met. The current study team assume that there may be corresponding reductions in exposure to other CMR substances present in welding fumes as a result of the introduction of the new OELs for chromium Vi and nickel. If an OEL for cobalt and its inorganic compounds is introduced following the current impact assessment, this is also likely to further reduce exposure to welding fumes from welding stainless steel. However, the effect of this reduction is predicted to be limited as cobalt is expensive and only used in limited specialist applications.

Some examples of arc welding processes for which Chromium VI and nickel are typically present in the welding fumes are summarised in Table 3-20 to illustrate some of the welding processes which are likely to require additional risk management measures to achieve the new OELs for chromium VI and nickel, and for which exposure to welding fumes in general will correspondingly decrease when these new OELs are introduced. These arc welding processes are commonly used across almost all of the sectors undertaking welding+ activities as discussed in section 3.2.6, which indicates that additional RMMs will be introduced (or have been introduced where needed during the current transition period) to meet the new OELs for Chromium VI and nickel across almost all of the sectors. The sectors undertaking these arc welding processes include: shipbuilding; automotive engineering – body shell construction; plant, container and pipeline construction, steel construction (e.g. road or railway bridges); (architectural) metal products manufacturing construction. It is worth noting however, that TIG only produces low emissions of welding fumes so additional RMMs may not be needed for TIG welding.

Table 3-20 Welding processes for which Chromium VI and nickel are typical principal components of arc welding fumes.

Process	Consumable	Typical principal components
Manual metal arc welding	Unalloyed and low alloyed steel	Ni, Cr(VI), Cr, Fe, Mn, Cu
	High alloy steel	Ni, Cr(VI), Cr, Fe, Mn
	Cast iron	Ni, Cu, Fe, Mn
	Hardfacing	Ni, Cr(VI), Cr, Co, Fe, Mn
	Nickel-based	Ni, Cr(VI), Cr, Co, Fe, Mn
	Copper-based	Ni, Cu
MIG/MAG/TIG	Unalloyed and low alloyed steel	Ni, Cr(VI), Cr, Fe, Mn, Cu
	High alloy steel	Ni, Cr(VI), Cr, Fe, Mn
	Nickel-based	Ni, Cr(VI), Cr, Co, Mn
	Copper-based	Ni, Cu
Gas-shielded tubular cored arc welding (FCAW)	Unalloyed and low alloyed steel	Ni, Cr(VI), Cr, Fe, Mn, Cu
	High alloy steel	Ni, Cr(VI), Cr, Fe, Mn
	Hardfacing	Ni, Cr(VI), Cr, Co, Mn
	Nickel-based	Ni, Cr(VI), Cr, Mn, Co
Self-shielded tubular cores arc welding (FCAW)	Unalloyed and low alloyed steel	Ni, Cr, Fe, Mn, Cu, Al
	High alloy steel	Ni, Cr(VI), Cr, Fe, Mn, Al
	Hardfacing	Ni, Cr(VI), Cr, Fe, Mn, Al, Co

Source: ISO/TR 13392, 2014 in EC, 2019.

3.3.9 Summary of exposure concentrations used for the further analysis

Not applicable to welding fumes

3.3.10 Values used in the benefits and costs models

Not applicable to welding fumes.

3.4 Exposed workforce

3.4.1 Introduction

This section includes a discussion about the types of workers (in welding+ activities) exposed to welding fumes+, exposed workforce by sector, average number of exposed workers per sector, trends in exposed workers and then a summary of the exposed workforce.

It was not possible for the study team to estimate the number of workers working in the vicinity of welding+ activities, as this varies between working environments. The meta-analysis of lung cancer associated with exposure to welding fumes (Loomis *et al.*, 2022), upon which the ER was calculated, was based on studies of full-time workers in welding workplaces ('*studies of workers whose jobs may include occasional or infrequent welding*' were excluded). Therefore, the excess risk calculated applies to full time workers in welding environments. For the above reasons, this study has focused on full time equivalent (FTE) welders.

Available figures for the numbers engaged in welding+ processes vary between sources; with the definition of 'welders' also varying. The breakdown of workers undertaking welding+ processes per sector is also difficult to clarify, so different sources were used to extrapolate what the likely numbers would be per sector. The exposed workforce can include non welders who are working in the same area of the factor or workshop; results from the stakeholder consultation 2023 have been summarised.

3.4.1.1 Types of workers

Welding is a complex activity carried out by:

- Individuals whose main occupation at work is welding; and
- Individuals whose main occupation is not (categorised as) welding as such, but they carry out some welding+ activities as a (large or small) part of their work.

Many of these individuals will be contracted as an employee but some may also work on a self-employed basis – for example undertaking welding for construction projects, several automotive repair shops or fabrication units as and when welding skills are required. However, self-employed workers are outside the scope of the CMRD, and therefore this impact assessment. However, there are still some small enterprises which employ one person, and these are within the scope of this assessment.

As a complex activity, it is difficult to get an accurate picture of working patterns and hence the likely frequency and duration of 'welding' from available data.

In general, it seems sensible to suggest that those workers that are categorised as *7012 welders and flamecutters* on Eurostat/ASA are individuals whose main work activity is, more often than not, welding.

Whilst there is no data on the practices of all workers currently employed (or self-employed) as 'welders', some insight into these issues can be gleaned from looking at the jobs market for welders. EURES[16], the European Employment Services, is a European cooperation network of employment services which was designed to facilitate the free movement of workers in the EU. A search of EURES for vacancies where welding is specifically identified as the profession identified 17,891 vacancies within the last month. Table 3-21 provides a breakdown of these vacancies by both work schedule and by contract type providing: the number of vacancies in the last month; the percentage of the total and the same percentage as adjusted for 'non-specified' categories.

These data suggest that the vast majority (around 89%) of welding jobs may be full-time with the remainder (11%) being part-time or flexible. With regard to self-employment, the data identifies that less than 1% of the welding vacancies advertised were for self-employed contracts. At the same time, it is likely that the overwhelming majority of vacancies posted on EURES (if not all) will be posted by companies, i.e. entities that employ people. As such, the 1% self-employed in the vacancies may not provide a direct read-across to the current proportion of welders in the EU who operate on a self-employed basis.

[16] https://eures.ec.europa.eu/index_en

That said, the Finnish labour statistics[17] are subdivided into 'wage and salary earners' and 'entrepreneurs' which could be interpreted as 'employed' versus 'self-employed'. The Finnish statistics suggest that 99.9% of 'welders and flamecutters' are 'wage and salary earners'; which may also suggest that that the overwhelming majority (nearly all) of *7012 welders and flamecutters* are employed as opposed to being self-employed.

Table 3-21 Breakdown of vacancies for welders on EURES.

Type of workers	Number of vacancies in the last month*	As a percentage of the total	Percentages as adjusted for 'non-specified' categories
By work schedule			
Full-time	14,658	76.5%	89.3%
Not Specified	2,732	14.3%	
Flexible	1,624	8.5%	9.9%
Part-time	140	0.7%	0.9%
By contract type			
Direct hire	9,512	53.2%	57.9%
Temporary	3,179	17.8%	19.4%
Temporary to hire	1,718	9.6%	10.5%
Not Specified	1,465	8.2%	
Contract	1,338	7.5%	8.1%
Contract to hire	584	3.3%	3.6%
Recruitment reserve	41	0.23%	0.25%
Apprenticeship	18	0.10%	0.11%
Internship	18	0.10%	0.11%
Self-employed	12	0.07%	0.07%
Seasonal	5	0.03%	0.03%
On call	1	0.01%	0.01%
Volunteer	0	0.00%	0.00%

Source: EURES website search on 'welders'

Note: The implied number of welders in Table 3-25 below is unlikely to be an accurate reflection of the true number of welders.

3.4.1.2 Workers with an existing health condition (optional)

No data has been found.

3.4.2 Data on exposed workforce

3.4.2.1 Total number of welders: DVS, EWA, EWF and ELA data

Estimates on the total number of welders across the EU27 vary considerably. It is important to note that the ECHA definition of welding+ is a broader definition of welding processes than previous definitions (since it includes soldering, brazing, thermal cutting/gouging, thermal spraying, flame straightening and 3D printing using metal powder), so previous estimates of the 'number of

[17] https://pxdata.stat.fi/PxWeb/pxweb/en/StatFin/StatFin__tyokay/statfin_tyokay_pxt_115q.px/table/tableViewLayout1/

welders' that were based on the smaller list of traditional welding processes will underestimate the total number of welders.

The German Welding Institute (DVS) estimated that there were just under one million people employed full-time in joining technologies in 2015 in the EU28, plus part time workers (Kersting *et al*, 2017). The DVS estimate that in Germany, two thirds of workers in joining technologies were full time and one third part time, so if this ratio is applied to the EU28 figure, there would have been an estimated 1,500,000 full and part-time workers in the joining industries across the EU28 in 2015. Welding work occurs across all of the European Member States, but data is not readily available for all countries.

According to EURES data, in 2020 there were **678,000 people** employed in the occupation **'welders and flame cutters'**, of which some 4% are female (European Labour Authority, 2021). In addition, of note to this study, in 2020 'welders and flame cutters' were identified as a high magnitude labour shortage[18] in seven countries or regions. However, this definition of 'welders and flame cutters' is likely to be tightly defined along the lines of workers with welding as their occupation, therefore this definition does not cover all of the welding+ activities in the ECHA definition used in this study, so will be an underestimate. The estimate in the ELA report references Eurostat data from the Labour Force Survey (LFS). Publicly available Eurostat Data (online) provides employment data down to the level of ISCO 721 Sheet and structural metal workers, moulders and welders, and related worker and not the sub-category of ISCO 7212 Welders and flamecutters that is the source of the ELA estimate of 678,000 welders in the EU. At the time of writing this report, the only year for which there is an estimate of the number of welders and flamecutters is 2020.

In a 2021 study[19], the DVS estimate that there are **1.2 million workers** in the **'joining, cutting and coating technologies' (JCC technologies) in Europe in 2019.** Please note that this figure is for the EU 28 including the UK, before the British exit from the EU. The figure can be adjusted based upon the population to give an estimated number of workers in JCC technologies for the EU 27 of 1.06 million (see section 3.4.6). The DVS were contacted to clarify the full definition of JCC technologies, and they referred to the definition used in TRGS 528 which includes: welding, thermal cutting and gouging, thermal spraying, soldering, flame straightening, additive manufacturing processes with metal powders, related procedures and incidental work (e.g. grinding) associated with welding. Therefore, this includes more of the welding+ processes defined in this study. However, this number is likely to only include full time workers. If the above DVS ratio of 2/3 full time to 1/3 part time workers is applied to this figure, the **total figure for full time, part time and occasional workers in JCC technologies in Europe could be 1.8 million**. Further investigation into the types of workers undertaking welding is included in section 3.4.1.1 below.

The EWA (*pers comm,* Feb 2023) estimate that there are **2 million welders in Europe**, if part time and occasional welders are taken into account and applying the broader definition of workers undertaking all the welding+ processes.

Numbers of qualified and certified welders were obtained from the EWF in case these were useful in identifying the number of welders (Table 3-24 and Table 3-23 respectively). However, the

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[18] Defined as 'a lack of employees amounting to more than 3% of the current employment in that occupation'.

number of qualified or certified welders is a subset of the total number of welders; many welders operating in Europe are not qualified (hold an EWF qualification) or certified (have earned an EWF certificate).

Table 3-22 Numbers of EWF qualified welders

Qualification level	Cumulative Number up to 2021
European Welding Engineer (EWE)	31,000
European Welding Technologist (EWT)	8,100
European Welding Specialist (EWS)	33,000
European Welding Practitioner (EWP)	8,500
European Welder (EW)	40,000
Total	**120,600**

Source: EWF, 2023 (pers comm by email)

Table 3-23 Numbers of EWF certified welders.

Year	Certificates issued by the four authorised EWF Members[20]
2021	36,800
2020	37,000
2019	29,100
Total	**102,900**

Source: EWF, 2023 (pers comm by email)

According to 2017 European Welding Association data (confidential source, *pers comm*, January 2023), the top ten Member States [21]based upon the *value* of welding consumables market were: Germany (24%), Italy (15%), France 15%), Poland (7%), Spain (5%), Netherlands (5%), Austria (4%), Czech Republic (4%), Finland (4%), Sweden (3%). The top ten Member States based upon *unit sales* of welding consumables were in a slightly different order: Czech Republic, Belgium, Poland, Italy, Austria, Spain, Sweden, Finland, Hungary, and lastly Slovakia. (Turkey was also a key country for welding, but it is not an EU Member State, so it is outside the scope of this impact assessment.)

Kersting *et al* (2017) ranked the top six EU27 countries employing joining technologists as: Germany, Italy, France, Poland, Netherlands and Romania, and estimated that the majority of welding

[20] Certificates are valid for three years, so certificates issued over the last three years of records have been provided.

[21] However, only 19 Member States are included in the welding consumables market: Austria, Belgium, Croatia, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Italy, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden. The eight Member States which are not included in the EWA welding market data are: Bulgaria, Republic of Cyprus, Estonia, Ireland, Latvia, Lithuania, Luxembourg, and Malta.

is undertaken in those countries in Europe. This is a similar list to the EWA 2017 list above for sales of welding consumables by value.

The top ten Member States based upon the volume (tons) of welding consumables sold were in a similar order in 2020 (according to 2020 EWA data, *pers comm,* February 2023): Germany (21%), Italy (12%), Spain (8%), Poland (8%), France (8%), Netherlands (5%), Czech Republic (5%), Romania (4%), Portugal (2%), Hungary (2%). However, as noted previously, 2020 cannot be taken to be a representative year as working practices changed due to the Covid 19 pandemic.

Numbers of welders in each country were collated from publicly available data in the IARC, 2018 study (extract included in Table 3-24). However, these national totals are for different years, and the definitions of what constitutes the 'welding' occupation vary, so cannot be directly compared or added up. Also, these national totals do not cover all EU27 Member States.

Table 3-24 Numbers of EWF qualified welders.

Country	Year	Number	Occupational designation
France	2011	36,164	Skilled metal welders
Germany (West)	1987	110,040	Welder
Greece	2001	11,330	Welders and flame cutters
Ireland	2006	10,090	Welders and steel erectors
Netherlands	1996	75,000	Welders
Portugal	2011	76,580	Sheet and structural metal workers, moulders and welders, and related workers
Spain	2001	262,620	Welders, laminators, metal structure assemblers, blacksmiths, toolmakers, and similar

Source: IARC, 2018

The number of workers in stainless steel works was compiled for an impact assessment on Chromium VI (EU, 2018b), with an estimated breakdown for different welding processes (Table 3-25). However, this table does not include welding+ processes such as soldering, flame straightening and additive manufacturing.

Table 3-25: Number of workers in stainless steel works.

Process	Subprocess	Workers
Stainless steel welders	SMAW/MMA	8,000
	GMAW[1]	13,000
	FCAW[1]	4,000
	TIG	5,000

Process	Subprocess	Workers
	SAW[2]	1,000
	Total	31,000
Stainless steel thermal cutters		5,100
Stainless steel thermal sprayers		15,000

[1] GMAW and FCAW includes a substantial percentage of automated welding stations with a limited fumes exposure for the welder.

[2]With SAW there is no exposure to welding fumes.

Source: EWA, 2017, pers comm, in EU 2018b.

3.4.2.1.1 Number of welders by type/end use

No information on the number of people carrying out welding either by the type of welding process or by occupation/industry has been identified by this study.

The 2019 Accuray Research report Global Welding Equipment Market Analysis & Trends - Industry Forecast to 2027 provides an overview of the value of the global welding market (in US$) broken down by equipment, level of automation, technology/process, end-user and geographic region. These data can be used to express the relative value of the different categories of market as a percentage. These percentages can then be applied to the estimates of the total number of welders (low = 678,000 high = 2,000,000) to give a tentative estimate of the implied number of welders under each category.

Table 3-26 provides the market distribution by welding technologies for the European region and the total number of welders implied for each. Clearly, as the market value of the welding technologies will depend also on the cost of the associated equipment (which may vary by welding technology), estimates of the number of welders implied may well be skewed towards the more expensive technologies (and away from the less expensive ones). As such, the implied number of welders in Table 3-26 is unlikely to be an accurate reflection of the true number but, if the relative cost of each of the technologies could be compensated for, the estimate could be improved.

Table 3-26 Market distribution by welding technologies as a percentage of total market value applied to estimates of the total number of welders.

Total number of welders		**Estimate from EWA**	**ELA: Report on Labour Shortages and Surpluses**
		2,000,000	**678,000**
Welding technology	**Market distribution 2020[1]**	**Implied number of welders in each category (high)**	**Implied number of welders in each category (low)**
Oxy-fuel welding	21%	427,981	145,086

Total number of welders		**Estimate from EWA**	**ELA: Report on Labour Shortages and Surpluses**
		2,000,000	**678,000**
Welding technology	**Market distribution 2020[1]**	**Implied number of welders in each category (high)**	**Implied number of welders in each category (low)**
Arc welding	34%	687,998	233,231
Resistance welding	16%	322,019	109,164
Laser- beam welding	19%	377,991	128,139
Ultrasonic welding	6%	111,311	37,734
Plasma welding	4%	72,700	24,645

Source: study team, [1]proportions obtained from Accuray Research, 2019.

Notes: The potential difference in equipment price/cost across various methods could make the application to a number of welders unreliable.

Table 3-27 provides the market distribution by end-user as a percentage and the total number of welders implied for each. It also provides information on the main welding technologies used in each category of end-user as stated in the Accuray Global Market report (often it is not stated). As with the welding technology data in Table 3-26, when applied to the total number of welders these data will be influenced by the relative cost of the welding methods and technologies used. However, as a mixture of different methods may be used in each category, the influence of this factor on the magnitude of the estimates of numbers of welders is likely to be less than for the estimates in Table 3-26. Whilst these estimates are perhaps highly tentative, they may potentially be the only ones that are available to indicate the number/proportion of welders in different end uses.

Table 3-27 Market distribution by end-user as a percentage of total market value applied to estimates of the total number of welders (regression analysis).

End-use or sector	NACE	Market distribution 2020[1]	Estimate from EWA	ELA: Report on Labour Shortages and Surpluses	
			2,000,000	678,000	
			Implied number of welders in each category (high)	Implied number of welders in each category (low)	Welding types referred to in the report where reference is made
Pipe mills (manufacture of steel pipes)	C24.2	2%	41,572	14,093	Most popular method for welding pipe is the shielded metal-arc process. However, gas shielded arc methods have made big inroads as a result of new advances in welding technology.
Metalworking	C25	14%	271,169	91,926	-
General fabrication	C25	11%	220,990	74,916	-
Heavy fabrication	C28, C27.1, C25.3	3%	61,411	20,818	Type of metal that is being welded determines the welding technique that will be used. Most welding in metal fabrication involves common metals like steel, iron, aluminum, copper and other metals that can be joined using different welding techniques.
Automobile and transportation	C29	20%	401,964	136,266	-
Shipbuilding	C30	2%	46,386	15,725	Two basic welding types are spot welding and arc welding. In shipbuilding, the most common technique is electrical arc welding. Ceramic welding is much stated to be used especially on the shell plating's and block connections.

End-use or sector	NACE	Market distribution 2020[1]	Estimate from EWA	ELA: Report on Labour Shortages and Surpluses	
			2,000,000	678,000	
			Implied number of welders in each category (high)	Implied number of welders in each category (low)	Welding types referred to in the report where reference is made
Aerospace & defence	C30	5%	97,197	32,950	Gas welding was the method most commonly used in production on aerospace materials. Electric arc welding is used extensively by the aerospace industry in both the manufacture and repair of aerospace.
Marine application	C30	2%	38,412	13,022	Underwater welding
Power generation	C35	7%	143,000	48,477	-
Building and construction	F41, F42 & F43	15%	309,970	105,080	-
Oil & gas pipelines	F42.21, F49.50	2%	39,579	13,417	-
Offshore pipelines	F42.21, F49.50	2%	33,987	11,522	In offshore pipeline system, welding joints are made in the barge during the laying process. Most of the welding process in the barge use welding machine instead of human welder. Arc welding continues to be the preferred welding method for the manufacture of offshore structures and process equipment.
Pipelines	F42.21, F49.50	2%	34,376	11,654	-
Maintenance & repair	Various	2%	44,393	15,049	-

End-use or sector	NACE	Market distribution 2020[1]	Estimate from EWA	ELA: Report on Labour Shortages and Surpluses	
			2,000,000	678,000	
			Implied number of welders in each category (high)	Implied number of welders in each category (low)	Welding types referred to in the report where reference is made
Structural	Various	9%	175,577	59,521	-
Other end users	Various	2%	40,017	13,566	-

Source: Study team

Note 1: Market distribution by end user was inferred from Eurostat data for NACE codes from 2020.

3.4.2.2 ASA Finland

As part of examining the data in relation to potentially exposed individuals, a means (albeit approximate) of potentially predicting the number of welders in professions other than ISCO 7212 *Welders and flamecutters* became apparent.

In Finland, employers are obliged by law to maintain a list of any carcinogenic or mutagenic substances, compounds and working methods used at the workplace. The employer must also maintain a list of the employees exposed and report these individuals to the ASA register maintained by the Finnish Institute of Occupational Health. There are also matching data on the total number of people employed in Finland in different occupations including *welders and flamecutters*. As welding stainless steel exposes workers to hexavalent chromium and nickel, these workers are registered as exposed to nickel and chromium in the ASA register.

Table 3-28 provides the Finnish ASA data on the number of exposures to Cr(VI) and to Ni for each occupation in 2019. The published data only reflect exposures where Cr(VI) or Ni were in the top five exposure agents (Uuksulainen, 2021). This means that for those occupations where either no Cr(VI) or no Ni exposures are indicated (as blanks in the table) this does not mean that there were zero exposures; only that exposures to the relevant exposure agent were not in the top 5 ASA exposures for that agent.

As can be seen from Table 3-28 below, for welders and flamecutters, the number of ASA exposures is 2,640 and 2,293 for Cr(VI) and Ni respectively within a total employed of 7,564. For the other occupations listed, Cr(VI) and/or Ni are also in the top five exposure agents. For some of these occupations (such as '*Structural-metal preparers and erectors*') it is conceivable that the source activity of the exposures is (wholly or in part) owing to the carrying out of welding as part of activities undertaken as part of that occupation. For other occupations (such as '*Life science technicians (excluding medical)*' welding activity is unlikely to have been the reason for the exposure.

Building on this, if one identifies which of the occupations and exposures could conceivably be owing to welding activity one has a means of beginning to identify:

- how many welders in those other occupations were exposed to Cr(VI) and/or Ni; and
- based on the exposure rates amongst '*welders and flamecutters*' (Cr(VI)=35% and Ni=30%), the total number of people in those other occupations that carry out welding.

In Table 3-28, the welding relevant occupations have been indicated, based upon the judgement of the study team. Whether occupational exposures to Cr(VI) and/or Ni are likely to be (wholly or partly) owing to welding carried out as part of that occupation has been determined loosely by:

- The type of occupation and whether it is possible/likely that welding activities might be a part of that occupation and the cause (wholly or partly) of the reported exposures;
- The 'distance' or difference between the number of Cr(VI) and Ni exposures. Here, for welders and flamecutters the numbers of exposures to Cr(VI) and Ni are similar. Thus, where this is also the case for another occupation this may provide some indication of whether the exposures are or are not welding related; and
- Whether, as for welding and flamecutters, both Cr(VI) and Ni exposures are in the top five exposures for that occupation.

Table 3-28 Number of exposures to Cr(VI) and/or nickel in occupations in Finland in 2019

Occupation name	Number of ASA exposures		Total employed	CR (VI) and Nickel in Top 5 exposure agents?	'Distance' between # of exposures	Welding+ relevant occupation?[22]
	Cr (VI)	Ni				
Welders and flamecutters	2,640	2,293	7,564	Cr(VI) + Ni	13%	**Yes**
Metal production process controllers	33	267	526	Cr(VI) + Ni	88%	
Structural-metal preparers and erectors	568	523	2,224	Cr(VI) + Ni	8%	**Yes**
Metal finishing plating and coating machine operators	165	181	1,664	Cr(VI) + Ni	9%	**Yes**
Metal polishers wheel grinders and tool sharpeners	98	94	1,050	Cr(VI) + Ni	4%	
Power production plant operators	50	73	834	Cr(VI) + Ni	68%	
Incinerator and water treatment plant operators	83	85	1,158	Cr(VI) + Ni	2%	
Miners and quarriers	5	156	1,160	Cr(VI) + Ni	97%	
Aircraft engine mechanics and repairers	87	31	936	Cr(VI) + Ni	64%	**Yes**
Blacksmiths hammersmiths and forging press workers	14	14	279	Cr(VI) + Ni	0%	**Yes**
Refuse sorters	53	32	917	Cr(VI) + Ni	40%	
Life science technicians (excluding medical)	156	177	3,871	Cr(VI) + Ni	12%	
Sheet-metal workers	204	192	4,789	Cr(VI) + Ni	6%	**Yes**

[22] Based upon the study team's judgement.

Occupation name	Number of ASA exposures		Total employed	CR (VI) and Nickel in Top 5 exposure agents?	'Distance' between # of exposures	Welding+ relevant occupation?[22]
	Cr (VI)	Ni				
Agricultural and industrial machinery mechanics and repairers	769	875	21,061	Cr(VI) + Ni	12%	**Yes**
Metal moulders and coremakers	44	25	1,045	Cr(VI) + Ni	43%	
Hand packers	17	17	538	Cr(VI) + Ni	0%	
Precision-instrument makers and repairers	20	21	812	Cr(VI) + Ni	5%	**Yes**
Manufacturing supervisors	91	156	5,033	Cr(VI) + Ni	42%	
Toolmakers and related workers	151	121	5,738	Cr(VI) + Ni	20%	**Yes**
Plumbers and pipe fitters	324	315	14,793	Cr(VI) + Ni	3%	**Yes**
Metal working machine tool setters and operators	309	312	14,704	Cr(VI) + Ni	1%	**Yes**
Spray painters and varnishers	44	6	2,025	Cr(VI) + Ni	86%	**Yes**
Mechanical machinery assemblers	131	105	10,457	Cr(VI) + Ni	20%	**Yes**
Industrial and production engineers	35	67	4,584	Cr(VI) + Ni	48%	
Electrical mechanics and fitters	58	121	10,594	Cr(VI) + Ni	52%	**Yes**
Air conditioning and refrigeration mechanics	17	17	2,930	Cr(VI) + Ni	0%	**Yes**
Engineering professionals not elsewhere classified	73	58	11,309	Cr(VI) + Ni	21%	**Yes**

Occupation name	Number of ASA exposures		Total employed	CR (VI) and Nickel in Top 5 exposure agents?	'Distance' between # of exposures	Welding+ relevant occupation?[22]
	Cr (VI)	Ni				
Pulp and papermaking plant operators	43	44	8,357	Cr(VI) + Ni	2%	
Heavy truck and lorry drivers	66	346	43,527	Cr(VI) + Ni	81%	
Mechanical engineering technicians	59	69	15,181	Cr(VI) + Ni	14%	**Yes**
Lifting-truck operators etc.	8	8	1,989	Cr(VI) + Ni	0%	
Earthmoving and related plant operators	10	93	13,764	Cr(VI) + Ni	89%	
Packing bottling and labelling machine operators	10	11	3,916	Cr(VI) + Ni	9%	
Mechanical engineers	38	67	19,724	Cr(VI) + Ni	43%	**Yes**
Electrical and electronic equipment assemblers	11	20	6,109	Cr(VI) + Ni	45%	**Yes**
Freight handlers	44	67	38,834	Cr(VI) + Ni	34%	
Motor vehicle mechanics and repairers	47	16	23,582	Cr(VI) + Ni	66%	**Yes**
Physical and engineering science technicians not elsewhere classified	21	13	12,986	Cr(VI) + Ni	38%	
Manufacturing managers	11	9	8,800	Cr(VI) + Ni	18%	**Yes**
Buyers	7	9	7,484	Cr(VI) + Ni	22%	
Vocational education teachers	6	13	12,590	Cr(VI) + Ni	54%	**Yes**

Occupation name	Number of ASA exposures		Total employed	CR (VI) and Nickel in Top 5 exposure agents?	'Distance' between # of exposures	Welding+ relevant occupation?[22]
	Cr (VI)	Ni				
Well drillers and borers and related workers		101	1,131	Ni	n/a	
Metal processing plant operators		265	3,186	Ni	n/a	**Yes**
Armed forces occupations other ranks	9		159	Cr(VI)	n/a	
Chemical processing plant controllers	25		470	Cr(VI)	n/a	
Non-commissioned armed forces officers	163		3,242	Cr(VI)	n/a	
Mining supervisors		9	237	Ni	n/a	
Other cleaners not elsewhere classified		94	3,291	Ni	n/a	
Process control technicians not elsewhere classified		7	268	Ni	n/a	
Automation installers and repairers		47	1,855	Ni	n/a	**Yes**
Chemical and physical science technicians	6		243	Cr(VI)	n/a	
Mining engineers metallurgists and related professionals		22	1,001	Ni	n/a	
Bricklayers and related workers		17	867	Ni	n/a	
Commissioned armed forces officers	88		4,697	Cr(VI)	n/a	
Glass and ceramics plant operators		33	1,767	Ni	n/a	
Chemists		29	1,714	Ni	n/a	

Occupation name	Number of ASA exposures		Total employed	CR (VI) and Nickel in Top 5 exposure agents?	'Distance' between # of exposures	Welding+ relevant occupation?[22]
	Cr (VI)	Ni				
Building frame and related trades workers not elsewhere classified		54	3,327	Ni	n/a	**Yes**
Insulation workers		38	2,781	Ni	n/a	
Teachers in mathematical subjects	5		447	Cr(VI)	n/a	
Upholsterers and related workers	10		931	Cr(VI)	n/a	
Environmental engineers		7	714	Ni	n/a	
Crane hoist and related plant operators		15	1,980	Ni	n/a	
Construction supervisors		54	8,494	Ni	n/a	**Yes**
Civil engineers		76	15,398	Ni	n/a	
Civil engineering labourers		23	5,241	Ni	n/a	**Yes**
Chemical products plant and machine operators	23		7,319	Cr(VI)	n/a	
Chemical engineers		11	4,571	Ni	n/a	
Chemical engineering technicians		6	2,525	Ni	n/a	
Stock clerks		11	5,137	Ni	n/a	
Gardeners horticultural and nursery growers and workers	9		5,094	Cr(VI)	n/a	
House builders		58	37,071	Ni	n/a	
Building construction technicians		8	5,206	Ni	n/a	**Yes**
Electrical engineering technicians		6	4,332	Ni	n/a	**Yes**

Occupation name	Number of ASA exposures		Total employed	CR (VI) and Nickel in Top 5 exposure agents?	'Distance' between # of exposures	Welding+ relevant occupation?[22]
	Cr (VI)	Ni				
Carpenters and joiners		23	17,407	Ni	n/a	
Mobile farm and forestry plant operators		9	6,827	Ni	n/a	
Electrical engineers		8	9,281	Ni	n/a	**Yes**
Construction managers		6	9,134	Ni	n/a	
Building and related electricians		9	14,546	Ni	n/a	**Yes**
Building caretakers		5	25,978	Ni	n/a	
Commercial sales representatives		6	40,331	Ni	n/a	

Source: Study team.

As can be seen from the data in Table 3-28, for *Welders and flame cutters* 35% of the total employed (7,564) were exposed to Cr(VI) in 2019 and 30% were exposed to Ni. For *Structural-metal preparers and erectors,* 568 were exposed to Cr(VI) and 523 exposed to Ni. With such information it is possible to estimate the total number of people undertaking welding amongst *Structural-metal preparers and erectors (*and all other welding relevant occupations).

Continuing the example, if it is assumed that all of the exposures to Cr(VI) and Ni amongst *Structural-metal preparers and erectors* occurred while carrying out welding activities then, as with *Welders and flamecutters*, one would expect the number of Cr(VI) exposures to represent around 35% of the total number of people welding in that occupation or, alternatively, the Ni exposures to represent around 30% of the people welding in that occupation. From this one can calculated the expected total number of *Structural-metal preparers and erectors* who undertook welding in 2019 as follows:

- For Cr(VI) exposures - (1 ÷ 0.349) x the number of Cr(VI) exposures, i.e. 2.865 x 568 = 1,628 welders total;
- For Ni exposures - (1 ÷ 0.303) x the number of Ni exposures, i.e. 3.300 x 523 = 1,726 welders total; and
- The average of the two estimates suggests that there are a total of 1,677 Structural-metal preparers and erectors in Finland who undertook welding in 2019. This represents approximately 75% of the total number of people employed in the occupation.

In theory one might seek to aggregate this to EU level by applying the 75% to statistics on the total number of *Structural-metal preparers and erectors* in the EU27. Unfortunately, as already noted, Eurostat data to the required resolution of occupations are not readily available.

An alternative is to use the value from the ELA report giving a total of 678,000 *Welders and flamecutters* in the EU27 combined with the accompanying value of 7,564 welders in Finland. This suggests that Finnish *Welders and flamecutters* account for 1.12% of the welders in the EU and, hence, welders in the other occupations might similarly account for 1.12% of welders in those occupations.

The results of the described aggregations are provided in Table 3-29 and provide the estimate that there are a total of around 1.5 million 'welders' – 678,000 in the occupational category *Welders and flamecutters* and 825,674 in the other occupations. Clearly this is an estimate, and it is based on a the relatively (very) small EU27 cohort of Finnish welders and welding relevant occupations.

Table 3-29 Aggregation to number of welders in all occupations in Finland in 2019.

Occupation name		Number of people doing at least some welding in Finland		Average	Aggregated to EU based on 678,000 in category 7212 in EU	Distribution
	NACE Code	based on Cr (VI) exposure	based on Ni exposure			
Welders and flamecutters	**Various**	**7,564**	**7,564**	**7,564**	**678,000**	45.1%
Structural-metal preparers and erectors	C24.1	1,627	1,725	1,676	150,228	10.00%
Precision-instrument makers and repairers	C26.51, C32.5	57	69	63	5,647	0.40%
Manufacturing managers	C25	32	30	31	2,779	0.20%
Blacksmiths hammersmiths and forging press workers	C25.5	40	46	43	3,854	0.30%
Metal working machine tool setters and operators	C25.62	885	1,029	957	85,781	5.70%
Mechanical machinery assemblers	C28	375	346	361	32,313	2.10%

Occupation name		Number of people doing at least some welding in Finland		Average	Aggregated to EU based on 678,000 in category 7212 in EU	Distribution
	NACE Code	based on Cr (VI) exposure	based on Ni exposure			
Toolmakers and related workers	C28.4	433	399	416	37,288	2.50%
Aircraft engine mechanics and repairers	C30.3, C33.16	249	102	176	15,731	1.00%
Automation installers and repairers	C33	0	155	155	13,893	0.90%
Building frame and related trades workers not elsewhere classified	F41	0	178	178	15,955	1.10%
Construction supervisors	F41	0	178	178	15,955	1.10%
Building construction technicians	F41	0	26	26	2,331	0.20%
Civil engineering labourers	F42	0	76	76	6,812	0.50%
Sheet-metal workers	F43	584	633	609	54,543	3.60%
Plumbers and pipe fitters	F43.22	928	1,039	984	88,156	5.90%
Air conditioning and refrigeration mechanics	F43.22	49	56	53	4,706	0.30%
Agricultural and industrial machinery mechanics and repairers	G45.2	2,203	2,886	2,545	228,077	15.20%
Motor vehicle mechanics and repairers	G45.2	135	53	94	8,426	0.60%
Mechanical engineering technicians	M71.12	169	228	199	17,793	1.20%
Mechanical engineers	M71.12	109	221	165	14,790	1.00%

Occupation name		Number of people doing at least some welding in Finland		Average	Aggregated to EU based on 678,000 in category 7212 in EU	Distribution
	NACE Code	based on Cr (VI) exposure	based on Ni exposure			
Vocational education teachers	P85.32, P85.5	17	43	30	2,689	0.20%
Engineering professionals not elsewhere classified	various	209	191	200	17,927	1.20%
Total		**15,665**	**17,273**	**16,776**	**1,503,674**	**100%**

Source: Study team

3.4.2.3 CAREX

Originally a product of work under the EU 'Europe Against Cancer' program, the original CAREX (CARcinogen Exposure) database was developed by the Finnish Institute of Occupation Health (FIOH) in association with an international group of experts. It provided estimates of occupational exposure to carcinogens over the period 1990-1993 in the (then 15) EU MS. Owing to the paucity of direct information on exposure in most of the countries, estimates were derived indirectly from two reference countries with reasonably comprehensive data (Finland and the United States). Data was extracted and combined from three Finnish databases (including the ASA database described in the previous section) and one from the US. Estimates were adjusted for the workforce distribution of each country and refined by the national experts in view of similarity/dissimilarity to the perceived exposure patterns in their own countries.

The database is not available online and so has not been accessed for this study. However, in Canada the database has been used to produce estimates of Canadians' exposure to carcinogens in 2016 by similarly refining the estimates produced for 1990-1993 by FIOH. It cannot be assumed that the Canadian estimates are a direct reflection of the FIOH estimates for the EU over the time period. Nonetheless it is useful to examine what they would suggest when applied to more up to date estimates of the number of welders in the EU.

As identified by CAREX Canada[23] the magnitude of exposure to welding fumes is influenced by many factors, including:

- The type of welding process (e.g. arc or gas welding);
- The composition of the welding rod;
- The type of filler materials and base metals used;

[23] CARcinogen EXposure - https://www.carexcanada.ca/profile/welding-fumes-occupational-exposures/

- The type of coatings present;
- The setting in which welding is performed (e.g. open area or a confined space);
- Type of ventilation in the workspace (e.g. mechanical, local, natural or no ventilation); and
- The work practices of the welder (e.g. use of personal protective equipment, removal of coatings, cleaning surfaces, working upwind when welding outdoors).

When presenting the breakdown of potential exposure by industry, CAREX provides the following three categories of exposure:

- Low – main route of exposure is via bystander effect, such as working near welding activities more often than not (e.g. near a welding bay);
- Moderate – main job duties include welding intermittently or working in close proximity to welding activities often; and
- High – main job duties include welding more often than not.

Table 3-30 provides the numbers of Canadian workers exposed to welding fumes by exposure level and industry in 2016.

Table 3-30 CAREX – Number of Canadian workers exposed to welding fumes by exposure level and industry in 2016.

	NACE code	Low – main route of exposure is via bystander effect, such as working near welding activities more often than not (e.g. near a welding bay).	Moderate – main job duties include welding intermittently or working in close proximity to welding activities often.	High – main job duties include welding more often than not.	Total
Speciality trade contractors	Various	15,000	14,000	28,000	**57,000**
Repair and maintenance	Various	1,600	5,700	38,000	**45,300**
Primary metal manufacturing	C24	740	3,400	4,000	**8,140**
Fabricated metal product manufacturing	C25	1,700	7,000	23,000	**31,700**
Machinery manufacturing	C28	1,600	4,500	11,000	**17,100**
Transportation equipment manufacturing	C29, C30	2,800	4,500	22,000	**29,300**

	NACE code	Low – main route of exposure is via bystander effect, such as working near welding activities more often than not (e.g. near a welding bay).	Moderate – main job duties include welding intermittently or working in close proximity to welding activities often.	High – main job duties include welding more often than not.	Total
Construction of buildings	F41	5,600	10,000	5,100	**20,700**
Heavy and civil engineering construction	F42	2,000	6,000	4,500	**12,500**
Motor vehicle and parts dealers	G45	1,200	410	6,700	**8,310**
Federal government public administration	O84.12	420	5,300	790	**6,510**
Overall average		32,660	60,810	143,090	**236,560**

The distribution of 'welders' between the occupations can be calculated from these numbers and is provided in Table 3-29 based on distribution according to the numbers of high (main job welding) plus moderate (intermittent welding/frequent proximity) and also based on high alone.

Table 3-31 Distribution of the number of exposed workers between occupations.

CAREX	NACE code	high (main job welding) and moderate (intermittent/frequent proximity)	high (main job welding)
Speciality trade contractors	Various	21%	20%
Repair and maintenance	Various	21%	27%
Primary metal manufacturing	C24	4%	3%
Fabricated metal product manufacturing	C25	15%	16%
Machinery manufacturing	C28	8%	8%
Transportation equipment manufacturing	C29, C30	13%	15%
Construction of buildings	F41	7%	4%
Heavy and civil engineering construction	F42	5%	3%

CAREX	NACE code	high (main job welding) and moderate (intermittent/frequent proximity)	high (main job welding)
Motor vehicle and parts dealers	F45	3%	5%
Federal government public administration	O84.12	3%	1%

Source: Study team

These distributions can then be applied to the two estimates of welders in the EU derived thus far. Namely the 2,000,000 welders estimate from EWA and the 1,503,674 estimate by application of the Finnish ASA data to the 678,000 Eurostat figure given by ELA. The resulting numbers are provided in Table 3-32.

Table 3-32 Estimates of numbers of welders: Canadian CAREX data applied to total EU estimates of welders.

		High (main job welding) or moderate (intermittent/frequent proximity)			High (main job welding)		
Sectors	**NACE code**	**Distribution between categories**	**ASA applied to ELA[1]**	**EWA applied to ELA[2]**	**Distribution between categories**	**ASA applied to ELA[1]**	**EWA applied to ELA[2]**
Speciality trade contractors	Various	21%	309,732	411,967	20%	294,240	391,362
Repair and maintenance	Various	21%	322,269	428,641	27%	399,326	531,134
Primary metal manufacturing	C24	4%	54,572	72,585	3%	42,034	55,909
Fabricated metal product manufacturing	C25	15%	221,237	294,262	16%	241,698	321,476
Machinery manufacturing	C28	8%	114,306	152,035	8%	115,594	153,749
Transportation equipment manufacturing	C29, C30	13%	195,426	259,931	15%	231,189	307,499
Construction of buildings	F41	7%	111,356	148,112	4%	53,594	71,284
Heavy and civil engineering construction	F42	5%	77,433	102,992	3%	47,289	62,897
Motor vehicle and parts dealers	F45	3%	52,433	69,740	5%	70,408	93,647
Federal government public administration	O84.12	3%	44,911	59,735	1%	8,302	11,042

		High (main job welding) or moderate (intermittent/frequent proximity)			High (main job welding)		
Sectors	**NACE code**	**Distribution between categories**	**ASA applied to ELA[1]**	**EWA applied to ELA[2]**	**Distribution between categories**	**ASA applied to ELA[1]**	**EWA applied to ELA[2]**
Totals		100%	1,503,674	2,000,000	100%	1,503,674	2,000,000

Source: Study team

Notes:

[1] Distribution of welders from ASA data, aggregated using the ELA estimate of 7,212 welders and flamecutters.

[2]Distribution of welders from ASA data, aggregated using the EWA estimate of 2 million welders.

3.4.2.4 EUROSTAT

Data on employees in the relevant sectors is taken from Eurostat (2020). The study team has estimated the proportion of employees that are likely to be exposed by the size of enterprise and the estimated numbers of exposed workers as shown in Table 3-33.

The following assumptions were made:

- For the industrial manufacturers and processors, it was assumed that large parts of manufacture are automated even in small enterprises and therefore it was assumed that of the workforce:
  - In small enterprises 25% are welders;
  - In medium enterprises 10% are welders;
  - In large enterprises 5% are welders;
- For the more craft-driven manufacturing sectors like furniture, medical device, musical instruments, it was assumed that assembling products requires manual welding particularly in smaller enterprises and it was therefore assumed that:
  - In small enterprises 40% are welders;
  - In medium enterprises 10% are welders;
  - In large enterprises 5% are welders; and
- For the sectors that heavily rely on manual welding, such as materials recovery (E38), construction of buildings (F41), civil engineering (F42), specialised construction activities (F43), repair of motor vehicles and motorcycles (G45) the same percentages as for the craft driven sectors were applied.

Table 3-33 Estimates of numbers of welders based on Eurostat (2020) data by sector

Sector	Eurostat employees				Estimated %			Estimated numbers				% of employees in sector
	Small	Medium	Large	Total	Small	Medium	Large	Small	Medium	Large	Total	
C24 Basic metals	6,796	28,248	359,499	394,543	25%	10%	5%	1,699	2,826	17,975	22,500	1.8%
C25 Fabricated metal products	310,557	440,532	608,374	1,359,463	25%	10%	5%	77,640	44,055	30,418	152,113	11.9%
C28 Machinery & equipment	13,986	72,276	491,722	577,984	25%	10%	5%	3,497	7,228	24,586	35,311	2.8%
C29 Motor vehicles,	20,972	103,170	1,088,100	1,212,242	25%	10%	5%	5,243	10,317	54,405	69,965	5.5%
C30 Manufacture of other transport equipment	12,965	42,800	452,577	508,342	25%	10%	5%	3,241	4,280	22,629	30,150	2.4%
C31 Furniture	4,844	21,318	26,598	52,760	40%	10%	5%	1,938	2,132	1,330	5,400	0.4%
C32 Other manufacturing	4,255	16,104	30,767	51,126	40%	10%	5%	1,702	1,611	1,539	4,852	0.4%
C33 Repair & installation of machinery & equipment	124,320	117,306	250,452	492,078	40%	10%	5%	49,728	11,731	12,523	73,982	5.8%
E38 Materials recovery	16,420	22,470	50,320	89,210	40%	10%	5%	6,568	2,247	2,516	11,331	0.9%
F41 Construction of buildings	514,158	243,450	301,902	1,059,510	40%	10%	5%	205,663	24,345	15,095	245,103	19.2%
F42 Civil engineering	38,850	86,700	374,544	500,094	40%	10%	5%	15,540	8,670	18,727	42,937	3.4%
F43 Specialised construction activities	1,026,404	310,833	428,901	1,766,138	40%	10%	5%	410,562	31,084	21,445	463,091	36.2%
G45 Repair of motor vehicles & motorcycles	295,094	37,032	28,330	360,456	40%	10%	5%	118,037	3,703	1,417	123,157	9.6%
Total	2,389,621	1,542,239	4,492,086	8,423,946	-	-	-	901,058	154,229	224,605	1,279,892	100%

Source: Study team estimates applied to EUROSTAT data.

3.4.3 Exposed workforce by sector

A summary of the estimates discussed above (section 3.4.2.1) is provided in Table 3-34. This includes the European Labour Authority estimate for 'welders and flame cutters'; the DVS estimate of full time workers in the joining, cutting and coating (JCC) technologies; projected estimate of part-time, occasional and full time workers in the JCC technologies based on the DVS estimate and assumption of ratio of part time to full time workers; and the EWA estimate of part time, full time and occasional welders across welding+ processes. Of these estimates, the most comprehensive estimates of total welders would include all types of workers (full time, part time, occasional welders) across the full range of welding+ processes according to the ECHA definition used in this study. Therefore, the study team propose that 1.8 million to 2 million welders across the EU27 are the best estimates of all exposed welders; and 1.2 million is the best estimate of full time equivalent workers in welding+ processes across the EU27.

The epidemiological studies studied by Loomis *et* al. (2022) included professional welders with 'welder' as their stated occupation, with 'occasional' or 'infrequent' welders being excluded from the meta analysis, therefore the estimated excess risk derived from these studies is assumed to be for full time welders. For consistency with the ER calculation for full time welders, this study has therefore used the 1.2 million as the figure for full time workers in welding+ processes in calculating the costs and benefits of the policy options.

Table 3-34 Summary of estimates of total welders in EU27.

Estimated total welders in EU27	Definition	Source
678,000	Welders and flame cutters	European Labour Authority, 2021; EURES
1,200,000	Workers in the joining, cutting and coating (JCC) technologies: welding, thermal cutting and gouging, thermal spraying, soldering, flame straightening, additive manufacturing processes with metal powders, related procedures and incidental work (e.g. grinding) associated with welding. Full time workers.	DVS, 2021
1,800,000	Calculated as 1.5 x 1.2 million full time workers to take account of part time and occasional workers, based upon the DVS previous assumption that there are approximately 2/3 full time to 1/3 part time workers.	Estimation by the study team based on 1.2 million full time workers in JCC technologies, DVS, 2021.
2,000,000	Welders, including full time, part time and occasional welders across welding+processes.	EWA, *pers comm*, Feb 2023

Source: Study team

Note: The definition of Joining, Cutting and Coating technologies is similar to the definition of welding+ processes, and includes welding, thermal cutting and gouging, thermal spraying, soldering, flame straightening, additive manufacturing processes with metal powders, related procedures and incidental work (e.g. grinding) associated with welding.

In Table 3-35 below, the number of workers exposed to welding fumes in the EU27 have been estimated by sector with sources quoted. The original list of sectors with potential risk of exposure to welding fumes was based upon the sectors listed in ECHA (2022), supplemented by the study team's judgement (Table 3-10); and then sectors solely using soldering were excluded from the list as soldering does not contain any category 1A or 1B CMR substances. Please note that higher level NACE codes have been given to shorten the list; sub codes that have been grouped under each NACE code are listed in section 3.2.8.

The categories of sectors listed in the CAREX and ASA data were mapped across to NACE codes as well as possible, but there are some gaps in sectors compared with the EUROSTAT sectors. That said, the numbers are in the main largely comparable. There may have been some issues with mapping the sectors across which could explain the discrepancies. The extrapolated number of exposed workers:

- In C25 based on the CAREX data could potentially include other categories of manufactured metal items (C30, C31, C32 which are empty);
- C29 is shown as combined with C30 using the CAREX data as these two categories could not be separated, and the number for G45 seems quite low, but if they are all added together the total number for the automotive sector (315,809) is similar to the total in EUROSTAT data for C29, C30 and G45 added together (373,379);
- In the construction and civil engineering sectors (F41 and F42) seem low based on the CAREX data;
- In the construction and civil engineering sectors (F41 and F42) seem low based on the ASA data, but the estimated number for F43 is relatively higher; and
- For G45 comes out quite low based on the CAREX data, as does the extrapolated number of exposed workers for F42 based on the ASA data.

These last few points could mean that the EUROSTAT estimates for exposed workers in the construction, civil engineering and wholesale and retail trade and repair of motor vehicles and motorcycles sectors could be overestimates.

Table 3-35 Estimated number of exposed workers in the EU27 by sector, data modelled from different sources to distribute welders across sectors.

NACE code	Sector	Estimated number of exposed workers in EU27 (EUROSTAT)	Estimated number of exposed workers in EU 27 (CAREX)	Estimated number of exposed workers in EU27 (ASA Finnish study)
C24	Manufacture of basic metals	22,500	55,909	150,228
C25	Manufacture of fabricated metal products (excl. machinery & equipment)	152,113	321,476	92,414
C28	Manufacture of machinery & equipment	35,311	153,749	69,601
C29	Manufacture of motor vehicles, trailers & semi-trailers	69,965	307,499	

NACE code	Sector	Estimated number of exposed workers in EU27 (EUROSTAT)	Estimated number of exposed workers in EU 27 (CAREX)	Estimated number of exposed workers in EU27 (ASA Finnish study)
C30	Manufacture of other transport equipment	30,150		15,731
C31	Manufacture of furniture	5,400		
C32	Other manufacturing	4,852		
C33	Repair & installation of machinery & equipment	73,982	38,000	13,893
E38	Waste collection, treatment & disposal, materials recovery	11,331		
F41	Construction of buildings	245,103	71,284	18,286
F42	Civil engineering	42,937	62,897	6,812
F43	Specialised construction activities	463,091		147,405
G45	Wholesale & retail trade & repair of motor vehicles & motorcycles	123,157	8,310	236,503
Totals		**1,279,892**	**1,019,124**	**750,873**

Source: study team.

Notes: For CAREX 'repair and maintenance' was assumed to equate mainly to NACE code C33; and 'motor vehicle & parts dealers' to equate to G45.

Note that exposure to Cr(VI) and nickel compounds (Finnish study) may not provide a good proxy for exposure to welding fumes, especially as mild steel is the main metal welded across Europe - welding fumes from which usually contain no or low concentrations of Cr(VI) and nickel compounds. On the other hand, emissions of fumes from (low alloy) mild steel can contain significant amounts of Cr(VI) and nickel compounds if high emission welding processes are used.

3.4.4 Average number of exposed workers per company (consultation)

Table 3-36 Stakeholder consultation 2023 results for average number of exposed workers per company, by sector

Sector (n)	Number of workers per company exposed to Welding Average (min - max)	Percentage of workers in companies exposed to Welding Average (min - max)
C17.12 Manufacture of paper and paperboard (1)[24]	8 (8 - 8)	2% (2% - 2%)

[24] These three sectors seem to be an anomaly. The respondents did not give permission to be contacted after the survey. The study team's educated guess is that these companies undertake welding for installation, repair and maintenance of manufacturing equipment.

Sector (n)	Number of workers per company exposed to Welding Average (min - max)	Percentage of workers in companies exposed to Welding Average (min - max)
C21 Manufacture of basic pharmaceutical products (1)[11]	6 (6 - 6)	9% (9% - 9%)
C23.1 Manufacture of glass and glass products (1)[11]	150 (150 - 150)	7% (7% - 7%)
C24.2 Manufacture of tubes, pipes, hollow profiles and related fittings, of steel (1)	120 (120 - 120)	15% (15% - 15%)
C24.42 Aluminium production (1)	230 (230 - 230)	14% (14% - 14%)
C24.51 Casting of iron (2)	45 (25 - 65)	28% (23% - 33%)
C25 Manufacture of fabricated metal products (24)	65 (2 - 1090)	63% (6% - 200%*)
C25.2 Manufacture of other general-purpose machinery (1)	12 (12 - 12)	46% (46% - 46%)
C25.99 Manufacture of other fabricated metal products (1)	150 (150 - 150)	5% (5% - 5%)
C28 Manufacture of machinery and equipment n.e.c. (6)	14 (1 – 32)	15% (0.1% - 41%)
C29 Manufacture of motor vehicles, trailers and semi-trailers (6)	1,043 (30 – 5,150)	25% (0.3% - 74%)
C33 Repair and installation of machinery and equipment (6)	199 (10 – 800)	16% (3.4% - 25%)
C33.11 Repair of fabricated metal products (1)	3 (3 - 3)	4% (4% - 4%)
G45.2 Repair of motor vehicles and motorcycles (1)	9 (9 - 9)	69% (69% - 69%)
P85 Education (1)	3 (3 – 3)	50% (50% - 50%)

Source: Study team on basis of stakeholder responses.

**200% could have been due to employing one welder and hiring a contractor who was also exposed, hence 200% of the (employed) workers were exposed.*

Of these total number of workers exposed per company (Table 3-36), this can be broken down into welders and non welders as per the tables below.

Table 3-37 Number of workers per company whose primary role is welding+.

Sector (n)	Number of welders whose primary role is welding. Average (Min-Max)	Percentage of all workers whose primary role is welding. Average (Min-Max)
C17.12 Manufacture of paper and paperboard (1)	8 (8-8)	2% (2%-2%)
C21 Manufacture of basic pharmaceutical products (1)	2 (2-2)	3% (3%-3%)
C23.1 Manufacture of glass and glass products (1)	100 (100-100)	5% (5%-5%)
C24.2 Manufacture of tubes, pipes, hollow profiles and related fittings, of steel (1)	20 (20-20)	3% (3%-3%)
C24.42 Aluminium production (1)	0 (0-0)	0% (0%-0%)
C24.51 Casting of iron (2)	10 (5-15)	6% (5%-8%)
C25 Manufacture of fabricated metal products (26)	12 (0-90)	29% (0%-100%)
C25.2 Manufacture of other general-purpose machinery (1)	8 (8-8)	31% (31%-31%)
C25.99 Manufacture of other fabricated metal products (1)	120 (120-120)	4% (4%-4%)
C28 Manufacture of machinery and equipment n.e.c. (8)	20 (0-100)	16% (0%-77%)
C29 Manufacture of motor vehicles, trailers and semi-trailers (6)	249 (20-650)	10% (0%-47%)
C33 Repair and installation of machinery and equipment (6)	67 (0-300)	10% (3%-25%)
C33.11 Repair of fabricated metal products (1)	3 (3-3)	4% (4%-4%)
G45.2 Repair of motor vehicles and motorcycles (1)	9 (9-9)	69% (69%-69%)
P85 Education (1)	3 (3-3)	50% (50%-50%)

Source: Study team on basis of stakeholder responses.

Table 3-38 Number of non welders per company that are potentially exposed to welding fumes+.

Sector (n)	Average (Min-Max)	Potentially exposed non welders as a percentage of all workers
C17.12 Manufacture of paper and paperboard (1)	0 (0-0)	0% (0%-0%)

Sector (n)	Average (Min-Max)	Potentially exposed non welders as a percentage of all workers
C21 Manufacture of basic pharmaceutical products (1)	4 (4-4)	6% (6%-6%)
C23.1 Manufacture of glass and glass products (1)	50 (50-50)	2% (2%-2%)
C24.2 Manufacture of tubes, pipes, hollow profiles and related fittings, of steel (1)	100 (100-100)	13% (13%-13%)
C24.42 Aluminium production (1)	230 (230-230)	14% (14%-14%)
C24.51 Casting of iron (2)	35 (20-50)	22% (18%-25%)
C25 Manufacture of fabricated metal products (26)	53 (0-1000)	32% (0%-100%)
C25.2 Manufacture of other general-purpose machinery (1)	4 (4-4)	15% (15%-15%)
C25.99 Manufacture of other fabricated metal products (1)	30 (30-30)	1% (1%-1%)
C28 Manufacture of machinery and equipment n.e.c. (8)	19 (0-130)	17% (0%-100%)
C29 Manufacture of motor vehicles, trailers and semi-trailers (6)	793 (0-4500)	15% (0%-64%)
C33 Repair and installation of machinery and equipment (6)	99 (0-500)	7% (0%-11%)
C33.11 Repair of fabricated metal products (1)	0 (0-0)	0% (0%-0%)
G45.2 Repair of motor vehicles and motorcycles (1)	0 (0-0)	0% (0%-0%)
P85 Education (1)	0 (0-0)	0% (0%-0%)
Grand total		21% (0%-100%)

Source: Study team on basis of stakeholder responses.

The stakeholder consultation 2023 also asked how many welders work on high risk welding+ activities, with many of the sectors that responded saying there were no welders working on high risk welding+ activities.

Table 3-39 Number of welders per company working on high risk welding+ activities-.

Sector (n)	Average (Min-Max)
C17.12 Manufacture of paper and paperboard (1)	0 (0-0)
C21 Manufacture of basic pharmaceutical products (1)	0 (0-0)
C23.1 Manufacture of glass and glass products (1)	0 (0-0)
C24.2 Manufacture of tubes, pipes, hollow profiles and related fittings, of steel (1)	0 (0-0)

Sector (n)	Average (Min-Max)
C24.42 Aluminium production (1)	0 (0-0)
C24.51 Casting of iron (2)	0 (0-0)
C25 Manufacture of fabricated metal products (26)	5 (0-40)
C25.2 Manufacture of other general-purpose machinery (1)	0 (0-0)
C25.99 Manufacture of other fabricated metal products (1)	120 (120-120)
C28 Manufacture of machinery and equipment n.e.c. (8)	4 (0-20)
C29 Manufacture of motor vehicles, trailers and semi-trailers (6)	15 (0-20)
C33 Repair and installation of machinery and equipment (6)	18 (0-32)
C33.11 Repair of fabricated metal products (1)	3 (3-3)
G45.2 Repair of motor vehicles and motorcycles (1)	0 (0-0)
P85 Education (1)	3 (3-3)

Source: Study team on basis of stakeholder responses.

The proportions of workers whose primary role was welding, as reported in the stakeholder consultation 2023, ranged from 0% (C28 Manufacture of motor vehicles, trailers and semi-trailers) up to 69% (C25.2 Manufacture of other general purpose machinery – which could be an anomaly) (Table 3-37). For most sectors, the proportion of workers whose primary role was welding was 10% or less. However, the stakeholder consultation 2023 is unlikely to be representative of the entire welding community for the reasons discussed in section 3.6.3. For example there were no responses from the construction sector and the sample size (58) is not large enough to be representative, so without further validation of the stakeholder consultation 2023 results they will be used with care.

With the caveat that the stakeholder consultation 2023 responses are not fully representative of welding across Europe, of the respondents, the two sectors with the highest number of welders working on high risk welding+ activities were C25.99 Manufacture of other fabricated metal products and C33 Repair and installation of machinery and equipment, which loosely corresponds to two of the key sectors identified in the EUROSTAT and CAREX data (Table 3-39). Most of the sectors identified responded to the stakeholder consultation 2023, but unfortunately there were no responses from the construction or civil engineering sectors.

3.4.5 Trends in exposed workers

By reviewing Eurostat data from 2011-2020 the study team has been able to calculate the annualised compound trend for the sectors relevant to welding, which could be used to estimate the change in the number of workers employed in each sector relevant for welding. However, the growth in each sector will not directly correlate to the numbers of welders employed, as some sectors rely on manual welding more than others, and automation and other technologies are increasingly being adopted. The table below indicates for each sector the current compound annual growth rates (CAGR)[25]. It is interesting to note that manufacture of metal products, and manufacture of machinery and equipment are in slight decline. Whereas there is particularly strong growth in the repair of motor vehicles and motorcycles, repair and installation of machinery and equipment. There is also good growth in other manufacturing, civil engineering, and specialised construction activities.

Table 3-40 Annualised compound trend for each sector relevant to welding.

NACE code	NACE name	Annualised compound trend (%)
C24	Basic metals	0%
C25	Manufacture of fabricated metal products, except machinery and equipment	-1%
C28	Manufacture of machinery and equipment n.e.c.	-1%
C29	Manufacture of motor vehicles, trailers and semi-trailers	1%
C30	Manufacture of other transport equipment	1%
C31	Manufacture of furniture	1%
C32	Other manufacturing	2%
C33	Repair and installation of machinery and equipment	3%
E38	Materials recovery	1%
F41	Construction of buildings	1%
F42	Civil engineering	2%
F43	Specialised construction activities	2%
G45	Repair of motor vehicles & motorcycles	3%

Source: Eurostat

[25] The CAGR is the rate of return (smooth line) required for an investment to grow from its beginning balance to its ending balance, assuming that profits are reinvested at the end of each period of the investment's life span (Fernando, 2023). I t is one of the most accurate ways to calculate and determine returns for anything that can rise or fall in value over time. CAGR can be used by investors to compare one or more alternative investments to see how well one stock performed compared with others in a peer group or market index.

In general terms, work patterns are changing; more workers are working more than one job at once, there is an increase in part time working or irregular hours worked in many locations, young workers more likely to have temporary contracts, and a trend in women undertaking non-traditional jobs has been observed (EU OSHA, 2014). In some sectors, such as power, oil and gas, supply chains may be quite long with several subcontractors in a supply chain for a large project, with associated issues for accountability for Occupational Safety and Health (OSH) (pers comm, Kim Holler Foget, Force Technology, May 2023). For example, Mr Foget observed that power plant boiler parts may be ordered in one country, prefabricated in another company before being assembled on site. A long the supply chain there may be various subcontractors, and subcontractors may even hire in self-employed people to undertake welding. Mr Foget notes a trend for Western European countries to hire welders from Eastern European countries such as Poland, Romania and Croatia, but sometimes recruitment extends beyond Europe. For example, a Danish company ordered boiler parts from a company in Poland, and due to the EU welding skills shortage, the Polish company is recruiting welders in the Philippines. EU OSHA (2014) therefore identified a need for more studies on exposure to part time and temporary workers, as previous studies have focused on full time workers. For workers with multiple jobs, there is a need for cumulative exposure assessment.

In terms of the general trends in technologies, the associated improvements to worker health and safety are as follows (EU-OSHA, 2023). Digital technologies can enhance prevention at workplaces. They can help to separate workers from hazardous working situations, facilitate better and innovative ways of monitoring exposure, and might improve the quality of work by relieving workers from repetitive or routine tasks. The trend for improvements in technical and organisation measures to improve OSH is generally continuing, with improvements in exhaust and ventilation technologies to remove fumes and strong safety obligations for work in confined spaces according to EU-OSH (2023).

There is a skills shortage of welders on the factory floor, which could hinder market growth, or encourage further automation of the industry. Engineers reportedly more often learn to weld while they are performing operations, rather than through apprenticeships or formal welder training. Therefore, the risk of occupational accidents is heightened as the operators are not well informed about factors such as time needed to heat metals, supply of required current and noise considerations. This lack of training is likely to also have a negative impact on occupational exposure to welding fumes.

The 2019 Accuray Research report Global Welding Equipment Market Analysis & Trends - Industry Forecast to 2027 suggests a CAGR (compound annual growth rate) for the European welding market of 4.5% which is unlikely to be met if there is a shortage of skilled welders. In addition, as some of this growth simply reflects growth in the value of the market, and much will also be related to new and automated technologies, it is unlikely that this 4.5% annual growth would result in the same rate of growth in the number of welders (particularly as welding remains a shortage occupation, which in turn may push up the value of the market). For the benefits analysis (section 6), the growth in the number of welders is taken at 0.45%, or 10% of the forecast market growth in the sector. The study team has no data to indicate what the percentage is, but it cannot be 100% and seems unlikely to be as high as 50%: and given the shortage of welders and the substantial ongoing investment in robotics, 10% is the study team’s best estimate. This assumption has not been questioned by any stakeholders. The figure below plots the increase in number of welders over the 40 year study period and reflects 1.2 million welders in year 0 rising to 1.436 at year 40 (and beyond that to 1.536 million in year 55).

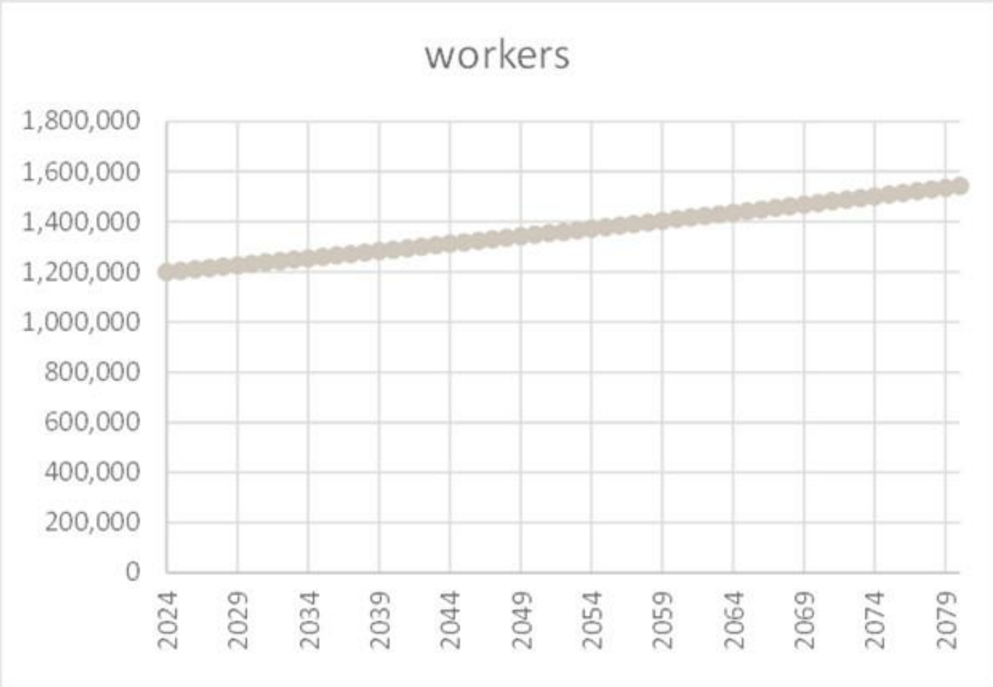

Table 3-41 Trend in number of welders over 55 years

Source: Study team

3.4.6 Summary of exposed workforce

Estimates of the numbers of workers in welding+ processes range from 0.678 to 2 million welders in the EU27 (Table 3-42).

Table 3-42 Summary of data on workers exposed to welding fumes.

Source, year	Geographic coverage	Definition of exposed workers	Number estimated	Extrapolated number of workers in the EU27 exposed to welding fumes
ASA, 2021 (Uuksulainen, 2021)	Finland	Workers with exposure to Cr(VI) and nickel compounds		750,873
CAREX, 2016	Canada	Canadian workers exposed to welding fumes		1,019,124
DVS, 2021	EU28	Full time workers in joining, cutting & coating (JCC)	1,200,000	Adjusted to EU 27 without UK workers, based upon population:

Source, year	Geographic coverage	Definition of exposed workers	Number estimated	Extrapolated number of workers in the EU27 exposed to welding fumes
		technologies[26] in 2019		1.2 million x 450[27]/510[28] million = 1.06 million
DVS, 2021	EU28	Full time, and part time workers in JCC technologies in 2019		1,800,000
ELA, 2021	EU27	Welders and flame cutters	678,000	
EUROSTAT, 2023	EU27	Sectors in which welding+ processes take place[29]	1,279,892	
EWA, 2023	EU27	Workers in welding+ processes including full time, part time and occasional welders in 2023.	2,000,000	

Source: Study team

Based upon the estimates in Table 3-42, the study team has taken the value of 1.2 million as the best estimate of the number of welders for the calculations in this study.

The DVS figure of 1.2 million full time workers in the joining, cutting and coating technologies seems like the most accurate estimate available to the study team as the categories of processes included in the definition correspond well to the ECHA definition of welding+ processes. This figure was estimated for the EU28 (in 2019) before the UK left the EU. However, the number of welders in the EU will have grown since 2019, and the number of welders in the UK is only estimated to be 31,900 in 2023 (TWI, *pers comm*, April 2023) and would have been less in 2019. The study team therefore believes that 1.2 million full time workers in welding+ processes to be a good estimate for the EU27.

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[26] Welding, thermal cutting and gouging, thermal spraying, soldering, flame straightening, additive manufacturing processes with metal powders, related procedures and incidental work (e.g. grinding) associated with welding.

[27] Approximate population of EU27.

[28] Approximate population of EU28 including the UK.

[29] Please see the assumptions associated with Table 3-33.

The focus of the cost benefit analysis will be on full time workers, since the risk of developing health effects is linked to the length of exposure to welding fumes (ECHA, 2022) and it is easier to make assumptions about occupational exposure for full time workers as this group is better documented in the literature. Therefore, the study team's judgement is that when calculating the costs and benefits of the potential Annex I entry, it makes more sense to use a number for full time equivalents (FTE) when applying a top down cost based on the market value of RMMs (industry figures) rather than use the total number of exposed workers (part time and full time workers).

EUROSTAT data has been used to model the estimated number of exposed workers, and distribution of exposed workers across all sectors (as detailed in Table 3-33). The resulting total number of estimated exposed workers (1.28 million) is similar to the expected number of FTE welders in each sector using 1.2 million as the overall total (Table 3-43). Bearing in mind the large uncertainty around all of these estimated figures, the estimated number of exposed workers per sector (taken to be equivalent to an estimated number of FTE welders per sector) will be used to estimate the costs and benefits per sector.

Table 3-43 Estimated number of workers in the EU27 exposed to welding fumes in key sectors

Sector		Estimated number of exposed workers	% of exposed workers distributed across sectors
C24	Manufacture of basic metals	22,500	1.8%
C25	Manufacture of fabricated metal products (excl. machinery & equipment)	152,113	11.9%
C28	Manufacture of machinery & equipment	35,311	2.8%
C29	Manufacture of motor vehicles, trailers & semi-trailers	69,965	5.5%
C30	Manufacture of other transport equipment	30,150	2.4%
C31	Manufacture of furniture	5,400	0.4%
C32	Other manufacturing	4,852	0.4%
C33	Repair & installation of machinery & equipment	73,982	5.8%
E38	Waste collection, treatment & disposal, materials recovery	11,331	0.9%
F41	Construction of buildings	245,103	19.2%
F42	Civil engineering	42,937	3.4%
F43	Specialised construction activities	463,091	36.2%
G45	Wholesale & retail trade & repair of motor vehicles & motorcycles	123,157	9.6%
Total		**1,279,892**	**100%**

Source: Study team based on information presented in this section.

3.5 Use as intermediates not covered by parts of the REACH Regulation

Not applicable to welding fumes.

3.6 Current risk management measures (RMMs)

3.6.1 Types of RMMs

Table 3-44 Hierarchy of measures to be applied by the employers, as listed in the CMRD

Type of measure	Measures specified in the CMD
Reducing the quantities of the chemical agents used (substitution and material reduction)	(a) limitation of the quantities of a carcinogen or mutagen at the place of work;
Reducing the number of workers exposed	(b) keeping as low as possible the number of workers exposed or likely to be exposed;
Reducing the concentration of the chemical agents at the workplace	(c) design of work processes and engineering control measures so as to avoid or minimise the release of carcinogens or mutagens into the place of work;
	(d) evacuation of carcinogens or mutagens at source, local extraction system or general ventilation, all such methods to be appropriate and compatible with the need to protect public health and the environment;
	(e) use of existing appropriate procedures for the measurement of carcinogens or mutagens, in particular for the early detection of abnormal exposures resulting from an unforeseeable event or an accident;
	(f) application of suitable working procedures and methods;
Reducing the exposure of workers by protective measures	(g) collective protection measures and/or, where exposure cannot be avoided by other means, individual protection measures;
	(h) hygiene measures, in particular regular cleaning of floors, walls, and other surfaces;
	(i) information for workers;
	(j) demarcation of risk areas and use of adequate warning and safety signs including 'no smoking' signs in areas where workers are exposed or likely to be exposed to carcinogens or mutagens;
	(k) drawing up plans to deal with emergencies likely to result in abnormally high exposure;
Other measures	(l) means for safe storage, handling and transportation, in particular by using sealed and clearly and visibly labelled containers.

Source: CMRD

Welding+ processes have different emission rates due to different technologies being applied and other factors such as the temperature of the operation (with emissions being higher at higher temperatures). The Ausschuss für Gefahrstoffe (AGS, German Committee on Hazardous Substances) grouped welding and associated processes into emission groups ranging from low (<1 mg/s) –

very high >25 mg/s) (Table 3-46 extracted from TRGS 528). As a general rule, more RMMs are required the higher the emission group. The Vereinigung der Metall Berufsgenossenschaften (VBMG) classified the emission classes into health hazard classes (from I, low to IV,very high) based upon health effects on the respiratory tract and lung; toxic or toxic irritating substances; and of particular interest to this study - presence of carcinogenic substances (Table 3-45). This table shows that very low emission welding processes such as UP ('Unter-Pulver' which is translated as Submerged Arc Welding or SAW) and TIG at one end of the scale have low health hazard classes (I) across the categories, whilst the very high emission welding process MAG has very high health hazard classes (IV) across the categories. The study team have mapped across the VBMG hazard class for carcinogenic substances to a list of welding+ processes based upon their emission rates, to provide an indication of the carcinogenic hazard classes. According to the German classification system, these hazard classes only apply if the alloys or cover/filler components contain more than 5% carcinogenic substance. Please note this was a simplistic read across without full knowledge of other factors involved in the classification process (final column, Table 3-46).

Table 3-45 Welding processes with associated hazard classes (extracted from VBMG, 2007)

Welding fumes: Emission classes, emission rates [mg/s]		**Process examples**	**Welding fumes: effect**		
			Effect class A	**Effect class B**	**Effect class C**
			Substances straining respiratory tract and lung[1] e.g. Fe_2O_3	**Toxic or toxic irritating substances[2] e.g. F^-, MnO, CuO**	**Carcinogenic substances[2] e.g. Cr(VI), NiO**
			Hazard	**Hazard**	**Hazard**
1	<1	e.g. UP[3]	I (A1)	I (B1)	I (C1)
	<1	e.g. TIG[4]	I (A1)	I (B1)	I (C1)
2	1 to 2	e.g. laser welding	II (A2)	II (B2)	II (C2)
3	2 to 25	e.g. MMA, MAG (solid wire)	III (A3)	III (B3)	III (C3)
4	>25	e.g. MAG	IV (A4)	IV (B4)	IV (C4)

Source: VBMG, 2007 (translated from German)

Notes:

I = low health hazard

II = medium health hazard

III = high health hazard

IV = very high health hazard; A1 to C4: welding fumes classes

[1] If alloying or cover/filler components are each <5% content

[2] If alloying or cover/filler components are each >5% content

[3] Automated

[4] See BG Information "Welding activities with chromium and nickel alloy filler and parent materials" (BGI 855) and "BG/BGIA Recommendations for Hazard Evaluation according to the Hazardous Substances Ordinance – Tungsten Inert Gas Welding (TIG Welding)"(BGI 790-012)

Table 3-46 Welding and associated processes listed in ascending order of emission rates for particulate matter from welding fumes, and assigned to emission groups (adapted from AGS, 2021).

Process (sample list)	Emission rate (mg/s)	Emission group	Indicative health hazard class for effect class C: carcinogenic substances[1)]
Submerged arc welding	< 1	low	I (C1)
Gas fusion welding (autogenous process)	< 1	low	I (C1)
TIG	< 1	low	I (C1)
Soft soldering	< 1	low	I (C1)
MIG (aluminium materials)	0.8 to 29	low to very high	I (C1) to IV (C4)
Laser beam cutting without addition materials	1 to 2	medium	II (C2)
MIG/MAG (low-energy protective gas welding)	1 to 4	medium to high	II (C2) to III (C3)
Brazing	1 to 4	medium to high	II (C2) to III (C3)
MIG soldering	1 to 9	medium to high	II (C2) III (C3)
Laser beam cutting with addition materials	2 to 5	high	III (C3)
MIG (solid wire, nickel, nickel- based alloys)	2 to 6	high	III (C3)
MAG (solid wire)	2 to 12	high	III (C3)
MMA	2 to 22	high	III (C3)
MAG (flux-cored arc welding with shielding gas)	6 to > 25	high to very high	III (C3) to IV (C4)
Laser beam cutting	9 to 25	high to very high	III (C3)
MAG (flux-cored arc welding without shielding gas)	> 25	very high	IV (C4)
Autogenous flame cutting	> 25	very high	IV (C4)
Plasma cutting	> 25	very high	IV (C4)
Arc spraying	> 25	very high	IV (C4)
Flame spraying	> 25	very high	IV (C4)

Source: Study team based on information presented in this section.

Notes:

[1)] If alloying or cover/filler components are each >5% content

I = low health hazard

II = medium health hazard

III = high health hazard

IV = very high health hazard

C1-C4 welding fumes classes

3.6.2 Current use of RMMs by sector

Annex I contains tables of RMMs currently used by respondents to the stakeholder consultation 2023, sorted by sector (NACE code) and by welding process for each sector. Companies could list information for up to four welding processes. To save space in the tables, empty columns (RMMs) and rows (sectors) were excluded, so only the cells containing results are displayed.

58 responses were received to the stakeholder consultation 2023; although this is a relatively good response rate for an OEL study compared with previous studies (often only ~20 responses are received), please note that the responses received were not a representative sample of organisations undertaking welding in terms of:

- Sectors: the major sectors for welding are likely to be: construction (F41), automotive (C29), manufacture of machinery and equipment (C28), manufacture of fabricated metal products (C25), manufacture of steel tubes (C24); however there were no responses from the construction industry unfortunately. 27 of the 58 responses were from the manufacture of fabricated metal products sector (C25) which could have skewed the results;
- The size of companies that responded: There was a good response rate from small companies (25) and large companies (18) but fewer medium sized companies (11); and
- Turnover of companies: responses were fairly evenly distributed across companies with turnovers between <2 million Euros to >200 million Euros. Each category had at least 20% of respondents, but there were few companies with a turnover of 50-100 million Euros (only 3.6%).

Due to the lack of representativeness of the survey responses, it is hard to draw strong conclusions from the results; the results have only been used to provide an indication of the current situation.

3.6.3 Data from stakeholder consultation 2023

3.6.3.1 Survey - RMMs needed to achieve compliance

Not applicable for welding fumes; so this question was not asked during the survey. In any case, the Annex I entry had not been fully defined at the time of the questionnaire survey.

3.6.3.2 Survey - Companies' estimated costs of compliance

The most common estimate by small enterprises was that the initial investment to comply with an entry into Annex I of the CMRD for welding fumes at €10,000 – 100,000 (Table 3-48). The most common estimate for large enterprises for this initial investment was for this to cost more than €100,000. Please note however that at the time of the questionnaire survey, policy option two (Annex I) was not fully defined. The Annex I entry would only apply to welding fumes containing CMR substances, so these could have been costs could have been overestimated if respondents thought that all welding fumes would be covered by Annex I.

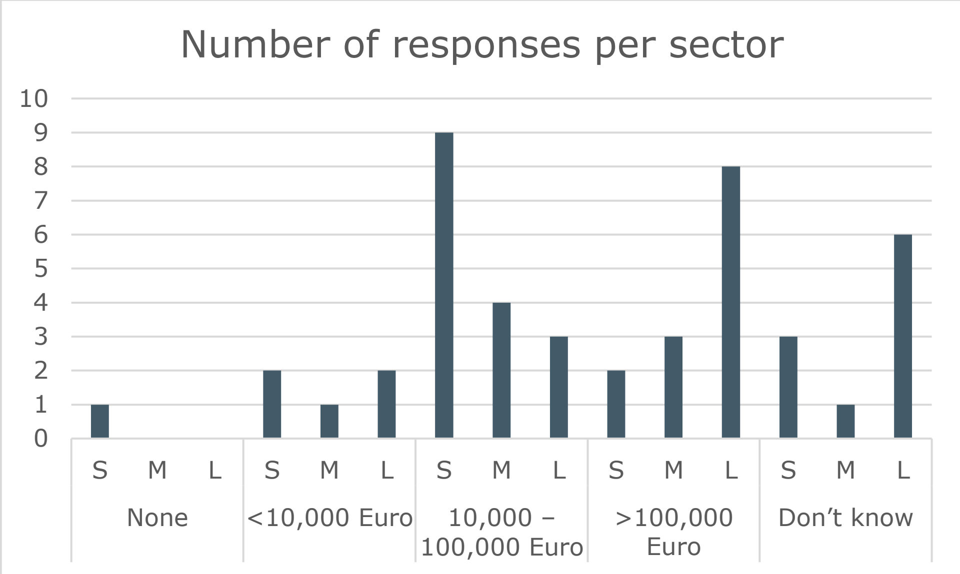

Table 3-47 Estimated range of total initial investment costs-

Source: Stakeholder consultation 2023

The most common ongoing costs for an Annex I entry, for small enterprises was less than €10,000, closely followed by €10,000-100,000 (Table 3-48). For medium and large enterprises the most common estimate was €10,000-100,000. However, an even higher number of large enterprises were unable to estimate this cost.

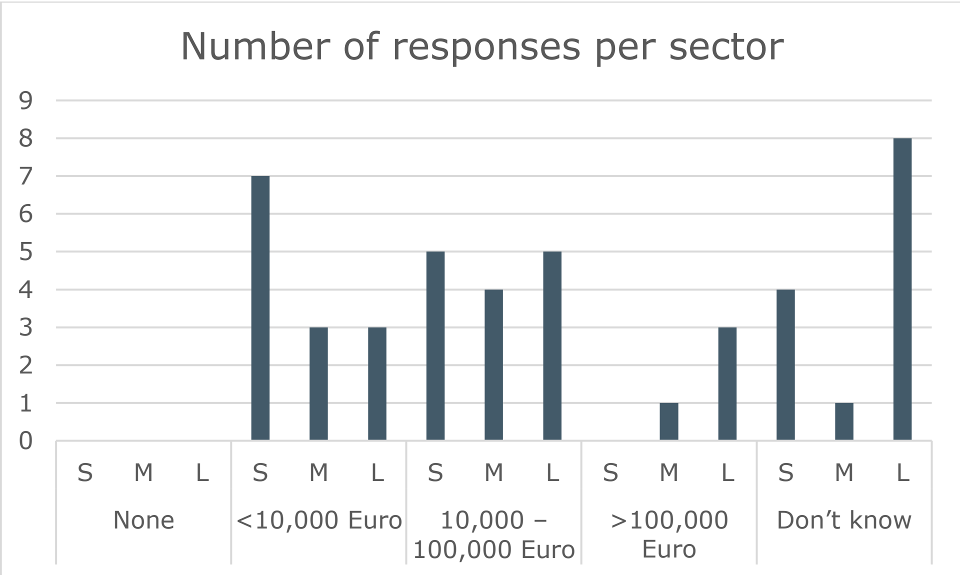

Table 3-48 Estimated range for ongoing costs

Source: Stakeholder consultation 2023

3.6.3.3 Survey - Lowest technically possible and economically feasible option

In the consultation responses, the lowest technically feasible levels for welding fumes ranged from 0.001 mg/m^3 to 5 mg/m^3. One respondent stated the lowest technically feasible levels in terms of inhalable and respirable total dust as 7 mg/m^3 and 1 mg/m^3 respectively.

In terms of the lowest economically feasible levels, for welding fumes the consultation respondents gave a range of values from 0.001 – 5 mg/m^3. One respondent gave these in terms of inhalable and respirable total dust as 10 mg/m^3 and 1.25 mg/m^3 respectively.

3.6.3.4 Survey - EU Member State Authorities (MSAs)

The most common response from MSAs was that an entry into Annex I for welding fumes would have 'no impact' on:

- Costs for companies (56%);
- Costs for public authorities (71%);
- Competitiveness (82%);
- SMEs (82%);
- Occupational health (72%); or
- Environment (75%).

Although a small proportion of MSAs said that policy option two (Annex I) would have a moderate or significant impact on occupational health (12.6%) and the environment (13.3%) respectively.

Many of the MSAs did not attempt to predict what would happen if companies could not comply and would have to cease trading. However, four of 22 MSAs (14%) said that "*The majority of employees would not find alternative work of a similar level and pay within six months, and the impact on the local region (city or region) would be severe.*"

3.6.3.5 Survey undertaken by the SNCT

The French Syndicat de la Chaudronnerie, Tuyauterie, Tolerie and Maintenance Industrielle (SNCT) has undertaken a survey of their members before this study, to understand the impact of including work involving exposure to welding fumes in the list of carcinogenic processes (in response to the ANSES, 2022 report).

3.7 Voluntary industry initiatives

Various voluntary industry initiatives exist around the world to improve the occupational health of welders by providing guidance and training to welders and developing innovative methods and new technologies to reduce occupational exposure to welding fumes. Some key examples in Europe and the UK are summarised below.

In Germany, the 'REarc welding' initiative was started in 2020 by the German Welding Association (DVS), in response to industry demands for advice on worker protection, with the aim of substantially Reducing Exposures in arc welding (DVS, 2023). The REarc welding initiative is a collaboration between manufacturers, users, associations, employee representatives, educational institutions, state and trade association committees and research groups. The initiative is developing and coordinating a comprehensive prevention approach for all those working in welding technology, and covers all forms of emissions from gas metal arc welding, both welding fumes and radiation. Recent research has shown that welding processes can be optimised with demonstrable reductions in emissions, but advanced process optimisation is not yet widely adopted. The DVS has two workstreams, one on 'Innovation' and one on 'Information'.

In Germany, a welding fumes reduction program is being developed as part of the Welding Fumes Colloquium (Linde, 2023). This program supports the implementation of TRGS 528 in operational practice, and is under continuous development. At the moment, work is underway to optimise the measurement strategy for welding fumes. Based on the optimised measurements, a forecasting tool is being created. The welding fumes reduction measures developed in the colloquium are being trialled for their effectiveness in various companies. The InterWeld study (Lerhnert *et al.*, 2020) was launched for this purpose, amongst other reasons. In addition to welding fumes reduction measures, occupational health aspects are also considered in this study. The measures for reducing welding fumes are shared with companies through information and training for the different target groups (welders, managers, entrepreneurs, occupational safety specialists, supervisory authorities, and so on).

In 2021, the EWA created a technical committee dedicated to the health and safety of welders which is developing guidance for welders. Guidance on worker protection from occupational exposure from arc welding was due to be published in autumn 2023. A separate group of EWA members, comprised of equipment suppliers, is discussing guidance on choice of extraction systems.

The EWA has created a technical committee dedicated to the health and safety of welders which is developing guidance for welders. This committee is composed of European manufacturers of welding consumables, arc welding equipment and safety equipment (including welding fumes extraction systems). A guidance document on worker protection from occupational exposure (Welding exposure scenario) is available in 21 languages on the EWA website (this document is regularly updated and was written with Eurofer and the IIW). Another guidance document on the selection of extraction systems was due to be published in autumn 2023.

The ‘Breathe Freely’ campaign is an initiative of the British Occupational Hygiene Society (BOHS), aimed at reducing occupational lung disease in the UK, which has also been adopted in Australia and New Zealand (BOHS, 2015). The Breathe Freely campaign began in 2015 aimed at the construction sector initially, and then extended to the manufacturing sector in 2017. The campaign aims to raise awareness of occupational lung disease, present mitigation measures, and offer free practical advice. The free advice includes toolbox talks, factsheets, guides, and online tools. There is a ‘welding fumes control selector tool’ created by a panel of experts, to provide guidance on welding fumes control for common welding activities (this tool is summarised in Table 3-49 below). It can be used by managers and supervisors to select welding fumes control measures to protect workers. However, it comes with the caveat that it is not a substitute for completing a full risk assessment, and the individual circumstances of the welding work and location of the work should be factored in with any recommendations from the tool. The control and management factsheets should also be used alongside the tool, as they may suggest more suitable alternatives and provide advice on proper use and training of equipment.

The ‘5xbeter’ (five times better) initiative was established in the Netherlands to improve health and safety in the metal working industries. Set up by the Royal Metal Union, the FME (entrepreneurial organisation for the technology industry), FNV Metaal (trade union for professionals working in technology and metal), De Unie (trade union) and CNV Professionals (trade union), the initiative includes an occupational health and safety catalogue, practical tools and ‘Improvement Coaches’. The 5xbeter online decision making tool which recommends which control measures should be taken is summarised in Table 3-49 below, and the results of the exposure modelling are discussed in section 3.3.7.

Table 3-49 Summary of a few selected decision-making tools to recommend control measures for welding fumes.

	Factors considered by the decision tool											
Decision tool	**Welding materials**	**Welding processes**	**Fumes composition**	**Fumes concentration**	**Location of welding processes**	**Ventilation**	**Source extraction**	**RPE used**	**Worker details**	**Coatings present?**	**Duration of welding session**	**Size of workpiece**
Breathe Freely (BOHS, 2015)	Welding materials: Aluminium, mild steel, stainless steel, exotic metals	Welding processes: MIG, MMA, TIG, Oxy-gas brazing, Oxy-gas cutting, Arc-air gauging, Manual plasma cutting	-	-	-	-	-	-	-	-	Duration of welding session: <15 mins, 15-60 mins, >60 mins	<1.0 x 0.5m; <2.0 x 1.0m; <2.0 x 4.0m; >2.0 x 4.0m
5xbeter	Unalloyed, stainless steel, duplex	TIG suturing, TIG adhesion, TIG welding, MIG/MAG solid wire adhesion, MIG/MAG solid wire bonding, MIG/MAG solid wire welding, MIG/MAG bonded wire or electrode, MIG/MAG corroborated wire or electrode welding, MIG/MAG flux-cored wire or electrode bonding, under powder	-	-	Open air, indoors, confined space	Ventilation flow rate or air changes per hour	Source extraction or torch extraction	Improved welding hood, handheld welding hood, dust mask (FFP2/FFP3), fresh air helmet (TH2/TH3) with or without wide folding window (where the helmet remains closed)	e.g. worker's head in the plume?	e.g. oil, grease, coating, paint, mill skin	-	-
5xbeter	Unalloyed, stainless steel, duplex	Cutting processes: plasma & oxy-fuel cutting (manual) (duty cycle <15%	-	-	Open air, indoors, confined space	Ventilation flow rate or air	Source extraction or torch	Improved welding hood, handheld	e.g. sharpening by or in the	e.g. oil, grease,	-	-

	Factors considered by the decision tool										
Decision tool	**Welding materials**	**Welding processes**	**Fumes composition**	**Fumes concentration**	**Location of welding processes**	**Ventilation**	**Source extraction**	**RPE used**	**Worker details**	**Coatings present?**	**Duration of welding session**	**Size of workpiece**
		or >15%); plasma & oxy-fuel (machine) (duty cycle <15% or >15%), plasma cutting under water (duty cycle <15%), plasma cutting under water with a maintenance time >15%				changes per hour	extraction	welding hood, dust mask (FFP2/FFP3), fresh air helmet (TH2/TH3) with or without wide folding window (where the helmet remains closed)	immediate vicinity of the cutter?	coating, paint, mill skin		
TRGS 528, Annex 2 flow chart decision tool (BAUA, 2021)	-	1. Optimised process from a procedural point of view?	-	-	5. Structural or organisational separation?	6. Room ventilation measures	2. Capture at source?	Use PPE for welders. 4. Protection measures sufficient for other employees in the hazard area? If not, use PPE for all exposed persons	3.Protection measures sufficient for the welder?	-	-	-
SLIC (2018) Guidance	Mild steel, stainless/	GMAW, MIG, MAG, SMAW, MMA, FCAW	How to calculate a	If exposure	Outdoors, large open	LEV, LEV but poor design or	-	-	-	Oil, grease,	% of working period when the arc is	-

	Factors considered by the decision tool											
Decision tool	**Welding materials**	**Welding processes**	**Fumes composition**	**Fumes concentration**	**Location of welding processes**	**Ventilation**	**Source extraction**	**RPE used**	**Worker details**	**Coatings present?**	**Duration of welding session**	**Size of workpiece**
for National Labour Inspectors	chromium steel		rating based on likely health effects	monitoring data is lacking, how to estimate fumes concentration from a visual appraisal	shop, smaller shop, enclosed	poor maintenance of non-use, no LEV or other engineering controls				degreasing residues, anti-corrosion primers, historic coatings	struck (<5% spot welders, 5-10% platers, intermittent welding, 10-25% full time manual welders, >25% full time welders, with pre-set activities	

Source: Study team

3.8 Examples of good/best practice

3.8.1 European Guidance for Inspectors of welding activities

Although this guidance was developed for inspectors, companies can also follow the guidance to ensure they are meeting their requirements before being inspected. The Guidance for National Labour Inspectors to address health risks from Welding Fumes was developed in response to an identified need to improve the effectiveness of National Labour Inspectors when inspecting welding activities undertaken in the manufacturing sector and other sectors such as construction (EC, 2018a). A CHEMEX working group including National Labour Inspectors (NLIs) was set up to advise on the guidance on the control of fumes from welding and associated processes (plasma cutting, laser cutting, flame cutting, arc-air gauging). The guidance is quite comprehensive, including in part one background information such as health risks, types of welding, the legal framework for regulation, typical control measures, health surveillance and key information. Part two includes Welding Fumes Task Sheets with specialised guidance on each welding activity including approaches to control welding fumes exposure, illustrative photographs, recommended actions for National Labour Inspectors, as well as NLI personal safety and consideration of other health and safety hazards from welding activities in addition to welding fumes. It is noted that NLIs will be enforcing national requirements which may sometimes go beyond the EU Directive minimum requirements, and NLIs always have the choice of which activities to recommend that are appropriate to an individual workplace.

↓ Decreasing effectiveness	Control	Method	Comments
	Elimination	**Is process required?**	
		✓ Cold cut, e.g. guillotine	*No fume*
		✓ Redesign of the job so there is less need to weld	*Less fume, due to use of pre-cast components or extruded shapes*
	Substitution	**Can a cleaner process be used?**	
		✓ MMA to MIG/MAG; MIG to TIG	*Less fume, reduced post-weld grinding*
		✓ Flame cut to plasma cut to laser cut	*Less fume, easier to control, better quality cut*
		Can different consumable be used?	
		✓ Cleaner rods/wires	*Less fume*
	Process change	**Can it be automated?**	
		✓ Robotic Welding, CNC cutting	*Usually enclosed and distant from worker, lower exposure*
		Can the workpiece be better positioned?	
		✓ Use of jigs rigs, etc. may require better planning	*Worker not in fume plume*
		Is the workpiece clean?	
		✓ Remove grease, flash rust, debris or surface coatings prior to welding	*Fume only from weld, not other sources*
		Can the process be enclosed?	
		-	*Associated with automation*
	Ventilation	**Can fume be extracted at source (LEV)?**	
		✓ On-gun extraction	*Only applicable to MIG/MAG, requires training of workers to proper use, very effective*
		✓ Extracted benches – rear slots	*Very effective for smaller components* *Requires maintenance and testing effectiveness*
		✓ Flexible or hinged arm	*Requires worker to reposition with weld* *Flexible ducting & capture hoods are prone to damage* *Capture hood design need to be appropriate for weld* *Requires maintenance and testing effectiveness*
		✓ Mobile fume extractors	*As above*
		Can fume be extracted by general ventilation?	
		✓ Wall or roof fans	*Not recommended as effectiveness is low and does not remove fume from workers at source. Can result in accumulation in some areas*
	Administrative control & work practices	**Can number of exposed workers be reduced?**	
		✓ Use dedicated area for welding with restricted access	*Isolates nearby workers from the welding plume*
		What information, instruction & training is required?	
		✓ in addition to technical training for the equipment used, workers must receive Health & Safety training	*Correct use of equipment to minimise fume production & exposure* *Training in the use and maintenance of LEV and RPE*
	Respiratory Protective Equipment (RPE)	**Is this appropriate exposure control?**	
		✓ If other engineering controls are not adequate	*Must be appropriate to fume hazards and wearer (fit properly)* *Workers with facial hair must use positive pressure RPE (e.g. battery powered respirator with welding visor or helmet)*

Table 3-50 Implementation of the Hierarchy of Controls for welding fumes, by National Labour Inspectors (extracted from EC, 2018a).

3.8.2 European Welding Association recommendations on Risk Management Measures

The European Welding Association (EWA) has developed guidance for different exposure scenarios and operational conditions, with recommended Risk Management Measures (RMMs), with the aim of outlining how metals, alloys and metallic articles and mixtures can be safely welded with respect to exposure to welding fumes and gases *see* Table 3-52. The EWA note that a systematic approach to exposure assessment is necessary, taking into account the set of circumstances of exposure for the operator and ancillary workers. The guidance has been developed on the basis that:

- The degree of occupational exposure risk will depend on:
    - The composition of the fumes;
    - The concentration of the fumes;
    - The duration of exposure;
- The fumes composition depends upon:
    - The material being worked;
    - The welding process;
    - The consumables being used;
- The amount of fumes generated depends upon:
    - The welding process;
    - The welding parameters;
    - The shielding gas;
    - The type of consumable; and
    - Any potential surface coating.

In order to reduce exposure to welding fumes and gases from welding, brazing or cutting metals, the EWA recommend firstly ranking Risk Management Measures (RMMs) by applying the principles of STOP (Substitution, Technological means, Organisational measures and PPE). Secondly, the Safety Data Sheet (SDS) information should be used, issued in accordance with REACH as provided by the welding consumable manufacturer. Employers should eliminate or reduce to a minimum the risk to the safety and health of workers from exposure to welding fumes. Before a new welding activity is undertaking an Occupational Safety and Health Risk Inventory should be completed. Any national legislation on the exposure of welders and other workers must be complied with, including any OELs.

Guidance on technological RMMs is provided in Table 3-51 below, based upon the welding or allied process to be used. Each welding or allied process and base material combination has been approximately ranked to mitigate the risk of exposure to welding fumes and gases. Each welding process/base material combination has been ranked from the lowest emission (class I) to the highest emission (Class VIII) combination. For each class, recommendations on ventilation, extraction and/or filtration and PPE are provided.

Table 3-51 Risk Management Measures by welding process/ base materials combination (extracted from EWA, 2021)

Class[1]	Process (with reference number according to ISO 4063)	Base Materials	Remarks	Ventilation/ Extraction/ Filtration[14]	PPE[2] DC<15 %	PPE[2] DC>15%
Non-confined space[16]						
I	GTAW *141*	All	Except Aluminium	GV low[3]	n.r.	n.r.
	SAW *12*					
	Autogenous *3*					
	PAW 15					
	ESW/EGW *72/73*					
	Resistance *2*					
	Stud welding *78*					
	Solid state *521*					
	Gases Brazing *9*	All	Except Cd- alloys	GV low[3]	n.r.	n.r.
II	GTAW *141*	Aluminium	n.a.	GV medium[4]	n.a.	FFP2[5]
III	MMAW *111*	All	Except Be-, V-, Mn-, Ni-alloys and Stainless[6]	GC low[7] LEV low[12]	Improved helmet[16]	FFP2[2]
	FCAW *136/137*	All	Except Stainless and Ni-alloys[6]			
	GMAW *131/135*	All	Except Ci-, Be-, V- alloys[6]			
	Powder Plasma Arc *152*	All	Except Be-, V-, Cu-, Mn-, Ni-alloys and Stainless[6]			
IV	All processes class I	Painted/ primed/ oiled/ galvanized	No Pb containing primer	GV low[3]	FFP2[5]	FFP3[8], TH2/P2, or LDH3
	All processes class III	Painted/ primed/ oiled/ galvanized	No Pb containing primer	GV low[7] LEV low[12]		
V	MMAW *111*	Stainless, Ni-, Be-, and V-alloys	n.a.	LEV high[10]	TH3/P3, LDH3[11]	TH3/P3, LDH3[11]

Class[1]	Process (with reference number according to ISO 4063)	Base Materials	Remarks	Ventilation/ Extraction/ Filtration[14]	PPE[2] DC<15 %	PPE[2] DC>15%
	FCAW *136/137*	Stainless, Mn-and Ni-alloys				
	GMAW *131*	Cu-alloys				
	Powder Plasma Arc *152*	Stainless, Mn-, Ni-, and Cu- alloys				
VI	GMAW *131*	Be-, and V-alloys	n.a.	Reduced (negative) pressured area[9] LEV low[12]	TH3/P3, LDH3[11]	TH3/P3, LDH3[11]
	Powder Plasma Arc *152*					
VII	Self-shielded FCAW *114*	Un-, high alloyed steel	Cored wire, not containing Ba	Reduced (negative) pressured area[9] LEV medium[13]	TH3/P3, LDH3[11]	TH3/P3, LDH3[11]
	Self-shielded FCAW *114*	Un-, high alloyed steel	Cored wire, not containing Ba	Reduced (negative) pressured area[9] LEV high[10]	TH3/P3, LDH3[11]	TH3/P3, LDH3[11]
	All	Painted/ primed/ galvanized	Paint/ Primer containing Pb			
	Arc Gouging and cutting *8*	All	n.a.			
	Thermal Spray	All	n.a.			
	Gases Brazing *9*	Cd- alloys	n.a.			
Closed system or Confined space[15]						
I	Laser Welding *52*	All	Closed system	GV medium[4]	n.a.	n.a.
	Laser Cutting *84*					
	Electron Beam *51*					
VIII	All	All	Confined space	LEV high[10] External air supply	LDH3[11]	LDH3[11]

Source: EWA, 2021

Notes:

1 Class: approximate ranking to mitigate risk by selecting process/material combinations with the lowest value.

Identified collective and individual risk management measures shall be applied

2 Personal Protective Equipment (PPE) required avoiding exceeding the National Exposure Limit Value (DC: Duty cycle expressed on 8 hours)

3 General Ventilation (GV) Low. With additional Local Exhaust Ventilation (LEV) and extracted air to the outside, the GV *or LEV capacity may be reduced to 1/5 of the original requirement.*

4 General Ventilation (GV) Medium (double compared to Low)

5 Filtrating half mask (FFP2)

6 When an alloyed consumable is used, measures from "Class V" are required

7 General Ventilation (GV) Low. When no Local Exhaust Ventilation, the ventilation requirement is 5-fold

8 Filtrating half mask (FFP3), helmet with powered filters (TH2/P2), or helmet with external air supply (LDH2)

9 Reduced (negative) pressured Area: A separate, ventilated area where reduced (negative) pressure, compared to the surrounded area, is maintained

10 Local Exhaust Ventilation (LEV) High, extraction at source (includes table, hood, arm or torch extraction)

11 Helmet with powered filters (TH3/P3), or helmet with external air supply (LDH3)

12 Local Exhaust Ventilation (LEV) Low, extraction at source (includes table, hood, arm or torch extraction)

13 Local Exhaust Ventilation (LEV) Medium, extraction at source (includes table, hood, arm or torch extraction)

14 Recommended measures to comply with national maximum allowable limits. Extracted fumes, for all materials except unalloyed steel and aluminum, shall be filtered before release in the outside environment.

15 A confined space, despite its name, is not necessarily small. Examples of confined spaces include ship, silos, vats, utility vaults, tanks, etc.

16 Improved helmet, designed to avoid direct flow of welding fumes inside

n.a. Not applicable

n.r. Not recommended

3.8.3 HSE guidance for recommended RMMs

The UK Health and Safety Executive (HSE) guidance on recommended RMMs for welding (Table 3-52) is much simpler than the above EWA guidance.

Table 3-52 Good control practice for welding fumes (from HSE, 2021)

Frequency and duration of welding	Type of welding	Good control practice
Sporadic low-intensity welding	Gas, MMA, FCA, MIG, MAG	LEV where reasonably practicable. Otherwise, good general ventilation and RPE
Regular and/or high-intensity welding	Gas, MMA, FCA, MIG, MIG	LEV and consider supplementary RPE
Regular and/or high intensity welding outdoors in the open air	Gas, MMA, FCA, MIG, MAG, TIG	RPE where LEV is not reasonably possible
Sporadic low-intensity welding	TIG and resistance spot welding	Good general ventilation
Regular and/or high-intensity welding	TIG and resistance spot welding	LEV

Source: HSE, 2021

Notes:

High-intensity welding: repeated welding throughout the shift. Welding arc time of more than 1 hour per welder per shift

Low-intensity welding: welding lasting less than 1 hour per welder per shift

Regular welding: daily or weekly welding at any intensity

Sporadic welding: occasional welding carried out less than once per week which is incidental to the businesses core activity and cannot be planned for, for example repair or maintenance work.

3.8.4 European Welding Federation qualifications and certifications

The EWF has developed an internationally harmonised system of qualifications for welding and associated activities, accepted Europe-wide and internationally (approved by the IIW), including training for welding coordination.

For welding coordination there are certain qualifications to help companies to achieve the ISO standard EN ISO 14731:2019 on 'Welding coordination: Tasks and Responsibilities' including:

- Welding inspection;
- Welding (MMA, TIG, MIG/MAG-FCAW, OFW);
- Resistance welding;
- Laser processing (cutting/welding/surface treatments);
- Mechanised welding/orbital welding/robotic welding;
- Thermal spraying; and
- Welding for the rail industry.

In addition to the above, special short courses are run to meet industry needs.

EWF qualifications are outlined in Table 3-53 below.

Table 3-53 EWF European and International welding qualifications.

Source EWF, 2023.

The EWF also run Europe-wide personnel certification schemes for certification in welding coordination, and as a welding operator and brazer. The former scheme helps companies achieve compliance with EN ISO 14731. The latter scheme helps companies achieve compliance with ISO 3834 (Quality requirements for fusion welding of metallic materials). There are four levels of certification, by diploma: Engineer, Technologist, Specialist and Practitioner.

3.8.5 TWI diploma in welding engineering

The TWI diploma was developed as an alternative to the EWF diploma above, for candidates who do not fulfil the acceptance criteria for the EWF diploma (TWI, 2023). The TWI diploma in welding engineering is also recognised internationally, with three levels of qualification: Specialist, Technologist and Engineer. The diplomas confirm that candidates have achieved a high level of knowledge, expertise, and organisational understanding of welding. They also fulfil the quality requirements required for welding coordination, covering a large variety of applications, materials, and processes.

3.8.6 Svetsa Rätt Swedish guidelines for welding

The Svetsa Rätt website[30] includes a range of resources providing guidance on best practice in welding, including advice for welders, advice for companies, guidance for premises, guidance on welding methods, health hazards and facts. The website includes a link to comprehensive 'Prevent' health and safety checklists[31] for welding workshops. The checklist includes a list of 72 health and safety questions, which go beyond welding fumes, with five key sections on: planning and organisation of work; goods reception and warehousing; the welding hall; the welding site; equipment; gas cylinders and pipelines; protective equipment; hazardous work steps and painting; and slagging, grinding and direction.

3.8.7 Options for making good practice available to stakeholders

Best practice in welding is shared on various websites, such as the Roadmap on carcinogens website which includes a page on good practice in welding: https://roadmaponcarcinogens.eu/solutions/good-practices/?fwp_solution_substances=2312

3.9 Standard monitoring methods/tools

3.9.1 Compliance monitoring

Procedures for monitoring of contaminants in the workplace are typically established by national guidelines prepared by the national working environment authorities. These guidelines would typically refer to European standards to be used for the monitoring.

As concerns the monitoring of substances in the workplace, guidelines refer to two European standards:

- EN 482:2012+A1:2015 : Workplace exposure. General requirements for the performance of procedures for the measurement of chemical agents; and
- EN 689:2018+AC:2019: Workplace exposure. Measurement of exposure by inhalation to chemical agents. Strategy for testing compliance with occupational exposure limit values

The strategy described in EN 689:2018 gives a procedure for the employer to overcome the problem of variability and to use a relatively small number of measurements to demonstrate with a

[30] http://www.svetsaratt.se/sidor/svetsmetoder.html (accessed 24 February 2023).

[31] https://checklists.prevent.se/checklist/answer/118 (accessed 24 February, 2023).

high degree of confidence that workers are unlikely to be exposed to concentrations exceeding the OELs. The procedures are further described in the Methodological Note.

[The study team anticipates obtaining from the DVS more details of this ISO standard EN 689:2018 and related standards which are used by employers in Germany to determine whether a category 1A/1B CMR substance will be present at a concentration greater than 0.5%, whether the CMRD must be applied, and therefore occupational exposure from welding fumes must be measured.]

Other ISO standards relevant to welding fumes include (from EWA, 2021):

- ISO 4063:2009, Welding and allied processes -- Nomenclature of processes and reference numbers;
- ISO EN 21904-1:2020, Health and safety in welding and allied processes -- Equipment for capture and separation of welding fumes -- Part 1: General requirements;
- ISO EN 21904-2:2020, Health and safety in welding and allied processes -- Equipment for capture and separation of welding fumes -- Part 2: Requirements for testing and marking of separation efficiency;
- ISO EN 21904-3:2018, Health and safety in welding and allied processes — Requirements, testing and marking of equipment for air filtration — Part 3: Determination of the capture efficiency of on-torch welding fumes extraction devices;
- ISO EN 21904-4:2020, Health and safety in welding and allied processes -- Equipment for capture and separation of welding fumes -- Part 4: Determination of the minimum air volume flow rate of capture devices;
- ISO 15607:2003, Specification and qualification of welding procedures for metallic materials — General rules;
- EN ISO 15609:, Specification and qualification of welding procedures for metallic materials - Welding procedure specification part 1 - part 6;
- ISO 17916:2016, Safety of thermal cutting machines;
- EN 149:2001+A1:2009, Respiratory protective devices. Filtering half masks to protect against particles. Requirements, testing, marking;
- EN 14594:2018, Respiratory protective devices. Continuous flow compressed air line breathing devices. Requirements, testing and marking;
- EN 12941:1998+A2:2008, Respiratory protective devices. Powered filtering devices incorporating a helmet or a hood. Requirements, testing, marking;
- EN 143:2000, Respiratory protective devices. Particle filters. Requirements, testing, marking; and

- ISO/TC44/SC9 - Health and safety in welding and allied processes: a series of standards referring to the exposure assessment of welding fumes, fumes data sheets, Emission rates determinations, etc. are available.

3.9.2 Available analytical methods

To measure personal exposure to gaseous substances, either continuous measurement methods are used or discontinuous measurement methods (VBMG, 2007) (Table 3-54 below). Continuous measurement requires using direct reading measurement instruments such as direct reading electrical apparatus or detector tubes. Whereas discontinuous (also known as indirect) measurement includes use of sorption tubes or passive samplers.

Direct reading electrical apparatus use infrared analysers to determine carbon monoxide concentrations or chemiluminescence to measure nitrogen oxides and ozone. By measuring the amount and time of potential exposures to hazardous substances in the workplace, it is possible to determine:

- variations in concentration in time; and
- time weighted average concentration.

This enables comparison with limit values and periodic measurements to be taken.

Detector tubes work by aspirating a set volume of air from the open detector tube, using a manual or battery-driven pump. An indicator compound changes colour depending upon the presence of a specific hazardous substance or group of substances. Detector tubes can be used for short term or long-term monitoring. Detector tubes are more useful for screening measurements or time weighted average concentration rather than for comparison with limit values or periodic measurements.

Discontinuous methods of measurement of gases include drawing air through a sorption tube such as activated carbon or silica gel, using a motor driven pump. The sorption tube must have an adequately high absorbing capacity. The air may be sampled at fixed points or directly on the person. Passive samplers can also be used. Analysis must then be undertaken in laboratories.

Table 3-54 Measurement of individual gases and organic vapours from welding (excerpt from EN ISO 10882 Health and safety in welding and allied processes, in VBMG, 2007).

Measurement method	**Gases and vapours**				
	ozone (O_3)	**carbon monoxide (CO)**	**carbon dioxide (CO_2)**	**nitrogen oxide (NO) & nitrogen dioxide (NO_2)**	**organic vapours**
	0.01 ppm to 3 ppm	**3 ppm to 500 ppm**	**500 ppm to 10%**	**0.3 ppm to 250 ppm**	**-**
Direct reading electrical apparatus	Generally used	Generally used	Generally used	Generally used	Available, but usefulness

Measurement method	Gases and vapours				
	ozone (O_3)	**carbon monoxide (CO)**	**carbon dioxide (CO_2)**	**nitrogen oxide (NO) & nitrogen dioxide (NO_2)**	**organic vapours**
	0.01 ppm to 3 ppm	**3 ppm to 500 ppm**	**500 ppm to 10%**	**0.3 ppm to 250 ppm**	**-**
					limited by poor specificity
Detector tubes	Available but no recommended	Generally used	Generally used	Generally used	Available, but usefulness limited by poor specificity
Indirect (or discontinuous) methods involving laboratory analysis	Not generally applicable	Not generally applicable	Not generally applicable	Available, but not generally used	Generally used

ISO 15011 standards defining laboratory methods for measuring possible hazardous fumes and gases for different welding techniques. ISO 15011 consists of the following parts, under the general title Health and safety in welding and allied processes — Laboratory method for sampling fumes and gases:

- Part 1: Determination of fumes emission rate during arc welding and collection of fumes for analysis;
- Part 2: Determination of the emission rates of carbon monoxide (CO), carbon dioxide (CO2), nitrogen;
- monoxide (NO) and nitrogen dioxide (NO2) during arc welding, cutting and gouging;
- Part 3: Determination of ozone emission rate during arc welding;
- Part 4: Fumes data sheets;
- Part 5: Identification of thermal-degradation products generated when welding or cutting through products;
- composed wholly or partly of organic materials; and
- Part 6: Procedure for quantitative determination of fumes and gases from resistance spot welding.

3.9.3 Summary of monitoring methods/tools

Monitoring of personal exposure to welding fumes can be undertaken through continuous measurement or discontinuous measurement. Continuous measurement requires using direct reading measurement instruments such as direct reading electrical apparatus or detector tubes which can give exposure measurements almost instantly. Whereas discontinuous (also known as indirect) measurement includes use of sorption tubes or passive samplers, which must then be sent to a laboratory for analysis.

3.10 Intermediate uses not covered by certain REACH procedures

Not relevant for welding fumes.

3.11 Market analysis

Not applicable to welding fumes, as the costs are entirely dependent on the number of welders that either need additional RMMs or need to use the RMMs they already have.

3.11.1 Sources of data on enterprises with exposed workers

Not applicable to welding fumes.

3.11.2 Study team analysis of Eurostat, survey and industry data

Estimated numbers of enterprises with workers exposed to welding fumes are provided in Table 3-55, distributed by sector and by small, medium and large enterprises; including the overall proportion of enterprises with exposed workers across sectors. These should be read and interpreted with caution as there is large uncertainty around the assumptions that these estimates are based upon. A discussion of the assumptions and the reliability of the questionnaire survey is provided below.

In the below Table 3-55 the study team's assumptions (from expert judgement, not published literature, and then validated through interviews with key stakeholders to gain their opinion of the study team's estimates) were that:

- For most sectors the assumption was that 20%, 50% and 80% of enterprises for small, medium and large (SML) enterprises respectively undertake welding;
- Except for: furniture manufacturing and "other manufacturing" where the proportions applied were 1%, 10% and 10% for specialist SML enterprises respectively, as the assumption was that fewer of these enterprises would undertake welding activities. For example, some furniture manufacturers would only be producing plastic or wooden furniture with no need for welding.

In the below Table 3-56, the number of enterprises with exposed workers (Table 3-55) was taken and the following assumptions applied to estimate the number of welders by sector and SML enterprise:

- For the industrial manufacturers and processors, it is assumed that there is large degree of automation in larger enterprises (and relatively less manual welding in larger enterprises) and therefore:
    - In small enterprises 25% are welders;

  - In medium enterprises 10% are welders; and
  - In large enterprises 5% are welders.

- For the more craft-driven manufacturing sectors, it is assumed that there is a higher degree of manual welding in smaller enterprises (for example for metal furniture manufacturing), and therefore:
  - In small enterprises 40% are welders;
  - In medium enterprises 10% are welders; and
  - In large enterprises 5% are welders.

- For the sectors that heavily rely on manual welding (such as construction), the same assumptions have been applied as for craft-driven manufacturing sectors.

The sectors with the estimated greatest total numbers of welders, broadly correspond to those identified in other datasets (CAREX and Finnish ASA): F43 Specialised construction activities, F43 Construction of buildings, C25 Fabricated metal products and G45 Repair of motor vehicles and motorcycles; followed by C33 Repair and installation of machinery and equipment, and C29 Motor vehicles manufacture. The total number of estimated exposed workers is 1.280 million welders, which is close to the 1.2 million full time welders figure which has been used in the cost benefit analysis in this study.

Six key stakeholders were interviewed during June – July 2023 (three European level stakeholders and three national stakeholders[32]) to discuss the assumptions and calculations in this study (section 6.1.2). There was general agreement amongst the key stakeholders that 1.2 million[33] full time welders in the EU27 was about right. The calculations in this study are based on full time welders, as the evidence base for exposure is stronger for full time welders.

Most stakeholders agreed in principle with the sectors identified as undertaking welding, and the distribution of welding across small, medium and large enterprises within those sectors. Most stakeholders also agreed with the estimated number of welders in each sector and across small, medium and large enterprises. However, some revisions were suggested:

- The assumptions on the enterprises that undertake welding should be as follows: 50% are small, 15% are medium-sized, and 5% are large. This distribution reflects the prevalence of small enterprises offering welding as a key service (a national stakeholder);

- C25 metal product manufacturing may be under representing small enterprises as most metal products involve some welding. There may also be less controlled conditions in small enterprises, and more exposed welders (an EU level stakeholder);

[32] From Germany, Greece and Italy.

[33] Although one EU level stakeholder estimated there are approximately 1.4 million to 2.4 million total welders in the EU27, comprising of full time (700,000-800,000 professional welders), part time and occasional welders.

- C30 could have more enterprises undertaking welding than noted, due to shipbuilding, rail carriages etc. As welding in that sector is manual, there should be more welders (an EU level stakeholder). (*The study team note that according to Europa, there were only 120,000 workers employed in 150 shipyards across Europe in 2012*[34]*, with an unknown number of welders amongst them, and this number may have decreased since then due to competition with Asian shipyards*. *According to Statista*[35]*, European shipyards tend to specialise in the cruise, yacht and military sectors. Since the Covid pandemic, European shipyards have experienced a fall in demand, although cruise ships are still popular. The main shipyards for cruise ships are in Italy, Germany, France, and Finland.*);

- F41, 40% of small enterprise workers being welders seems a bit high, as other trades would be involved in construction (e.g. carpentry, carpet laying etc) – F41 should be 20% for small enterprises (an EU level stakeholder); and

- G45 also seems a bit low for small enterprises, most will be able to do some welding (an EU level stakeholder).

Other comments were that:

- There is a need to factor in part time welders and bystanders to estimate the total number of exposed workers (a national stakeholder); and

- There is a need to take into account the fact that different welding processes have different emission rates (a national stakeholder).

Regarding the questionnaire survey, there was some concern expressed by welding trade associations (IIW, EWA, EWF) that the questions in the stakeholder consultation 2023 were too comprehensive and the consultation period (one month) was too short. There were no responses from the construction sector, and more than half of the responses (55%) were from Germany, which means the responses were not representative of all sectors undertaking welding across Europe.

There was concern that the questionnaire survey was difficult to complete, which represented a barrier. The IIW pointed out that the type of employee who would likely be completing the consultation would have been a welding engineer who would not have the information (exposure data) or time to answer all of the questions. Whereas an occupational health expert would not have the technical knowledge about welding processes to answer the questions. In other words, no single person would have both the technical knowledge and information on occupational exposure necessary to answer the questions.

The welding trade associations were also concerned that the responses may not be representative of the welding industries as a whole, as large companies are more likely to be able to complete the consultation than SMEs. Responses were actually received from large enterprises and small enterprises, but fewer from medium sized enterprises (see Annex I section D). Whereas, according to

[34] https://single-market-economy.ec.europa.eu/sectors/maritime-industries/shipbuilding-sector_en

[35] https://www.statista.com/topics/6558/cruise-shipbuilding-industry-worldwide/#editorsPicks

the EWA, a large proportion of the organisations undertaking welding+ activities are SMEs; thus, the responses received may indeed not be representative of the welding community. SMEs are unlikely to measure occupational exposure to welding fumes, but large companies are more likely to have the resources to do so. As the first step to managing an issue is measuring it, this means that there is likely to be a disparity in how welding fumes are managed, but also in the ability of smaller companies to be able to answer some of the questions in the survey. The EWA estimate that there are more than 80,000 companies in Europe that undertake welding+ activities (*pers comm,* March 2023).

Table 3-55 Estimates of numbers of enterprises with workers exposed to welding fumes applying the study team's assumptions to Eurostat (2020) data by sector.

Sector	Eurostat enterprises				Estimated % of companies that have exposed workers[36]			Estimated enterprises with exposed workers				% of enterprises with exposed workers
	Small	Medium	Large	Total	Small	Medium	Large	Small	Medium	Large	Total	
C24 Basic metals	5,705	504	330	6,539	20%	50%	80%	1,141	252	264	1,657	0.2%
C25 Fabricated metal products	347,206	9,104	1,210	357,520	20%	50%	80%	69,441	4,554	967	74,962	8.9%
C28 Machinery & equipment	7,772	1,268	543	9,583	20%	50%	80%	1,554	634	434	2,622	0.3%
C29 Motor vehicles,	14,982	1,810	1,170	17,962	20%	50%	80%	2,996	905	585	4,486	0.5%
C30 Manufacture of other transport equipment	12,966	800	321	14,087	20%	50%	80%	2,593	400	257	3,250	0.4%
C31 Furniture	121,123	2,085	393	123,601	1%	10%	10%	1,211	209	39	1,459	0.2%
C32 Other manufacturing	153,553	1,587	385	155,525	1%	10%	10%	1,536	159	39	1,734	0.2%
C33 Repair & installation of machinery & equipment	207,202	2,393	405	210,000	20%	50%	80%	41,440	1,197	324	42,961	5.1%
E38 Materials recovery	16,422	428	50	16,900	20%	50%	80%	3,284	214	40	3,538	0.4%

[36] Based on assumptions explained on page 171.

Sector	Eurostat enterprises				Estimated % of companies that have exposed workers[36]			Estimated enterprises with exposed workers				% of enterprises with exposed workers
	Small	Medium	Large	Total	Small	Medium	Large	Small	Medium	Large	Total	
F41 Construction of buildings	856,930	5,409	502	862,841	20%	50%	80%	171,386	2,705	402	174,493	20.7%
F42 Civil engineering	38,851	1,700	382	40,933	20%	50%	80%	7,770	850	306	8,926	1.1%
F43 Specialised construction activities	2,079,372	7,027	597	2,086,996	20%	50%	80%	415,875	3,514	478	419,867	49.9%
G45 Repair of motor vehicles & motorcycles	504,278	837	66	505,181	20%	50%	80%	100,856	419	52	101,327	12.0%
Total	**4,366,362**	**34,952**	**6,354**	**4,407,668**	**-**	**-**	**-**	**821,083**	**16,012**	**4,187**	**841,282**	**100%**

Source: Study team estimates applied to EUROSTAT data for 2020.

Table 3-56 Number of welders by sector and by SML enterprise, applying the study team's assumptions to Eurostat (2020) data.

Sector	Eurostat employees				Estimated % of employees undertaking welding+ activities			Estimated exposed welders				Estimated distribution across sectors
	Small	Medium	Large	Total	Small	Medium	Large	Small	Medium	Large	Total	
C24 Basic metals	6,796	28,248	359,499	394,543	25%	10%	5%	1,699.00	2,826	17,975	22,500	1.8%
C25 Fabricated metal products	310,557	440,532	608,374	1,359,463	25%	10%	5%	77,640.0 0	44,055	30,418	152,113	11.9%
C28 Machinery & equipment	13,986	72,276	491,722	577,984	25%	10%	5%	3,497.00	7,228	24,586	35,311	2.8%
C29 Motor vehicles,	20,972	103,170	1,088,100	1,212,242	25%	10%	5%	5,243.00	10,317	54,405	69,965	5.5%
C30 Manufacture of other transport equipment	12,965	42,800	452,577	508,342	25%	10%	5%	3,241.00	4,280	22,629	30,150	2.4%
C31 Furniture	4,844	21,318	26,598	52,760	40%	10%	5%	1,938.00	2,132	1,330	5,400	0.4%
C32 Other manufacturing	4,255	16,104	30,767	51,126	40%	10%	5%	1,702.00	1,611	1,539	4,852	0.4%
C33 Repair & installation of machinery & equipment	124,320	117,306	250,452	492,078	40%	10%	5%	49,728	11,731	12,523	73,982	5.8%
E38 Materials recovery	16,420	22,470	50,320	89,210	40%	10%	5%	6,568	2,247	2,516	11,331	0.9%
F41 Construction of buildings	514,158	243,450	301,902	1,059,510	40%	10%	5%	205,663	24,345	15,095	245,103	19.2%
F42 Civil engineering	38,850	86,700	374,544	500,094	40%	10%	5%	15,540	8,670	18,727	42,937	3.4%
F43 Specialised construction activities	1,026,404	310,833	428,901	1,766,138	40%	10%	5%	410,562	31,084	21,445	463,091	36.2%
G45 Repair of motor vehicles & motorcycles	295,094	37,032	28,330	360,456	40%	10%	5%	118,037	3,703	1,417	123,157	9.6%
Total	**2,389,621**	**1,542,239**	**4,492,086**	**8,423,946**	**-**	**-**	**-**	**901,058**	**154,229**	**224,605**	**1,279,892**	**100%**

Source: Study team estimates applied to EUROSTAT data for 2020.

3.11.3 Cross border aspects

Not applicable to welding fumes.

3.11.4 Market trends

Please see the table of estimated current compound annual growth rates based upon Eurostat data from 2011-2020 (Table 3-40).

Regarding sectors that undertake welding, manufacturing of automotive vehicles is forecast to grow from 2021-2028 (Fortune Business Insights, 2021), and governments are predicted to increase expenditure on aerospace and defence over the same period which will probably increase the demand for equipment. Heavy engineering is forecast to grow exponentially from 2021-2028 due to the introduction of smart factories, industry 4.0 (also known as the digital industrial revolution), rising automation and other factors. The demand for precision welding, mainly to join two different metals without losing their properties is further adding to growth in the welding market. There is a high demand for residential and commercial projects, so the building and construction sector is forecast to have strong growth from 2021-2028. The construction sector is being bolstered by government initiatives for infrastructure development, and the availability of bank loans at low rates (at the time of writing, 2021). The oil and gas and railway sectors are predicted to have moderate growth from 2021-2028, due to the construction of infrastructure in developing economies, and the adoption of various precision techniques to perform critical operations such as railway tracks and underwater pipelines etc.

The latest trends specific to welding are towards joining dissimilar and non-metallic materials, customised metal shapes and designs, and the emergence of advanced technologies such as robotic welding and additive manufacturing including 3D printing using metal powder (Fortune Business Insights, 2021). Robotic welding is increasingly being adopted (Table 3-57), especially in the automotive industry, to increase productivity and provide high precision welds. Apart from a dip in demand for installation of industrial robots during 2019 and 2020, in other years since 2016 there has been an increase in the number of installations. As the demand has varied considerably from -12% to +20%, and the data is only for a short time series it is hard to use this data to predict the average growth rate from this data, but in general there is a trend for increasing use of automation and robotics.

Further to the above, various technologies are being embedded in robotic solutions, including the internet of things[37], artificial intelligence, cloud data and smart sensors, and miniaturisation of equipment which is enabling the reduction of accidents in the workplace.

Table 3-57 Installations of industrial robots for welding and soldering.

Year	Europe		Germany		Italy		France	
	Units	Change from previous year (%)	Units	Change from previous year (%)	Units	Change from previous year (%)	Units	Change from previous year (%)
2016	**8,727**	--	2,298	--	550	--	713	--

[37] The Internet of Things is defined as the connection via the internet between computing devices embedded in everyday objects, enabling them to send and receive data.

Year	Europe		Germany		Italy		France	
	Units	Change from previous year (%)	Units	Change from previous year (%)	Units	Change from previous year (%)	Units	Change from previous year (%)
2017	**10,446**	**20%**	265	-88%	379	-31%	650	-9%
2018	**11,291**	**8%**	4,408	1,563%	763	101%	924	42%
2019	**10,571**	**- 6%**	2,966	-33%	1,135	49%	1,470	59%
2020	**9,348**	**- 12%**	3,957	33%	817	-28%	770	-48%
2021	**9,874**	**6%**	2,829	-29%	1,318	61%	572	-26%

Source: International Federation of Robotics (n.d.): Statistiques robots de soudage, data supplied via the EWA, pers comm, June 2023.

The market for additive manufacturing systems, relevant services and raw materials has been growing significantly since 2008 (Kersting *et al.*, 2017). In 2013, the worldwide turnover for the sale of powdered raw materials for additive manufacturing was an estimated €400 million. The global turnover for products created by additive manufacturing was approximately 10 billion Euros in 2016, with products manufactured in Germany making up 10% of this figure. However, this includes both plastic and metal powder applications added together, so it is not possible to say what proportion 3D printing using metal powder has been growing by. The sectors using additive manufacturing are the same sectors that use joining, cutting and coating (JCC) or welding+ activities, and it is suggested that additive manufacturing is partly in competition with traditional JCC processes.

Some companies offer services across the entire additive manufacturing value chain and have metal 3D-printing technologies in-house. Through additive manufacturing, previously impossible metal structures can be produced. Additive manufacturing can also be useful for printing prototypes before scaling up production. Additive manufacturing is a more expensive process than traditional welding, and is undertaken in fully enclosed, controlled conditions inside a factory or workshop to produce metal products or structures. It cannot be used to replace welding outside on a construction site, or underwater on deep sea infrastructure projects for example. It is currently used for high end and bespoke metal products for the aerospace and medical sectors, but is also by the automotive, energy and infrastructure sectors for some applications. In summary, the market for additive manufacturing is growing, and may displace some of the demand for other more conventional welding+ processes. However, it is not suitable for all applications of welding and is also more expensive, so it is likely to have a limited overall impact on the growing demand for welding.

In conclusion, demand for welding is growing across various sectors (automotive, aerospace and defence, heavy industry, civil engineering and construction). This demand will be met partly by manual welding and partly by automation (robotic welding, mechanised welding, additive manufacturing). The skills shortage of welders in the EU is likely to drive further automation of welding.

3.12 Alternatives

Substitution is a key risk management measure for reducing or eliminating exposure to welding fumes by using processes with lower emissions. Therefore, it is important to know whether alternatives exist for welding fumes. The possible alternatives are summarised below:

- Partial substitution of welding+ processes: for example, TIG has lower emissions than MMA, MAG; solid wire has lower emissions than MAG flux cored wire, automated welding with integrated extraction instead of conventional welding. Which processes are technically feasible will depend upon the working environment, materials to be welded, equipment available and expertise of the welders;
- Substitution of welding or associated processes with other joining processes such as gluing, folding or mechanical joining (screws, rivets). These options will not always be feasible, as they may not achieve the desired strength of join or water tightness for example;
- Partial substitution of content base material and addition material such as low manganese materials, replacement with high alloy steel with low alloy steel. This will not always be possible as the materials used will have been chosen for their desired properties;
- Substitution of content base material and addition material such as low manganese materials. This will not always be possible as the materials used will have been chosen for their desired properties;
- Discontinuation of activity using welding or associated processes. However, it is unlikely that industry would be willing to discontinue welding+ processes completely, as it is often the only feasible option for joining metals; and
- Partial substitution of conventional welding+ processes with optimised welding processes using innovative approaches that generate less welding fumes: for example, for MIG/MAG an innovative waveform controlled process can be used which generates less welding fumes and particles (EWA, 2021). The REarc welding initiative is demonstrating that industry can find smarter ways to reduce emissions of welding fumes though technological changes to the materials and processes used (DVS, 2023). From the REarc initiative, Linde identify three levers which have been proven in the lab environment but need to be tested by implementation in the industrial environment (Table 3-58). Linde recommend that industry needs to invest in these three levers to improve understanding of the links between cause and effect.

Table 3-58 Three levers for substitution of conventional processes with process optimisation identified by Linde (2023).

Equipment	Filler	Process gas
Metal transfer mode	Chemical composition	Chemical composition
Temperature distribution	Diameter	Flow
U/I dynamics	Solid/cored	

Source: Linde, 2023

3.12.1 Summary of availability of alternatives by welding process

For welding, it is not relevant to list alternatives by sector as is standard practice, alternatives must be considered on a case by case basis which is not practical to summarise here.

3.13 Impact of Covid 19 on current situation

The Covid-19 pandemic had a huge economic and labour market impact, and also large negative impacts on the supply chain and value chain operation in the manufacturing industry (Fortune Business Insights, 2021). The latter was due to volatility in demand and supply and strict restrictions on logistics operations which curbed operations in the market. The welding market is predicted to continue to have a strong recovery post pandemic due to the reopening of manufacturing facilities and government initiatives to reshape the economic downfall during the pandemic. EUROSTAT figures show that some sectors that undertake welding had stronger growth rates in January 2022 than in January 2020 (computer, electronic and optical products; machinery and equipment; fabricated metal products); whilst others show negative growth rates (repair and installation of equipment; motor vehicles, trailers and semi-trailers; other transport equipment) (EC, 2022). The sectors experiencing growth probably approximately balanced the sectors experiencing a downturn in demand for welding in January 2022 compared with January 2020.

From February 2022 onwards the Russian invasion of Ukraine is another significant event that has affected global markets and supply chains, in terms of raw material availability and cost, and the cost of energy, and it is hard to distinguish the effects on the manufacturing industry of the pandemic versus the Russia-Ukraine war.

3.14 Current disease burden (CDB)

The current burden of disease for lung cancer is estimated using the data in the preceding sections for exposed workers, combined with data on excess risk (ER). The data are combined with data on past trends in exposure concentrations and exposed workforce, latency and workforce turnover.

3.14.1 Past trend in exposure concentrations and exposed workforce

In general, there is a trend for occupational exposure to welding fumes to decrease over time, as improvements in worker protection are adopted as noted in section 3.3.8. As previously explained (in section 3.3.8) the assumption is that occupational exposure to welding fumes has decreased by 1% per year since the year 2000.

3.14.2 Latency and workforce turnover

The value for lung cancer latency is taken as 30 years and the value for staff turnover is taken as 5% per year: these areas explained in the Methodological Note.

3.14.3 Current disease burden

Using the estimated extra cancer risk of 0.034 (section 2.2.2.2), the current burden of disease (i.e. the number of cases diagnosed in 2023) is estimated on the basis of historical exposure. For example, if cancer endpoint has a latency of 30 years and MinEx of 2 years, the model assumes that the cases diagnosed in 2023 reflect the risk that occurred 32 years ago in 1991, and thus reflects the number of workers exposed in 1991 and the exposure concentrations in 1991. The number of exposed workers (full time workers in welding+ processes) is assumed to be 1.2 million. The study team note that other workers working in the vicinity of welding+ activities are exposed to welding fumes, but it was not possible to estimate how many there would be as this would vary depending upon different working environments. Therefore, the current disease burden is likely to be an underestimate as it does not include other exposed workers besides welders.

Table 3-59 Current burden of disease due to past exposure (based upon data from 1983 to present day)

Endpoint	New cases per year (incidence) in 2023
Lung cancer	806

Source: Study team on basis of information presented in this section.

In addition, as for other endpoints with latency greater than zero, there will continue to be lung cancer cases due to exposure in the last 40 years which occur in the next 40 years. These are provided below as the legacy burden of disease, together with the current burden of disease. In this example, due to latency and MinEx, the legacy number of cases reflects the number of workers exposed in 1991-2023 and the exposure concentrations in 1991-2023: these cases will occur between 2024 and 2053.

Table 3-60 Legacy burden of disease that will occur in the next 40 years due to exposure in the last 40 years

Endpoint	Number of cases over 40 years
Lung cancer	27,804

Source: Study team

3.14.4 Comparison with data on recognised cases and epidemiological data

To establish the context of the incidence of lung cancer from welding+ occupations, the number of new cases of lung cancer (from all causes) in the EU27 in 2020 is estimated at 318,327 (113,074 in women, 205,253 in men) (EC, 2021b). The number of deaths from lung cancer (from all causes) in the EU27 in 2020 is estimated at 257,293 deaths (86,731 in women, 170,562 in men) (EC, 2021b).

The background, lifetime risk to contract lung cancer for the male EU population was 7% (RAC in ECHA, 2018b).

The study team contacted the DGUV to see if there is German health insurance data on the incidence of cancer in welders. Unfortunately, the DGUV said that they do not have access to this data, and suspect that health insurers do not have this data and if they did it would not help inform the excess cancer risk in welders (DGUV 2023b). The DGUV were able to provide data on recognised occupational diseases that are associated with welding work and lung cancer. However, the data was aggregated for lung cancer first diagnosed between 2002 and 2021, rather than annual diagnoses of lung cancer. In Germany, diseases can only be categorised as 'recognised occupational diseases' if scientific evidence shows that they are caused by occupational factors with exposure levels significantly higher than average exposure levels in the rest of the population. The classification of occupational diseases is based on exposure to specific substances and therefore includes multiple diseases and occupations. Only three diseases are currently categorised as recognised occupational diseases (BK) in German which can be associated with welding work (ISCO-08 Occupation 7212 welder, flame cutter) and lung cancer:

- BK 1103 Diseases caused by chromium or its compounds;
- BK 1104 Diseases caused by cadmium or its compounds; and
- BK 4109 Malignant neoplasms of the respiratory tract and the lungs caused by nickel or its compounds.

Of these, there were 94 diagnoses for BK 1103 and 25 diagnoses for BK 4109 from 2002 to 2021 respectively. For various reasons, this is an underrepresentation of occupational incidence of cancer from welding+ activities. The link between cause and effect may not have always been established due to other factors such as smoking. Also, the ISCO occupational code for 'sheet metal workers-boiler makers' should also be considered, in addition to welders and flamecutters, to represent workers in welding+ activities (as per the estimation of workers in welding+ activities used by ANSES, 2017).

A report by the Netherlands Labour Inspectorate (Inspectie SZW, 2016) includes an estimate of 49-280 deaths annually in the Netherlands due to lung cancer attributed to exposure to welding fumes amongst people with 'welder' as their profession. The Netherlands is one of the top 10 EU Member States for welding activities, either according to number employed in joining technologies or by market data on welding consumables (section 3.4.2.1). But even so, this could mean that the estimated current burden of disease due to lung cancer from occupational exposure to welding fumes could be an underestimate.

3.15 Summary of the current situation

3.15.1 Risk to workers' health

The estimates for exposed workforce and current disease burden are summarised below. Due to uncertainty around the estimates of total welders in the EU27, and for the sake of simplicity, the exposed workforce was taken to be 1.2 million.

Table 3-61 Summary of estimates taken forward for the assessment of options

Carcinogen	Exposed workforce (number of workers)	Health effects caused	Major occupational exposure route
Welding fumes	1,200,000	Lung cancer	Inhalation

Source: Study team.

Table 3-62 Current disease burden related to occupational exposure to welding fumes (number of cases)

Carcinogen	Health effects caused	Current disease burden (number of cases/year) in 2023
Welding fumes	Lung cancer	806

Source: Study team.

3.15.2 Relationship with other EU policies

The ongoing conflict between Russia and Ukraine which intensified since February 2022 has resulted in instability in the global energy market. In response, the European Commission has developed the 'REPowerEU' plan, launched in May 2022, to reduce reliance on Russian gas (EC, 2023a). The REPowerEU plan aims to help the EU: save energy, produce clean energy and diversify its energy supplies. This has led to a massive investment in renewable energy as well as establishing other sources for energy supply across Europe. These objectives require investment in infrastructure projects have resulted in a large increase in demand for welding across Europe. Implementation of the REPowerEU plan is speeding up the green transition to clean energy which was already planned. These energy projects are ongoing to meet renewable energy targets in 2030 and ultimately carbon neutrality in the EU by 2050 (EC, 2023b), reflecting a sustained increase in demand for welding until 2050 to build the necessary infrastructure to meet these targets.

For welding in particular, the European strategy for a circular economy will increasingly result in more steel being reused or recycled, for example through the eco-design of products for improved recyclability and through the End of Life Vehicles Directive[38] ;also ferrous slags and mill scales will become secondary raw materials under the Waste Framework Directive[39]. This will decouple the welding market by a small extent from steel consumption, but the reuse of steel will require welding. It can be assumed that the loss in demand for welding virgin materials will be replaced by welding reused materials.

Recent communications from the European Commission have made reference to 'green steel' or 'low carbon steel' or 'clean steel', in order to improve the sustainability and lower the carbon footprint of steel, however there is not yet a clear definition of these terms. The European steel association (EUROFER) currently has a project looking at the definition of 'green steel', which can be recognised by end customers, consumers, and product regulations. Once defined and regulated, the European market for 'green steel' would be expected to grow with resulting impacts on welding fumes from increased use of low carbon steel. Low carbon steel is also known as mild steel, which is a no alloy or low alloy steel; containing no or only small amounts of other metals (such as chromium VI and nickel). The welding fumes generated from welding mild steel will therefore contain fewer CMR metals than high alloy or stainless steel. However, ECHA (2022) on evaluating the IARC study, note that welding fumes from mild steel do carry an occupational exposure risk for lung cancer.

3.15.3 National OELs

13 Member States have OELs for welding fumes or dust (Table 11-16). Table 3-63 provides a summary of the lowest and highest national OELs and a list of Member States without an OEL for welding fumes or dust.

Substance specific OELs are also in place in different Member States. These include aluminium, cobalt, copper, iron, magnesium and vanadium (Table 11-17) EU wide OELs exist for barium, chromium metal and Cr(II)/(III), hexavalent chromium, manganese and nickel compounds (Table 11-17).

Table 3-63 Summary of national OELs for welding fumes (or dust) in EU Member States

Carcinogen	Lowest (strictest) national binding OEL (mg/m^3)	Highest (least strict) national binding OEL (mg/m^3)	Member States with no OEL
Welding fumes	1 Inhalable (Netherlands)	7 Inhalable (France)	Bulgaria, Croatia, Estonia, Finland, Greece, Hungary, Italy, Luxembourg, Malta, Poland, Portugal, Romania, Slovenia, Sweden.

Source: Study team on the basis of section 3.1.

Notes: In July 2023, France will move to an OEL of 4mg/m^3 (inhalable). From this point, the new highest OEL will be 5mg/m^3 which will be in place in Belgium, Czechia, Ireland, Lithuania, Slovakia and Spain.

38 https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A32000L0053

39 https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32008L0098

3.15.4 Potential for lowering exposure to welding fumes

Dutch and German experts on the 5xBeter modelling team have looked at welding exposure levels across Germany and the Netherlands; a total of ~700 exposure measurements from the past 15 years. This data was supplemented with the modelling team's own measurements for stainless steel and duplex welding (MIG/TIG), solid wire welding (MIG/MAG) and submerged arc welding (SAW) (approximately 300 measurements) to refine the tool further. Regression analysis was combined with expert judgement to calculate process factors and estimated reduction in exposure levels from different Risk Management Measures, see Table 3-64. The aim of 5xbeter is to provide an online decision tool ("de Verbetercheck Lasrook" or "Welding Fumes reduction check") to help companies identify whether particular Risk Management Measures (RMMs) will achieve the Dutch OELs for welding fumes, and if not identify which further RMMs should be taken to achieve the necessary reduction in exposure levels. The decision tool is limited to four welding processes: TIG, MIG/MAG (solid wire), MIG/MAG (cored wire plus electrode) and SAW. The project commenced in 2005, organised by social partners (employers (Royal Metaalunie, FME) and labour unions (FNV Metaalunie, CNV Vakmensen, de Unie). The TNO (an independent research organisation which covers innovation and health and safety) developed the methodology with Weldox and the resulting verbetercheck Lasrook tool was tested and approved by the Dutch Labour Inspectorate in 2021.

In Table 3-64, the 'process factor' is multiplied by the 'factor' to produce the 'basic emission factor'[40]. The basic emission factor for each welding process is then multiplied by each of the 'exposure factors' associated with each risk management measure to see how much they reduce worker exposure, or in the case of confined working, increase worker exposure. To summarise the results of regression analysis:

- source extraction (LEV) reduces worker exposure by 25%;
- wearing a simple face mask (FFP2/FFP3) reduces worker exposure by 50%;
- a welding helmet with fresh air (TH2/TH3) reduces worker exposure by 76%;
- an improved welding helmet with fresh air and a wide folding window reduces worker exposure by 88%;
- confined spaces increase worker exposure by 142%;
- removing the welder's head from the welding plume reduces worker exposure by 32%; and
- removing surface coatings from metals being welded reduces worker exposure by 17%.

The effectiveness of room (or general) ventilation is more complicated, as it was found that it does not make much difference to an individual worker's exposure to welding fumes, but it does make a difference to other workers in the room, and as expected room ventilation helps to remove air pollution which builds up over time. Room ventilation is still considered a requirement in the Netherlands; without it air pollution builds up to unsafe levels over time. In the Netherlands, the national

[40] The basic emission factors listed are broadly in line with the emission rates listed in AGS, 2021 (Table 3 26).

OEL for welding fumes is low at 1 mg/m^3. The RMMs necessary to meet this level depend on the welding process. For stainless steel and duplex welding, it is necessary to apply the maximum possible RMMs. 5xbeter modelling found that for stainless steel and duplex welding, if the measured welding fumes value is less than 1 mg/m^3 then the concentration of chromium VI remains below 1 µg/m^3. This finding has been integrated into the de verbetercheck tool.

The effectiveness of fumes extraction in reducing exposure to welding fumes can be inferred from the German MEGA exposure data summarised in Table 3-14, in which the 90th percentile concentration of dust is 0.4 – 6.9 mg/m^3 less across most welding processes with fumes extraction, apart from MIG in which the exposure concentration was interestingly the same with or without extraction. However, strong conclusions should not be drawn from the MEGA database dataset as these measurements were taken in real workplace conditions rather than test conditions and all other variables may not have been controlled for.

Table 3-64 Process factors for four selected welding processes and associated exposure factors from different Risk Reduction Measures.

Welding process	TIG		MIG/MAG (solid wire)		MIG/MAG (flux cored wire plus electrode)		SAW
Process factor	1.14		3.88		5.76		1
Tacking/ welding	Tacking	Welding	Tacking	Welding	Tacking	Welding	
Factor	0.82	1	0.82	1	0.82	1,00	
Basic emission factor (without RMMs)	0.93	1.14	3.18	3.88	4.72	5.76	1.00
Exposure factor from source extraction (LEV)	0.75	0.75	0.75	0.75	0.75	0.75	0.75
Why source extraction is not possible	+	+	+	+	+	+	+
Exposure factor from a simple face mask (FFP2/FFP3)	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Exposure factor from a welding helmet with fresh air (TH2/TH3)	0.24	0.24	0.24	0.24	0.24	0.24	0.24
Exposure factor from a welding helmet with fresh air and a wide folding window	0.12	0.12	0.12	0.12	0.12	0.12	0.12
Exposure factor from room ventilation according to standards	+	+	+	+	+ ******	+	+
Exposure factor for confined space	1.42	1.42	1.42	1.42	1.42	1.42	1.42
Exposure factor from head not in welding fumes plume	0.68	0.68	0.68	0.68	0.68	0.68	0.68
Exposure factor from removal of surface coatings	0.83	0.83	0.83	0.83	0.83	0.83	0.83

Source: 5xbeter Ijzersterk voor veilig werk (Rock solid for safe work) presentation, 23 November 2021.

*Notes: + obligatory for stainless steel and duplex welding; ****** if this measure is not possible the company must declare the reasons why it is not possible.*

4 BASELINE SCENARIO

The baseline scenario describes how the problem is expected to evolve if no action is taken at EU level.

This chapter comprises the following sections:

- Section 4.1: Impact of the implementation of other OELs;
- Section 4.2: Effects of forthcoming changes in national OELs or protective regulation, self-regulatory initiatives;
- Section 4.3: Effects of REACH;
- Section 4.4: Effects of EU Strategic Foresight megatrends;
- Section 4.5: Future trend in use of welding;
- Section 4.6: Future trend in exposure concentrations due to technical improvements;
- Section 4.7: Future trend in exposed workforce;
- Section 4.8: Other factors of importance for the baseline;
- Section 4.9: Future disease burden (FDB); and
- Section 4.10: Summary of the baseline scenario.

4.1 Impact of the implementation of other OELs

Some relevant CMR (category 1A and 1B) substances are already covered by entries in Annex III of the CMRD, which lists the majority of the metals and metal compounds (with a limit value) that are both carcinogenic and present in welding fumes. The transition to introducing tighter OELs for hexavalent chromium (Cr(VI)) and nickel compounds ends in January 2025 (as discussed in section 3.3.8), and new OELs for cobalt and PAH (respectively) are being evaluated. The potential impact of implementation of other OELs is discussed below. However, due to the paucity of data for welding fumes exposure in general, it was not possible to take account of the potential impact of implementation of other OELs in the calculation of the baseline.

Cr(VI) and nickel compounds are of particular concern as carcinogens in welding fumes from welding stainless steel. Sectors which use stainless steel include the food industry, medical industry and energy sector (petrochemical and power/heating plants), so the installation and repair of stainless steel equipment in these sectors (C33) will be impacted by the new OELs for Cr(VI) and nickel compounds (*pers comm*, Force Technology, March 2023). Stainless steel is much less used than mild steel in the EU; an estimated 93% of metal welded in the EU is mild steel according to the EWA (EWA, *pers comm*, February 2023).

Even welding mild steel may also be impacted by these new OELs, despite having lower amounts of these metals as constituents, since ECHA (2022) point out that there can still be high concentrations when high emission welding processes are used. According to ECHA (2022), the workplace concentrations of Cr(VI) may be one order of magnitude higher in fumes from MMA/SMA and in FCW/FCAW compared to MIG/MAG/GMAW. Thirty to ninety percent of the emitted chromium may be hexavalent in the welding fumes from the former techniques, compared to only 1-5% hexavalent chromium in welding fumes from MIG/MAG/GMAW. ECHA also note that these differences can also be observed in terms of the absolute emission rates of Cr(VI). The working environment also strongly influences exposure levels. In the case of welding work in confined spaces, in areas with a low air exchange and/or welding jobs in a constrained posture, where the welding fumes pass directly into the welder's respiration zone, higher exposures must be expected (Weiss et al. 2013; BAuA, 2009 in EC, 2018b).

However, the RMMs for achieving Cr(VI) exposure reduction also help to reduce exposure to nickel compounds, so a co-benefit of using RMMs to achieve the OEL for Cr(VI) will also help to achieve the nickel compounds OEL (section 3.3.8). Arc welding processes for which Cr(VI) and nickel compounds are typically present are used across almost all sectors undertaking welding and may need additional RMMs if they have not already been installed during the current transition period (Table 3-20). However, responses to the questionnaire survey, albeit an unrepresentative sample, suggest that many companies have yet to install RMMs to achieve the OELs coming into force in 2025. Only around 15% of respondents stated that they had invested in RMMs to achieve the new OELs.

The potential introduction of a new OEL for cobalt is currently being evaluated. Steel containing cobalt is used in more specialised applications; but the EWA estimate that only ~0.1% of welding activities are welding cobalt alloys (*pers comm*, April 2023). Therefore a new OEL for cobalt would have a more limited impact than that for Cr(VI) and nickel compounds OELs, but nonetheless it could help to reduce exposure to other CMR substances in welding fumes if additional RMMs are implemented for compliance. In general, control measures to limit exposure to new OELs has the co-benefit of minimising exposure to other substances.

If the new OEL for cobalt is low, then the situation may arise where cobalt is picked up in occupational monitoring when it was not expected to be present. This is because the threshold for notification of substances that are CMR (category 1A or 1B under the CLP) and present in a mixture for inclusion in safety data sheets (SDS) is greater than or equal to 0.1% concentration (ECHA, 2020). If a substance is present below this threshold there is no obligation for the producer to list it on the SDS, and the user (welder) will not know it is present. However, according to the German classification system for health hazards, hazard classes only apply if the alloys or cover/filler components for welding contain more than 5% carcinogenic substance (VBMG, 2007).

If a new OEL is introduced for PAH, it is likely to have only a minimal impact on welding fumes as the only key source of PAH from welding is likely to be from welding railway tracks due to fumes arising from the wooden railway sleepers impregnated with creosote. A small amount of PAH could be present in welding metals contaminated with oil, but best practice is to remove surface oil before welding, so this could be addressed through education and training.

A summary of the likely impact of implementation of other EU OELs is provided below (Table 4-1). In conclusion, the OEL for Cr(VI) is likely to have the biggest impact on exposure to welding fumes, as the RMMs necessary for worker protection will have the co-benefit of reducing welding fumes exposure in general. Unfortunately it is not possible to quantify the resulting reduction in exposure to welding fumes exposure as exposure to Cr(VI) is not directly related to welding fumes exposure. The quantities of Cr(VI) present in welding fumes vary depending upon the materials and welding process being used; the baseline of worker exposure levels has not been well quantified but is likely to vary across the EU27 and within each Member State. However, awareness of the risk of exposure to Cr(VI) from welding stainless steel is already good in various places across Europe, with professional welders already using RMMs when welding stainless steel (a European stakeholder and national stakeholder, *pers comm,* June 2023).

Table 4-1 Summary of the potential impact of the implementation of other OELs

Substance	Reduction factor *	Timeline	Sectors impacted	Impact on baseline for welding fumes
Cr(VI)	80% reduction in Cr(VI) as moving from OEL of 0.025 to 0.005 mg/m^3 inhalable	January 2025	C24 plant, container and pipeline construction; C25 (architectural) metal products manufacturing construction; C29 automotive engineering – body shell construction; C30 shipbuilding; C33 installation & repair of machinery; F41, F42, F43 steel construction (e.g. road or railway bridges) (see 3.3.8)	Large impact: additional RMMs to achieve the new Cr(VI) OEL exposure will concurrently reduce exposure to welding fumes in general, **for the following welding processes** which generate Cr(VI) air emissions: MMA; MIG/MAG/TIG; Gas-shielded tubular cored arc welding (FCAW); or Self-shielded tubular cores arc welding (FCAW). **When welding some of the following metals**: Unalloyed and low alloyed steel; High alloy steel; Cast iron; Hardfacing; Nickel-based; and Copper-based (see section 3.3.8 to map metals welded to welding processes and resulting composition of emissions).
Nickel compounds	50% reduction of nickel compounds: EU OEL of 0.1 mg/m^3 until January 2025; transitioning to 0.05 mg/m^3	January 2025	Same sectors as for Cr (VI)	Assumed to be same as impact on Cr (VI) exposure as studies have shown a reduction in Cr (VI) exposure coincides with a reduction in nickel compounds exposure.

Sub-stance	Reduction factor *	Timeline	Sectors impacted	Impact on baseline for welding fumes
	from January 2025			
Co	Reduction in cobalt depends upon chosen OEL	depending upon results of impact assessment and length of legislative process	C23.4, C25.5, C25.61, C25.62, C25.73, C25.99, C26.1, C28.11 are the most impacted sectors	Minimal impact as cobalt alloyed steel is estimated to be only 0.1% of the metal welded in the EU (EWA, *pers comm*, April 2023)
PAH	Reduction in PAH depends upon chosen OEL	depending upon results of impact assessment and length of legislative process	C19.1, C19.2, C20.13, C20.14, C24.45, F42.12 are the most impacted sectors	Minimal; a new OEL could help to reduce welding fumes exposure from welding railway tracks; in other situations PAH can be removed from welding fumes by ensuring surface contamination (oil) is removed before welding.

** Express the average exposure reduction expected by implementation of the OEL*

Source: Study team.

4.2 Effects of forthcoming changes in national OELs or protective regulation, self-regulatory initiatives

Stricter OELs for welding fumes came into force in France in July 2023, with a change from 7 to 4 mg/m^3 (inhalable fraction) and 3.5 to 0.9 mg/m^3 (respirable fraction) (Table 11-16). This will result in employers implementing more RMMs to achieve these tighter OELs. No other changes in national OELs have been identified by the study team.

Current voluntary industry initiatives providing guidance and training to welders including the BGHM 'welding fumes reduction program' in Germany (Linde, 2023) and the EWA technical committee are helping to improve awareness of which RMMs should be used in welding+ processes (see section 3.7). The REarc initiative by the DVS in Germany is also developing innovative approaches and new technologies to reduce occupational exposure to arc welding fumes (DVS, 2023). All of these initiatives by leading authorities in the welding community will help to reduce occupational exposure to welding fumes. Indeed, best practice may spread from the German initiatives to other countries. However, it is hard to quantify the positive impact of all of these initiatives, and to understand the timeframe of any impacts.

Members of the German Welding Association (DVS) (personal communication, April and July 2023) pointed out that in Germany thresholds are currently applied to the percentage CMR content of welding materials being used to indicate to companies whether they need to monitor CMRs present for occupational exposure. According to the German classification system for health hazards, hazard classes only apply if the alloys or cover/filler components for welding contain more than 5% carcinogenic substance (VBMG, 2007). The DVS members identified a need to introduce a definition of the 'relevant amount' of CMR substance present in welding materials before measures should be taken under the CMRD. Without this, if the legislation simply says 'containing CMR substances' they believe that the employer may in effect have a duty to prove the absence of CMR substances which would be impractical.

Indeed, as has been explained for welding filler materials (see section 1.3.6), safety data sheets (SDS) will contain harmonised classifications of substances so can be used to check for the classification 1A or 1B for carcinogenicity, mutagenicity or reproductive effects. However, the threshold for notification of substances that are CMR (category 1A or 1B under the CLP) and present in a mixture for inclusion in SDS is greater than or equal to 0.1% concentration (ECHA, 2020). If a substance is present below this threshold there is no obligation for the producer to list it on the SDS, and the user (welder) will not know it is present, but the situation may arise where such a substance may be picked up in occupational monitoring for a CMR substance with an established OEL.

4.3 Effects of REACH

Not applicable to welding fumes.

4.4 Effects of megatrends

In terms of megatrends, the study team notes the following trends in the EU with implications for welding include:

- Continuing urbanisation since this requires investment in construction and urban infrastructure such as power networks and transport networks; this would be expected to contribute to the projected increase in demand for welding across the EU;

- Resource scarcity as natural resources such as metals become scarcer and as a consequence, more expensive. This could result in some welding projects becoming economically unviable, but on the other hand could encourage reuse of waste materials and a boost to the circular economy;

- Growing consumption by the consumer class, was a previously noted trend (EC, 2021c). However, purchasing power in some areas has been set back by the cost-of-living crisis currently being experienced. Consumers are spending a higher proportion of their income on essentials such as food and energy and have less disposable income to spend on non-essential items (such as upgrading electronic goods before the end of their useful life or house improvements). It is hard to predict future consumption patterns and how they will impact the demand for welding, but the cost of living crisis may encourage consumers to buy products which last well and are repairable, and extend the life of products by repairing them, reusing them or upcycling them for example. Repairing, reusing and recycling products may involve welding+ processes;

- Increasing migration can help address the welding skills shortage being experienced in Europe. The study team note anecdotal evidence that Eastern European welders (from Croatia, Poland and Romania for example) have been contracted to work in Western Europe (Force Technology, April,2023, *pers comm*). Force Technology (April 2023, *pers comm*) also noted that one enterprise had opened an office in Asia (the Philippines) to recruit and train welders to work in Europe due to the skills shortage in Europe;

- Technological improvements are likely to continue to be adopted to optimise welding+ process control and reduce workers' exposure (see section 3.4.5);

- Internationalisation of decision-making means that a multinational company improving working practices in Europe may wish to roll these out to operations outside of Europe to create a level playing field for their workers (anecdotal evidence during an interview with the DVS and members in April 2023);

- Increasing global demographic imbalances could have a negative impact on the number of welders, since there is an ageing population in Europe and increasingly limited number of working age people (EC, 2023c). This is likely to increase the demand for working age migrants to fill vacancies, including welding; and

- The changing nature of work has been noted (Section 3.4.5), there is an increase in part time workers, temporary or contract workers and workers working multiple jobs. There is a need to understand exposure levels better in workers who are not employed full time as welders, potentially through cumulative exposure assessment.

Therefore, the baseline trends for welding are:

- An increased demand for welding (from infrastructure projects);
- Raw material costs (price of metals) increasing and therefore recycling increasing;
- Likely increased demand for repairing, reusing, and recycling metal products which adds to the demand for welding;
- Increase in immigration of migrant workers from non-EU countries to meet the skills shortage for welders in the EU27 and the increasing demand for welding, who may not be fully qualified or trained;
- Increase in part time, temporary or contract workers undertaking welding who may not be fully qualified or trained; and
- Technological improvements continue to reduce worker's exposure to welding fumes by automating previously manual welding and by improving the effectiveness of RMMs.

It is not possible to quantify the individual negative and positive impacts of these megatrends on the baseline trends for worker exposure to welding fumes. Instead, the estimated trend of all potential impacts on the numbers of welders is derived in section 3.4.5.

4.5 Future trend in uses of welding

Green transition targets for renewable energy and carbon neutrality require investment in energy infrastructure (such as power networks, electric vehicle charging infrastructure, hydrogen energy infrastructure, and wind turbines) which has increased the demand for welding. The green transition has been hastened by Russia's invasion of Ukraine which has intensified the demand for welding across Europe. It is not possible to quantify the increased demand for welding from green transition targets. In the cost calculations, one of the methods used is based upon market growth from other sources and therefore the baseline is dynamic see section 6.2.2.3.

4.6 Future trend in exposure concentrations due to technical improvements

Increasing automation of welding processes will lead to reductions in exposure to welding fumes, particularly in the automotive sector. However, some stakeholders (DVS, Germany automotive manufacturers) have noted (pers comm, March 2023) that best practice is already applied and additional RMMs will not reduce worker exposure any further (optimal protection has already been achieved). Countries (or enterprises) with lower current worker protection from exposure to welding fumes have more to gain from investing in RMMs.

If the market for additive manufacturing continues to grow (as noted in section 3.11.4) and starts to replace traditional joining, cutting and coating technologies processes, as it could do in certain high end applications (for example medical implants, high technology aerospace and defence applications), then this would also reduce occupational exposure to welding fumes as additive manufacturing is enclosed.

The adoption of innovative practices to optimise welding processes could also lead to reductions in exposure to welding fumes. Roll out of the BGHM welding fumes reduction programme in Germany and increased adoption of the methods developed by the REarc initiative for arc welding are examples of this (Section 3.7). Some countries are more advanced in the implementation of RMMs and adoption of innovative processes than others. Western European Member States generally have stricter regulation of welding fumes and occupational health and safety in general than Eastern European Member States (*pers* comm, interviews with key stakeholders, June 2023).

In conclusion, the future trend is likely to be for welding fumes exposure concentrations to reduce over time, but it is not possible to quantify this trend. There is only limited data available about exposure concentrations (from the German MEGA database, Table 3-14). This data cannot be applied across the rest of the EU as the factors affecting exposure vary so widely in different contexts, and therefore they have not been used in the calculations of costs and benefits.

4.7 Future trend in exposed workforce

There is currently a skills shortage of trained welders in Europe, with a projected increase in demand for welding and welders over the coming years (sections 3.4.5 and 4.4). The study team has assumed a growth of 0.45% in the number of welders per year, see, which is 10% of the forecast market growth as much of this growth will be in new and automated technologies, and some manual welding will be replaced with automated processes and additive manufacturing. For example, assuming an annual growth in welders of 0.45%, if the number of welders in Europe is assumed to be 1.2 million in 2023, then the number of welders is projected to rise to 1.436 million in 2063.

Due to the demand for welding and skills shortage in the EU, welders may migrate into the EU from non-EU countries to meet this demand, and they may be less aware of the need to use RMMs. These migrant workers may be more at risk from exposure to CMRs in welding fumes.

4.8 Other factors of importance for the baseline

The Russia-Ukraine war has caused instability in the global energy market. In response, the European REPowerEU plan (EC, 2023a) is speeding up the green transition to clean energy which was already planned. Ongoing energy projects aim to meet renewable energy targets in 2030 and ultimately carbon neutrality in the EU by 2050 (EC, 2023b), with a sustained increase in demand for welding until 2050 to build the necessary infrastructure to meet these targets.

Another factor potentially affecting the baseline was the Covid-19 pandemic which had a large negative impact on the manufacturing industry, due to fluctuating demand and supply and usual working operations being curbed (section 3.13). However, the welding market has made a strong recovery post pandemic after manufacturing facilities were reopened and with the launch of government initiatives to stimulate the economy.

4.9 Summary of trends

Throughout the assessment of the current situation and the development of the baseline scenario, there are many sources of information about likely trends that will affect the demand for welding and ways in which the industry will evolve. However, this information is largely qualitative, with few quantitative assessments, and any of these that do exist tend to represent only a small part of the total market.

One source of quantitative information is the 2019 Accuray Research report Global Welding Equipment Market Analysis & Trends, which provides predictions of market growth. This is explained in section 3.4.5 and is used to create a dynamic baseline for the numbers of exposed workers used in calculations of benefits in section 6.1.3.3.1. The calculation of bottom-up calculation of costs in section 6.2.2.2 is also based upon the number of exposed workers, but it is not possible to calculate bottom-up costs to enable a dynamic baseline. However, the Accuray data is used to estimate the risk management measure costs in the top down calculation of costs in section 6.2.2.3, because this uses a completely different methodology. The different trends and how they are used are shown in Table 4-2.

Table 4-2 Summary of trends for exposed workers, exposure concentrations, and market size, together with impacts of megatrends and trends for future use of welding

Variable	Source (section number)	Value	Use of data (section number)
Exposed workers	3.4.5, 4.7	0.45% increase per year, based upon 10% of projected market values	Benefits 6.1.3.3.1
Exposure concentrations	3.3.8, 4.6	Many trends, cannot be quantified	Not used
Market trends	3.11.4	Many trends, cannot be quantified	Not used
Market size	6.2.2.3	4.5% increase per year based upon projected market values	6.2.2.3
Megatrends	4.4	Many trends, cannot be quantified	Not used
Future uses of welding	4.5	Many trends, cannot be quantified	NA Not used
Other factors	4.8	Many trends, cannot be quantified	NA Not used

Source: Study team summary on basis of the information presented in this chapter.

4.10 Future disease burden (FDB)

4.10.1 Future disease burden

The future disease burden is given below as the estimated number of cases of lung cancer over the next 40 years: it is the number of cases generated by exposure over the next 40 years (and not the number of cases actually happening in the next 40 years). Latency may cause many of the cases caused by exposure in the next 40 years, particularly of cancer, to occur beyond the 40 year period. For this reason, the number of cases is not divided by 40 to indicate a number of cases per year as this would be misleading. The number of welders is assumed to be 1.2 million in 2023. The turnover for welding is assumed to be 5% (relatively low) due to the skill shortages and high demand for welders in Europe. The study team notes that other workers working in the vicinity of welding+ activities are exposed to welding fumes, but it is not possible to estimate how many there would be as this would vary depending upon different working environments. Also, other health endpoints, besides lung cancer, have been excluded from this study due to insufficient data. Therefore, the future disease burden is likely to be an underestimate as it does not include other exposed workers besides welders.

Table 4-3 Baseline future burden of disease; staff turnover of 5% for all sectors -

Endpoint	Number of cases over 40 years
Lung cancer	28,821

Source: Study team.

The number of cases (Table 4-3) split by sector, based simply upon the estimated proportion of exposed workers by sector (Table 3-43) are shown in Table 4-4. There is insufficient data to suggest how to weight these cases, so no weighting has been applied. Similarly, the present value over 40 years by sector of these cases of ill-health for the two methods of calculation M1 and M2 (see section 6.1.4.1), are shown in Table 4-5. The present value by sector, for M1 and M2, was calculated simply based upon the estimated proportion of exposed workers by sector (Table 3-43) multiplied by the estimated total for M1 and M2 (see section 6.1.3.1 and the methodological note), again without any weighting as there is insufficient data to indicate how to add any weighting.

Table 4-4 Baseline future burden of disease by sector; staff turnover of 5% for all sectors

Sector	Number of cases of lung cancer over 40 years*	Percent of total cases
C24 Basic metals	507	1.8%
C25 Fabricated metal products	3,425	11.9%
C28 Machinery & equipment	795	2.8%
C29 Motor vehicles, trailers & semi-trailers	1,575	5.5%
C30 Manufacture of other transport equipment	679	2.4%
C31 Furniture	122	0.4%
C32 Other manufacturing	109	0.4%
C33 Repair & installation of machinery & equipment	1,666	5.8%
E38 Waste collection, treatment & disposal, materials recovery	255	0.9%
F41 Construction of buildings	5,519	19.2%
F42 Civil engineering	967	3.4%
F43 Specialised construction activities	10,428	36.2%
G45 Wholesale & retail trade & repair of motor vehicles & motorcycles	2,773	9.6%
Total	**28,821**	**100%**

** Multiple of estimated percentage of welders between sectors and total predicted lung cancer cases from ER.*

Source: Study team.

Table 4-5 Baseline future burden of disease (PV40) by sector, 5% turnover of workforce a year, 3% static discount rate

Sector	PV40 over 40 years, static discount rate	
	Lung cancer – M2	Lung cancer – M1
C24 Basic metals	€206,736,168	€396,455,544

Sector	PV40 over 40 years, static discount rate	
	Lung cancer – M2	Lung cancer – M1
C25 Fabricated metal products	€1,397,655,944	€2,680,268,542
C28 Machinery & equipment	€324,447,148	€622,188,521
C29 Motor vehicles, trailers & semi-trailers	€642,857,600	€1,232,800,540
C30 Manufacture of other transport equipment	€277,026,465	€531,250,429
C31 Furniture	€49,616,680	€95,149,331
C32 Other manufacturing	€44,581,506	€85,493,436
C33 Repair & installation of machinery & equipment	€679,766,898	€1,303,581,070
E38 Waste collection, treatment & disposal, materials recovery	€104,112,334	€199,655,012
F41 Construction of buildings	€2,252,073,557	€4,318,775,255
F42 Civil engineering	€394,516,927	€756,560,520
F43 Specialised construction activities	€4,255,007,060	€8,159,777,528
G45 Wholesale & retail trade & repair of motor vehicles & motorcycles	€1,131,600,278	€2,170,056,687
Total	€11,759,998,567	€22,552,012,413

Source: Study team.

A summary of the baseline costs related to exposure to welding fumes is provided in Table 4-6, using figures presented in section 6.1. A discussion of the definition of the problem of welding fumes is provided in section 5.1, incorporating comments from key stakeholders on the magnitude of the problem. Benefits of policy option two, as expected by stakeholders, are discussed in section 6.1.7. Key limitations and uncertainties of the analysis of the impacts of policy option two are discussed in section 6.9.

Table 4-6 A summary of the baseline costs for future burden of disease, (PV40) in €.

Workers and families (M1)	Workers and families (M2)	Employers	Public Authorities	Grand total (M1)	Grand total (M2)
22,085,605,511	11,293,363,707	103,461,727	363,173,133	22,552,012,414	11,759,998,567

Source: Study team.

4.10.2 Legacy burden of disease

Previous OEL studies have not included the calculation of future burden of disease from legacy exposure. The reason is that this burden of disease would not be affected by the assessed policy options but might be added to all scenarios and making differences between the scenarios less prominent.

The basis of the calculation of legacy cases is given in section 3.14.3.

4.11 Summary of the baseline scenario

The baseline scenario for 40 years of exposure to welding fumes+ and the estimated number of expected cancer cases and associated health costs are summarised in Table 4-7 and Table 4-8 below. Please note that the cancer cases and associated health costs have only been calculated for lung cancer (not other health endpoints) in full time workers in welding+ processes, other exposed workers have not been taken into account, so the number of cancer cases and associated health costs are likely to be an underestimate.

Table 4-7 Baseline scenario over 40 years for welding fumes

Item	Detail
Chemical agent/process	Welding fumes (generated from welding+ processes): a mixture of particulate matter (dust) containing metals and their oxides, 'spinels' or complex compounds formed after the fumes are released, and gases (either produced by or used during welding).
Classification	Group 1, human carcinogen (IARC, 2018)
Sectors	C24 Manufacture of basic metals C25 Manufacture of fabricated metal products (excl. machinery & equipment) C28 Manufacture of machinery & equipment C29 Manufacture of motor vehicles, trailers & semi-trailers C30 Manufacture of other transport equipment C31 Manufacture of furniture C32 Other manufacturing C33 Repair & installation of machinery & equipment E38 Waste collection, treatment & disposal, materials recovery F41 Construction of buildings F42 Civil engineering F43 Specialised construction activities G45 Wholesale & retail trade & repair of motor vehicles & motorcycles
Period for estimation	40 years
Types of cancer caused	Lung cancer (established by IARC, 2018) Other cancers are associated with exposure, but the weight of evidence is not yet sufficient for establishing causation: brain cancer, head and

Item	Detail
	neck cancer, haematopoietic cancer, kidney cancer, mesothelioma, urinary bladder, ocular melanoma.
Other adverse health effects	Acute effects in the respiratory tract: acute irritation to the throat and larger airways of the lungs; acute irritation-induced asthma (also known as RADS); metal fumes fever; acute pneumonia (pneumococcal pneumonia). Chronic effects in the respiratory tract: occupational asthma; bronchitis; lung function changes and COPD; welder's lung (siderosis); neurological disorders; nephrotoxicity; cardiovascular disease; possible association with reprotoxic effects but the results are inconclusive.
No. of exp. workers	Estimated exposed workers (full time workers in welding+ processes) based on EUROSTAT data: 1.2 million. NB: This is an underestimate of total workers exposed to welding fumes which would also include others working in the vicinity of welding+ activities.
Change exp. level	1% reduction in exposure to welding fumes per year (estimated).
Change no. of exp. workers	0.45% annual growth in numbers of welders over 40 years.
Current disease burden (CDB) - no. of cancer cases/year (2023)	806 per year.
Future disease burden (FDB) - no. of cancer cases/over 40 years	28,821 cases of lung cancer over 40 years.
CDB - no. of other adverse health effects, no. of cases/year (2023)	Cannot be estimated as insufficient data.
FDB - no. of other adverse health effects, no. of cases over 40 years	Cannot be estimated as insufficient data.
Estimated deaths due to FDB cancer over 40 years	23,057
Estimated deaths due to FDB other adverse health effects over 40 years	Cannot be estimated due to insufficient data.
Monetary value FDB cancer over 40 years (static discount rate)	€11,759,998,567 - €22,552,012,414 (M2-M1)
Monetary value FDB other adverse health effects over 40 years	Cannot be estimated due to insufficient data.

Source: Study team summary on basis of the information presented in this chapter.

Table 4-8 Estimated number of exposed workers, expected number of cancers and other hazardous diseases cases and related health costs in case no action is taken (baseline scenario), over a 40 year period-

Carcinogen	No. of exposed workers	Expected no. of lung cancer cases	Expected no. of cases of other adverse health effects	Estimated health costs, EUR	Possible underestimations (non exhaustive list)
Welding fumes	1,200,000	28,821	Cannot be estimated.	€11,759,998,567 - €22,552,012,414	Some health endpoints could not be quantified, see section 2.1.5, part time or occasional workers in welding+ and bystanders have been excluded.

Source: Study team summary on basis of the information presented in this chapter.

5 POLICY OPTIONS

5.1 Definition of the problem

The problem is that despite the legislation in the CMRD, there still appears to be a significant number of workers that are not adequately protected from exposure to CMRs due to welding fumes.

The ECHA scoping study (ECHA, 2022) raised three arguments in favour of including welding fumes in the Annex I. These are that it would address:

> *"a prominent concern that welders are at high risk from various diseases, including cancers, which seems to indicate that more needs to be done to ensure that the needed measures are in place. In case some employers are not doing enough to protect the health of their employees, an entry brings some prominence to this issue, that welding is an activity/ process that merits specific attention."*

And:

> *"bring clarity about employers' duties and which measures have to be taken under CMRD and under CAD (even though the principles to protect workers are similar)"*
>
> *"define the welding and other processes and corresponding (hazardous) welding fumes+, and what is included (or not) brings clarity and simplicity about duties"*

The study Terms of Reference state:

> *"In 2018, the World Health Organisation's International Agency for Research on Cancer (IARC) classified welding fumes and UV radiation from welding as "carcinogenic to humans" (Group 1). (…) Welding fumes, which are process-generated substances, are not classified as carcinogenic in the CLP Regulation and therefore do no fall within the scope of the CMRD until they are included in the Annex I. Consequently, there is a need for assessing the appropriateness of adding welding fumes within the scope of the CMRD by means of their inclusion in Annex I."*

Therefore, the problem is one of legal clarity (leading to insufficient RMMs), further points are that:

- "Welding fumes, which are process-generated substances, are not classified as carcinogenic in the CLP Regulation and therefore do not fall within the scope of the CMRD until they are included in the Annex I" (Terms of Reference); and
- "More needs to be done to ensure that the needed measures are in place" (ECHA scoping study).

CMR substances contained in welding fumes do already fall within the scope of the CMRD. Many of the CMR substances which may be contained in welding fumes are already included in Annex III, which tends to bring more people's attention to the CMR. The problem may be that stakeholders are not aware that the fumes generated by their welding processes and similar processes may contain CMR substances (see sections 4.1 and 4.2).

There is evidence of a causal link between exposure to welding fumes and various health effects (section 2.1.2). In this study an attempt has been made to quantify the effect of exposure to welding fumes on lung cancer only, although other health effects are associated with exposure to welding fumes.

Defining the problem involves quantifying the number of welders and bystanders exposed to CMRs in welding fumes due to inadequate risk mitigation measures (RMMs). This would require data about:

- Total number of welders in EU;
- Welding processes that contain CMRs;
- Proportion of welders exposed to CMRs; and
- Proportion of welders and bystanders exposed to CMRs with inadequate RMMs.

The extent that welders are exposed to CMRs is difficult to quantify due to uncertainties and gaps in the evidence base. However, the study team has consulted with stakeholders and experts at the European and Member State level to attempt to gauge the current situation.

5.1.1 Total number of welders in the EU

This study estimates that there are 1.2 million full time welders in the EU27 (section 3.4), with an estimated excess risk (ER) of 2.7% in 2023 (section 6.1.3.3.2). This equates to 28,822 lung cancer cases over 40 years. Data on the numbers of estimated welders in Europe vary by source. The difficulties experienced by the study team corroborate the experience of the authors of ANSES (2022) that the estimates of numbers of welders vary depending upon sampling and classification of occupation, inclusion criteria and year of data collection. However, the six key stakeholders interviewed (section 6.1.2) generally agreed with the figure of 1.2 million full time welders in the EU27.

The sectors with the largest numbers of workers (welders[41]) exposed to welding fumes, identified by this study, include specialised construction activities; construction; manufacture of fabricated metal products; repair of motor vehicles and motorcycles; repair and installation of machinery and equipment; manufacture of motor vehicles; civil engineering; and manufacture of machinery and equipment. These sectors are broadly supported by ANSES (2022) and other studies (CAREX, Finnish ASA data (section 3.4.2)), although the ranking is slightly different in other data and in other studies the delineation of categories were different and it was therefore difficult to convert the data to the equivalent EUROSTAT category.

5.1.2 Welding processes that contain CMRs

This study estimates that the excess risk (ER) to lung cancer in welders is 2.7% in the year 2023. This ER is calculated from figures in a meta analysis by Loomis *et al* (2022), in which the median year for the studies was the year 2000. An assumption was made that exposure levels would decrease by 1% per year due to improvements in protective measures, to arrive at the ER for 2023 which is lower than in 2000 (section 2.2, section 3.3.8 and section 6.1.3.3.2). The study team concur with ANSES (2022) that "*the majority of studies report only the title of the profession or the work task without further information on the welding technique used. It is therefore not possible to attribute the appearance of cancer specifically to a type of welding process, to the types of metals welded or to the method of treatment of the surface to be welded*". ANSES (2022)

[41] The number of exposed bystanders has not been estimated; the level of confidence in the estimated number of welders, although based on the best available data, is low.

recommended that further epidemiological studies are needed to further understand the health effects from exposures from different welding processes, metals and alloys.

It is also difficult to quantify the size of the problem due to the fact that welding fumes are highly heterogeneous. The content of welding fumes (in terms of CMR substances present (Table 2-1 and Table 2-2)) depends largely upon the materials being welded. The majority (95%) of the components of welding fumes are emitted from the filler or consumables used and only 5% from the base material (ANSES, 2022). In most cases the filler or consumables are the same material as the parent materials being welded[42]. In a minority of cases the filler (or consumables) are different to the parent materials, with the former being chosen for their desirable properties for a specific purpose (TWI, *pers comm*, July 2023).

The rate of emissions of welding fumes depends largely upon the welding process being used see Table 3-46. Galarneau (2021) in a study to construct and calibrate an exposure matrix for welding trades, found the highest total dust exposure levels were from FCAW; the highest manganese levels were from welding mild steel (although manganese exposure is not covered by the CMRD it is regulated under the CAD); the highest nickel compound levels were from high alloyed steel using GMAW; the highest chromium levels were from welding stainless steel using MMA; and the highest aluminium levels were from welding aluminium using FCAW. There are exceptions to general 'rules of thumb' about how welding+ processes should be ranked according to the levels of emissions they generate. SMAW is often considered a relatively low emission welding process, however Pesch *et al* (2015) found exposure levels for Chromium VI were highest from SMAW and FCAW.

Other factors affecting the rate of emissions include the thickness of the sheet being welded, or whether the metal part being welded has been moulded (automotive manufacturer, *personal communication*, July 2023). The level of experience of the welder (ANSES, 2022), and the angle of the welding (VBMG, 2007) also influence emission rates. The presence of coatings and arc time also affect the composition and rates of emissions respectively (ANSES, 2022).

Exposure levels have been found to vary between countries (higher levels in Finland), industries (highest in manufacturing, lowest in automotive), and trades (highest in boilermakers, lowest in pipe fitters and welders) (ANSES, 2022).

There is an ongoing debate about the need to measure the number of ultrafine particles that workers are exposed to from welding; the total *mass* of particulates could be low but contain a high *number* of ultrafine particles. Certain welding+ processes produce a large amount of ultrafine particles, for example thermal spraying (Bémer et al., 2010 in ECHA, 2022). Also, although TIG generates low concentrations of welding fumes, it has been found to have the highest number of small particles including ultrafine particles with a diameter of less than 0.1µm (ANSES, 2022). In welding fumes exposure by TIG welders, Graczyk et al. (in IARC, 2018) found that 92% of the particles were ultrafine particles. A study by Kendzia *et al.,* (2019) found the opposite, that TIG welding usually generates low numbers of particles that are small enough to enter the respiratory tract, so there is some conflicting evidence.

[42] EWA, *pers comm*, June 2023; TWI, *pers* comm, June 2023; DGUV, *pers comm*, July 2023.

Further, the toxicity of welding fumes is associated with the size distribution and surface characteristics of particles generated (ANSES, 2022). Hewitt *et al.* (1995b, in IARC, 2018) estimated that MAG welding delivered three times the surface area of particles to the respiratory system compared with manual welding with coated electrode, even when taking into account the differences in specific surface of the particles and the greater deposit during MAG welding.

In general, welding of high alloy steels (for example >5% nickel content) will generate higher emissions of the alloys present (such as nickel). Exposure to nickel compounds increases as the nickel content of the material welded increases, irrespective of welding process used (Koppisch *et al*, 2022 in DGUV, *pers comm*, July 2023). The highest exposure levels for nickel compounds occurred from welding using MAG or SMAW with high alloyed steel and high-alloy nickel-coated electrodes. However, exposure data in the German MEGA database shows that low alloy steels (<5% nickel content) if welded using a high emission welding process (such as MIG) can generate exposure levels of nickel that are greater than the new OEL for nickel compounds[43].

The above generalisation about high alloy steels containing a higher content of CMRs does not necessarily correlate to the amounts of generic 'welding fumes' generated from welding high alloyed steels. Kendzia *et al* (2019) found greater exposure levels of welding fumes (1.67 times higher) from welding mild steel (low alloyed steel) compared with stainless steel (high alloyed steel), for both the inhalable fraction and respirable fraction.

There is evidence that both welders of mild steel and stainless steel experience an excess risk for lung cancer (Honaryar *et al.*, 2019, Sorensen *et al.*, 2007 in ECHA, 2022). There are also some papers that provide evidence of the mechanistic carcinogenic potency from welding mild steel (Badding *et al*, 2014; Dierschke *et al*, 2017; Falcone *et al*, 2018; Leonard *et al*, 2019; Zeidler-Erdely *et al.*, 2012 in DGUV, *pers comm*, July 2023).

5.1.3 Definition of welders exposed to CMRs

Six key stakeholders (section 6.1.2) were asked to provide definitions of welders at high risk of exposure to CMRs, and at low risk of exposure to CMRs. A summary of responses is provided in Table 5-1. When asked to estimate the percentage of welders at high risk of exposure, stakeholders that were willing to put a figure on it, estimated that between 5-15% of welders would be in this category.

Stakeholders estimated that 20-75% of welders would be at risk from <u>any</u> exposure to CMRs. This is a large range of estimates and it is difficult to draw any clear conclusions from this small sample of experts (although these experts represent a large number of welders). One national stakeholder said that in their country welders are generally well protected, but bystanders need more protection. One EU level stakeholder estimated that, although less than 15% of welders would be in the high risk category for exposure to CMRs, between five and seven times as many bystanders would be exposed to CMRs across Europe (~1-2.5 million bystanders according to their estimates).

[43] According to exposure levels from the MEGA database, taken between 2010-2016 (data provided by the DGUV, *personal communication,* July 2023).

Table 5-1 Stakeholders' definitions of welders at high risk and low risk of exposure to CMRs.

Factors	Welders at high risk of exposure to CMRs	Welders at low risk of exposure to CMRs
Welding	All manual welders are potentially exposed to CMRs. Some automated welding. Mechanised welding has some exposure as people are monitoring the operation – one person might be operating 3 or 4 robotic cells. Welding of stainless steel with covered electrode (MMA, process 111) or flux cared wire welding (FCAW, process 136/138). Cr: fumes from cutting and welding stainless steel and chrome plated materials. Ni: fumes from cutting and welding stainless steel and from the electrodes used.	Enclosed, robotic (automated) welding e.g. automotive manufacturing industry. Low emission welding processes, for example TIG.
Welders	Only professional welders weld stainless steel and they know to use RPE (in Italy). Fully qualified and certified professional welders weld in high risk situations and use RPE (in Germany[44]). Migrant workers.	
Materials	Welding high alloy (stainless steel) which contains Cr(VI) and nickel compounds. More use of high alloy steel in metal fabrication in Germany that in other countries, so higher potential exposure in Germany.	Low alloy steel (mild steel) – low Cr(VI) content e.g. for shipbuilding
Sectors	Pressure and boiler sectors, pipeline sectors, construction, maintenance, and specialist uses e.g. turbines.	
Working environment	Confined spaces. Forced welding positions (when breathing is fast). Corrosive environments. Outdoor welding can be high risk if the welder has their head in the welding plume under a shelter (with limited ventilation) – this becomes a confined space. An outdoor shelter is often needed to produce a good quality weld in wet or windy	Factories/shop welding where RMMs can be incorporated into the design. Welding outside with natural ventilation.

[44] *Pers comm*, call with the DGUV in June 2023.

Factors	Welders at high risk of exposure to CMRs	Welders at low risk of exposure to CMRs
	conditions. Welders need portable extraction inside a shelter.	
Worker protection	Less worker protection in: • Eastern Europe • Southern Europe • Repair industry • Smaller companies • Part time welders	Use of LEVs, helmets with fresh air, masks with filters. Better worker protection in: • Northern Europe

Source: Interviews with key stakeholders in June – July 2023.

In addition, the regulatory regime (including inspections and fines for non compliance) and level of awareness of the need for RMMs varies across Europe. The generally held view as identified by the study team, is that compliance with best practice RMMs for welding is better in western and northern Europe compared with southern and eastern Europe (interviews with key stakeholders, June and July 2023). The ECRHS II survey partly validated this as the survey found that cumulative exposure to welding fumes was lower in northern Europe compared with southern Europe, but RMMs use is only one possible reason for this (Olsson and Kromhout, 2021). The level of awareness also varies within each Member State. In general, larger enterprises are more likely to have the resources to have a dedicated health and safety expert or team (interviews with key stakeholders, June and July 2023). Smaller enterprises are less likely to have these resources (interviews with key stakeholders, June and July 2023).

5.1.4 Proportion of welders exposed to CMRs with inadequate RMMs

Six key stakeholders (section 6.1.2) that represent a large number of welders across the EU, were asked to estimate the proportion of welders that currently have access to and use best practice, reasonable practice or poor RMMs, for welders with a high risk of exposure to CMRs and for all welders. The responses have been divided into tables providing a summary of the European perspective (Table 5-2) and the national perspective (Table 5-3).

The range of answers given by national representatives was wider (Table 5-3)than the answers given for Europe in general (Table 5-2). As would be expected, 'all welders' (including welders at low risk of exposure to CMRs) were believed to be slightly less protected than welders at high risk of exposure to CMRs, both by European stakeholders and national stakeholders. However, one national stakeholder gave the same proportions of welders in each category of access to RMMs, both for welders at high risk of exposure to CMRs and for all welders.

The lowest national estimate of the proportion of high risk welders with access to and using best practice RMMs was 10%, whilst the highest estimate for this figure was 90%. The current level of awareness of the risk of welding fumes exposure was perceived to be low, with some exceptions, for this low level of worker protection. The explanation for the high level of best practice was that high risk welders in that Member State are already well protected because this is critical, but some low risk welders may currently not be using RMMs.

Table 5-2 Baseline access to and use of RMMs, European perspective from key stakeholders.

	Welders with high risk of exposure to CMRs	All welders
Best practice	20-60%	20-25%
Reasonable practice	20-40%	40-50%
Poor practice	20-40%	25-40%

Source: interviews with key European stakeholders, June – July 2023.

Table 5-3 Baseline access to and use of RMMs, national perspective from key stakeholders.

	Welders with high risk of exposure to CMRs	All welders
Best practice	10-90%	10-95%
Reasonable practice	5-20%	20-50%
Poor practice	10-70%	20-70%

Source: interviews with key national stakeholders, June-July 2023.

The study team undertook a separate survey during June – July 2023. This comprised of interviews with welding stakeholders in five Member States spanning Europe: Croatia, Estonia, France, Netherlands and Slovenia. In general, representatives of eastern European Member States estimated fairly high proportions of workers using best practice (Table 5-4)[45]. The one Netherlands representative who ventured an estimate gave a surprisingly low estimate for best practice in the Netherlands (20%) and relatively high estimate for poor practice (20%). This may have been based upon recent unpublished findings of inspections undertaken by the Netherlands Labour Inspectorate. A recently obtained, older report on inspections undertaken in the Netherlands from 2009-2015 (Inspectie SZW, 2016) found 217 infringements of the occupational health and safety risk of exposure to welding fumes (43% of all violations). The key reasons highlighted for these infringements was a lack of familiarity with the Working Conditions Catalogue for welding fumes and not obtaining advice from an improvement coach.

The above viewpoints from stakeholders from Member States are contrary to opinions expressed to the study team from other stakeholders that awareness of CMRs in welding fumes and worker protection is greater in western Europe than in eastern Europe (interviews with key stakeholders, June – July 2023, *pers comm*, car manufacturer, Germany, July 2023).

Table 5-4 Baseline estimated access to and use of RMMs for workers exposed to welding fumes containing CMRs, Member State perspective.

Member State (number of interviewees)	Best practice	Reasonable practice	Poor practice
Croatia (3)	5-100%	0-50%	0-45%
Estonia (4)	10-100%	0-70%	0-20%

[45] Except in one case where a representative of Croatia estimated best practice at only 5%, with reasonable practice at 50% and poor practice at 45%.

Member State (number of interviewees)	Best practice	Reasonable practice	Poor practice
France (1)	95%	5%	0%
Netherlands (3)	20%[1]	60%[1]	20%[1]
Slovenia (1)	80%	18%	2%
Notes: [1]Only one representative from the Netherlands felt able to estimate the proportion of best practice, reasonable and poor practice.			

Source: short interviews with stakeholders June – July 2023.

The perceived levels of compliance with regulations and implementation of best practice may not always match the reality in workplaces across Europe. Taking one example, the Netherlands is sometimes assumed to have good levels of worker protection due to having a strict welding fumes OEL in place (1 mg/m^3). However, one stakeholder from the Netherlands pointed out according to data from the national pension fund, one in five welders does not survive to retirement age due to health issues[46]. Their opinion was that the situation would only improve if more control and enforcement measures were undertaken by the Labour Inspectorate because it was currently understaffed. Another stakeholder from the Netherlands pointed out that despite national legislation in place, tackling welding fumes is difficult and worker protection is currently less than ideal:

"*Most welders underestimate the risks of inhaling welding fumes. The Netherlands Labour Authority (NLA) found that employers were still not providing sufficient information and instructions to their employees[47]. Welders (often less educated workers) are often loyal to their employer and point to their own autonomy (or: unwillingness) to use the right control measures. The employer does not adequately monitor the use of the measures. Employers also often wait too long to call in experts (occupational health and safety service or occupational hygienist) to support them in carrying out a (mandatory) good risk assessment and choosing the right control measures*."

5.2 Definition of the problem drivers

The problem drivers for the welding fumes exposure include:

- Lack of awareness of CMRs in welding fumes;
- Lack of awareness of health risks from exposure to welding fumes;
- Lack of understanding of the requirements of the CMRD;
- Cultural or logistical barriers to using RMMs;
- Lack of understanding of the optimal RMMs to use; and
- Lack of inspections and penalties for non-compliance with CMRD.

[46] The study team notes that welders may be exposed to other factors impacting their health besides welding fumes, such as smoking and exposure to asbestos, so without further evidence this statistic cannot be attributed solely to exposure to welding fumes.

[47] Personal experience of the stakeholder, of a current, not yet published exploratory project in the Netherlands.

All of the above drivers are generally considered to be important by key stakeholders (interviews with three key EU level and three[48] key Member State stakeholders, June and July 2023), however only the first two are addressed by policy option two (Annex I). Other comments made be the key stakeholders were that:

- Awareness level depends on the country (a national stakeholder);
- Awareness in Germany is good and improving, cultural/logistical barriers to using RMMs are not believed to be an issue in Germany (a national stakeholder);
- Awareness is fairly good, few welders do not care about the risks from welding fumes, but there may be less awareness of the risks from welding low alloy steel (an EU level stakeholder);
- Agreement that there are cultural or logistical barriers to using RMMs, for example there is a high cost to installing LEV and therefore it is not always used. Smaller companies will cut more corners regarding health and safety than larger companies and have less access to the best RMMs – it is difficult to implement RMMs (an EU level stakeholder);
- The drivers can be synergistic for example cultural barriers added to a lack of understanding can represent a bigger hindrance (an EU level stakeholder);
- There is also a lack of guidance for companies/workers on the use of RMMs (an EU level stakeholder);
- Extraction alone is not enough to control exposure (a national stakeholder) – this statement is supported by a study by Lehnert et al (2020)[49];
- There is also a lack of obligation to use RMMs (an EU level stakeholder); and
- Lack of inspections and penalties is important (a national stakeholder).

The results of a separate survey of twelve[50] national stakeholders (from five Member States[51]) undertaken by the study team included the finding that although the stakeholders themselves were not always aware of the CMRD, they were generally aware of CMRs in welding fumes. Similarly, stakeholders said that awareness of the CMRD varied amongst their members, employees, or students. This time, the perceived estimated level of awareness of CMRs in welding fumes in their members, employees, or students ranged widely from 20-100%.

Despite previous awareness raising campaigns, one stakeholder estimated that this awareness of CMRs in welding fumes was as low as 20% in the Netherlands; and one stakeholder in Estonia estimated that this awareness of CMRs in welding fumes was 30%. Conversely, one stakeholder in the Netherlands said that around 85% of welders knew not to inhale welding fumes, and two stakeholders in Estonia estimated that the awareness of CMRs was high at 70-80% or even 100%. This awareness of CMRs was also considered to be high in Croatia (as high as 100%) and Slovenia (again 100%).

[48] From Germany, Greece and Italy.

[49] The limit value (20µg/m^3) for respirable manganese was exceeded in >80% of measurements from MAG welding in the WELDOX I study in Germany as evidenced by Lehnert et al, 2020.

[50] Comprising one company, two trade unions, three OSH experts and six training/trade associations.

[51] From Croatia, Estonia, France, Netherlands and Slovenia.

However, the study team assert that without a campaign of unannounced inspections of welding sites across Europe, it is impossible to gauge the actual level of awareness and worker protection.

A problem tree describing the problem, its drivers or root causes, and its consequences of branches is shown in Table 5-5.

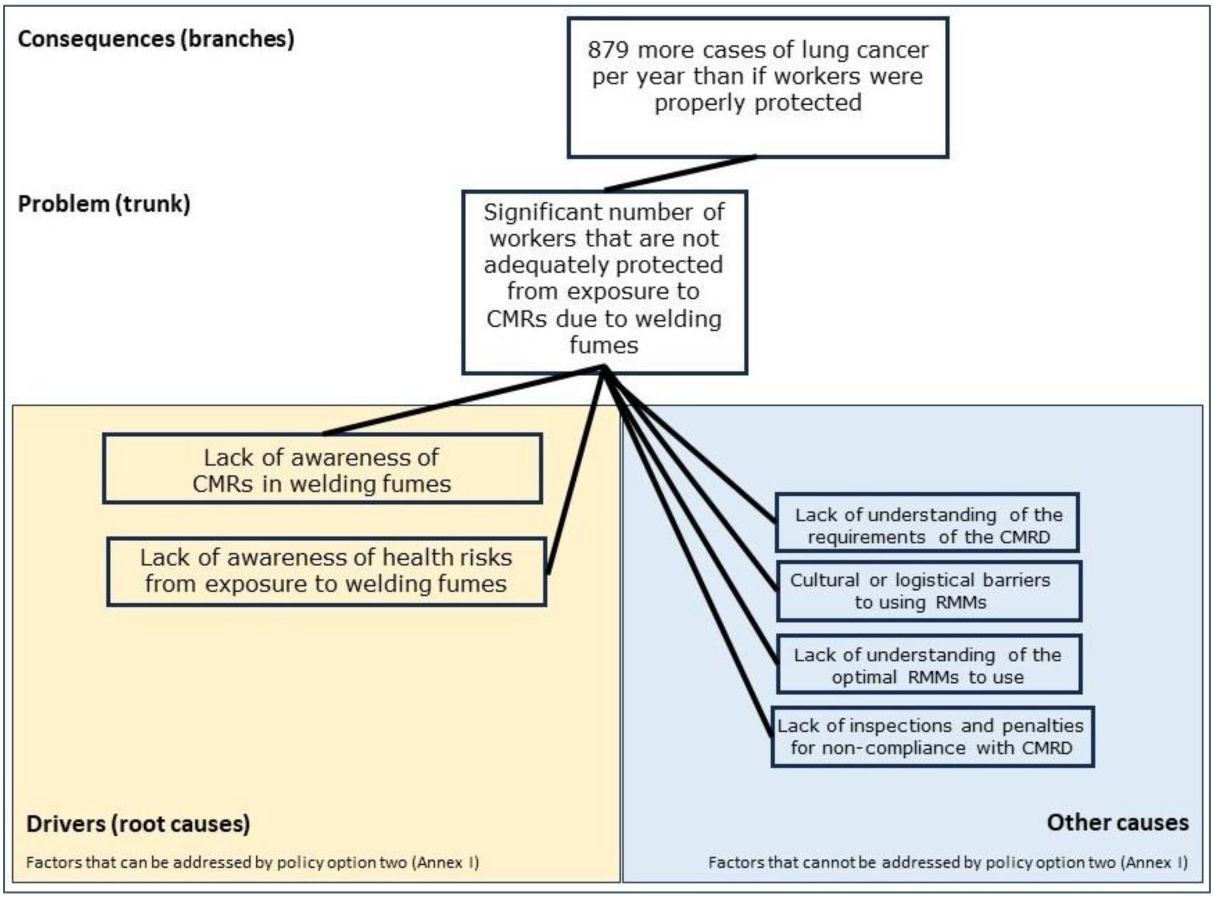

Table 5-5 Problem tree for policy option two (Annex I).
Source: ECHA, 2022, study team (current burden of disease)

5.3 Overview of the policy options

The study team has been asked to "*investigate the costs and benefits in relation to bringing them* (welding fumes) *under the scope of the CMRD by introducing an entry in Annex I to the Directive*" to improve legal clarity. At least the following policy options shall be investigated:

- **Policy option 1 (Baseline scenario):** no new measures at EU level (i.e. taking into account existing requirements under OSH legislation, chemicals legislation and other relevant legislation, without any entry in Annex I to the CMRD); and

- **Policy option 2:** introducing into Annex I to the CMRD the following processes: *"Work involving exposure to fumes from welding (and similar) processes containing substances that meet the criteria for carcinogens, mutagens or reprotoxic substances Category 1A or 1B set out in Annex I to the CLP Regulation"*.

In addition, the study team was asked to assess qualitatively the impact of two further policy options that could be applied to welding fumes+, in addition to an entry in Annex I of the CMRD, in a future revision of the CMRD. These policy options are based on the ECHA scoping study (ECHA, 2022)

- A generic OEL for inhalable and respirable dust specific to welding fumes*; and
- A non-specific generic dust metric (inhalable and respirable limits) applicable to all dusts.

*In this study the study team has taken this to mean an OEL to apply to all welding+ processes. These are assessed in sections 7 and 8 respectively.

An intervention logic to summarise policy option two (Annex I) is included in Table 5-6.

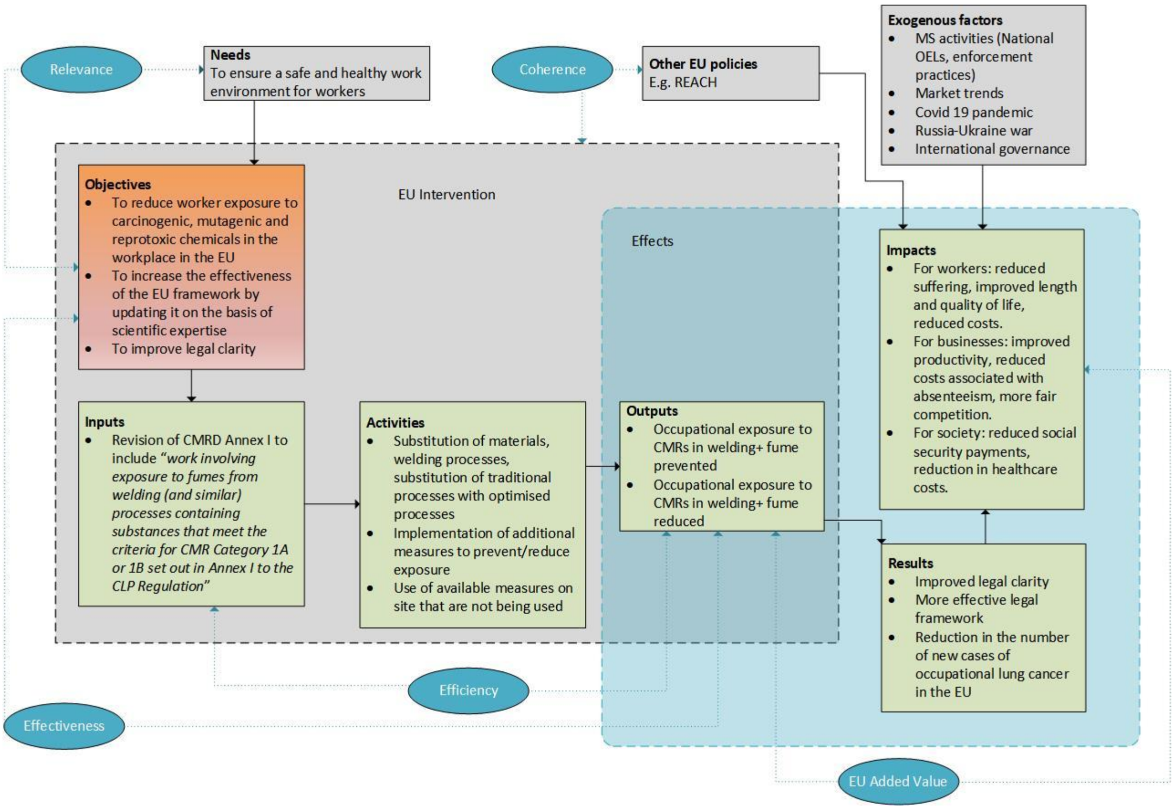

Table 5-6 Intervention logic for policy option two (Annex I).

5.4 *Issues relating to the policy options*

To "*investigate the costs and benefits in relation to bringing them (welding fumes) under the scope of the CMRD by introducing an entry in Annex I to the Directive*" the study team needs to verify (and assess) whether:

- There are any welding processes and other similar processes containing substances with CLH as CMR 1A or 1B which are not already covered by entries in Annex III; and

- Adding welding fumes to Annex I would bring additional legal clarity and increased awareness on the necessity of implementing all (already required) risk mitigation measures.

Regarding the first point, ECHA argues that "*The majority (but not all) of the relevant substances are already covered by entries in Annex III*". If the remaining relevant substances were included in Annex III as a priority (and indeed the addition of cobalt compounds is being assessed in this same study), ECHA questions whether there would be any value in having welding fumes added to Annex I. It must be noted that whether CMR substances are included in Annex III does not make any difference when considering the baseline, as it is not the inclusion in Annex III that brings them within the scope of the CMRD but rather their classification as CMRs.

Regarding the second point, ECHA questions whether adding welding fumes to Annex I is the best way to increase clarity and awareness, providing both pros and cons to the argument.

The study team is also concerned that, in terms of clarity, the inclusion of welding fumes in Annex I, as in the current formulation, may work against it. In particular, the introduction of welding fumes in Annex I would require a clear definition of its scope. In the absence of such a clarification, this could create confusion about whether mutagenic and reprotoxic substances are also covered by this entry. The study team understands that additional text will be added to the Directive or Annex I, which should clarify the situation. However, the study team has no information about these potential changes and, thus, as the policy option stands, the inclusion of welding fumes containing CMR substances in Annex I may cause confusion.

The consultation of key stakeholders also showed that the inclusion of welding fumes in Annex I would require some clarifications about its implications: many do not understand that there is no legal difference and spent time trying to understand what has changed. At least eight key stakeholders (membership organisations and two major car manufacturers) out of fifteen stakeholders were clearly confused in various conversations during site visits, interviews and email exchanges.

Regarding awareness, while the inclusion of welding fumes in Annex I may focus attention on welding and welders, the amendment of a Directive to increase awareness is not a usual move and, from an impact assessment perspective, brings the following problem: normally, in an impact assessment, either no assumptions on compliance are made, or better, 100% compliance is assumed; in other words, the (unstated) assumption is that if there was 100% compliance, these would be the costs, these would be the benefits. When defining policy options, there are considerations of enforceability but not rate of compliance.

The costs and benefits of policy option 2 equate to zero, because they relate to risk management measures (RMMs) that companies should already be implementing.

The study team has estimated the costs and benefits of additional companies applying already required RMMs, assuming that policy option 2 would result in increased awareness. But, in summary the costs and benefits of increasing awareness through policy option 2 can be quantified but raise the issue of whether they should be accounted for in the impact assessment, as they relate to RMMs that should be already implemented by companies within the EU.

6 QUANTITATIVE IMPACT ASSESSMENT FOR POLICY OPTION TWO (ANNEX I)

As explained in section 5.4, the benefits of policy option 2 equate to zero, because they relate to risk mitigation measures (RMMs) that companies should already be implementing.

The study team estimates costs and benefits of additional companies applying already required RMMs, assuming that policy option 2 would result in increased awareness, subject to the caveat in section 5.4.

This chapter comprises the following sections:

- Section 6.1.1: Summary of the assessment framework;
- Section 6.1.2: Improved welfare, assumptions and avoided cases of ill health;
- Section 6.1.3: Benefits to workers & families;
- Section 6.1.4: Benefits to employers;
- Section 6.1.5: Benefits to the public sector; and
- Section 6.1.6: Summary of the benefits of the measures.

6.1 Benefits of policy option two (Annex I).

6.1.1 Summary of the key assessment framework

The model developed to estimate the benefits in terms of reduced costs takes into account the cost categories set out in Table 6-1 below. More details are presented in the methodology report.

Table 6-1 The benefits framework

Category		Benefits	Notes
Direct	Improved welfare	Reduced healthcare costs	Avoided cost of medical treatment, including hospitalisation, surgery, consultations, radiation therapy, chemotherapy/immunotherapy, etc. Avoided private direct and indirect medical costs and rehabilitation costs
		Reduced informal care costs[52]	Avoided opportunity cost of unpaid care (i.e. the monetary value of the working and/or leisure time that relatives or friends provide to those with ill health)
		Reduced cost for employers	E.g. avoided costs due to insurance payments and absence from work
		Safety	

[52] A decision has been taken to include informal care costs in this analysis even though some elements of these costs may also have been included in individuals' willingness to pay values to avoid a future case of ill health. This decision may result in an overestimate of the benefits as generated by this study.

Category		Benefits	Notes
		Direct economic benefits	
		Environment	See sections 6.5, 7.5 and 8.5 not monetised
	Improved market efficiency	Cost savings	Include higher economic productivity, improved allocation of resources, removal of regulatory or market failures or cost savings.
		Improved information	Includes improved information availability
		Wider range of products/services	Enhanced product and service variety and quality for end consumers
Indirect	Indirect compliance benefits	Reduced mortality – productivity loss.	Avoided costs to society due to premature death
		Reduced morbidity – lost working days.	Avoided earnings and output due to absence from work due to illness or treatment
		Other indirect benefits to workers and families	
		Indirect benefits to administrations	Avoided tax revenue losses Avoided administrative and legal costs Avoided costs linked to the process of defining a national OEL
	Wider economic benefits	Including higher GDP, productivity enhancements, greater employment rates, improved job quality etc.	Employment may increase as a result of industry 'clean up' due to better perception of workplaces and increased acceptability of risks
	Other, non-monetary benefits	Protection of fundamental rights, social cohesion, reduced gender discrimination, international and national stability	
Intangible	Improved welfare	Approach 1 WTP[53]: Mortality	A monetary value of the impact on quality of life of affected workers Avoided moral pain and suffering Avoided loss of present and future income Avoided cost of time claiming benefits, waiting for treatment etc. Reduction in insurance contributions
		Approach 1 WTP: Morbidity	
		Approach 2 DALY[54]: Mortality	
		Approach 2 DALY: Morbidity	

The abbreviations are explained in Table 6-2 below.

6.1.2 Note about the assumptions

There is little data available to build estimates of costs and benefits. Section 2.2.2 and section 3.4 explain the estimates for the excess risk and number of welders respectively, together with the uncertainties. As the estimates for benefits and costs are developed in this study, many assumptions

[53] Willingness to Pay: The maximum sum an individual is willing to pay for service/goods in order to avoid loss, in this case, in terms of health treatment.

[54] DALY = Disability Adjusted Life Year. DALY is whereby one year of health is lost. It is used to calculate the gap between current health status and the ideal health situation (WHO, accessed Feb 2018).

are made by the study team, often with little evidence other than stakeholders' input. To attempt to validate these estimates, the study team held six interviews with key stakeholders which are estimated to represent approximately 1,000 EU organisations (representing businesses, trade unions and training organisations) involved in welding. None of those interviewed had any clearer knowledge of the variables that required estimates than the study team. When assured that they would not be identified, and the study team was only looking for their opinions about the likely accuracy, some interviewees were willing to give an opinion. Generally, the consensus was that the study team's estimates were reasonable. In a few cases, one or more stakeholders felt that an assumption was too high or too low, and this is indicated where applicable.

6.1.3 Improved welfare, assumptions and avoided cases of ill health

6.1.3.1 Benefits categories for improved welfare

Table 6-2 Overview of benefits categories for improved welfare

Category	Code	Cost to be avoided
Direct	Ch	Healthcare
	Ci	Informal care
	Ce	Total cost to an employer
Indirect	Cp	Productivity loss due to mortality
	Cl	Lost earnings due to morbidity
Intangible	Cvsl	Value of statistical life
	Cvsm	Value of cancer morbidity/value of statistical morbidity
	Cdaly	Value of DALYs

Source: Study team.

The total avoided cost of ill health is calculated using the following two methods:

Method 1: *Ctotal= Ch+Ci+Ce+Cp+Cvsl+Cvsm*

Method 2: *Ctotal= Ch+Ci+Ce+Cp+Cl+Cdaly*

Cl is not considered under Method 1 since *Cvsm* may already include these costs. Further detail is in the Methodological Note.

6.1.3.2 Relevant health endpoints for welding fumes

As explained in section 2.4.2, there are many potential endpoints for welding, both cancer and non-cancer. But the data does not exist to derive an exposure risk relationship (ERR) and a dose response relationship (DRR) for any of them and the only endpoint for which an excess risk can be estimated is lung cancer.

6.1.3.3 Summary of the key assumptions for welding fumes

6.1.3.3.1 Number of welders

A discussion on the number of welders in the EU has been provided in section 3.4.6. This provides all available information on welders working in different sectors, use of different welding methods etc. As is discussed there (and elsewhere), the resolution of the data on the number of welders is relatively poor and, in combination with available estimates of the exposure risk and the excess risk value (which applies only to 'welding' and is not differentiated further) this means that the analysis must be carried out on the total number of welders undifferentiated by type/sector of welding.

Whilst this may appear simplistic, the main overall purpose of the assessment is to identify the relative costs and benefits of policy option two (Annex I) as a means to identify whether the policy option two is justifiable in cost-benefit terms. Thus, while the resulting estimates of the number of cases of ill health and their associated monetary value cannot be regarded as representing a highly accurate estimate of the benefit of the actions, they do provide the order of magnitude of the benefits which provides insight into the question of whether the action is justified in cost-benefit terms.

Given the varying estimates of the number of welders, the analysis applies 1,200,000 welders as the default. The key stakeholders interviewed, which between them represent a large number of welders, generally agreed with this estimate of full time workers in welding+ processes across the EU.

A trend of 0.45% growth in welders is estimated over the next 40 years as explained in section 3.4.5.

6.1.3.3.2 Excess risk

Section 2.2.2.3 provides lung cancer excess risk of 3.4% based on a review of epidemiological studies by Loomis et al. (2022) and others. As a number of the studies feeding into this estimate are pre-2000, it might be assumed that this 3.4% excess risk estimate reflects the situation around year 2000 and that some reduction in excess risk might have occurred since that time owing to improvements in working practices. As noted in section 2.2.2.3, Olsson and Kromhout (2021) assumed a reduction of exposure of 2-3% per year. However, the studies included by Loomis et al. (2022) with study periods after 2000 do not show clear differences compared to studies with periods before 2000.

For the baseline analysis, a 1% per year reduction in ER is assumed which, when applied to the 3.4% ER for 2000, suggests an excess risk (ER) of 2.7% in year 0 (2023). Under the baseline it is assumed that this 1% per year reduction in ER continues into the future. In year 40, this equates to an ER of 1.81%.

One of the EU level stakeholders agreed with this baseline 1% reduction in ER due to the trend for increased automation. Two of the key stakeholders (an EU level and a national stakeholder respectively) thought that this baseline estimate of reduction in ER of 1% per year is an underestimate. The EU level stakeholder thought the baseline reduction to welding fumes should be more than 2% per year due to the existing trend in automation, better use of RMMs and use of low emission welding processes. The national stakeholder agreed that there have been strong improvements in RMMs in their country which would improve the baseline. Another national stakeholder thought that the baseline reduction should be higher due to the number of smokers decreasing nationally. The study team note that confounding factors including smoking and asbestos exposure were taken into account in the studies analysed by Loomis et al 2022 which was used to calculate the ER in this study, and these confounding factors have therefore in effect been removed from the calculated ER for lung cancer from welding.

Estimates of the impact of policy option two (Annex I) on ER varied amongst the key stakeholders interviewed. One EU level stakeholder thought that the achievable health benefits going forward might be lower now as there has already been a step change over the last 50 years in welding practices and worker protection. One national stakeholder predicted that policy option two (Annex I) would make no difference to excess risk. Another national stakeholder pointed out that although compliance was good in their country, improvements could be made in smaller companies and for part time welders. One EU stakeholder estimated that reductions of an additional 2-3% above the baseline could be made due to short term improvements in practice up to five years after the implementation of policy option two (Annex I). Another EU level stakeholder thought that the benefits of option two could be as high as a 5% reduction in exposure to welding fumes per year if the policy initiative increases awareness of the risks. If the latter two predictions turn out to be correct, this would mean that the below calculated benefits are an underestimate.

The above feedback from key stakeholders has been taken to validate the 1% reduction in ER as a result of policy option two (Annex I) which has been used in this study's calculations. This 1% reduction may even be a conservative estimate of the resulting improvements in practice depending upon the effectiveness of any associated communication campaigns (beyond the scope of this study), and resulting improvements in training, management and habits.

For the policy option two (Annex I) it is assumed that the measure increases the rate of ER reduction to 2% per year for the first five years[55,56] before returning to a reduction of 1% per year (as per the baseline). In year 40 this equates to an ER of 1.72% (Table 6-3). This step change assumption has been validated by one EU stakeholder's feedback as noted above that they predict improvements in practice in the short term, up to five years after implementation of policy option two (Annex I). Also, there was anecdotal evidence from one national stakeholder interviewed that there was a peak in their campaigning activities 10 years ago when they introduced a stricter OEL for welding fumes, but awareness of CMRs in welding fumes is only estimated to be ~20% now. However CMRs may not have been covered explicitly in the campaign. The study team assumes that only a proportion of workers will have improved RMMs as a result of the policy option. The change in ER over the study period under the baseline and policy option two (Annex I) are plotted below.

[55] The idea of applying a step change in improvements which then goes back to a baseline level has been validated in principle by an EU level stakeholder who agrees that in their opinion this would allow time for the market to adapt.

[56] This step change also seems to be corroborated anecdotally by a national stakeholder in the Netherlands who described a peak in awareness raising activities 10 years ago when the current tighter national OEL for welding fumes was introduced, but says that awareness of CMRs in welding fumes is now as low as 20%

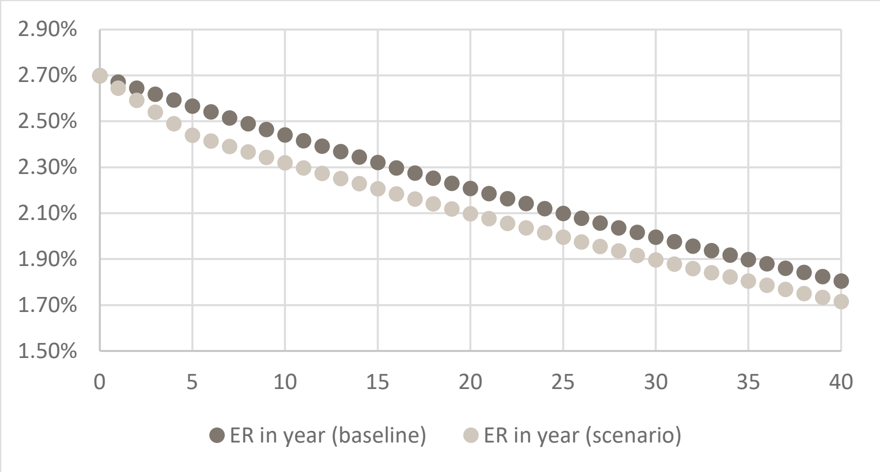

Table 6-3 Trend in excess risk over the last 40 years

Source: Study team

6.1.3.3.3 Onset of the disease

The key assumptions relating to the onset of disease used to model the benefits from reduced exposure to welding fumes+ are summarised below. For a detailed explanation of the model and the assumptions, please refer to the Methodology Note.

Table 6-4 Onset of disease: assumptions for lung cancer)

Onset of disease	Assumptions
MinEx	2 years
MaxEx	40 years
Latency	30 years

Source: Study team, see Methodological Note for more details.

6.1.3.3.4 The effects of the disease

The key assumptions relating to the effects of disease used to model the benefits from reduced exposure to welding fumes+ are summarised below. For a detailed explanation of the model and the assumptions, please refer to the methodology report.

Table 6-5 Effects of disease: assumptions for lung cancer

Effects of disease	Assumptions
Treatment period (years)	5 years
Years lived with disability/disease (YLD)	5 years
Fatality rates (MoR)	80%
Additional life expectancy at death	22 years
Disability weights (during treatment)	0.265
Disability weights (after treatment)	0.515

Source: Study team, see Methodological note for more details.

6.1.3.3.5 Unit costs used for the benefits

Table 6-6 Unit costs used for the benefits assessment

Category	Code	Item	Cost, €/case Lung cancer
Direct	Ch	Healthcare	€11,500
	Ci	Informal care	€3,000
	Ce	Cost for employers	€13,200
Indirect	Cp	Mortality – productivity loss due to mortality	€5,000
	Cl	Morbidity – lost working days due to morbidity	€1,000
Intangible	Cvsl	Approach 1 WTP: Value of statistical life	€4,710,000
	Cvsm	Approach 1 WTP: Value of cancer morbidity/value of statistical morbidity	€455,000
	Cdaly	Approach 2 DALY: Value of DALYs	€100,000

Source: Study team.

6.1.3.4 Avoided cases of ill health (cancer and non-cancer)

For policy option two (Annex I), assuming a 1% of reduction in excess risk in addition to current trends (see section 6.1.3.3.2) for five years leads to a reduction of cases compared with the baseline for 1.2 million welders shown in the Table 6-7. This 1% was validated by feedback from key stakeholders interviewed during June-July 2023 (as discussed in section 6.1.3.3.2); it may be on the conservative side according to two EU stakeholders, but it is an approximate median of the expected impact of policy option two (Annex I). The study team assumes a return to current 1% reduction after five years, because it does not seem reasonable to think that policy option two (Annex I) would have an impact indefinitely. This predicted step change was also validated by one of the EU stakeholders (section 6.1.3.3.2). In Table 6-8, the number of fatalities and non-fatalities are shown over 40 years per million welders.

Table 6-7 Cases of lung cancer over 40 years for the baseline and policy option two (Annex I)

Policy option	Lung cancer
Baseline	28,821
Policy option two (annex I)	27,473
Reduction due to policy option two (Annex I)	1,348

Source: Study team.

Table 6-8 Fatalities and non-fatalities from lung cancer over 40 years for the baseline and the policy option two (Annex 2),

Policy option	Fatalities	Non-fatalities
Baseline	23,057	5,764
Policy option two (Annex I)	21,978	5,495
Reduction due to policy option two (Annex I)	1,079	270

Source: Study team.

6.1.4 Benefits to workers and families

6.1.4.1 Avoided costs of ill health

The benefits that will be realised by exposed workers (full time workers in welding+ processes) and their families are first of all intangible benefits of reduced mortality rates. All the categories are presented in the table below.

Table 6-9 Benefits for workers and their families (avoided cost of ill health)

Stakeholder group	Costs	Method of summation
Workers/family	Ci, Cl, Cvsl, Cvcm, Cdaly	Method 1: CtotalWorker&Family=Ci+Cvsl+Cvcm Method 2: CtotalWorker&Family=Ci+Cl+Cdaly

Source: See Methodological note for more details.

The benefits of each policy option are summarised in Table 6-10. Method 1 relies on WTP values for morbidity, and Method 2 relies on monetised DALYs: the cost of ill-health under the baseline and the cost of ill-health with policy option 2 (Annex 1) are given and the difference between the two is the value of the benefit under policy option 2 (Annex 1). The workforce turnover is 5% per year and a static discount rate of 3% is used.

Table 6-10 Benefits to WORKERS & FAMILIES (M1 and M2) for the baseline and policy option two (Annex I), € over 40 years

Policy option	M1: Lung cancer	M2: Lung cancer
Baseline cost	€22,085,605,511	€11,293,363,707
Policy option two (Annex I)	€21,088,109,288	€10,783,299,012
Reduction due to policy option two (Annex I)	€997,496,222	€510,064,695

Source: Study team.

6.1.4.2 Other benefits to workers and families

No other benefits to workers and families are identified.

6.1.5 Benefits to employers

6.1.5.1 Avoided costs of ill health

The benefits (avoided costs of ill health relative to the baseline) accrued by employers are calculated using the method summarised below.

Table 6-11 Benefits to EMPLOYERS (avoided cost of ill health)

Stakeholder group	Costs	Method of summation
Employers	Ce, Cp	CtotalEmployer=Ce+0.8*Cp

Source: Study team.

The benefits of each policy option are summarised below in Table 6-12. The workforce turnover is 5% per year and a static discount rate of 3% is used.

Table 6-12 Benefits to EMPLOYERS for the baseline and policy option two (Annex I), € over 40 years

Policy option	Lung cancer
Baseline	€103,461,727
Policy option two (Annex I)	€98,788,879
Reduction due to policy option two (Annex I)	€4,672,848

Source: Study team.

6.1.5.2 Better company image, public perception

Generally, any improvements to workers' safety tends to help companies to create safer, better image, therefore, policy option two (Annex I) may improving the public's perception of welding and companies employing welders. However, some stakeholders were concerned that the association of CMRs with welding might lead to worries about safety and might stop people deciding to train to be welders, particularly women (EWA and IIW *pers comm*, February 2023).

A representative of the EWA said *"I believe it will stigmatise welding as a carcinogenic process,"* and went on to say that in their opinion, *"Including welding fumes+ in Annex 1 of CMRD, will generate high industry and societal cost, without any improvement of the welders' working conditions. Stamping welding as a carcinogenic activity in the EU will consequently trigger the export of workplaces, value generation and welding fumes to countries with lower OSH standards and regulation, which brings up an ethical question. Metal fabrication will lose competitiveness and innovation power in the EU, which is required for instance for important topics in Europe like the green energy transition, automotive electrification and hydrogen industry infrastructure."* (EWA, *pers comm,* April 2023).

6.1.5.3 Level playing field

Since policy option two (Annex I) is largely an awareness raising exercise of the presence of CMR substances in welding fumes+ and the need for worker protection under the CMRD, which enterprises should already be following across the EU, it is difficult to say whether policy option two (Annex I) will create a level playing field. In theory, enterprises across the EU should already be applying the CMRD, although in practice compliance may vary between enterprises and across the EU. Raising awareness could help some enterprises or Member States to better understand the importance of compliance and improve their worker's protection from exposure to welding fumes.

6.1.5.4 Harmonisation of policy across all Member States

Policy option two (Annex I) may help to improve awareness across Member States as discussed above and could provide a driver for improvements (section 6.1.5.3), however an EU Directive may be implemented in different ways by Member States. If policy option two (Annex I) is implemented, Member States may still have their own national OELs relating to other CMRs in welding fumes, welding fumes and generic dust, so there will still be variations between Member States.

6.1.6 Benefits to public administrations

6.1.6.1 Avoided costs of ill health

The benefits (avoided costs of ill health, relative to the baseline) for the public administrations are calculated using the method summarised Table 6-13. These costs include healthcare treatment costs, which assume that the costs are borne by the public administrations. These costs do not include informal care costs, which are costs for workers and families covered in section 6.1.4.

Table 6-13 Benefits to the PUBLIC ADMINISTRATIONS (avoided cost of ill health)

Stakeholder group	Costs	Method of summation
Governments	Ch, part of Cp (loss of tax revenue), part of Cl (loss of tax revenue)	CtotalGov=Ch+0.2(Cp+Cl) (Note 1)

Note 1: Assumes 20% tax.

Source: Study team.

The benefits of each policy option (relative to the baseline) are summarised in Table 6-14. The workforce turnover is 5% per year and a static discount rate of 3% is used.

Table 6-14 Benefits to the PUBLIC ADMINISTRATIONS for the baseline and policy option two (Annex I), € over 40 years

Policy option	Lung cancer
Baseline	363,173,133
Policy option two (Annex I)	346,770,421
Reduction due to policy option two (Annex I)	16,402,712

Source: Study team.

6.1.6.2 Other benefits to public administrations

No other benefits to public administrations are identified.

6.1.6.3 Avoided costs linked to the process of defining a national OEL

This does not apply to welding.

6.1.7 Benefits as expected by stakeholders

It has been difficult to quantify the potential impact of policy option two (Annex I). At the time of the questionnaire survey, policy option two (Annex I) had not been fully defined, so stakeholders were unable to comment properly on policy option two (Annex I). The baseline is not well understood in terms of existing awareness of CMRs in welding fumes and compliance with best practice for worker protection (and therefore exposure to welding fumes). The level of reduction in exposure to welding fumes as a result of policy option two (Annex I) is difficult to gauge as it is not a legal change, but an awareness raising exercise. Some key stakeholders (both EU and national stakeholders) surveyed more recently pointed out that the communication campaign associated with the policy change, and improvements to training programmes, will be critical in its success.

The most common response from the 40 representatives of Member State Authorities that responded to the questionnaire survey was that policy option two (Annex I) would have 'no impact' on costs for companies, costs for public authorities, competitiveness, SMEs, occupational health or the environment.

Feedback from the key stakeholders interviewed ranged from a neutral opinion that policy option two (Annex I) would make no difference at all to positive opinions. One national stakeholder believes that policy option two (Annex I) would make no difference at all, zero costs in terms of increased expenditure on RMMs and zero benefits. An EU level stakeholder is of the opinion that if policy option two (Annex I) was implemented, the resulting communication campaign could reduce exposure by an additional 2 or 3% per year above baseline improvements (with their estimate of baseline improvements being more than 1-2% per year due to the trends for automation and use of welding processes generating less fumes). Another EU level stakeholder agreed that the reduction in exposure levels, as a result of policy option two (Annex I) accompanied by a communication campaign and training, could be as high as 5% per year. A national stakeholder believes that the policy change may increase pressure on employers to ensure workers are using RMMs properly. Although unable to quantify the impact, the stakeholder believes that the goal for improvements from policy option two (Annex I) should be greater than 1% reduction in exposure to make it worthwhile.

One national stakeholder's opinion was that a change in EU policy will result in a change of policy globally, so costs (and benefits) will be incurred outside the EU as well as inside the EU. They explained that this is due to multinational companies applying policies across their operations.

The key stakeholders were asked to estimate the impact of policy option two (Annex I) in terms of improved practice in the use of RMMs (Table 6-15 and Source: interviews with key European stakeholders, June – July 2023.

Table 6-16). Although the range of estimates varied between the European versus the national perspective, the amount of change predicted was similar.

European stakeholders estimated that the policy change would result in an increase in the use of best practice RMMs by 5-10% by both welders at high risk and all welders, and a decrease in poor practice by 5-30% by welders at high risk. An EU level stakeholder estimated a small improvement as a result of policy option two (Annex I), and questioned how much the Annex I change would filter down to national enforcement. A different EU level stakeholder was more optimistic about the resulting improvement in practices and pointed out that their estimate was for the short term (up to five years after the policy was implemented), as policy option two (Annex I) would speed up the awareness of inappropriate welding practices, result in improvements in training, better management, improved habits. They predicted growth in expenditure on protection and extraction RMMs of a total of ~7% per year adding the baseline growth and growth from policy option two (Annex I) together. Another EU level stakeholder however, agrees with the study team's suggested 1% increase in sales of RMMs as a result of policy option two (Annex I). A third EU stakeholder was also optimistic that policy option two (Annex I) would improve best practice, if coupled with a communication strategy and training programme to raise awareness. This representative pointed out that a good opportunity for awareness raising would be during the European week on health and safety at work. One EU level stakeholder predicted that in the longer term (ten years) more improvements could be achieved for all welders, with 50% using best practice, 40% reasonable and only 10% poor practice RMMs. They hope to have an effect on promoting the safe use of welding through their education campaign which is being launched in 2024.

National stakeholders estimated that the policy change would result in an increase in the use of best practice RMMs by 5-15% by welders at high risk and 0-15% by all welders respectively. They also predicted that poor practice in RMMs would decrease by 5-30% in high risk welders and 5-20% in all welders. One national representative said that their estimate of improvements in practice was dependent upon improved training to raise awareness; in their experience welders do not always realise the risks as there is a time lag in the health effects experienced. Another national stakeholder abstained from estimating the improvement in use of RMMs, but they had already stated that baseline use of RMMs is good in their country (90% best practice). Another national stakeholder pointed out that welding fumes has already been addressed through a legal mechanism, and said it would be good to address welding fumes at the European level as well to ensure a level playing field.

Table 6-15 Estimates of the impact of policy option two (Annex I) on the access and use of RMMs, European perspective.

	Welders with high risk of exposure to CMRs (change from baseline estimate is provided in brackets)	**All welders (change from baseline estimate is provided in brackets)**
Best practice	35-65% (+5-10%)	30-35% (+5-10%)
Reasonable practice	35-40% (+0-5%)	35-50% (+0-10%)
Poor practice	10-30% (-5- -30%)	20-30% (-5- -20%)

Source: interviews with key European stakeholders, June – July 2023.

Table 6-16 Estimates of the impact of policy option two (Annex I) on the access and use of RMMs, national perspective.

	Welders with high risk of exposure to CMRs	**All welders**
Best practice	25-80% (+5-15%)	25-30% (+0-15%)
Reasonable practice	15-30% (+0-10%)	30-50% (+0-10%)
Poor practice	5-45% (-5- -25%)	20-45% (-0- -25%)

Source: interviews with key national stakeholders, June – July 2023.

Interestingly, when the study team asked the same question to stakeholders in their respective Member States about the predicted impact of policy option two (Annex I), none of the interviewees in France, the Netherlands or Slovenia thought there would be any resulting improvements in practice (Table 6-17). One of the stakeholders pointed out that even if policy option two (Annex I) does not represent a legal change, it would be important for welders suffering personal damages, enabling them to sue the employer and hold the employer accountable for the health and income damage; and this may also have a preventative effect.

Most of the interviewees in Croatia and Estonia thought policy option two (Annex I) would result in improvements in best or reasonable practice and reductions in poor practice. These findings should be caveated as the sample size was small. Opinions ranged quite widely even in this small sample of stakeholders so it is difficult to draw strong conclusions. Also, these are just estimates from individual representatives not based on comprehensive company surveys of levels of awareness or inspections to assess compliance with best practice in different Member States.

Table 6-17 Summary of Member State representatives' opinions on the impact of policy option two (Annex I).

Member State (number of interviewees)	Best practice	Reasonable practice	Poor practice
Croatia (3)	10-100% (+0-25%)	0-60% (-25% - +10%)	0-30% (-0-15%)
Estonia (4)	30-100% (+0-20%)	0-60% (-10 - +15%)	0-10% (0 - -10%)
France (1)	95% (0% change)	5% (0% change)	0% (0% change)
Netherlands (3)	20%[1] (0% change)	60%[1] (0% change)	20%[1] (0% change)
Slovenia (1)	80% (0% change)	18% (0% change)	2% (0% change)
Notes: [1]*Only one Netherlands representative felt able to estimate best practice, reasonable or poor practice. They added the comments that "These percentages will only change when the Labour Inspectorate starts carrying out more, and more effective, control and enforcement actions. The inspectorate is however understaffed. Even if inclusion in the Annex does not have direct legal effects, it will be of importance for welders who suffer personal damages. From the pension fund we know that* ***1 out of 5 welders does not make it to retirement age because of health problems***[57]*. Inclusion of welding fumes in the Annex can help to sue the employer and to hold him accountable for the health and income damage. This may also have a preventative effect."*			

Source: Short interviews with stakeholders June – July 2023.

6.1.8 Summary of the benefits of the measures

6.1.8.1 Benefits from avoided ill health

Please note that as the below benefits from avoided ill health only relate to the endpoint of lung cancer, they are an underestimation of the total benefits as exposure to welding fumes is associated with many other health effects (as discussed in section 2.1 and summarised in section 2.4.1).

[57] The study team note this is an interesting point, but there is no mention of confounding factors such as smoking or exposure to asbestos which in addition to welding fumes could have impacted on welders health. Therefore, this figure on its own cannot be taken to represent the risk to welders from exposure to welding fumes.

In addition, estimated number workers exposed to welding fumes is also likely to be an underestimate as it has not been possible to estimate the number of workers working in the vicinity of welding+ activities, who may also be exposed (bystanders).

The total Method 1 and Method 2 benefits are shown in Table 6-18: the workforce turnover is 5% per year and a static discount rate of 3% is used.

The total Method 1 and Method 2 benefits split by sector based upon the percentages of exposed workers (full time workers in welding+ processes) estimated in Table 3-43, are presented in Table 6-19.

Table 6-18 METHOD 1 and METHOD 2: Benefits from avoided ill health for the baseline and policy option two (Annex I) € over 40 years

Policy option	M1: Lung cancer	M2: Lung cancer
Baseline	€ 22,552,012,414	€ 11,759,998,567
Policy option two (Annex I)	€ 21,533,450,927	€ 11,228,858,312
Reduction due to policy option two (Annex I)	€ 1,018,561,485	€ 531,140,254

Source: Study team.

Table 6-19 METHOD 1 and METHOD 2: Benefits from avoided ill health by sector, for policy option two (Annex I) relative to € over 40 years

Sector	M1: Lung cancer	M2: Lung cancer
C24 Basic metals	€17,905,912	€9,337,238
C25 Fabricated metal products	€121,054,310	€63,125,121
C28 Machinery & equipment	€28,101,140	€14,653,653
C29 Motor vehicles, trailers & semi-trailers	€55,679,428	€29,034,659
C30 Manufacture of other transport equipment	€23,993,922	€12,511,898
C31 Furniture	€4,297,419	€2,240,937
C32 Other manufacturing	€3,861,310	€2,013,523
C33 Repair & installation of machinery & equipment	€58,876,230	€30,701,667
E38 Waste collection, treatment & disposal, materials recovery	€9,017,417	€4,702,233
F41 Construction of buildings	€195,057,455	€101,714,887
F42 Civil engineering	€34,170,051	€17,818,354
F43 Specialised construction activities	€368,536,296	€192,177,365
G45 Wholesale & retail trade & repair of motor vehicles & motorcycles	€98,010,595	€51,108,719
Total	**€1,018,561,485**	**€531,140,254**

Source: Study team.

6.1.8.2 Other benefits

There are no other benefits that can be quantified.

6.1.8.3 Benefits expected by stakeholders

The benefits of policy option two as estimated by key stakeholders were in many cases premised upon being accompanied by a good communication campaign and/or improvements to training (6.1.7).

6.1.8.4 Total benefits

Table 6-20 Overview of benefits of policy option two (Annex I) (for all provisions), € over 40 years

Description		M1	M2
Health and safety	Avoided costs for workers & families M1	€997,496,222	€510,064,695
	Avoided costs for employers	€4,672,848	
	Avoided costs for public administrations	€16,402,712	
Other benefits	Avoided costs for workers & families	None identified	None identified
	Avoided costs for employers	None are quantifiable	None are quantifiable
	Avoided costs for public administrations	None identified	None identified
	Total benefits	**€1,018,561,485**	**€531,140,254**

Note: Estimates are relative to the baseline as a whole (i.e. the impact of individual actions/obligations of the preferred option are aggregated together).

Source: Study team.

6.2 Costs of policy option two (Annex I)

As explained in section 5.4, the costs of policy option 2 equate to zero, because they relate to risk mitigation measures (RMMs) that companies should already be implementing.

For this study, the study team estimates costs and benefits of additional companies applying already required RMMs, assuming that policy option 2 would result in increased awareness, subject to the caveat in section 5.4.

This chapter comprises the following sections:

- Section 6.2.1: The cost framework;
- Section 6.2.2: Direct adjustment costs for companies;
- Section 6.2.3: Indirect costs for companies;
- Section 6.2.4: Costs for public administrations;
- Section 6.2.5: Impact of transitional periods on costs; and

- Section 6.2.6: Summary of the costs of the measures.

6.2.1 The cost framework

The costs assessed in this section, together with an indication of which stakeholders are likely to be affected, are presented in Table 6-21.

Table 6-21 Impact of costs on different stakeholders

Type of cost		Citizens	Con-sumers	Work-ers	Busi-ness	Public admin-istra-tions
Direct costs						
Direct compliance costs	Adjustment costs				✔	
	Administrative costs				✓	
	Charges					
Enforcement costs	Transposition					✔
	Information & monitoring					
	Inspections and sanctions					
	Complaint handling					
	Adjudication/litigation					
Hassle costs						
Indirect costs						
Indirect compliance costs				✓	✓	
Other indirect costs	Offsetting/substitution effects					
	Transaction costs					
	Opportunity costs				✓	
	Reduced competition					
	Reduced market access					
	Reduced investment/innovation				✓	
	Confusion & lack of clarity				✓	✓

Source: Study team on the basis of the Better Regulation Toolbox (EC, 2021c).

Notes: ✔= key cost, quantified where possible, ✓ = minor cost, covered qualitatively where possible

6.2.2 Direct adjustment costs to companies

6.2.2.1 Introduction

The estimates of the potential cost for companies as a result of the policy option are derived using two different methods. Although the costs will fall upon companies, neither of these estimates is based upon the number of companies with exposed welders. The two methods are:

- Bottom up - based upon the number of welders that are estimated to move from having poor or no risk management measures (RMMs) to adequate RMMs, multiplying this by the estimated additional average cost of these RMMs. This enables a cost for these RMMs to be estimated; and

- Top down - based upon the current market value of RMMs being used annually, an estimate of an assumed 1% increase in the sale of RMMs as a result of policy option two (Annex I) can be calculated.

These two methods are initially calculated for a single estimated value and then for a range of values. The range of values for each cost method is then compared with a range of values for both benefits estimates, Method 1 and Method 2, together with their benefit cost ratios, see section 6.3. These values were discussed with key stakeholder to assess their views.

6.2.2.2 Bottom-up approach based on welders using additional RMMs

The bottom-up cost model proposed by the study team, is based upon the cost of implementing the additional risk management measures that would be required to achieve improved RMMs for 1% of workers. The cost is estimated by multiplying together the following four factors:

- Percentage of exposed workers (full time workers in welding+ processes) whose RMMs are predicted to rise from none or poor to adequate as a result of policy option two (Annex I) (1%);
- 1,200,000 (exposed full time workers in welding+ processes);
- Percentage of the workers whose improved use of RMMs causes additional cost; and
- Average cost of the improvement in RMMs.

A percentage of 1% is taken for those improving their practice as a result of policy option two (Annex I), together with 1,200,000 full time workers in welding+ processes. The study team has assumed 1% because, whilst there is no data to inform this decision, it seems to be a reasonable starting point. Many organisations (such as larger enterprises) will already be applying best practice measures and will not need to change their practices. Some organisations will not be applying best practice measures, but of these some will ignore a policy change and only a small number will improve their practice (taken to represent 1% of full time workers in welding+ processes). During interviews with key stakeholders about the assumptions of this study (*pers comm*, June – July 2023), there was no disagreement with this estimate of 1% of welders improving their practice. This has been interpreted by the study team as validation of this 1% estimate. However, this could have been because stakeholders felt unable to provide a better estimate of this.

An EU stakeholder (*pers comm*, July 2023) estimates that the baseline growth in expenditure on protection and extraction RMMs will be more than 1% per year, more like ~4% per year, taking into account the effect of the EWA campaign being launched in 2024 and running for three or four years (until ~2027-2028). This could mean that the calculations here are an underestimate of the costs.

6.2.2.2.1 Average cost of the improvement in RMMs

Several scenarios of existing risk management measures that were likely to be in place for workers but inadequate, were established and for each scenario, the RMMs that are likely to be implemented were identified. These are shown in Table 6-22.

For each scenario, the additional costs per worker is calculated, discounted for 40 years, based on the following assumptions:

- Costs for equipment for individual workers are those used in the cost model used for the other OELs in this study;
- Costs include one-off and recurrent costs added together;
- Some costs are only available by size of company rather than by worker and in these cases the cost has been taken as 50% of the average cost to a small company; and
- An FFP1 mask costs approximately the same as an FFP2/FFP3 mask.

The study team acknowledge that in reality a combination of different types of RMMs is needed to reduce occupational exposure to welding fumes. However, the average costs seem to the study team reasonable over 40 years.

Table 6-22 Cost per worker of improving risk management measures to achieve adequate protection, all costs discounted over 40 years

RMMs before	RMMs after	Before cost	After cost	Difference
No organisational measures	Rework	€0	€12,500	€12,500
No ventilation system	General dilution ventilation	€0	€52,000	€52,000
No ventilation system	LEV/hood	€0	€27,000	€27,000
General dilution ventilation	LEV/hood	€0	€27,000	€27,000
FFP1 mask	FFP2/FFP3 mask	€5,300	€5,300	€0
FFP1 mask	welding helmet	€5,300	€38,000	€32,700
FFP2/FFP3 mask	welding helmet	€5,300	€38,000	€32,700
Approximate average additional cost of improved RMMs over 40 years				**€26,000**

Source: Study team

An EU level stakeholder pointed out that all welders should have a welding helmet with air supply as a minimum, high risk welders should have additional RMMs including general ventilation to protect bystanders. Costs were estimated to start at 12,000 euro per worker (without discounting over 40 years).

In response to the question of how much respondents thought the initial investment cost would be for policy option two (Annex I) from the online survey, 20 respondents in SMEs indicated a range of one-off costs and 19 indicated a range of recurrent costs. The ranges are wide, and they are the costs for the company and not one worker. The approximate cost for one-off costs was €9,000 and for recurrent costs was €3,500 per worker per year. These costs when discounted over 40 years are approximately €90,000. This is three times higher than the estimate in Table 6-22. However, the study team believes that this is likely to be an overestimation for three reasons:

- The ranges of costs are wide, for example, €10,000 - €100,000 and €100,00 - 1,000,000: the estimated values for these two ranges are €50,000 and €500,000 respectively, which could be significantly different to the real values[58];
- Policy option two (Annex I) had not been fully defined at the time of the questionnaire survey, so respondents would not have known the full implications of the policy option;
- The survey was not representative of all sectors undertaking welding, for example:
    - there was no response at all from the construction sector which is the biggest employer of welders – in this sector the cost of RMMs per worker could be lower as much of the work is undertaken outside and therefore no need for installation of general ventilation into a workshop, but RPE is still important and local ventilation or extraction is still necessary for example if working in a shelter; and
    - 55% of responses were from Germany – the level of worker protection is comparatively good in Germany already compared with other Member States, so the responses are unlikely to be representative of the whole of the EU27. In some cases, there are no further RMMs that can be added, but more advanced techniques are being developed for process optimisation to minimise welding fumes at source.

Approximately 40% of the total respondents did not know how much their initial investment would be, which reflects a lack of awareness of which RMMs would be required if policy option two (Annex I) was implemented.

6.2.2.2.2 Percentage of the workers whose RMMs will cause additional cost

The study team does not have data to estimate:

- the current status of workplaces where welding+ processes are undertaken; or
- how many workplaces would need to adopt additional measures.

The study team also notes the complex decision-making process involved in recommending RMMs for different welding+ processes, depending upon the base materials and working environment for example, non-confined spaces compared with closed systems or confined spaces, and permanent versus temporary working spaces.

58 Even with these issues, these values are better than having no data at all, and the study team has found in the past, that asking respondents to give a specific value results in no data at all, because respondents do not know. But many will indicate the range they think applies.

The study team assumes that across Europe, a proportion of workers already have optimal protection from using RMMs, but they are not using them; they do not need investment in additional RMMs and therefore no cost would be incurred from the policy option.

In view of the above points, the study team propose a simplified cost model assumption that European workers undertaking welding+ processes which alter their use of RMMs as a result of the policy option comprise the following two groups:

- Workers that already have optimal RMMs but do not currently use them but will as a result of the policy option use them or switch them on (no additional cost incurred). This group is assumed to be 50% of workers whose protection is improved due to the policy option; and

- Workers that need additional RMMs because they do not yet have optimal protection (at an average cost of €26,000 per worker); also assumed to be 50% of workers whose protection is improved due to the policy option.

The study team have assumed that improvements would be made for 1% of 1.2 million exposed welders across the EU27:

- 1% of 1,200,000 full time workers in welding+ processes moving from none or poor RMMs to adequate RMMs as a result of policy option two (Annex I), which equates to 12,000 workers[59];

- If all workers require additional RMMs, 12,000 workers x average cost of €26,000 = **€312,000,000** estimated additional cost discounted over 40 years.[60]; and

- If half of all workers need additional RMMs, then the estimated additional cost discounted over 40 years is **€156,000,000.**[61]

As noted earlier, the estimated cost per worker may be an underestimate and may be up to ten times greater, indicating an estimated cost of over 40 years of **€1,560,000,000.**

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[59] This 1% was validated during interviews with the six key stakeholders (*pers comm*, June-July 2023). O f the stakeholders who felt able to provide an estimate, one said 0% impact from P1, two said 1% was reasonable, and two said P2 would or should have a greater impact than 1% (possibly up to 5% improvement). Therefore 1% is approximately the median.

[60] The six key stakeholders were not asked specifically about the likely average cost per worker for additional RMMs, however one EU stakeholder volunteered that the cost per worker would be at least 12,000 Euro (not discounted) based on providing a helmet with air supply as a minimum and high risk welding should have general ventilation as well. T his is in the same ballpark as the 26,000 Euro used in these calculations, so is taken to validate this figure.

[61] Of the key stakeholders able to estimate the proportion of welders that would need to buy additional RMMs, three (two EU stakeholders, one national stakeholder) agreed that 50% of the welders changing their practice As a result of P2 was reasonable (although one caveated this saying this impact would likely be during the four years after P2 was implemented), one said greater than 50%, and one said 60-70%. This was taken to validate the estimated 50% of the welders changing their practice as a result of P2 that would need to buy additional RMMs which the study team used in the calculations presented here.

6.2.2.3 Top-down *approach based upon market values of RMMs*

A rough top-down estimate of the costs of risk management measures (RMMs) has been derived by considering data on likely current spend on RMMs. Here EWA statistics for electric welding record the value of the combined value of fumes extraction and individual protection as being 4.7% of the total market for electric welding equipment (confidential source, *pers comm* 2023). No value is available for the total welding market (i.e. including other types of welding/equipment) this 4.7% has been applied to a total estimated value of the European welding market of €2,012 million (Accuray, 2019). This was derived from the total European market of €2,861 million, see Table 6-23. Thus, the implied annual expenditure of on fumes extraction and personal protection in 2017 was of the order of €94.6 million per year.

Table 6-23 Europe welding equipment market by country, market forecast (2015-2027) (€ million)

Country	2017 (€ million)
Germany	675.2
U.K	783.9
Italy	517.8
France	489.2
Spain	134.5
Rest of Europe	260.3
Total	**2,861**
Total minus UK	2,077
Less 25% data for countries outside EU27	65
Total EU27	**2,012**

Source: Accuray, 2019

Accuray (2019) also suggests a compound annual growth rate (CAGR) for the European welding market of 4.5%. Assuming that the same overall 4.5% annual growth would apply to fumes extraction as well as all other components of the market, expenditure on 'fumes extraction and individual protection' can be calculated as around €123.1 million in year 0 (2023). This figure has since been validated by market statistics provided by the EWA, that current expenditure on protection and extraction RMMs is €120-135 million (EWA, pers comm, June 2023).

Assuming a continuous 4.5% increase in the market over the successive years under study (to year 40) provides modelled expenditure on fumes extraction and personal protection under the baseline to year 40. (A national stakeholder pointed out that the forecast growth in demand for welding in Europe could be greater than 4.5%; conversely an EU stakeholder said that growth is less than 4.5% due to a slight recession in welding in Poland and Romania caused by the Russian invasion of Ukraine.) An EU level stakeholder pointed out that sales of extraction and protection RMMs may not directly correlate with growth in welding due to automation increasing. Newer installations will have more automated processes with extraction built in, therefore the baseline growth in sales of RMMs may be less than predicted as the figure will exclude built in RMMs in these automated processes.

Under policy option two (Annex I), it has been assumed that expenditure on fumes extraction and personal protection is 1% higher than under the baseline for each of the years to year 40.

Discounting all costs (baseline and policy option two (Annex I)) at 3% provides the following present value (PV) estimates over 40 years:

- Total PV costs under the baseline: €6,717,698,645; and
- Total PV costs under the policy option two (Annex I): €6,784,875,631.

The total PV costs of increased measures to reduce exposure are the difference between the baseline and the policy option two (Annex I), providing an estimate of €67,176,985 or approximately **€67 million**.

6.2.2.4 Monitoring and administrative costs

No monitoring or administrative costs are expected.

6.2.2.5 Regulatory charges

No regulatory charges are expected.

6.2.2.6 Costs for companies by sector

The costs for companies by sector have been estimated based on the bottom up and top down approaches; Table 6-24 includes a comparison of the two sets of estimates.

6.2.2.7 Comparison of cost estimates

The two cost estimates by sector are provided in Table 6-24.

Bottom up costs (€26,000 PV per worker) in this study may have been underestimated by up to a magnitude of 10, compared with an extrapolated value from the survey respondents opinions on the costs (€270,000 PV per worker). However, as discussed in section 6.2.2.2.1, there are many possible reasons for this disparity. Typical respondents were larger SMEs that may be factoring in installation of expensive large scale general ventilation systems; a median was taken to represent the large range of figures provided by respondents which may have been inaccurate. It was hard for respondents to estimate the cost of policy option two (Annex I) as it had not been fully defined at the time of the questionnaire survey; and the survey responses were not representative of all sectors undertaking welding – there were no responses from the construction sector and more than half the responses were from Germany. There was also considerable uncertainty as one fifth of respondents did not know what the costs would be.

Table 6-24 Cost estimates by sector, € over 40 years

Sector	Bottom up costs based on welders using additional RMMs (€)	Top down cost based upon market values of RMMs (€)
C24 Basic metals	2,742,419	1,180,945
C25 Fabricated metal products	18,540,336	7,983,871
C28 Machinery & equipment	4,303,891	1,853,349
C29 Motor vehicles, trailers & semi-trailers	8,527,704	3,672,214
C30 Manufacture of other transport equipment	3,674,841	1,582,466
C31 Furniture	658,181	283,427
C32 Other manufacturing	591,387	254,664
C33 Repair & installation of machinery & equipment	9,017,317	3,883,052

Sector	Bottom up costs based on welders using additional RMMs (€)	Top down cost based upon market values of RMMs (€)
E38 Waste collection, treatment & disposal, materials recovery	1,381,082	594,724
F41 Construction of buildings	29,874,449	12,864,586
F42 Civil engineering	5,233,388	2,253,611
F43 Specialised construction activities	56,443,978	24,306,002
G45 Wholesale & retail trade & repair of motor vehicles & motorcycles	15,011,026	6,464,074
Total	**156,000,000**	**67,176,985**

Source: Study team.

6.2.3 Indirect costs for companies

Indirect costs reported by stakeholders (IIW, EWA, DVS and members of DVS, *pers comm*, March and April 2023) include:

- Impact on attracting the next generation and hiring workers if welding occupation is stigmatised as being carcinogenic; potentially larger impact on hiring women;
- Loss of research and development into new welding technologies, both at the national and EU level is predicted by the German welding community – Germany is a global leader in welding R&D. It is anticipated that governments will avoid funding R&D into a 'carcinogenic' activity; and
- Impact of moving welding activities out of the EU into poorer countries with lower occupational health and safety standards; which represents an ethical issue.

The study team have also identified another indirect cost for companies; that if an entry is made to Annex I this could lead to confusion and lack of clarity for companies, particularly among companies that understand the CMRD legislation. This confusion has already been observed in responses from stakeholders. It may be time consuming for dedicated staff to understand the change in the legal situation, or rather the fact that a change has been made which makes no legal difference.

6.2.4 Costs for public administrations

6.2.4.1 Costs of transposition

The assumption is that transposition of an entry of:

"work involving exposure to fumes from welding (and similar) processes containing substances that meet the criteria for CMR Category 1A or 1B set out in Annex I to the CLP Regulation"

into Annex I of the CMRD would cost each Member State approximately € 100,000. This assumption is based on the expectation that each Member State already has a section in their legislation where they list Annex I entries. The current lack of clarity around the implementation of a change to Annex I could make transposition more complicated than the cost of inserting an OEL where the Member State does not already have an OEL, which has previously been assumed to be €50,000 per Member State with no existing OEL. The lack of clarity relates to the other changes to the CMRD that would be required to ensure that the contradiction between adding welding fume into Annex I of the CMRD and article 2, described in section 5.4, which are not within the scope of this study.

It is also likely to be more complicated than introducing an OEL for the thirteen Member States that already have OELs or regulations relating to welding fume or generic dust (Table 11-16).

If Member States introduce multiple OELs at the same time, the costs of transposition may be less than if each OEL is introduced individually. However, the study team does not know which, if any, OELs will actually be introduced and when, and therefore this factor cannot be incorporated into the cost of transposition.

Table 6-25 Transposition costs for Member State public administrations

Member States: situation	Transposition cost per Member State (€)	Total cost across the EU 27 (€)
CMRD Annex I Entry	100,000	2,700,000

Source: Study team.

6.2.4.2 Enforcement costs

No additional enforcement costs are anticipated.

6.2.5 Impact of transitional periods on costs

No transitional periods are expected.

6.2.6 Summary of costs of the measures

Table 6-26 Overview of costs (for all provisions), € over 40 years

Description	Stakeholders affected	Policy option two (Annex I) (€)
Adjustment costs	Companies	67 – 156 million
Monitoring costs	Companies	N/A
Administrative costs	Companies	N/A
Administrative costs	Public authorities	N/A
Transposition costs	Public authorities	2.7 million
Total across all sectors /companies /stakeholders		**69.7 – 158.7 million**

Source: Study team.

6.3 Benefit cost ratios

The costs and benefits were estimated for a range of values as follows:

- Benefits (M1 and M2): increase in excess risk of 0.1, 0.5, 1, 2, 5 and 10%

- Costs, bottom up, increase in spend on RMMs due to reduction of welders being exposed of 0.1, 0.5, 1, 2, 5 and 10%

- Costs, top down, increase of market value of RMMs of 0.1, 0.5, 1, 2, 5 and 10%

As there is no means of linking a cost scenario to a benefit scenario, all of the possible benefit to cost ratios are estimated and shown in the tables below. As in this report benefits always exceed costs, these ratios are easier to understand as benefit to cost ratios which appear as whole numbers. In the below tables of benefit to cost ratio (Table 626 to Table 6-32), the figures in the middle of the range in each table have been presented in red to indicate what the study team believes to represent the most likely range of ratios. In each case, this most likely range of benefit to cost ratios lies between 0.5 – 2.0% benefit and 0.5-2% cost for policy option two (Annex I) compared with the baseline, and excludes extreme benefits or costs which are less likely to occur in reality in the study team's view.

Because the bottom up approach to costs is also highly dependent on the percentage of workers who will need additional RMMs (as opposed to those that simply need to use the RMMs that they already have) which is difficult to estimate, two further sets of cost benefit analysis are provided for the benefits (M1) versus bottom up costs. These show the percentage of welders needing additional RMMs of 25% and 75%, enabling a comparison with the initial estimate of 50%.

Some of the six key stakeholders interviewed (section 6.1.2) preferred the top down approach and others preferred the bottom up approach. When asked about the proportion of welders that would improve their practice as a result of policy option two (Annex I) and buy additional RMMs most of them (4/6) estimated that the ratio would be 50% or higher up to 75%, this could mean that this study's estimate of costs (based on 50%) is an underestimate. However, one national stakeholder said that 0% of welders would change their practice as a result of policy option two (Annex I). The remaining national stakeholder said that welders are required to use RMMs in their country and employers are fined if not (implying that there was no need for additional RMMs); but policy option two (Annex I) may result in pressure on organisations to ensure that employees use RMMs properly. One EU stakeholder and one national stakeholder thought that the benefits of policy option two (Annex I) would be greater than a 1% reduction in ER, and estimated the resulting improvement to be between 2-3% or as high as 5% above the baseline respectively due to the associated awareness raising of the risks of exposure to welding fumes.

The study team believes that the most likely health benefits are within the range of 0.5 – 2% due to the reduction in exposure to welding fumes and the most likely increase in costs for RMMs bought are within the range of 0.5 – 2% as a result of policy option two (Annex I). Within this range, the benefit cost ratios in all cases are within a relatively small range (for BCRs) of 0.9 – 59.5.

A comparison of the ranges in Table 6-33 reveals no extreme differences when comparing the effect of M1 vs M2 health benefits approaches; top-down vs bottom-up approach to calculating costs; or indeed between the proportion of welders buying RMMs (25-75%). That said, the M1 health benefits approach gave slightly higher BCR figures than the M2 health benefits approach; and the top down costs approach gave slightly higher BCR figures than the bottom up approach to calculating costs.

Table 6-27 Benefit cost ratios: Benefits M1 v Costs top down based on RMM market value (50% of welders buying additional RMMs)

Increase in rate of change in excess risk per year post year 0 and benefits from avoided ill health (Method 1)		% increase in RMM market value relative to baseline and total PV costs of increased measures to reduce exposure					
		0.1%	0.5%	1%	2%	5%	10%
		€6,717,699	€33,588,493	€67,176,986	€134,353,973	€335,884,932	€671,769,865
0.1%	€103,634,745	15.4	3.1	1.5	0.8	0.3	0.2
0.5%	€514,201,757	76.5	15.3	7.7	3.8	1.5	0.8
1%	€1,018,561,487	151.6	30.3	15.2	7.6	3.0	1.5
2%	€1,998,335,250	297.5	59.5	29.7	14.9	5.9	3.0
5%	€4,716,277,889	702.1	140.4	70.2	35.1	14.0	7.0
10%	€8,572,939,831	1,276.2	255.2	127.6	63.8	25.5	12.8

Source: Study team

Table 6-28 Benefit cost ratios: Benefits M2 v Costs top down based on RMM market value (50% of welders buying additional RMMs)

Increase in rate of change in excess risk per year post year 0 and benefits from avoided ill health (Method 2)		Increase in RMM market value relative to baseline and total PV costs of increased measures to reduce exposure					
		0.1%	0.5%	1%	2%	5%	10%
		€6,717,699	€33,588,493	€67,176,986	€134,353,973	€335,884,932	€671,769,865
0.1%	€54,041,494	8.0	1.6	0.8	0.4	0.2	0.1
0.5%	€268,136,245	39.9	8.0	4.0	2.0	0.8	0.4
1%	€531,140,255	79.1	15.8	7.9	4.0	1.6	0.8
2%	€1,042,054,219	155.1	31.0	15.5	7.8	3.1	1.6
5%	€2,459,355,741	366.1	73.2	36.6	18.3	7.3	3.7
10%	€4,470,455,154	665.5	133.1	66.5	33.3	13.3	6.7

Source: Study team.

Table 6-29 Benefit cost ratios: Benefits M1 v Costs bottom up based on exposed workers (full time welders) and use of RMMs (50% of welders buying additional RMMs)

Increase in rate of change in excess risk per year post year 0 and benefits from avoided ill health (Method 1)		Increase in RMM expenditure based on workers removed from exposure relative to baseline and total PV costs of increased measures to reduce exposure					
		0.1%	0.5%	1%	2%	5%	10%
		€15,600,000	€78,000,000	€156,000,000	€312,000,000	€780,000,000	€1,560,000,000
0.1%	€103,634,745	6.6	1.3	0.7	0.3	0.1	0.1
0.5%	€514,201,757	33.0	6.6	3.3	1.6	0.7	0.3
1%	€1,018,561,487	65.3	13.1	6.5	3.3	1.3	0.7
2%	€1,998,335,250	128.1	25.6	12.8	6.4	2.6	1.3
5%	€4,716,277,889	302.3	60.5	30.2	15.1	6.0	3.0
10%	€8,572,939,831	549.5	109.9	55.0	27.5	11.0	5.5

Source: Study team.

Table 6-30 Benefit cost ratios: Benefits M2 v Costs bottom up based on exposed workers (full time welders) and use of RMMs (50% of welders needing additional RMMs)

Increase in rate of change in excess risk per year post year 0 and benefits from avoided ill health (Method 2)		Increase in RMM expenditure based on workers removed from exposure relative to baseline and total PV costs of increased measures to reduce exposure					
		0.1%	0.5%	1%	2%	5%	10%
		€15,600,000	€78,000,000	€156,000,000	€312,000,000	€780,000,000	€1,560,000,000
0.1%	€54,041,494	3.5	0.7	0.3	0.2	0.1	0.0
0.5%	€268,136,245	17.2	3.4	1.7	0.9	0.3	0.2
1%	€531,140,255	34.0	6.8	3.4	1.7	0.7	0.3
2%	€1,042,054,219	66.8	13.4	6.7	3.3	1.3	0.7
5%	€2,459,355,741	157.7	31.5	15.8	7.9	3.2	1.6
10%	€4,470,455,154	286.6	57.3	28.7	14.3	5.7	2.9

Source: Study team.

Table 6-31 Benefit cost ratios: Benefits M1 v Costs bottom up based on exposed workers (full time welders) and use of RMMs (25% of welders needing additional RMMs)-

Increase in rate of change in excess risk per year post year 0 and benefits from avoided ill health (Method 1)		Increase in RMM expenditure based on workers removed from exposure relative to baseline and total PV costs of increased measures to reduce exposure					
		0.1%	0.5%	1%	2%	5%	10%
		€7,800,000	€39,000,000	€78,000,000	€156,000,000	€390,000,000	€780,000,000
0.1%	€103,634,745	13.3	2.7	1.3	0.7	0.3	0.1
0.5%	€514,201,757	65.9	13.2	6.6	3.3	1.3	0.7
1%	€1,018,561,487	130.6	26.1	13.1	6.5	2.6	1.3
2%	€1,998,335,250	256.2	51.2	25.6	12.8	5.1	2.6
5%	€4,716,277,889	604.7	120.9	60.5	30.2	12.1	6.0
10%	€8,572,939,831	1,099.1	219.8	109.9	55.0	22.0	11.0

Source: Study team.

Table 6-32 Benefit cost ratios: Benefits M1 v Costs bottom up based on exposed workers (full time welders) and use of RMMs (75% of welders needing additional RMMs)

Increase in rate of change in excess risk per year post year 0 and benefits from avoided ill health (Method 1)		Increase in RMM expenditure based on workers removed from exposure relative to baseline and total PV costs of increased measures to reduce exposure					
		0.1%	0.5%	1%	2%	5%	10%
		€23,400,000	€117,000,000	€234,000,000	€468,000,000	€1,170,000,000	€2,340,000,000
0.1%	€103,634,745	4.4	0.9	0.4	0.2	0.1	0.0
0.5%	€514,201,757	22.0	4.4	2.2	1.1	0.4	0.2
1%	€1,018,561,487	43.5	8.7	4.4	2.2	0.9	0.4
2%	€1,998,335,250	85.4	17.1	8.5	4.3	1.7	0.9
5%	€4,716,277,889	201.6	40.3	20.2	10.1	4.0	2.0
10%	€8,572,939,831	366.4	73.3	36.6	18.3	7.3	3.7

Source: Study team.

Table 6-33 Meta sensitivity analysis comparison of BCR ranges as a result of different approaches to calculating costs, benefits and change in practice.-

Health benefits approach	Cost calculation approach	Welders buying RMMs (% of those changing their practice)	Most likely range of BCRs*	Full range of BCRs
M1	Top down	50%	3.8-59.5	0.2-1,276.2
M2	Top down	50%	2.0-31.0	0.1-665.5
M1	Bottom up	50%	1.6-25.6	0.1-549.5
M2	Bottom up	50%	0.9-13.4	0.0-286.6
M1	Bottom up	25%	3.3-51.2	0.1-1099.1
M1	Bottom up	50%	1.6-25.6	0.0-286.6
M1	Bottom up	75%	1.1-17.1	0.0-366.4

Source: study team

*Notes: * Range given is for 0.5-2% increase in RMM cost & 0.5-2% reduction in risk (benefit).*

The smallest most likely BCR ranges were calculated for:

- M2 health benefits approach with bottom up costs approach for 50% of the welders changing their practice buying RMMs (BCR range of 0.9-13.4); and
- M1 health benefits approach with bottom up costs approach for 75% of the welders changing their practice buying RMMs (BCR range of 1.1-17.1).

The largest most likely BCR ranges were calculated for:

- M1 health benefits approach with top down costs approach for 50% of the welders changing their practice buying RMMs (BCR range of 3.8-59.5); and
- M1 health benefits approach with bottom up costs approach for 25% of the welders changing their practice buying RMMs (BCR range of 3.3–51.2).

Two the key stakeholders interviewed thought that the proportion of welders that would need to buy additional RMMs as a result of policy option two (Annex I) is likely to be more than 50%, either estimating a percentage greater than 50% (exact percentage unspecified) or 60-70% or welders (one EU level stakeholder and one national stakeholder, respectively *pers comm*, July 2023). However, one national stakeholder thought that no welders would change their practice as a result of policy option two (Annex I), although their view independently of the CMRD was that 50% of welders need to improve their use of RMMs (national stakeholder, *pers* comm, July 2023). Another national stakeholder said that due to enforcement actions, in principle in their country RMMs are already being used (although this is more difficult to enforce in smaller companies), but policy option two (Annex I) could result in employers ensuring that their workers are using RMMs correctly (national stakeholder, *pers comm*, July 2023). This feedback is taken on average across the EU, to validate the assumption used in this study's calculations of costs, that 50% of welders would need to buy additional RMMs.

6.4 Market effects

6.4.1 Overall impact

Overall, market impacts (in terms of the effect on the single market, R&D, competitiveness of EU businesses and employment) are strongly influenced by the extent to which costs are incurred to comply with policy option two (Annex I).

The likely costs that would be incurred by policy option two (Annex I) as considered in this study are set out in section 6 above. However, it was not possible to undertake modelling to predict the likely number of companies (or business units) that would discontinue operations. In extreme cases, companies may be forced out of business if they are unable to implement policy option two (Annex I) at a cost that maintains profitability, but this is not anticipated.

Estimates of adjustment costs incurred by sector have been provided in Table 6-24.

The rest of the section provides an analysis of the likely impacts arising from the key drivers of competition in both the EU and overseas markets.

6.4.2 Research and innovation

Research and development (R&D) are key activities in an industry's capacity to develop new products and produce existing ones more efficiently and sustainably, in a way that protects the safety of workers. The ability of the different sectors to engage in R&D activities is likely to be affected by:

- The availability of financial resources to invest in R&D;
- The availability of human resources to conduct R&D activities; and
- The regulatory environment and whether it is conducive to invest in R&D activities.

Table 6-34 provides estimates of average R&D expenditures for small, medium and large companies in the sectors with workers exposed to welding fumes+, based on Eurostat data. Clearly significant investment is being made in large enterprises across the different sectors, in particular in the automotive manufacturing industry (C29) and the manufacturing of machinery and equipment (C28). Funding for R&D may be diverted into technical and operational measures, and soft measures such as training and education if policy option two (Annex I) is adopted.

In addition, the German welding community (represented by the DVS) predicts that if governments perceive all 'welding' as a carcinogenic activity, then governments will avoid funding R&D both at the national and EU level (*pers comm,* DVS members, April 2023). Germany is a global leader in welding R&D and has been developing innovative process optimisation techniques which minimise welding fumes. This emphasises the need for clear communication of policy option two (Annex I), should it be adopted, that the focus is on welding fumes containing CMR substances not blanket regulation of all welding activities.

Table 6-34 Average annual R&D expenditure per company, by company size, by sector (in million €)

Sector	Average annual R&D expenditure per company (€)		
	Small	Medium	Large
C24 Manufacture of basic metals	€49	€155	€779
C25 Manufacture of fabricated metal products (excl machinery & equipment)	€880	€864	€1,100
C26 Manufacture of computer, electronic & optical products)	€374	€552	€2,527
C28 Manufacture of machinery & equipment	€824	€2,022	€12,712
C29 Manufacture of motor vehicles, trailers and semi-trailers	€515	€1,171	€30,104
C30 Manufacture of other transport equipment	€346	€590	€6,749
C31 Manufacture of furniture	€97	€75	€102
C32 Other manufacturing	€825	€703	€944
C33 Repair and installation of machinery and equipment	€479	€236	€378
E38 Waste collection, treatment & disposal, materials recovery	€95	€70	€62
F41 Construction of buildings	€612	€196	€231
F42 Civil engineering	€187	€192	€661
F43 Specialised construction activities	€786	€141	€113
G45 Wholesale & retail trade & repair of motor vehicles & motorcycles	€5,501	€973	€230

Source: Eurostat (2020)

Note: 1. In most cases, R&D expenditure is not available at the level of the specific subsector in Eurostat. In these cases, the next level where data was available has been taken as a proxy for the sub-sector generating welding fumes, and so may be under- or over-estimated.

2. Data gaps exist for some Member States. In these cases, the most recent data was used.

3. Data in Eurostat is not presented by company size. It is assumed that share of R&D expenditure between different sized companies is the same as the share for turnover (based on 2018 data).

Adjustment costs (bottom up and top down) resulting from policy option two (Annex I) as a percentage of R&D costs by sector and across small, medium and large enterprises have not been calculated as the study team believes the resulting tables would be misleading because the estimated costs by sector and company size can only be based upon the total cost apportioned to the number of workers in small, medium and large companies in these sectors. There are no data available indicating which sectors or size of company are more or less compliant and might bear greater or smaller costs due to differing use of CMRs or RMMs.

Some sectors (for example, F41 Construction and G45 Repair of motor vehicles) do lots of manual welding and little R&D so would probably have a high percentage cost/R&D implying that policy option two (Annex I) would have a large impact on R&D when there is little R&D investment made anyway.

Conversely some sectors that do relatively little manual welding but invest heavily in R&D would probably have a small percentage cost/R&D implying that policy option two (Annex I) would have a small impact on R&D but this may not be the case (for example C29 Manufacture of motor vehicles).

Therefore, the study team is unable to predict whether R&D funding would be diverted to cover adjustment costs, and/or whether R&D funding would be increased to fund innovative techniques for example to reduce welding fumes at source by optimising welding processes.

6.4.3 Single market

6.4.3.1 Competition

Table 6-35 below includes the initial screening of impacts on competition to focus the analysis on those impacts likely to be the most significant, which are explored in the following paragraphs.

Table 6-35 Screening of competition impacts of policy option two (Annex I)

Impacts	Key questions	Yes/No
Existing firms	Additional costs?	Yes
	Scale of costs significant?	Don't know
	Old firms affected more than new?	Possibly
	Location influences?	Member States with better existing regulation of welding fumes and compliance with these regulations will need fewer improvements.
	Some firms will exit the market?	Don't know, unlikely
	Are competitors limited in growth potential?	Unknown, unlikely
	Increased collusion likely?	Don't know, unlikely
New entrants	Restrict entry?	Possibly
Prices	Increased prices for consumers	Potentially
Non-price impacts	Product quality/variety affected?	Potentially – better compliance with the CMRD may result in less use of CMR substances in welding (substitution with other materials), reducing the variety of welding products in the EU.
	Impact on innovation	Potentially, policy option two (Annex I) could result in more innovative practices to reduce worker exposure to welding fumes; or conversely if 'welding' is considered carcinogenic then governments may be less willing to fund innovation relating to welding.
Upstream and downstream market	Are vertically integrated companies more or less than non-integrated ones?	Larger, vertically integrated companies will have more direct control over worker protection than non-integrated companies and, therefore, they are more likely to already be in compliance with the CMRD. Smaller, non-integrated companies may find it harder and more costly to

Impacts	Key questions	Yes/No
		implement policy option two, and without enforcement may be tempted to avoid changes in their practices.
	Encouragement for greater integration and market barriers?	Unknown
	Impact on bargaining power of buyers or suppliers?	As there is growing awareness of working conditions in the supply chain (as part of the provenance of products), improvements in worker protection could potentially improve the bargaining power of suppliers; they could use this as a competitive advantage over suppliers in other parts of the world with weaker worker protection, despite possible increases in product prices.

Source: Study team.

6.4.3.1.1 Existing firms

In some cases, compliance with policy option two (Annex I) may be more difficult for older facilities, as space is often more limited in older factory designs, making it more challenging or even impossible to install space-consuming RMM such as ventilation systems needed for compliance. This study does not have access to any statistics on the age of facilities used by the welding community.

6.4.3.1.2 Firms leaving the market (discontinuations)

It was not possible to model predicted discontinuations under policy option two (Annex I).

6.4.3.1.3 New entrants

The resulting improved awareness of the need to protect workers from CMR in welding fumes+, from policy option two (Annex I), could make new businesses more aware of the need for compliance and the associated costs of compliance. One-off (capital) costs of installing general ventilation and/or local exhaust ventilation systems and organisational costs could represent deterrents to new entrants. The extent and distribution of this deterrent effect across sectors or across small, medium and large enterprises is impossible to ascertain from the available information.

6.4.3.2 Consumers

As summarised in Table 3-55, most enterprises undertaking welding+ activities are small or medium sized enterprises.

Larger enterprises are likely to be able to absorb the increase in compliance costs of policy option two (Annex I) without passing on this cost to consumers. Smaller enterprises may not be able to absorb the increase in compliance costs and might pass this cost on to consumers in the form of price increases.

Enterprises which cannot pass on price increases to consumers may pursue compensating the compliance cost by reducing the product quality or reducing the product variety. At the same time, such efforts can be risky, as a high degree of competition can provide a lot of market power to consumers. It is not possible to assess in specific detail which sectors are likely to pursue such efforts, as it would require primary data collection on consumer preference and their specific market power across sectors, which lies beyond the scope of this study.

6.4.3.3 Internal market

Improved awareness of the need to protect workers from CMR in welding fumes could lead to an increased harmonisation of worker protection across Europe, which would improve the level playing field for enterprises across the internal market, as the gap between the lowest and highest worker exposure levels would decrease. Member States where welding is a significant activity, but where worker protection is currently low would have a bigger compliance gap to close. Countries where welding is a significant activity (based on sales of welding consumables, EWA 2017 data from a confidential source, *pers comm*, January 2023), without OELs for welding fumes (Table 11-16), and therefore potentially less awareness of exposure to welding fumes include Hungary, Italy, Poland, Portugal and Romania. This is based on the assumption that policy option two (Annex I) is well communicated to enterprises, to provide them with the information needed to understand what they need to do to protect workers in different contexts; and that the requirements are complied with by enterprises across the EU.

However, differences in national transposition of the CMRD, enforcement activities and other legislation impacting workers' exposure to welding fumes may potentially compromise the level playing field conditions.

18 MSAs did not note that policy option two (Annex I) would help create a level playing field. Four MSAs (out of 22 surveyed) noted that policy option two (Annex I) would benefit companies by creating a level playing field. Three of these 4 MSAs also thought that companies would make savings, as a result of policy option two (Annex I), if they have multiple locations in different Member States with different regulations or OELs.

6.4.4 Competitiveness of EU businesses

The introduction of policy option two (Annex I) and resulting improved awareness of the requirements of the CMRD might have an impact on companies' cost competitiveness which will be more significant in Member States, enterprises and/or sectors with lower existing compliance. As indicated previously, the increase in costs due to having to implement more or better RMMs represents the burden of compliance on companies. This would make those companies incurring these costs less competitive where they are competing with companies not generating welding fumes and with any companies already compliant with the CMRD. For example companies that are able to automate (and enclose) all welding activities could be more competitive than companies with manual welding for example in bespoke automotive manufacturing.

There is a potential impact from policy option two (Annex I) in terms of the perception of the safety of welding as an occupation. If welding+ activities become stigmatised as being 'carcinogenic' (as some stakeholders are concerned would happen), this could deter workers from becoming welders in the EU, which would have a negative impact on the competitiveness of EU businesses which are already experiencing a skills shortage of welders. On the other hand, if regulation is perceived to have been strengthened by policy option two (Annex I), workers could be reassured that welding is a well-regulated occupation and feel confident in becoming welders. Suppliers of products or services in which workers are well protected could gain a competitive advantage over suppliers in countries without this worker protection. Which of these viewpoints dominates could in the end be largely down to the communication of the proposed policy change.

6.4.4.1 Sectors affected

Policy option two (Annex I) is likely to have a negligible impact on the various European sectors undertaking welding+ activities in terms of international competition, as explained below. There is insufficient data to calculate the Herfindahl–Hirschman Index (HHI) to provide an indicator of the level of market concentration within different sectors.

6.4.4.2 SME competitiveness

In general, large enterprises are more likely to have stronger health and safety practices in place already, including using RMMs (*pers comm*, interviews with key stakeholders, June 2023). Small enterprises are less likely to have sufficient RMMs in place, and therefore may need to invest in additional RMMs to comply with policy option two (Annex I). Achieving compliance also requires administrative effort, and small companies may need to divert resources to achieve compliance. In combination, this could put smaller enterprises at a competitive disadvantage compared with larger enterprises.

6.4.4.3 Cost competitiveness

European enterprises may need to increase their costs to cover the increased costs of compliance with policy option two (Annex I), in particular smaller enterprises may need to do this, and enterprises in Member States with less enforcement of the CMRD (study team, based on anecdotal evidence, and interviews with six key stakeholders June – July 2023).

6.4.4.4 Capacity to innovate

European enterprises may need to divert funding from research and innovation towards investment in RMMs to comply with policy option two (Annex I), which could reduce their capacity to innovate. Conversely, improved awareness of the need to reduce worker exposure to welding fumes could result in more investment in innovative practices to optimise welding processes for example REarc (Section 3.7). It is impossible to quantify the change in capacity to innovate due to the lack of information.

6.4.4.5 International competitiveness

Some countries already regulate worker exposure to welding fumes by implementing OELs (Table 11-16). It could be assumed therefore that implementing policy option two (Annex I) would have a low impact on competition between EU businesses and those countries with OELs for welding fumes: Australia, Canada (Quebec), China, India, Norway, South Korea. The same assumption could be applied to Japan where employers of welders are required to measure the concentration of manganese in the air and select the respirator with a sufficient protection factor for manganese. However, compliance with these regulations will depend on how well they are enforced in these countries, with some countries putting more resources into enforcement than others.

The regulatory regime for welding is not known in Russia or the Philippines however and these two countries are in competition with Europe for welding, in particular for the aeronautical and metal fabrication sectors respectively. Therefore, if the regulatory regime for welding fumes is lacking in Russia or the Philippines, these two countries could gain a competitive advantage if policy option two (Annex I) is implemented, in the aeronautical and metal fabrication sectors respectively. However, this will be countered by higher transport costs for products made in the Philippines and European Member States boycotting the purchase of products from Russia due to the current conflict between Russia and Ukraine.

The EWA (*pers comm,* April 2023) is concerned that if policy option two (Annex I) creates the stereotype that all 'welding+' are carcinogenic activities, this could result in the export of workplaces, value generation and welding fumes to countries with lower OSH standards and regulation. However, this concern and potential impact could be addressed through clear communication that policy option two (Annex I) focuses on CMR substances present in welding fumes+.

International competition is probably fairly low across many of the sectors undertaking welding+ activities as welding often needs to be undertaken on site rather than in a factory, which negates competition from international enterprises. For example, welding activities for construction, civil engineering, and installation and repair of equipment across sectors needs to be undertaken on site. Whereas metal products manufactured in factories could, in theory, more easily be exported outside of the EU.

The European metal product manufacturing industry is in competition with the Asia-Pacific region[62]. However, China, South Korea and India already have OELs in place for welding fumes. For India the OEL is binding, but this study was unable to ascertain whether for China or South Korea the limit value is indicative or binding. In Japan the regulatory regime is different and requires sufficient protection for exposure to manganese as an indicator of welding fumes (Table 11-16). It is difficult to compare these regimes directly as they require measurement of different factors. However, as welding fumes is regulated in some way in all of these countries, policy option two (Annex I) should have a negligible impact on competition with them. Although one of the key stakeholders predict that metal fabrication in particular will lose competitiveness and innovation power in the EU if policy option two (Annex I) is implemented (key stakeholder, pers comm by email, April 2023), the study team cannot find justification for this based on the above discussion.

Europe's automotive manufacturing industry is also in competition with Asia; with China, Japan and South Korea being strong players[63]. However, as these competitor countries already regulate welding fumes exposure (Table 11-16), then policy option two (Annex I) is unlikely to have a large impact on international competition. In addition, multinational automotive manufacturing companies have told the study team that they would apply new European policies throughout their global operations to create a level playing field of worker safety (*pers comm*, BMW and Audi, April 2023). In the global market, this might create a driver for non-European companies to improve their worker's safety to the same level.

Other sectors where there may be an impact on international competition could be the more marginal sectors undertaking welding activities. For example, an estimated 120,000 people are employed by shipyards across the whole of the EU[64], only a percentage of these are welders, and there is strong competition for ship building with East Asia (China, South Korea, Japan). However as already noted above, as these competitor countries regulate welding fumes exposure, then policy option two (Annex I) is unlikely to have a large impact on competition.

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[62] Allied Market Research (2022) Metal & Metal Manufactured Products Market Outlook – 2030. https://www.alliedmarketresearch.com/metal-and-metal-manufactured-products-market#:~:text=The%20global%20metal%20%26%20metal%20manufactured%20products%20market,a%20CAGR%20of%205.2%25%20from%202021%20to%202030.

[63] Statista (2023) Automotive industry worldwide – statistics and facts. https://www.statista.com/topics/1487/automotive-industry/#topicOverview

[64] EC (2023) Importance of the shipbuilding sector. https://single-market-economy.ec.europa.eu/sectors/maritime-industries/shipbuilding-sector_en

There may also be competition in specialised sectors such as the aeronautics industry, although the EU is a world leader in the production of civil aircraft[65]. The large aeronautical enterprises are located in only a few Member States (France, Germany, Italy and Spain in particular) but the industry has an extended supply chain with SMEs throughout the EU. The European aeronautical industry is in competition with the US, China, the UK, Russia, Canada, Japan and India. Most of these countries regulate worker exposure to welding fumes, either through OSH regulations (US, UK), or via OELs, apart from Russia and mainland Canada; this implies that there would be no or only minimal impact of policy option two (Annex I) on international competition in the aeronautical industry. Whether Russia regulates exposure to welding fumes is unknown (an international supplier of extraction equipment was contacted but was not able to comment on the Russian regulatory system).

6.4.5 *Employment*

The company discontinuations and any related unemployment as a result of policy option two (Annex I) cannot be calculated, as noted above (section 6.4.3.1.2), however, they are expected to be minimal.

6.4.6 *Summary of market effects*

It was not possible to model the likely number of companies that would discontinue operations as a result of policy option two (Annex I), but it is unlikely that many companies would close. Company funding for R&D may be diverted into technical and operational measures and soft measures such as training and education if policy option two (Annex I) is adopted. The DVS expressed concern governments may be deterred from investing in national and EU R&D for welding if it is considered as ‘carcinogenic’; Germany is a world-leader in innovation into welding techniques (DVS members, *pers comm,* April 2023).

Existing firms would experience some additional costs as a result of policy option two (Annex I), but the scale of costs cannot be quantified. Older firms may be more affected than new firms, as it may be more difficult for them to retrofit RMMs. New entrants may be deterred from entering the welding market due to the extra costs of RMMs, but the extent and distribution of this deterrent effect across sectors or across small, medium and large enterprises is both unknown, but also likely to be small. Also it is worth noting that competition in the EU will be limited by the shortage of welders in the EU. I t is unknown whether collusion will increase.

Companies or Member States with better existing regulation of welding fumes (Austria, Belgium, Cyprus, Czechia, Denmark, France, Germany, Ireland, Latvia, Lithuania, Netherlands, Slovakia, Spain) and compliance with these regulations are likely to need fewer improvements. Member States where welding is a significant activity but where worker protection is currently low are likely to have a bigger compliance gap to close, for example countries where an OEL for welding fumes has not been confirmed (Bulgaria, Croatia, Estonia, Finland, Greece, Hungary, Italy, Luxembourg, Malta, Poland, Portugal, Romania, Slovenia, Sweden). The evidence for the level of enforcement and compliance in different Member States is weak. Ultimately, improved awareness of the need to protect workers from CMR in welding fumes could lead to an increased harmonisation of worker

[65] EC (2023) EU Aeronautics Industry. https://defence-industry-space.ec.europa.eu/eu-aeronautics-industry_en#:~:text=The%20European%20aeronautics%20industry%20develops%20and%20manufactures%20civil,provide%20support%20services%2C%20such%20as%20maintenance%20and%20training.

protection across Europe, improving the level playing field for enterprises across the internal market. However, differences in national transposition of the CMRD and enforcement actions may potentially compromise the level playing field conditions.

Companies, particularly SMEs, may increase the prices they charge consumers to cover the increased costs. Better compliance with the CMRD may result in less use of CMR substances in welding (substitution of materials), thus potentially reducing the variety of welding products in the EU. Companies could potentially even change the design of their products to avoid welding, by using gluing or rivets instead for example, which would decrease the strength of the join and therefore the decrease the quality (or robustness) of the product. This is unlikely however, as the alternative options will have limited applications and depend upon the specification of the product. Policy option two (Annex I) could also result in more innovative practices to reduce worker exposure to welding fumes. Conversely, the DVS predicts that if governments perceive all 'welding' as a carcinogenic activity, then some governments might cease funding R&D at both the national and EU level (*pers comm,* DVS members, April 2023). This highlights the need for clear communication of policy option two (Annex I) that the focus is on welding fumes containing CMR substances not all welding activities.

Larger, vertically integrated companies will have more direct control over worker protection than non-integrated companies. They may already be in compliance with the CMRD and it will be easier for them to implement policy option two (Annex I). Smaller, non-integrated companies may find it harder and more costly to implement policy option two (Annex I), and without enforcement may be tempted to avoid changes in their practices. It is unknown whether policy option two (Annex I) will encourage greater integration and reduce market barriers. As there is growing awareness of working conditions in the supply chain (as part of the provenance of products), improvements in worker protection could potentially improve the bargaining power of suppliers; they could use this as a competitive advantage over suppliers in other parts of the world with weaker worker protection, despite possible increases in product prices. However, whether this potential competitive advantage is seen would depend on communication of the better working conditions.

If welding+ activities becoming stigmatised as being 'carcinogenic' this could deter workers from becoming welders in the EU, which would compound the existing skills shortage of welders and decrease the competitiveness of EU businesses undertaking welding (EWA, *pers comm*, June 2023). Conversely, if workers are reassured that welding is a well-regulated occupation this could help them to feel confident in becoming welders. Suppliers of welding products or services that protect their workers could gain a competitive advantage over suppliers in other countries with weaker worker protection. Therefore, there is a risk to the effectiveness of the policy change if it is not accompanied by clear communication.

However, the study team's opinion is that policy option two (Annex I) is likely to have a negligible impact on the various EU sectors undertaking welding+ activities in terms of international competition as other countries in competition with the EU27 have their own regulation of welding fumes exposure. Multinational companies might apply the change in European policy across their global operations to create a level playing field of worker safety (according to feedback from stakeholders interviewed, *pers comm*, April 2023), and this could create a driver for non-European companies to improve their worker's safety to the same level.

6.5 Environmental impacts

This chapter comprises the following sections:

- Section 9.1: Potential environmental impacts;
- Section 9.2: Current environmental exposure to the substance;
- Section 9.3: Direct impact on the environment;
- Section 9.4: Indirect impacts on the environment and environmental legislation; and
- Section 9.5: Summary of environmental impacts.

6.5.1 Potential environmental impacts

The overall approach to the assessment of the environmental impacts, based on the Better Regulation (BR) Toolbox for environmental impacts (BR Tool #36) is described in the Methodological note. Initially the key questions listed in section 3.3. of the BR Tool #36 have been screened in order to identify which questions is relevant for the introduction of an OEL and should be answered in the impact assessment. From this screening the following potential environmental impacts are included in the assessment for welding fumes:

- Issues relating to the implementation and enforcement of existing environmental legislation – section 6.5.4;
- Climate change including impacts on climate neutrality objectives – section 6.5.4;
- Air, Water, Biodiversity and Soil – section 6.5.3;
- Waste – section 6.5.4;
- Zero pollution and toxicity – section 6.5.3;
- Efficient use of resources – section 6.5.4;
- Circular economy – section 6.5.4; and
- International environmental effects – section 6.5.4.

6.5.2 Current environmental exposure to the substance

6.5.2.1 Persistent, bio-accumulative, and toxic (PBT) screening

Table 6-36 outlines the persistent, bio-accumulative, and toxic (PBT) assessment status of metals and metal compounds that may be found in welding fumes. To be classified as PBT, all three criteria must be fulfilled however a PBT assessment (as set out in REACH regulation Annex XIII) only applies to organo-metals and as such the substances listed below do not have an assessment conducted as it is not deemed appropriate to do so. The table therefore only indicates harmonised classifications for the environment published under the CLP regulation.

Table 6-36 PBT assessment and harmonised classification with regard to the environment for welding fumes-

Substance	P	B	T	PBT	Harmonised classification (environment)	Notes
Aluminium and oxides	N/A	N/A	N/A	N/A	None	Based on aluminium (III) oxide
Barium and barium compounds (e.g. BaCO3)	N/A	N/A	N/A	N/A	None	Based on barium carbonate
Beryllium oxide	N/A	N/A	N/A	N/A	None	
Cadmium oxide	N/A	N/A	N/A	N/A	Aquatic Acute 1, Aquatic Chronic 1	
Cobalt and Oxides (e.g. CoO, Co2O3)	N/A	N/A	N/A	N/A	Aquatic Chronic 4	Based on elemental cobalt
Copper oxide	N/A	N/A	N/A	N/A	Aquatic Acute 1, Aquatic Chronic 1	
Chromium and Chromium(III) compounds	N/A	N/A	N/A	N/A	Aquatic Acute 1, Aquatic Chronic 1	Based on dichromium tris(chromate)
Hexavalent Chromium (Cr(VI)) compounds (e.g.Na2CrO4)	N/A	N/A	N/A	N/A	None (notified entries indicate Aquatic Chronic 1 and Aquatic Acute 1)	Based on Chromium VI
Iron oxides	N/A	N/A	N/A	N/A	None	Based on iron (II) oxide
Lead (II) oxide	N/A	N/A	N/A	N/A	None (notified entries indicate Aquatic Chronic 1)	Based on lead (II) oxide
Magnesium oxide	N/A	N/A	N/A	N/A	None	
Manganese oxides	N/A	N/A	N/A	N/A	None	Based on manganese (II) oxide
Molybdenum (VI) oxide	N/A	N/A	N/A	N/A	None	
Nickel and oxides (e.g. NiO)	N/A	N/A	N/A	N/A	Aquatic Chronic 4	Based on nickel oxide
Titanium dioxide	N/A	N/A	N/A	N/A	None	
Vanadium pentoxide	N/A	N/A	N/A	N/A	Aquatic Chronic 2	

Substance	P	B	T	PBT	Harmonised classification (environment)	Notes
Zinc oxide	N/A	N/A	N/A	N/A	Aquatic Acute 1, Aquatic Chronic 1	

PBT: Persistent, bio-accumulative and toxic.

Sources: ECHA Registration Dossiers (ECHA, 2023a) and CLP.

The above information indicates that it is likely that direct impacts of welding fumes on the environment may have mixed environmental impacts. If welding processes result in the release of particulates containing substances such as chromium, zinc oxide, copper oxide or cadmium oxide this could have significant negative impacts on aquatic ecosystems, whilst releases of particulate such as beryllium oxide or molybdenum (VI) oxide would not pose significant environmental hazards. Despite PBT assessment not being applicable for inorganic metals persistence, bioaccumulation and toxicity are observed for some of the metals listed above. For example, both cadmium and lead are known to be persistent, bioaccumulative and toxic within the environment (Faroon et al., 2012; Check and Marteel-Parish, 2013) so the release of these metals in welding fumes may pose serious environmental and indirect human health risks.

Some of the above metals are also classified as CMR (Table 1-1), and therefore their emissions may be reduced through substitution or using lower emission welding processes as a result of policy option two (Annex I).

Given the specific metals of concern stated above the further assessment may also reference heavy metal environmental contamination. Heavy metals are classified as metals with high atomic weight and a density at least 5 times greater than that of water (Tchounwou et al., 2012).

6.5.2.2 Sources

Whilst these substances have all been identified as potentially being released via welding processes, heavy metal contamination in the environment can also occur from other sources. Heavy metals significantly overlap with relevant substances for Welding Fumes and so could also be seen as a similar stream of environmental pollutants. Heavy metals such as cadmium, chromium and lead may be released from mining, combustion, smelting, petrochemical and broader chemical operations (UNEP, 2020).

Some substances covered under welding fumes+ will also be naturally occurring in the environment such as iron oxide and aluminium oxide. In these cases, however the substances are usually not present in nano-particulate form as would be released from welding operations (Ham et al., 2012). This is an important distinction as metal oxides in nano-particulate form will likely pose higher environmental toxicity (Table 6-36) than the more cohesive deposits found naturally in the environment.

6.5.2.3 Background exposure

Whilst heavy metals and their compounds are often found in natural sources in the environment, the major sources of contamination are generally associated with anthropogenic emissions (Tchounwou et al., 2012). As such background exposure to substances included in welding fumes+ from alternative sources may be possible. Based on data gathered in China in 2019 it was indicated that water pollution was identified as the major source of background exposure to heavy metals followed by air pollution and lastly soil pollution (Zhao et al., 2019). Other studies have conducted similar assessments with varying results, identifying additional background exposure sources from drinking water, diet, and soil in addition to inhalation of air pollutants.

Levels of heavy metal emissions in Europe have been declining over recent years following numerous policy incentives with an aim of improving air quality (Industrial Emissions Directive, Large Combustion Plant Directive, National Emission Reduction Commitments Directive) and reducing heavy metal emissions. Improvements in emissions to air will also benefit water and soil as airborne heavy metals eventually experience atmospheric deposition into either land or water. The European Environment Agency has noted that in 2020 a 39% and 49% decrease in cadmium and lead emissions respectively over 2005 levels (EEA, 2022a).

6.5.2.4 Environmental levels in relation to hazard data

It is difficult to assess the stocks of heavy metals in the environment and so instead only anthropogenic emissions are reported in this section. Based on data from the European Environment Agencies European Pollutant Release and Transfer Register (E-PRTR) data can be summarised on the environmental release levels of selected heavy metals in Europe. The data for these releases are summarised in Table 6-37 below.

Table 6-37 Releases of selected heavy metals in the EU27 in 2011 and 2021 based on latest available data (in tonnes)

Substance	Air emissions (2011)	Air emissions (2021)	Water emissions (2011)	Water emissions (2021)	Land emissions (2011)	Land emissions (2021)
Cadmium and compounds	9.77	5.23	15.96	20.53	0.23	0.01 (2020 data)
Chromium and compounds	72.01	41.08	497.99	138.66	9.04	0.64
Copper and compounds	106.53	65.26	248.35	204.23	53.48	7.75
Lead and compounds	274.27	89.26	140.04	81.12	21.75	0.63
Nickel and compounds	227.21	99.02	245.79	181.98	5.58	0.43
Zinc and compounds	825.47	528.19	1617.92	1414.70	413.03	12.56

Source: E-PRTR data (EEA, 2022b)

With the exception of releases of cadmium to water the general trends observed indicate that releases of heavy metals to the environment across EU27 countries have been decreasing over the period 2011-2021. As previously mentioned, this is due to further developments in pollution control policies which have resulted in the improved removal/avoidance of heavy metal pollutants in the environment.

Given that these substances may pose aquatic toxicity and in some cases bioaccumulation within food chains the levels of release to water should still be further reduced to avoid negative environmental impacts. It can be observed that the highest emissions are typically to water for all substances, except lead and its compounds, which in turn produces a risk to aquatic life. It is therefore important that any introduced policy options should not further contribute to aquatic releases and should where possible aim to reduce emissions. It is also likely that releases to air will eventually end in aquatic or terrestrial ecosystems via atmospheric deposition. As such policy options should also aim to ensure that releases to air are further reduced to avoid further negative environmental impacts.

Based on the above data it can be assumed that in specific ecosystems welding fumes emissions are contributing to negative environmental impacts as a result of emission of heavy metal nanoparticulates. In cases where these are released or deposited into aquatic ecosystems, ecotoxic effects may be realised in this water body or bioaccumulation of heavy metals may occur. This may later pose toxic effects for higher trophic levels such as apex predators and in some cases humans.

6.5.2.5 Summary of current environmental impact of welding fumes

The only source of environmental emissions for welding fumes is welding operations, which may take place in an industrial/professional or residential setting. However, substances listed under the definition of welding fumes+ include heavy metals and their compounds which in turn have alternative sources of environmental emissions. These include agriculture, industry, combustion, petrochemical/chemical operations, and metal smelting specifically. Heavy metals are also naturally occurring inorganic chemicals and so deposits may occur in various environmental compartments. Releases of heavy metals from welding fumes (and other industrial activities) may pose higher ecotoxicological risk as these are released in nano-particulate form which increases the potential for uptake into organisms. Depending on the substances released these may also have potential to bioaccumulate within food chains ultimately posing a risk to higher trophic levels causing both environmental and human toxicity.

6.5.3 Direct impact on the environment

Policy option two (Annex I) will lead to the installation of ventilation systems in certain cases, and increased use of existing ventilation systems in other cases. This means there is potential for increased environmental releases of welding fumes from these ventilation systems. The extent of these releases will be determined by the level of filtration that extracted air is subject to before release to the environment. However, as most ventilation systems use particulate filters with more than 99% efficiency, assuming that systems are well maintained with filters changed regularly, the resulting increase in release of particulates is predicted to be low. Filters containing these particulates however will still end as waste and as so appropriate waste treatment will be needed to limit emissions.

After filtration, ventilation systems will emit marginal amounts of welding fumes into the air outside the facility, with potential negative effects on external air quality. This arises from an increase in particulate matter release and depending upon the materials being welded, releases of CMR substances present in the welding fumes. The impacts of the negative effect on air quality will depend upon where the facility is located – the receiving environment and whether there are sensitive receptors in the local population. A facility in an urban environment will be adding to air quality issues already present and probably a higher population density whereas a rural environment is likely to have a greater capacity for receiving particulate matter and a lower local population that could be affected. In addition, ambient air quality varies on a seasonal basis, due to the use of wood-fired stoves in the winter which add to particulate matter in the air (as measured by an automotive manufacturer, Germany, *pers Comm*, July 2023). In either location release of particulate matter could result in increased risk to the natural environment via atmospheric deposition and uptake into ecosystems.

Once in aquatic or terrestrial ecosystems substance in welding fumes such as heavy metals and their compounds may bioaccumulate in food chains resulting in a risk to human and environmental health. As such it is important that ventilation systems have appropriate air filters and that these filters are properly disposed of to avoid additional risk to the environment or man via the environment.

6.5.4 Indirect impacts on the environment and environmental legislation

6.5.4.1 EU Green Deal

In 2019 the European Commission announced the European Green Deal to encourage future policies to be developed in line with minimal adverse impacts on the environment and to support efforts to move to sustainable practices (European Commission, 2019). This section reviews the implementation of policy option two (Annex I) for welding fumes in the context of the key elements of the green deal. This is also in line with the approach described in chapter 36 of the better regulation toolbox.

Table 6-38 outlines the key elements put forward in the EU Green Deal and contains a short overview of the expected impact (positive or negative) of introducing the policy option two (Annex I) for welding fumes on the progress towards each of these elements. A short explanation is given to indicate the justification for the expected impact.

Table 6-38 Potential for OELs to impact benefits of the EU Green Deal

<table>
<tr><th>Elements of the EU Green Deal</th><th>Policy option impact (Yes/No)</th><th>Comment</th></tr>
<tr><td>Increasing the EU's climate ambition for 2030 and 2050</td><td>N/A</td><td>See section 9.4.2 on the European Climate Law</td></tr>
<tr><td>Supplying clean affordable and secure energy</td><td>No</td><td rowspan="4">This policy option will not significantly impact the supply of welded products and so will not compromise the ability to meet the outlined elements of the Green Deal via 'green infrastructure'.</td></tr>
<tr><td>Mobilising industry for a clean and circular economy</td><td>No</td></tr>
<tr><td>Building and renovating in an energy and resource efficient way</td><td>No</td></tr>
<tr><td>Accelerating the shift to sustainable and smart mobility</td><td>No</td></tr>
<tr><td>Designing a fair, healthy and environmentally-friendly food system</td><td>Yes</td><td rowspan="3">Releases of welding fumes via increased ventilation systems may result in increased emissions of heavy metals which can build up in drinking water and may bioaccumulate in food chains.</td></tr>
<tr><td>Preserving and restoring ecosystems and biodiversity</td><td>Yes</td></tr>
<tr><td>Zero pollution ambition for a toxic-free environment</td><td>Yes</td></tr>
</table>

Source: Study team

Welding is an important process in the manufacture of many metal products and as such any policy option which is introduced and adversely impacts the welding industry may significantly disrupt supply chains. This would be the main method in which indirect environmental impacts may be realised via policy options relating to welding fumes as disruption of supply of basic metal goods could impact all major manufacturing. It is not however expected that the implementation of policy option two (Annex I) will impact any of this critical supply chain.

The introduction of better ventilation RMMs may mean marginal increases in welding fumes emissions to the environment either directly or via waste from particulate filters. These welding fumes, even in remote areas, may result in low negative environmental impacts as outlined in section 6.5.3 above.

6.5.4.2 European Climate Law

The European climate law was introduced in 2021 and sets out legally binding targets for emissions reductions proposed by the EU Green Deal. The main target proposed is to ensure that the European economy and society become climate neutral by 2050, with an intermediate goal to reduce greenhouse gas emissions 55% by 2030, compared to 1990 levels (EC, 2021d). It is therefore important that any implementation of policy option two (Annex I) for welding fumes should support the drive to climate neutrality and not contradict the objectives set out in this legislation.

The ventilation systems to be introduced in this policy option will lead to increased energy consumption, with potential impacts on the national carbon emissions depending upon the power source(s) used to generate power. One automotive manufacturer in Germany (*pers comm*, July 2023) explained to the study team that they had undertaken their own study by visualising extraction rates using theatrical fog to find the optimal extraction rate to ensure effective extraction for worker safety balanced against energy use. They found that for their factory environment 80% was the optimal extraction rate as it provided the same level of worker safety as a 100% extraction rate, but saved energy, carbon emissions and money. This indicates that the impacts can be offset via appropriate management, but it is still likely that increased energy consumption will likely be experienced.

Policy option two (Annex I) does not impact essential supply chains which rely on welding processes and so green infrastructure will not be impacted by this policy option.

6.5.4.3 Waste management and disposal

Policy option two (Annex I) may result in an increased occurrence of heavy metal containing waste to be treated. This is due to the implementation of better ventilation systems which will likely have a particulate filter which would need disposal/cleaning after a set period of operation.

Policy option two (Annex I) is unlikely to impact processing methodologies for general waste management and will not result in major changes to societies ability to safely handle hazardous wastes.

6.5.4.4 Resource consumption and circular economy

As policy option two (Annex I) will not impact the supply chains involving welding processes it is unlikely that any impacts would be felt in terms of resource consumption or ability to deliver the circular economy. Under the definition of welding processes, some of these may be relevant in the recycling of metallic materials. These processes however will likely not be impacted by policy option two (Annex I) and so the circular economy plans will not be compromised by introduction of welding fumes+ to annex I.

6.5.4.5 Global impacts

Given that policy option two (Annex I) will not impact supply chains, it is not expected that there will be any shift in global trade or emissions as a direct result of introducing this policy option. It is however possible introduction of welding fumes+ into annex I may inspire other global nations to take action on welding fumes which may in turn result in increases or decreases of environmental emissions of heavy metals depending on the action taken.

6.5.4.6 Green initiatives

It was noted via consultation that ongoing R&D operations are currently being conducted to reduce the emissions of welding fumes. Specifically, higher energy processes typically release more welding fumes and so lower energy techniques are currently being trialled and developed to reduce emissions. Based on the perceived impacts of policy option two (Annex I) it is unlikely that this will have any major impacts on these R&D operations. The inclusion in annex I may potentially provide a small shift towards greater investment for these new technologies although this would not be expected to be a major shift.

6.5.5 Summary of environmental impacts

Policy option two (Annex I) could have direct impacts on the environment through the increased release of heavy metals and particulate matter into the external environment from the increased use of extraction systems. However, the increased release of particulate matter is predicted to be small due to the highly effective filters used in extraction systems, assuming the systems are well maintained with filters changed regularly. The increased use of extraction systems would also result in indirect impacts on increased energy use and therefore carbon emissions from the energy sector. However, it is possible to find the optimal extraction rate for each facility, which provides the best level of worker safety whilst minimising energy consumption.

The PBT assessment set out under REACH Annex XIII is not applicable to inorganic metals, however these substances may still pose high levels of ecotoxicity and bioaccumulation. This in turn means some metal compounds released in welding fumes could have significant negative impacts on the environment, whereas other less harmful metals may pose no significant environmental hazards. Policy option two (Annex I) is only predicted to result in marginal increases in emissions to the environment. As some of these metals are also classified as CMR substances (Table 1-1), their emissions may be reduced through other measures such as substitution or using lower emission welding processes as a result of policy option two (Annex I).

Welding is noted as being important to civil infrastructure, but policy option two (Annex I) is unlikely to significantly compromise any EU initiatives such as carbon neutrality, circular economy, energy efficiency, or electric based mobility.

6.6 Other impacts

This chapter comprises the following sections:

- Section 6.6.1: Impacts on EU Strategic Goals;
- Section 6.6.2: Impacts on fundamental rights, including equality;

- Section 6.6.3: Impacts on digitalisation;
- Section 6.6.4: Contributions to the UN sustainable development goals; and
- Section 6.6.5: Summary of other impacts.

6.6.1 Impacts on EU Strategic Goals

The EU's agenda was agreed by the European Council in June 2019, setting out priority areas for the work programmes of all parts of the EU over the next five years (Council of the European Union, 2019).

It focuses on four priorities:

- Protecting citizens and freedoms;
- Developing a strong and vibrant economic base;
- Building a climate-neutral, green, fair and social Europe; and
- Promoting European interests and values on the global stage.

The first priority of the EU strategic goals is protecting citizens and freedoms, so that people feel free and safe. This would include worker safety which would improve under policy option two (see section 6.1.4).

The second priority is the development of a strong economic basis; negative impacts on international competitiveness from policy option two are predicted to be negligible (see section 6.4.6). I n terms of the internal market, SMEs may be at a disadvantage compared with large enterprises as costs make up a higher proportion of their turnover compared with large companies which are more able to absorb the additional costs. There is a risk that welding+ activities could be perceived as 'carcinogenic' and this could deter workers from training as welders; conversely the policy change could reassure workers that welding is a well-regulated occupation.

Adjustment costs as a percentage of research and development (R&D) expenditure have not been calculated. It is predicted that in general, adjustment costs as a percentage of R&D expenditure would likely be proportionally higher for smaller enterprises. Adjustment costs as a percentage of R&D are lower for larger enterprises. Therefore, it can be anticipated that there would be some adverse effects on innovation. However, innovation could also be stimulated as a result of policy option two, to develop advanced process optimisation techniques to reduce welding fumes emissions at source.

The third priority of the EU strategic goals is building a climate-neutral, green, fair and social Europe, and building the necessary infrastructure for low carbon energy increases the demand for welding (see section 3.15.2). There is therefore a need to ensure that policy option two (Annex I) is achievable and does not hinder welding activities, which would impact EU strategic goals. There is a risk that policy option two (Annex I) could create confusion amongst enterprises and Member States if not well communicated (see section 5.4).

In terms of the fourth priority of promoting European interests and values on the global stage, policy option two (Annex I) would not directly impact on this. Indirectly though, the study team received feedback from multinational companies that they have a level playing field for their workers and would roll out a European policy change across their global operations (see section 6.4.4.1). This could put pressure on competitors in non-EU countries to improve their worker protection.

A summary of the potential impact of policy option two (Annex I) on the EU Commission priority areas for 2019-2024 is provided in Table 6-39 below.

Table 6-39 Potential for policy option two (Annex I) to impact benefits of EU Commission priority areas for 2019-2024.

EU Commission Priority Areas 2019-2024	OELs impact (Yes/No)	Comment
A European Green Deal		See section 6.5.4.1
A Europe Fit for the Digital Age		See section 6.6.3
An Economy that Works for People		A qualitative discussion of the impact on SMEs is provided in section 6.7.2; SMEs may need financial support to provide best practice RMMs to their workers. Negligible impact on international competition (see section 6.4.4)
A Stronger Europe in the World	Yes	The introduction of policy option two (Annex I) will help to affirm the EU's reputation of delivering safe workplaces and respecting the fundamental rights of EU workforce.
Promoting our European Way of Life	Yes	The introduction of EU Binding OELs will mean all Member States are subject to the same regulation of hazardous substances set out in the CMRD. EU OELs therefore support an equal approach to chemical risk management and a united Europe when dealing with external markets.
A New Push for European Democracy	No	The introduction of policy option two does not impact the push for a maintained and renewed European democracy.

Source: Study team

6.6.2 Impacts on fundamental rights, including equality

Article 31.1 of the Charter of Fundamental Rights of the European Union states that "*Every worker has the right to working conditions which respecthis or her health, safety and dignity.*" (European Commission, 2012). Policy option two would probably lead to an improvement in air quality, although this is difficult to quantify, for some European workers that are currently exposed to welding fumes.

Welding fumes can contain lead (II) oxide which is a known reprotoxin, and reprotoxic effects are mentioned in ECHA's scoping study. However, more studies are needed to better understand the dose-response relationship. Some stakeholders were concerned that if welding is perceived to be 'carcinogenic' this may deter women in particular from training as welders (EWA and IIW, *pers comm,* February 2023).

6.6.3 Impacts on digitalisation

The Commission has in its 2030 Digital Compass Communication set out a vision, targets and avenues for a successful digital transformation of Europe by 2030 (European Commission, 2023). To support this process, the Commission committed to assess how the options under consideration reflect the 'digital by default' principle and contribute to the digital transformation.

The manufacture of computer, electronic & optical products sector (C26), a key sector to enable digitalisation, is unlikely to be impacted by policy option two as factories are high-tech, with a high degree of automation and little worker exposure, under the operation of large enterprises which are more likely to already have good OSH policies in place.

6.6.4 Contributions to the UN sustainable development goals

The third UN sustainable development goal (UN, 2023b), which calls for "*good health and wellbeing - improved worker and family health*" is directly relevant to the policy options for welding fumes.

Also policy option two would contribute towards Sustainable Development Goal (SDG) 8 which calls for "*Decent work & economic growth*" in particular towards the targets for:

- (8.2) Achieving higher levels of economic productivity through diversification, technological upgrading, and innovation, including through a focus on high-value added and labour-intensive sectors; and
- (8.8) Protecting labour rights and promoting safe and secure working environments for all workers, including migrant workers, in particular women migrants, and those in precarious employment.

6.6.5 Summary of other impacts

Table 6-40 below summarises other impacts in relation to EU strategic goals, fundamental rights, digitalisation and UN sustainable development goals.

Table 6-40 Summary of other impacts.

Other impacts	Impacts
EU Strategic goals	• Positive impacts on worker safety; • Negligible impact on international competitiveness; • Potential disadvantage for SMEs compared with large enterprises for internal competitiveness due to absorption of higher costs; • Potential impact on innovation if R&D budget is diverted to investment in RMMs but innovations in process optimisation could also result. • Potential hindrance to achieving Green transition if companies are confused about the policy change to welding+ activities or find it difficult to achieve. • No direct impact on promotion of European interests and values on the global stage, but a policy change could indirectly affect the global operations of multinational companies who choose to roll it out internationally and this

Other impacts	Impacts
	could result in pressure on competitors in non-EU countries to improve their worker protection.
Fundamental rights	Positive impact on health and safety. Perception of welding as 'carcinogenic' could deter women in particular from becoming welders.
Digitalisation	Negligible impact on digitalisation.
UN Sustainable Development Goals – Goal 3	Positive impact on improved worker health.
UN Sustainable Development Goals – Goal 8	Positive impact on technological upgrading and innovation, positive impact on promoting safe and secure working environments for all workers.

Source: Study team

6.7 Distribution of impacts

The impacts identified under the previous tasks will be broken down by stakeholder type and a systematic analysis of who will bear the costs and accrue the benefits is provided.

This chapter comprises the following sections:

- Section 6.7.1: Businesses;
- Section 6.7.2: SMEs;
- Section 6.7.3: Workers;
- Section 6.7.4: Consumers;
- Section 6.7.5: Taxpayers/public authorities;
- Section 6.7.6: Specific Member States/regions; and
- Section 6.7.7: Summary of distribution of the impacts.

6.7.1 Businesses

The costs and benefits for businesses (relative to the baseline) are summarised in Table 6-41 for the policy option two. Benefits are shown as negative costs and represent a cost saving.

The burden of the cost of continuing to trade for those enterprises that are not forced to close is shown in Table 6-26. The benefits for employers are based upon the reduced cost of having an employee become ill with lung cancer (see section 6.1.5.1).

Benefits and costs have been estimated by sector (Table 6-41 and Table 6-24 respectively), but due to a high level of uncertainty in the figures have not been calculated by company. The benefits are based on workforce with a turnover of 5%, which effectively means that on average workers spend an average of 20 years in an environment with welding fumes.

A comparison of costs and benefits to employers in the table below indicates that the cost of risk management measure (RMM) compliance over a period of 40 years is significantly higher than the value of benefits returned to enterprises (employers) for policy option two (Annex I). No additional monitoring costs or administrative burden are predicted for policy option two.

Table 6-41 Costs and benefits to EMPLOYERS (PV over 40 years, policy options relative to the baseline)

	Policy option two
Total benefits for employers (avoided disruption)	€4.7 million
Total RMM compliance, Monitoring, and administrative costs	€67-156 million
Number of companies minus those discontinuing	N/A
Benefits (avoided disruption) per enterprise	N/A
Compliance, monitoring and admin costs per enterprise	N/A

Source: Study team.

6.7.2 SMEs

Due to a high level of uncertainty in the figures, the costs and benefits have not been distributed by size of enterprise and a quantitative assessment is not possible. However, a qualitative discussion is provided below.

The greatest proportion of SMEs that undertake welding are in the following sectors (Table 3-56), and therefore the points below are most pertinent to these sectors:

- F43 Specialised construction activities;
- F41 Construction of buildings;
- C25 Fabricated metal products;
- G45 Repair of motor vehicles and motorcycles; and
- C33 Repair and installation of machinery and equipment.

Of these sectors, the workers at highest risk of exposure to CMRs, and therefore greater need of effective protective measures, are likely to be welding stainless steel (for example installing or repairing stainless steel equipment in the food industry, medical sector or energy sector) and/or using welding processes with higher emission rates (MMA and FCAW for example).

It seems likely that SMEs are likely to have more workers exposed to CMRs, and therefore could potentially benefit relatively more than large companies from policy option two (Annex I) for the following reasons:

- Feedback from stakeholders is that worker protection is often weaker in SMEs than in larger companies, even in Member States where compliance with the CRMD is believed to be good (interviews with stakeholders, June - July 2023);
- Smaller companies are less likely to be inspected than larger companies; micro companies may not be on the radar of the authorities (a national stakeholder's opinion, *pers comm*, July 2023); and
- Levels of understanding and awareness may be lower in SMEs, they may not have health and safety expertise inhouse (a national stakeholder's view, *pers comm*, July 2023).

However, the costs could be relatively greater for smaller companies than for large companies, with the following impacts and requirements:

- There is a greater need for SMEs to invest in additional RMMs and/or use RMMs they already have more effectively to protect their workers; and
- As SMEs have limited funds to invest in RMMs, they are more likely to need (study team's conclusions unless otherwise stated):
  - Clear communication of what is needed for the policy change;
  - To use their R&D budget to invest in RMMs;
  - To pass on additional costs to consumers through price increases;
  - To potentially consider options to avoid using CMRs in welding which could reduce the variety of products they sell;
  - To potentially avoid generating welding fumes by avoiding welding completely (for example replacing welding with gluing or rivets), which could reduce the quality (strength and robustness) of their products although this is considered unlikely;
  - To receive financial support from the authorities to invest in RMMs and achieve better worker protection (feedback from stakeholders, July 2023).

The assessment of the impact on SMEs are done following the principles of the SME test; see BR Tool #23. The SME test includes the following steps:

- Identification of affected business
- Consultation of SME stakeholders
- Assessment of the impacts on SMEs
- Minimising the negative impacts on SMEs

The results of the SME test are summarised in the below table.

Table 6-42 Summary of the SME test.

SME test	Summary assessment
Identification of affected businesses	
	A highly speculative estimate of the affected companies is that 97.6% are small companies and 1.9% are medium sized companies (Table 3-55). However, if the study team's

SME test	Summary assessment
	assumptions are applied to Eurostat (2020) data (Table 3-56), the estimated exposed workers has a different distribution across SMEs: 70.4% in small companies, 12% in medium companies.
	The sectors with the highest numbers of exposed workers in SMEs are estimated to be F43, F41, G45, C25 and C33.
Consultation with SME stakeholders	
	SMEs have been consulted as part of stakeholder consultation. The share of SME respondents is 64% of the stakeholder survey conducted for this study (Table 11-8). Although this share is lower than the share of SMEs in affected companies or SMEs as a share of enterprises with exposed workers, SMEs are still well represented. However, a large limitation is that there were no responses from the construction sector which is estimated to include approximately half of exposed workers employed by SMEs (F41, F43). Also 55% of the survey responses were from Germany, so the responses are unlikely to be representative of the EU27.
	The most common estimate by SMEs for the initial investment to comply with policy option 2 (Annex I) was €10,000 – 100,000, this compares with an equivalent estimate of more than €100,000 for large enterprises[66] (Table 3-48). At the time of the survey, policy option 2 had not been fully defined, so these estimates may not be accurate. However, key stakeholders interviewed (July 2023) identified that worker protection is often weaker in SMEs than in larger enterprises, and that there is likely to be a greater need for SMEs to invest in additional RMMs and/or use RMMs they already have more effectively to protect their workers.
Assessing the impacts on SMEs	
	SMEs have limited funds to invest in RMMs, so are more likely to need: • To use their R&D budget to invest in RMMs; • To pass on additional costs to consumers through price increases; • To potentially consider options to avoid using CMRs in welding which could reduce the variety of products they sell; and • To potentially avoid generating welding fumes by avoiding welding completely, which could reduce the quality (strength and robustness) of their products although this is considered unlikely.
Minimising the negative impacts on SMEs	
	The following measures have been identified to help minimise the negative impact on SMEs: • Clear communication of what is needed for the policy change; and • To receive financial support from the authorities to invest in RMMs and achieve better worker protection.

Source: Study team.

[66] The study team believes this is due to large enterprises expecting to install factory-wide extraction systems.

6.7.3 Workers

Table 6-43 presents the benefits for workers (relative to the baseline) for Method 1 and 2, for policy option two. The benefits are the avoided costs of ill health (see section 6.1.4.1). I t was not possible to calculate the costs due to unemployment, as it was not possible to estimate the number of discontinuations that would occur as a results of policy option two.

The benefits for workers are an underestimate as only avoided lung cancer has been calculated, other health endpoints are excluded as there is no data. Also, the estimates only include full time welders and not part time or occasional welders. Non welders (bystanders) also exposed to welding fumes in the workplace have also been excluded from the estimates due to uncertainty around the numbers.

Table 6-43 Comparison of the costs and benefits to WORKERS & THEIR FAMILIES (PV over 40 years, policy options, relative to the baseline)

Method	Policy option two
Number of workers	1,200,000
Benefits (avoided ill health) (M1)	€997,496,222
Benefits (avoided ill health) (M2)	€510,064,695
Costs (unemployment distress)	N/A
Benefits (avoided ill health) per worker (M1)	€831
Benefits (avoided ill health) per worker (M2)	€425
Costs (unemployment distress) per worker	N/A

Notes: Only additional costs and benefits (i.e. relative to the baseline) are presented in this table.
Source: Study team.

6.7.4 Consumers

As indicated in section 3.11.2 in Table 3-55, most enterprises undertaking welding+ activities are small or medium sized enterprises, which are less likely to be able to fully absorb additional costs without impacting consumer prices (e.g. repair of motor vehicles & motorcycles). Other small and medium enterprises typically provide their services to larger contractors and indirectly rather than directly to consumers (e.g. specialised construction activities, construction of buildings). The study team anticipate a mixed scenario in which the markets dominated by small and medium enterprises may result in increased prices for consumers. However, price increases would be unlikely and few, as the increased costs are likely to be small for each company.

The large companies in sectors such as, but not limited to, fabricated metal products (C25) and manufacture of motor vehicles (C29) may be better able to absorb the increase in costs associated with policy option two. Pressure from non-EU imports may also help to reduce consumer costs in these markets.

6.7.5 Taxpayers/public authorities

The costs and benefits for the public sector (relative to the baseline) are summarised in Table 6-44 for policy option two.

The avoided costs of ill health relative to the baseline to the public sector are composed of cost of treatment and tax revenue, as summarised in the table below. These costs include healthcare treatment costs, which assume that the costs are borne by the public sector. Transposition costs are explained in section 6.2.4.1.

Table 6-44 Comparison of the costs and benefits to the PUBLIC SECTOR (PV over 40 years, policy options relative to the baseline)

Cost elements	Policy option two (Annex I)
Benefits	
Avoided costs of healthcare and avoided loss of tax revenue	€16,402,712
Avoided costs of implementing OELs and STELs	N/A
Total benefits	**€16,402,712**
Costs	
Transposition costs	€2,700,000
Total costs	**€2,700,000**

Notes: Only additional costs and benefits (i.e. relative to the baseline) are presented in this table.
Source: Study team.

6.7.6 Specific Member States/regions

No publications were identified by this study that could provide an indication of the level of compliance with the CMRD in individual Member States or across the EU27.

The study team heard anecdotal evidence from the stakeholders surveyed that there is better worker protection for welding in Northern and Western Europe than in Southern and Eastern Europe. This may have been partly substantiated by a European Community Respiratory Health Survey (ECRHS) II study, which found that cumulative exposures in Northern Europe were lower than in Southern Europe (Olsson and Kromhout, 2021). Indeed, Olsson and Kromhout (2021) surmise that this finding could have been due to RMMs used, different welding techniques and/or hours spent welding per day or week as there was no different in the average number of years welding in Northern versus Southern Europe. Feedback from individual representatives from Member States did not concur with this though, with most people claiming that companies used best practice in their country. Only a couple of representatives admitted that worker protection was not perfect. Without undertaking a campaign of unannounced inspections across welding sites across the EU27 it is impossible to gauge the level of compliance with the CRMD.

Member States that have a national regulatory regime for welding fumes such as an OEL for welding fumes (or a dust limit which applies to welding and other activities) are likely to have better compliance with the CMRD (Table 11-16). These include 13 of the 27 Member States: Austria, Belgium, Cyprus, Czechia, Denmark, France, Germany, Ireland, Latvia, Lithuania, Netherlands, Slovakia and Spain.

The risk of worker exposure to CMRs is higher for sectors that weld high alloy steel (stainless steel) and therefore countries where those sectors are more dominant might be at higher risk. For example, equipment manufactured for the medical and food industries is often stainless steel as are pipes for the energy sector (Force Technology, *pers comm*, March 2023). There is higher risk of worker exposure to CMRs in Germany due to there being more high alloy metal fabrication undertaken there than in other countries (German stakeholder, *pers comm*, June 2023); however worker protection is generally good in Germany, especially for professional welders so this risk is probably well mitigated.

No detailed analysis of direct impacts on Member States can be derived from this assessment. This is because the distribution of companies undertaking welding activities across EU Member States has been modelled based on Eurostat data and so may have a level of uncertainty relating to the true distribution. As such any analysis of impacts on specific Member States would pose a level of uncertainty and may lead to inaccurate conclusions.

6.7.7 Summary of distribution of the impacts

The key points on the distribution of impacts are presented below:

- A comparison of costs and benefits to employers in the table indicates that RMM compliance, monitoring costs and administrative burden over a period of 40 years are significantly higher than the value of benefits returned to an enterprise for policy option two (Table 6-41). No additional monitoring costs or administrative burden are predicted for policy option two;
- Costs and benefits have not been distributed by size of enterprise in this study.
- The benefits of avoided ill health to workers and their families are estimated to be €510 – 997 million and whilst it is not possible to estimate the costs due to unemployment distress, this is likely to be minimal;
- There is a risk that if policy option two is not accompanied by effective communication, the full benefits will not be realised in SMEs (point 1 in section 6.7.2);
- Small and medium sized enterprises are less likely to be able to absorb increased costs of compliance and may be more likely to increase their prices for consumers, or to contractors (e.g. specialised construction activities, construction of buildings). Larger companies may be better able to absorb the increase in costs without passing on this cost to the consumer (e.g. fabricated metal products (C25) and manufacture of motor vehicles (C29));
- For the public sector, avoided costs of healthcare and avoided loss of tax revenue are €16.4 million whereas transposition costs are estimated to be €2.7 million; and
- The study team has heard anecdotal evidence that worker protection is better for welding in northern and western Europe than in southern and eastern Europe; this would indicate that the impact of policy option two could be larger in southern and eastern Europe. This has not been substantiated, although the ECRHS II survey did find that cumulative exposure to welding fumes was higher in Southern Europe than in Northern Europe (Ollson and Kromhout, 2021).

6.8 Summary of economic, social and environmental impacts

This chapter comprises the following sections:

- Section 6.8.1: Economic impacts;

- Section 6.8.2: Social impacts; and
- Section 6.8.3: Environmental impacts.

6.8.1 Economic impacts

The economic impacts relate to the direct and indirect costs that fall on companies that need to comply with the policy options, as shown in Table 6-45.

Table 6-45 Aggregated PV costs and benefits for companies discounted over 40 years by policy options

Cost or benefit	**Policy option two (Annex I)**
Cost	€ 67 – 156 million
Benefit (avoided cost)	€ 4.7 million

Source: Study team
Notes: M1 = Method 1, a methodology that relies on 'willingness to pay' values
M2 = Method 2, a methodology that relies on monetised Disability Adjusted Life Years

The costs outlined in the above table represent those related to risk management measure (RMM) adjustment costs as a range of estimates calculated via the bottom up and top down approach (see section 6.2.2). These costs are an underestimate as they do not include indirect costs (identified by stakeholders) which have not been monetised, but could include: a deterrent effect on attracting new workers to welding if the occupation is stigmatised as being 'carcinogenic'; loss of research and development (R&D) into new welding technologies if governments are less willing to invest in R&Dinto a 'carcinogenic' activity; and the potential impact of welding activities being exported to non-EU countries with weaker worker protection (see section 6.2.3).

The benefits to companies are avoided costs of ill health relative to the baseline, with a workforce turnover of 5% per year and a static discount rate of 5%. The benefits are an underestimate as they only include the avoided cost of ill health from lung cancer and exclude other health ill-effects associated with welding fumes that cannot be modelled due to a lack of data, see Table 6-12 and section 6.1.5.

Many companies in the sectors under review are estimated to be small and medium sized and are less likely to have capital available to absorb the adjustment costs at these levels. It is therefore probable that they would pass costs onto consumers resulting in an overall price increase in goods and services. The IIW recommends that financial support be provided to small and medium sized enterprises to enable them to improve provision of PPE, extraction and general ventilation systems (IIW, 2023).

Policy option two is not predicted to create a particular competitive disadvantage against international competitors as the majority of non-EU competitor countries (such as the US, China, South Korea, India, Japan) have their own regulatory regimes to protect workers from welding fumes. It is difficult to compare the regulatory regimes directly as they have different approaches. The regulatory regime in Russia and the Philippines is not known, and they may gain a competitive advantage over the EU welding sector, in particular for the aeronautical and metal fabrication sectors respectively. Some of the key welding sectors (such as construction; installation and repair of equipment and repair of motor vehicles), by their nature, require welding *in situ*, and therefore cannot be exported.

The adjustment costs from policy option two could be met by enterprises diverting funding from R&D (see Table 6-34), and this suggests that R&D, and by extension innovation research, could be negatively impacted for most sectors. Although R&D amongst large companies would be affected to a lesser extent. Conversely, policy option two may drive demand for more research into innovative techniques to reduce emissions from welding at source through process optimisation.

It was not possible to estimate the number of discontinuations that would occur as a result of policy option two.

6.8.2 Social impacts

The social impacts relate to the benefits and costs that fall on workers and public administrations, as shown in Table 6-46.

Table 6-46 Aggregated PV costs and benefits for workers and public administrations discounted over 40 years by policy options

Cost or benefit	Policy option two (Annex I)
Workers	
Cost	€0
Benefit (avoided cost) M1	€1,013 million
Benefit (avoided cost) M2	€526 million
Public administrations	
Transposition costs	€2.7 million
Cost to public enterprises	
Benefit (avoided cost)	€16.4 million
Benefit (indirect)	€0

Source: Study team

It was not possible to estimate the number of discontinuations, and therefore also not possible to estimate the cost for workers due to unemployment.

Costs incurred by public administrations include those spent on transposing the policy change (Annex I amendment) into national legislation.

6.8.3 Environmental impacts

Policy option two could have the following environmental impacts:

- Direct impacts on the environment through the increased release of particulate matter into the external environment from the increased use of extraction systems. However, the highly efficient filters (more than 99% effective) used in extraction systems are predicted to capture the majority of particulates;

- Indirect environmental impacts in terms of increased energy consumption from increased use of extraction systems, and therefore increased carbon emissions from the power sector; and

- Policy option two is unlikely to impact on EU environmental initiatives such as carbon neutrality, circular economy, energy efficiency or electric based mobility.

For further detail please see section 6.5.

6.9 Limitations and sensitivity analysis

This chapter presents the limitations and uncertainties relating to the impact assessment of policy option two (Annex I), and comprises the following sections:

- Section 6.9.1: Overview of limitations and uncertainties; and

- Section 6.9.2: Key limitations and uncertainties.

6.9.1 Overview of limitations and uncertainties

This section presents an overview of the limitations and uncertainties of this study and Table 6-47 summarises each element and assesses their significance for the results of this study.

Table 6-47 Overview of the key limitations/uncertainties and their significance

Limitation or uncertainty	Explanation	Estimates in this study are likely U (underestimates) or O (overestimates) *Indicates U or O likely to be significant	
		Costs	Benefits
Cost assessment assumptions	For costs, two key stakeholders thought that policy option two could result in a bigger investment in RMMs and therefore reduction in worker exposure to welding fumes than 1%, if accompanied by a good communication campaign. However, a couple of other key stakeholders thought that the policy change would have no or negligible impact on worker protection.	U* or O	U* or O
Exposed workforce	Only full-time welders have been taken into account, not part-time or occasional welders, or bystanders (non-welders)	U*	U*
Workforce turnover	Justified at 5% as skills shortage of welders provides demand for welders to remain in welding occupation.	-	-
Additional health endpoints	Additional health endpoints were not included and cannot be included in the calculations as there are no data available.	-	U*

Limitation or uncertainty	Explanation	Estimates in this study are likely U (underestimates) or O (overestimates) *Indicates U or O likely to be significant	
		Costs	Benefits
Response to policy option assumption	A couple of key stakeholders said that there has already been a step change in compliance in their country and implied or said that there is not much further to go in baseline adoption of additional RMMs over time to decrease worker exposure. A couple said their country has low baseline compliance.		U or O
The latency period for cancer	A shorter latency would increase the number of cases.		U*
Future trends	Increasing demand for welding due to Green Transition compounded by Russian invasion of Ukraine, requiring faster transition to renewables (nuclear power, solar photovoltaics, wind turbines, hydrogen economy, electric cars) with associated investment in infrastructure requiring welding.	U*	U*
Discount rate	A lower discount rate would relatively increase the estimated benefits more than the costs.	O*	O*
Positive biases in reported data	Bias in responses to the questionnaire survey: 55% from Germany where there is fairly good compliance already.	U	U
RMMs in place	Baseline little understood. Increase in use of RMMs depends upon the Member State – some Member States will be able to implement >1% improvement in RMMs per year, in others RMM use may already be good and have plateaued.	U* or O*	

Source: Study team.

6.9.2 Key limitations and uncertainties

The limitation that has the most potential impact is the analysis of benefits only based upon lung cancer and the exclusion of other endpoints as their inclusion would potentially increase the benefits and have no impact upon the costs. Unfortunately, as explained in sections 2.1.3 and 2.1.5, the data on other cancer and non-cancer endpoints are either inconsistent or unavailable.

Another limitation of the study is that there is also no means of linking a cost scenario to a benefit scenario, and, therefore, no clear benefit cost ratio. The study team provided a sensitivity analysis in the main section on benefit to cost ratios (BCRs) (see section 6.3), because it was important to indicate that only a range of BCRs could be estimated. Different BCRs were calculated to analyse the effect of:

- M1 vs M2 health benefits calculations;
- the top down vs bottom up approach to calculating costs; and
- the percentage of welders that would buy additional RMMs (25-75%).

7 QUALITATIVE IMPACT ASSESSMENT OF A COMPLEMENTARY GENERIC OEL (INHALABLE AND RESPIRABLE DUST) SPECIFIC TO WELDING FUMES

7.1 Introduction

In addition to policy option two (Annex I), a complementary generic EU OEL for inhalable and respirable dust specific to welding fumes is another policy option that could be adopted in future. This would introduce a harmonised level of protection for all workers working on welding+ activities across the EU.

To recap, according to the ECHA definition of welding fumes (section 1.3.6) welding fumes contain metal vapours which rapidly condense into particulates or dust. This particulate matter contains metals and their oxides, including 'spinels' which are complex compounds containing metals, oxygen, silicon and/or fluorine.

- The substances present in the particulates or dust will depend largely upon the materials being used (and the presence of contamination on surfaces) and the welding+ process (see Table 2-1, Table 2-2 and section 4.1);
- The rate of emissions depends largely upon the welding+ process being used (Table 2-4). F or example, chromium and nickel compounds are present in higher concentrations in (high alloy) stainless steel than in mild steel. However, mild steel is commonly welded with welding processes that generate higher mass concentrations of particulate matter than welding stainless steel (Honaryar *et al.*, 2019 in ECHA, 2022);
- The size of the particulates and spinels (complexes formed) will also depend largely upon the materials being used and the welding+ process (Table 7-2). Smaller primary particles can collide to form longer, chainlike agglomerates (ECHA, 2022). ECHA (2022) also notes the presence of larger non agglomerated more spherical particles in welding fumes. The geometry of particles is associated with their toxicology (DGUV, 2023a). Certain welding processes are more likely to generate ultra fine particulates (Table 7-2 below); and
- Other parameters that affect fumes emissions in particular are the welding current, or welding voltage and shielding gas type and composition and composition of the filler (consumable). These can all be optimised to reduce emissions from arc welding for example (see the REarc initiative in section 3.7).

7.2 Discussion of benefits/advantages for welding-specific OELs

If EU generic limits were set for dust (inhalable and respirable fractions), ECHA (2022) say that one advantage would be that these would cover a large number of substances in welding fumes without setting individual limits for each substance present. Generic dust limits would cover metals and their oxides, including spinels which would not need to be precisely identified. Another advantage identified by ECHA is that a relationship between particle size distribution and the deposition of inhaled particles in different parts of the respiratory tract would need to be established, and in turn this would lead to improved understanding of the potential health effects.

Welding-specific dust limits, applied across the EU could in theory help towards harmonisation across the EU and towards the simplification of OELs. Introduction of a dust limit would create a clear threshold for enterprises to reach, which could be argued is a clearer target than policy option two (Annex I) alone. The EWA and IIW support these principles, and indeed consider them critical success factors for the regulation of welding (EWA, 2023; IIW, 2023). As outlined below in section 8, harmonisation across the EU is useful to multinational enterprises that operate across national borders and helps to provide a level playing field of consistent protection for workers in different EU countries.

The EWA recommend the simplification of OELs, based upon 'the most hazardous substance' or 'fewer singular elements to be controlled' and 'subsuming OELs where possible'. In theory applying specific dust limits to welding could be used as a way for fewer singular elements to be controlled in welding activities or even for OELs to be subsumed under these generic dust limits. Specific dust limits could provide simplification in terms of providing clear, understandable, measurable and communicable OEL values to workers in welding+ processes. However existing substance specific OELs would still be in force, unless the current policy was changed.

At present, apart from lung cancer it is not clear whether health effects observed in welders are due to exposure to poorly soluble, low toxicity dusts or something specific to welding (ECHA, 2022). ECHA (2022) note that in addition to health effects from CMR substances, exposure to fumes, dusts and gases from welding and similar activities is associated with a number of other adverse health effects. However, the causal mechanisms are not all fully established. For many adverse health effects, substance specific exposures are relevant, while for other health effects more general exposures for example to irritative substances or dust are relevant. These observations also apply to the exact causal mechanisms of welding related lung cancer excess where it seems necessary to control both welding related specific exposures (such as Cr(VI)) and more generic exposures to ensure sufficient worker protection. More toxicological studies are needed to better understand the situation. If there is link between dust specifically from welding causing health effects then this would support the introduction of a welding specific dust limit.

Some studies have identified an urgent need for a health-based OEL for welding fumes, i.e. a n OEL which would provide protection from all toxicity caused by welding fumes including carcinogenicity, but point out that substances specific OELs would still be needed to ensure safe working environments for different types of welding (Sjögren *et al.*, 2022).

7.2.1 Summary of the key assessment framework

This is purely a qualitative assessment, with no attempt at quantification.

7.2.2 Improved welfare and avoided cases of ill health

Harmonised, generic, welding-specific dust limits could help to create a level playing field across welding activities across Europe. However, since limit values already exist for most metals relevant to welding work (Annex III of the CMRD), and are set at much lower levels than any threshold value that can be conceived to be set for inhalable and respirable dust; setting a generic dust limit may have limited additional value to using existing OELs for CMR substances.

Since it is not clear whether health effects observed in welders are due to exposure to poorly soluble, low toxicity dusts or something specific to welding (ECHA, 2022), it is hard to evaluate the health impact of introducing a welding-specific dust limit. As discussed above (section 7.2), ECHA (2022) note that in addition to health effects from CMR substances, exposure to fumes, dusts and gases from welding and similar activities is associated with a number of other adverse health effects. However, the causal mechanisms are not all fully established. More toxicological studies are needed to better understand the situation. If there is a link between dust specifically from welding causing health effects then this would support the introduction of a welding specific dust limit.

7.2.3 Benefits to workers and families

For the above reasons (section 7.2), it is not possible to say whether there would be any benefits to workers and their families from introducing a generic, welding-specific dust limit across the EU. If introducing a generic welding-specific dust limit encourages enterprises that were not taking adequate measures to protect their workers, and results in improved worker protection, then this would represent a benefit to workers and their families as improved health outcomes would be expected for workers. The study team note that often an OEL is needed for enterprises to have a concrete threshold to work to achieve (from anecdotal evidence, study team).

7.2.4 Benefits to employers

Introducing an OEL would usually help employers to avoid costs due to insurance payments and absence from work, but as the benefits of introducing a generic, welding-specific dust limit beyond the benefits of the existing substance specific OELs are unknown it is not possible to say whether employers would benefit. As above (section 7.2.3) if the OEL results in improved worker protection, in companies that were not previously using sufficient RMMs, then the above benefits for employers would ensue.

7.2.5 Benefits to public administrations

It is difficult to say whether a generic, welding-specific dust limit would result in avoided tax revenue losses, avoided administrative and legal costs. If the OEL resulted in improved worker protection in enterprises that were previously not using sufficient RMMs, then these benefits would ensue. An EU wide welding-specific dust limit would help public administrations avoid the costs linked to the process of defining a national OEL (if they do not have one already).

7.2.6 Summary of the benefits

The benefits of a generic, welding-specific OEL for dust are summarised in Table 7-1; they are potentially the same benefits as from policy option two (Annex I) as an OEL for dust would improve compliance. However, as stated above, since the causal links between dust and other components of welding fumes and health effects are not understood well it is difficult to distinguish them to be able to evaluate the health impact of a dust OEL. As there are already substance specific OELs for most of the hazardous substances in welding fumes, set at tighter, more meaningful limits to address health effects than can be foreseen for a generic dust limit, a dust limit may have limited additional value.

Table 7-1 Potential benefits of a generic, welding-specific OEL for dust.

Category		**Benefits**	**Notes**
Direct	Improved welfare	Reduced healthcare costs	Avoided cost of medical treatment, including hospitalisation, surgery, consultations, radiation therapy, chemotherapy/immunotherapy, etc. Avoided private direct and indirect medical costs and rehabilitation costs
		Reduced informal care costs[67]	Avoided opportunity cost of unpaid care (i.e. the monetary value of the working and/or leisure time that relatives or friends provide to those with ill health)
		Reduced cost for employers	E.g. avoided costs due to insurance payments and absence from work
		Safety	
		Direct economic benefits	
		Environment	See section 7.5, not monetised
	Improved market efficiency	Cost savings	Include higher economic productivity, improved allocation of resources, removal of regulatory or market failures or cost savings.
		Improved information	Includes improved information availability
		Wider range of products/services	Enhanced product and service variety and quality for end consumers
Indirect	Indirect compliance benefits	Reduced mortality – productivity loss.	Avoided costs to society due to premature death
		Reduced morbidity – lost working days.	Avoided earnings and output due to absence from work due to illness or treatment
		Other indirect benefits to workers and families	
		Indirect benefits to administrations	Avoided tax revenue losses Avoided administrative and legal costs Avoided costs linked to the process of defining a national OEL

[67] A decision has been taken to include informal care costs in this analysis even though some elements of these costs may also have been included in individuals' willingness to pay values to avoid a future case of ill health. This decision may result in an overestimate of the benefits as generated by this study.

Category		Benefits	Notes
	Wider economic benefits	including higher GDP, productivity enhancements, greater employment rates, improved job quality etc.	Employment may increase as a result of industry 'clean up' due to better perception of workplaces and increased acceptability of risks
	Other, non-monetary benefits	Protection of fundamental rights, social cohesion, reduced gender discrimination, international and national stability	

Source: Study team

7.3 Discussion of disadvantages

If an EU-wide generic dust OEL were to be set (whether specific to welding fumes or non-specific) ECHA (2022) say that it should be complemented with monitoring the gaseous phase for relevant gases, as it would be difficult to define a generic gas exposure metric. ECHA point out that this would mean a substance-specific approach for gases alongside a generic approach for particulate matter, even though particulate matter can contain some known specific carcinogens.

There is low confidence in setting a generic dust limit for the following reasons (ECHA, 2022):

- Item 1: The limit would not be specific enough. Values for dust concentrations and particle sizes at individual workplaces differ widely due to differences in the mechanism of dust formation, the type of dust and the measures taken to reduce dust exposure. The substances present in the dust also vary substantially;
- Item 2: The limit is likely to be set based upon an underestimation of dust present. A generic dust OEL would likely be established based upon static area dust sampling data. However, the actual concentrations of dust in the air inhaled by exposed workers (determined more accurately by personal sampling) tends to be higher; and
- Item 3: It is likely to be impossible to derive an exposure risk relationship (ERR) to correlate exposure level to the excess risk of cancer, due to insufficient toxicology data being available. (An ERR would be required to set a welding specific health-based OEL.).

On point 1, FoBig (*pers comm,* May, 2023) agree that a generic dust limit may not be specific enough as the presence of CMR substances in welding fumes needs to be determined. A generic dust limit would only help to avoid the effects caused by the particulate nature of the welding fumes and would not guarantee the absence of health effects. It is difficult to say whether it would be possible to determine a health-based limit value for the non-carcinogenic effects of welding fumes.

The DGUV (Deutsche Gesetzliche Unfallversicherung: German Social Accident Insurance) agree that a generic OEL for inhalable and respirable dust would not be specific enough, bearing in mind the highly heterogeneous composition of welding fumes (DGUV, 2023a). As noted above, the composition of welding fumes varies based upon materials used and processes. They also point out that OELs for CMR substances and other potentially harmful substances such as manganese would also need to be complied with, to determine the risk of occupational exposure during welding work. Limit values already exist for most metals relevant to welding work (Annex III of the CMRD), and are set at much lower levels than any threshold value that can be conceived to be set for inhalable and respirable dust, which implies that setting a generic dust limit may have limited additional value to using existing OELs for CMR substances. OELs set for non-cancer hazards, such as the OEL for manganese set under the Chemical Agents Directive (CAD, 98/24/EC), which in addition to the CMRD Annex III limit values may be more useful than generic dust limits (respirable and inhalable).

Further to the above discussion about existing OELs for components of welding fumes, a Finnish occupational hygienist surveyed for this study pointed out that an OEL for welding fumes would need to be low to account for the existing OELs for chromium VI, nickel compounds and manganese. For example, they believe that the guideline target of 0.1 mg/m^3/8 hours for welding fumes (inhalable) proposed by the Finnish Institute of Occupational Health (FIOH) is unachievable when hand welding in most industrial settings which typically have a mixture of different particle sources without the use of RPE. They further explained that in their opinion the FIOH target level of 0.1 mg/m^3 (inhalable) is useful for planning control measures and testing exposure control strategies with the use of direct reading dust measuring devices, but not for worker welding fumes exposure analysis in industrial settings or as an OEL. They also pointed out that an OEL specific to welding fumes is problematic because it is impossible to determine the source of particulates that are present in the working environment, and therefore whether they are from welding fumes or other sources. The same respondent pointed out that the particle fraction may or may not better describe the amount of welding fumes in the workplace, depending upon other particle generating activities.

The study team point out that there is a danger that enterprises that meet the welding-specific dust limits might mistakenly assume that this means they will already be meeting other substance-specific OELs, which would not necessarily be the case. All existing OELs would still need to be monitored and complied with.

Depending on the level that the dust limit would be set, it could be quite difficult to achieve an EU dust limit for welding. In Germany, analysis of MEGA exposure data[68] from 1999 to 2019 showed that the German (non-specific) dust limit[69] for the respirable fraction (1.25 mg/m^3) was exceeded (90^{th} percentile) for the following welding processes (Table 3-14, Koppisch *et al.*, 2023):

- MAG with or without extraction;
- MIG with or without extraction;
- MMA with extraction;

[68] The DGUV stressed that the MEGA database is not a representative sample of measurements, please see the discussion in 3.3.4.

[69] For granular bio-resistant dusts with a mean density of 2.5 g/cm^3.

- Metal cored wire welding with shielding gas; and
- SAW.

The dust limit for the respirable fraction was only fully met in the measurements analysed for TIG with fumes extraction and resistance spot welding, both of which have low emission rates. As Germany has strong rules in place to protect workers from welding fumes, with an inspection regime and the study team's impression is that compliance is good in Germany this implies that strict dust limits can be hard to achieve even with good RMMs in place.

On point C, ECHA point out that IARC was unable to characterise qualitatively the lung cancer hazard related to welding fumes exposures, so it is probably impossible to establish a quantitative ERR for these exposures. According to ECHA, one of the main reasons for this is that for process generated exposures there is usually no animal data that can be used, and the available human epidemiological data has already been analysed recently by IARC. ECHA further suggest that generic dust limits may need to be set based either on hazard endpoints other than cancer, or based upon technical feasibility or best practice.

Depending upon the chosen limit value, there is a risk that if the limit was set too high for welding fumes this could result in insufficient safety precautions for exposed workers in the most hazardous working environments. Conversely, if the limit was set too low for welding fumes this could lead to unnecessary safety precautions in relatively safe working environments (if the threshold was set too low) (DGUV, 2023a).

Sjogren *et al* (2022) endorse the development of an OEL for welding fumes taking into account the various welding processes, and based upon a critical appraisal of all the health effects of welding.

The heterogeneous nature of welding fumes from different processes could possibly be better addressed by implementing welding process specific OELs, as in Denmark (see notes under Table 11-16). Alternatively, since thermal spraying is the only welding+ process which generates dust particles greater than 10 µm in size (i.e. larger than respirable dust which is less than 10 µm in size)(see Table 7-2), it could be argued that a dust limit for the inhalable fraction of welding fumes is not needed (Arbo Advies Bureau Halm, *pers comm*, February 2023). In the Netherlands, the national OEL for welding fumes applies to the inhalable (or total dust) fraction. An EU dust limit solely set for the respirable fraction of welding fumes could be viewed as more relevant to welding fumes.

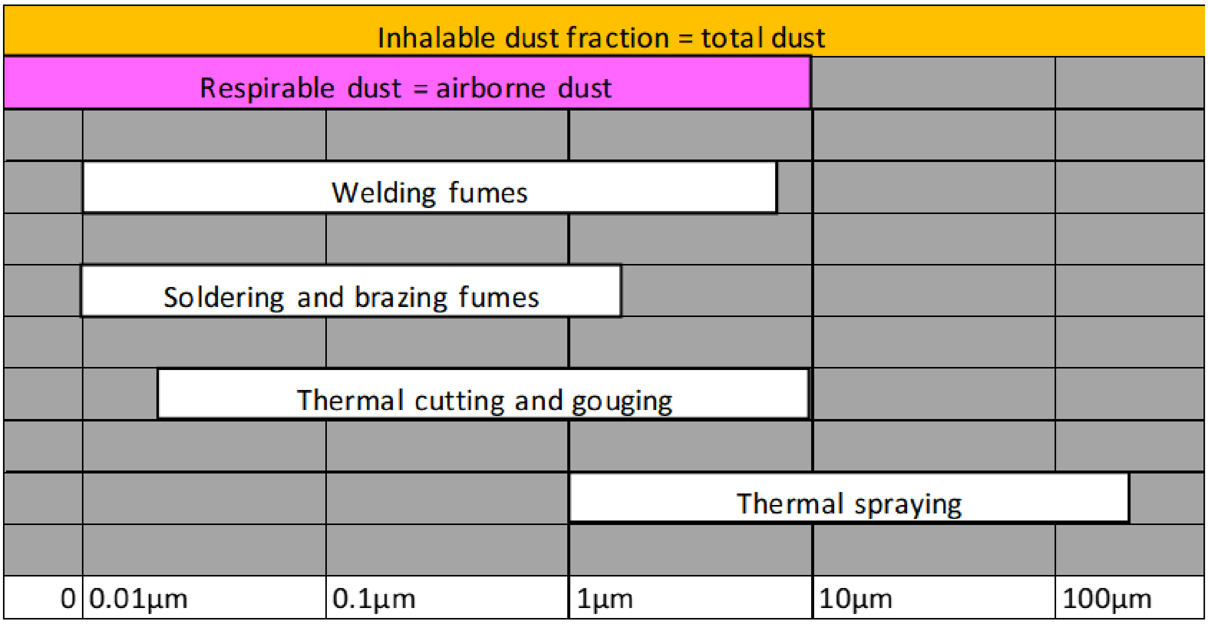

Table 7-2 Inhalable and respirable fractions of dust from welding+ processes.

Sources: Adapted from AGS, 2021 and VBMG, 2007.

7.3.1 The cost framework

This is purely a qualitative assessment without any attempt at quantification.

7.3.2 Direct adjustment costs to companies

There would be some direct adjustment costs for companies if a generic welding-specific dust limit was introduced; for companies that would need to introduce additional RMMs to achieve the limit value. The size of the adjustment costs would depend upon the limit level set. Some countries already have OELs for welding fumes or dust limits (either welding-specific or non-specific) (Table 11-16), and if compliance is good in those countries, companies in those nine countries could be assumed to have fewer adjustment costs for a new EU dust OEL. However, the remaining 18 Member States that do not have any existing OELs for welding fumes or dust could have significant adjustment costs to introduce a new EU OEL. This would depend upon whether these 18 Member States have other regulations or guidance in place already to protect welders from exposure to welding fumes, which has meant that they already have sufficient RMMs in place to meet the new OEL.

7.3.3 Indirect costs for companies

As mentioned above (section 7.3) if the generic welding-specific dust limit is set below equivalent dust limits in other globally competitive regions, then there is concern that welding workplaces and the associated value generated by them could move outside the EU (EWA, 2023; IIW, 2023).

7.3.4 Costs for public administrations

If a Member State does not already have an OEL, the cost of transposing an OEL into national legislation has in previous studies been assumed to be €50,000 per Member State with no existing OEL. If a Member State has an OEL, but it needs to be amended to align with the new EU OEL, the assumption is that the cost would be less than this.

7.3.5 Impact of transitional periods on costs

This policy option is being considered as a possible option for the future (in addition to policy option two), and no quantitative analysis has been undertaken.

7.3.6 Summary of costs of the measures [incl. previous Aggregated costs]

This is a qualitative assessment, so figures have not been provided.

7.4 Market effects

7.4.1 Overall impact

Overall, market impacts (in terms of the effect on the single market, research and development (R&D), competitiveness of EU businesses and employment) are strongly influenced by two key drivers, the extent to which costs are incurred to comply with policy option two and by the feasibility of meeting the required air concentrations. In extreme cases, companies will be forced out of business if they are unable to meet the OEL at a cost that maintains profitability. This is more likely if the welding specific dust limit was set at a stringent level.

In this case there is no proposed limit for a welding-specific OEL, so it has not been possible to model the impact of different OELs on sectors or enterprises.

Existing welding-specific OELs for dust range from 0.5 mg/m^3 for electrode methods using stainless steel (in Denmark) to 5 mg/m^3 for solid particles in welding aerosol (in Slovakia) (Table 11-16). Depending on the level of a proposed EU generic welding-specific OEL, the six countries with existing OELs (for welding fumes) may be less impacted than the 21 countries which would need to implement a new one. If the EU OEL is more stringent than existing national OELs then there would be impacts from implementing it in those Member States.

7.4.2 Research and innovation

Achieving compliance with a complementary generic welding-specific OEL may mean that enterprises divert funding away from research and innovation into investing in RMMs to achieve the OEL. A table of average estimates of R&D budgets by sector and across small, medium and large enterprises is included in Table 6-34. As existing compliance is likely to be less in smaller enterprises than larger enterprises (interviews with key stakeholders, June-July 2023), smaller enterprises may need to divert a larger proportion of their R&D budget into investing in risk management measures (RMMs) to achieve a new welding-specific OEL.

7.4.3 Single market

7.4.3.1 Competition

Table 7-3 below includes the initial screening of impacts on competition in order to focus the analysis on those impacts likely to be the most significant. The competition impacts of compliance with a new welding-specific dust OEL are similar to the corresponding impacts of policy option two (Annex I) (Table 6-35). The most significant impacts are further explored in the following paragraphs.

The answers in the table are the overall assessment following by more sector specific considerations.

Table 7-3 Screening of competition impacts

Impacts	Key questions	Yes/No
Existing firms	Additional costs?	Yes
	Scale of costs significant?	Don't know
	Old firms affected more than new?	Possibly
	Location influences?	Member States with better existing regulation of welding fumes and compliance with these regulations will need fewer improvements.
	Some firms will exit the market?	Don't know
	Are competitors limited in growth potential?	Yes, competitors will be limited by the shortage of welders in the EU
	Increased collusion likely?	Don't know
New entrants	Restrict entry?	Possibly
Prices	Increased prices for consumers	Potentially
Non-price impacts	Product quality/variety affected?	Probably not
	Impact on innovation	Innovation budgets may need to be diverted into investment in RMMs to achieve the new OEL; conversely innovative practices may be adopted to reduce worker exposure to dust.
Upstream and downstream market	Will OELs affect vertically integrated companies more or less than non-integrated ones?	Larger, vertically integrated companies will have more direct control over worker protection than non-integrated companies. They may already be in compliance with the new OEL and it will be easier for them to implement it. Smaller, non-integrated companies may find it harder and more costly to implement the new OEL, and without enforcement may be tempted to avoid changes in their practices.
	Will OELs encourage greater integration and market barriers?	Unknown
	Will OELs affect bargaining power of buyers or suppliers?	As there is growing awareness of working conditions in the supply chain (as part of the provenance of products), improvements in worker protection could potentially improve the bargaining power of suppliers; they could use this as a competitive advantage over suppliers in other parts of the world with weaker worker protection, despite possible increases in product prices.

Source: Study team.

7.4.3.2 Existing firms

As for policy option two (Annex I), compliance with a new welding-specific dust limit may sometimes be more difficult to reach for older facilities, as space is often more limited in older factory designs, making it more challenging or even impossible to install space-consuming RMM such as larger welfare facilities and/or ventilation systems needed for compliance.

7.4.3.3 Firms leaving the market (discontinuations)

Based on the available data it is not possible to estimate the number of business discontinuations.

If the welding-specific dust limit was set low, below existing OELs in Member States, then some businesses may decide to cease operating if they consider the OEL not economically viable for them to achieve.

7.4.3.4 New entrants

As for policy option two (Annex I) but perhaps to a greater extent, a new welding-specific dust limit could focus the attention of new businesses undertaking welding+ activities on the need for compliance and the associated costs of compliance with this threshold limit. One-off (capital) costs of installing general ventilation and/or local exhaust ventilation systems and organisational costs could represent deterrents to new entrants. The extent and distribution of this deterrent effect across sectors or across small, medium and large enterprises is difficult to ascertain from the available information, but is likely to be greater for smaller enterprises.

Significant capital expenditures are often incurred by new start-ups when entering the market. When entering the market companies are required to monitor exposure and so costs of running monitoring campaigns for start-ups cannot be attributed to the introduction of OELs. However, as limit values become lower more precise and more expensive monitoring techniques are required, potentially increasing the costs of the monitoring campaign and making entry to the market more challenging.

7.4.3.5 Consumers

As for policy option two (Annex I), enterprises which cannot pass on price increases to consumers may pursue compensating the compliance cost by reducing the product quality or reducing the product variety. At the same time, such efforts can be risky, as a high degree of competition can provide a lot of market power to consumers. It is not possible to assess in specific detail which sectors are likely to pursue such efforts, as it would require primary data collection on consumer preference and their specific market power across sectors, which lies beyond the scope of this assessment.

7.4.3.6 Internal market

Introducing a harmonised welding-specific dust limit across the EU would help to create a level playing field for enterprises across the internal market, as the gap between the lowest and highest worker exposure levels would decrease. In addition, as mentioned in section 7.2, the introduction of a dust limit would create a clear threshold for enterprises to reach, which could be argued is a clearer target than policy option two (Annex I) alone.

Although simplifying the OELs that apply to welding fumes is not currently proposed, it is worth pointing out the benefits that would ensue from this. In addition to the improvement of the playing field, medium and large enterprises with facilities across the EU facilities may benefit from a simplification of the applicable limit values, should the Commission decide to simplify the OELs that apply to welding fumes to focus on the welding specific dust limit. This could provide savings in terms of research- and design cost, as common solutions can be adopted across facilities, as opposed to designing site-specific solutions to meet different OEL requirements.

The sectors that mostly are composed of medium and, to a lesser extent, large enterprises, are likely to benefit most of the above simplifications (e.g. sectors C25, C28, C29, C31, C33, F41, F43). The automotive industry (C29) is for example dominantly composed of medium enterprise, of which at least three are confirmed to have multiple locations across the EU (i.e. Audi, BMW, Renault[70]).

7.4.4 Competitiveness of EU businesses

The introduction of a welding-specific dust limit would have an impact on companies' cost competitiveness but will be more significant for the Member States, enterprises and/or sectors which do not yet have a welding specific dust limit and those with lower existing compliance. As indicated previously, the increase in costs due to having to implement more or better RMMs represents the burden of compliance on companies. This would make those companies incurring these costs less competitive where they are competing with companies not generating welding fumes dust and with any companies already compliant at this level.

It is about equally common for Member States to have a welding specific OEL or a non-specific dust limit, although sometimes from the available information it was impossible to categorise the dust limit into 'welding fumes-specific' or 'generic' (Czechia, Ireland, Spain). Six Member States with an OEL of some kind for welding fumes include: Austria, Belgium, Denmark, Latvia, Lithuania, Slovakia (Table 11-16). Six Member States with a generic dust limit include: Cyprus, Croatia, France, Germany, Ireland, Netherlands. In terms of non-EU countries, from the information available it is often unclear whether the limit value is specific to welding fumes or a generic dust limit (Table 11-16).

A potential risk is that a welding fumes specific OEL could be set below equivalent welding fumes limits in other globally competitive regions (Table 11-16) which could result in welding workplaces and the associated value generated by them moving outside the EU, in which case neither employees or employers would benefit in the EU (EWA, 2023; IIW, 2023). The dust limit values in non-EU countries that have been identified range from 3 mg/m^3 (respirable fraction) (for particles not otherwise specified or PNOS in Ontario, Canada and the USA) up to 10 mg/m^3 (inhalable fraction) (PNOS in Ontario, Canada and the USA); with 5 mg/m^3 being a modal average (in Australia; Canada, Quebec; India; Norway, South Korea). The fact that most of the countries that the EU welding community is in competition with (China, Japan, South Korea, India, US) already regulate exposure to welding fumes in some way (mostly through OELs), indicates that this pull may not be as large as initially thought.

[70] Audi has manufacturing sites in Belgium, Germany, Hungary, Slovakia and Spain; BMW has manufacturing sites in Austria and Germany; Renault has manufacturing sites in France and Spain.

7.4.4.1 Sectors affected

For the same reasons as discussed in section 6.4.4.1, the introduction of a dust limit is unlikely to have a significant impact on the competitiveness of the European sectors undertaking welding+ activities.

Various EU sectors are in competition with Asia (metal product manufacturing, automotive manufacturing, shipbuilding and to some extent the aeronautical industry), but as many of the competing countries have OELs for welding fumes (China, South Korea, India) or regulate welding fumes via a limit on manganese in the case of Japan, an EU dust limit is unlikely to have a large impact on international competitiveness unless it is more stringent than OELs in non-EU countries. The US is a major competitor in the aeronautical industry, but there are guidelines on dust exposure in the US, so depending on how tight the threshold for the EU dust limit would be, the gradient between the EU dust limit and the US ACGIH guidelines may not be steep. In addition, many jurisdictions in Canada apply the American ACGIH guidelines for dust, so the same discussion for the US applies for Canada, again particularly for the EU aeronautical industry.

7.4.4.2 SME competitiveness

The same generalisation made for policy option two (Annex I) applies for a new EU dust limit, that large enterprises are more likely to have stronger health and safety practices in place already, including using RMMs (interviews with key stakeholders, June-July 2023). A gain, small enterprises are less likely to have sufficient RMMs in place, and therefore may need to invest in additional RMMs to comply with a welding-specific dust limit. Achieving compliance also requires administrative effort, and small companies may need to divert resources to achieve compliance. In combination, these effects could put smaller enterprises at a competitive disadvantage to larger enterprises.

7.4.4.3 Cost competitiveness

In common with and building on policy option two (Annex I), European enterprises may need to increase their costs to cover the increased costs of compliance with a complementary EU welding-specific dust limit. In particular smaller enterprises may need to do this, and enterprises in Member States with less enforcement of the CMRD (interviews with key stakeholders, June-July 2023).

7.4.4.4 Capacity to innovate

Again, in common with achieving policy option two (Annex I), European enterprises may need to divert funding from research and innovation towards investment in RMMs to comply with a new EU welding-specific dust limit, which could reduce their capacity to innovate. Conversely, improved awareness of the need to reduce worker exposure to dust in welding fumes could result in more investment in innovative practices to optimise welding processes for example REarc (Section 3.7). It is difficult to quantify the change in capacity to innovate as the available information is insufficient.

7.4.4.5 International competitiveness

Analogous to the discussion of international competitiveness for policy option two (Annex I), some countries already regulate worker exposure to welding fumes by implementing OELs (Table 11-16). It could be assumed therefore that implementing a new EU welding-specific dust limit would have a low impact on competition between EU businesses and those countries with OELs for welding fumes: Australia, Canada (Quebec), China, India, Norway, South Korea (Table 11-16). The same assumption could be applied to Japan where employers of welders are required to measure the concentration of Mn in the air and select the respirator with a sufficient protection factor for Mn. The ACGIH guidelines for particle exposure that are used in the US and in Canada are set at a similar level to the national dust limits set in Member States, so again this does not represent a significant impact on competition with the EU should a dust limit be introduced. Of course, the level of compliance with these regulations and guidelines will depend on how well they are enforced in these countries, with some countries putting more resources into enforcement than others.

7.4.5 Employment

It has not been possible to estimate the number of discontinuations that would occur due to an unspecified welding-specific OEL. Therefore, the impacts on employment cannot be estimated.

7.4.6 Summary of market effects

It is difficult to discuss in much detail the market effects from implementing a welding-specific OEL, when no limit has been proposed. This makes it impossible to make a comparison with existing welding fumes OELs.

However, it was possible to make some generalisations:

- The six Member States with existing welding-specific OELs may be less impacted than the 21 Member States that would need to implement a new OEL;
- Smaller enterprises may need to divert a larger proportion of their R&D budget into investing in RMMs to achieve a new welding specific OEL;
- In terms of the impacts of competition, the factors are similar to those discussed for policy option two (Annex I) (see Table 7-3);
- Compliance with a new welding-specific OEL may sometimes be more difficult for older facilities;
- It is not possible to estimate the number of business discontinuations, only to say that a tighter welding-specific dust limit is more likely to result in discontinuations;
- New entrants may be deterred from undertaken welding activities due to the necessary capital investment in extraction equipment and organisational costs, this is likely to be a greater deterrent for smaller enterprises;
- Enterprises may need to pass on the increased costs to consumers via price increases, or reduce product quality or product variety;
- A welding-specific OEL would help to create a level playing field across the internal market;
- Enterprises (smaller enterprises according to anecdotal evidence) with existing lower levels of compliance with best practice are more likely to be at a competitive disadvantage;
- As most of the countries that the EU welding community is in competition with (China, Japan, South Korea, India, US) already regulate exposure to welding fumes in some way (mostly through OELs), indicates that the risk that welding activities are exported out of the EU is probably low; and
- In common with policy option two (Annex I), enterprises may need to divert funding from R&D into investment in RMMs to comply with a new welding-specific OEL, which could reduce their capacity to innovate; but conversely a new OEL may provide a driver for investment in innovative practices to optimise welding processes to reduce welding fumes at source.

7.5 Environmental impacts

This chapter comprises the following sections:

- Section 7.5.1: Potential environmental impacts;
- Section 7.5.2: Current environmental exposure to the substance;
- Section 7.5.3: Direct impact on the environment;
- Section 7.5.4: Indirect impacts on the environment and environmental legislation; and
- Section 7.5.5: Summary of environmental impacts.

7.5.1 Potential environmental impacts

The potential environmental impacts are the same as those discussed in section 6.5.1.

7.5.2 Current environmental exposure to the substance

See section 6.5.2.

7.5.3 Direct impact on the environment

In this section the direct environmental impacts of policy option three are assessed based on the predicted response of industry. Under policy option three, involving the implementation of a specific OEL for welding fumes, the impacts on industry may vary significantly based on the level at which the OEL is introduced. This level has not been established in the current study and so environmental impacts associated with an OEL cannot be decisively indicated.

Should the OEL be established at a level which would not be achievable by most industry members it could be expected that many welding operations across Europe may close. In terms of environmental impact this would result in a direct reduction in emissions of welding fumes to the environment. The scale of this reduction would be determined by the level of RMMs which were implemented in the welding facility before closure. For example, the discontinuation of a welding facility with significant enclosure would likely result in a lower reduction of emissions than a facility which has no enclosure or ventilation.

Conversely if the OEL is set at a level which would not impact welders in Europe then no changes would be expected to be observed in welding fumes emissions. Should the OEL be set at a level which is mainly achievable by industry after changes to RMMs it could be expected that welding fumes emissions may marginally increase. This is based on the same principle as in section 6.5.3 where industry will likely introduce improved ventilation systems for welding processes. These ventilation systems usually have highly efficient filters which would remove the majority of emissions, however there is potential for small quantities of emissions to be removed from the facility to the environment.

Overall, the scale of the direct impacts cannot be accurately determined in this study however the above indicates the potential impacts which may occur at different OEL levels.

7.5.4 Indirect impacts on the environment and environmental legislation

7.5.4.1 EU Green Deal

In 2019 the European Commission announced the European Green Deal to encourage future policies to be developed in line with minimal adverse impacts on the environment and to support efforts to move to sustainable practices (European Commission, 2019).

Table 6-38 in section 6.5.4.1 outlines the key elements put forward in the EU Green Deal and contains a short overview of the expected impact (positive or negative) of introducing the policy option three for welding fumes on the progress towards each of these elements. A short explanation is given to indicate the justification for the expected impact.

This section reviews the implementation of policy option three for welding fumes in the context of the key elements of the green deal (Table 7-3). This is also in line with the approach described in chapter 36 of the better regulation toolbox.

Table 7-4 Potential for OELs to impact benefits of the EU Green Deal

Elements of the EU Green Deal	Policy option impact (Yes/No)	Comment
Increasing the EU's climate ambition for 2030 and 2050	N/A	See section 9.4.2 on the European Climate Law
Supplying clean affordable and secure energy	Yes	Introduction of Welding OELs could result in a loss of production of green infrastructure which would compromise the ability to deliver clean energy, electric mobility, efficient buildings.
Building and renovating in an energy and resource efficient way	Yes	
Accelerating the shift to sustainable and smart mobility	Yes	
Mobilising industry for a clean and circular economy	Yes	Welding operations are likely involved in the recycling of metal materials. Should welding be negatively impacted by introduction of an OEL this could impact EU capacity for recycling and thus impacting circular economy.
Designing a fair, healthy and environmentally-friendly food system	Yes	The implementation of an OEL for welding fumes may result in increased ventilation causing minor increases in the release of welding fumes to the environment. These may bioaccumulate in food
Preserving and restoring ecosystems and biodiversity	Yes	
Zero pollution ambition for a toxic-free environment	Yes	

Elements of the EU Green Deal	Policy option impact (Yes/No)	Comment
		chains and cause toxic effects in organisms. Conversely the OEL may result in closure of business which would reduce the environmental releases.

Source: Study team

7.5.4.2 European Climate Law

The European climate law was introduced in 2021 and sets out legally binding targets for emissions reductions proposed by the EU Green Deal. The main target proposed is to ensure that the European economy and society become climate neutral by 2050, with an intermediate goal to reduce greenhouse gas emissions 55% by 2030, compared to 1990 levels (EC, 2021d). It is therefore important that any implementation of policy option two (Annex I) for welding fumes should support the drive to climate neutrality and not contradict the objectives set out in this legislation.

The introduction of an OEL for welding fumes may result in disruption to supply chains involving welded products, depending on the level at which the OEL is set. Welding is an essential process for the production of many heavy goods/equipment and so should an OEL result in an inability to deliver these products many 'green' infrastructure' projects may not be deliverable. Green infrastructure may be items such as wind turbines, electric vehicles or building materials for energy efficient buildings. Should this infrastructure face limited availability of welded parts this could impact the ability to deliver climate targets.

7.5.4.3 Waste management and disposal

The implementation of OELs for welding fumes may have impacts on the circularity of metal products used in various applications. Welding activities are involved in the recycling of key metals such as steel and so should OELs disrupt the ability of welders to recycle used metals this will impact the circularity of these products. This will also likely result in higher resource consumption of virgin metals which could increase demands on mining and smelting activities, which generally have environmentally negative footprints. Overall, OELs may counteract the goals of the EU circular economy and so care would need to be taken to ensure OELs are introduced at a level which would not result in the above impacts.

7.5.4.4 Resource consumption and circular economy

See section 7.5.4.3 above.

7.5.4.5 Global impacts

OELs which may restrict welding processes in Europe may result in switching production of heavy machinery/welded metal to facilities outside of Europe. This would increase the carbon footprint of the final products welded metals are used in and would shift emissions of welding fumes to other regions as opposed to reducing welding emissions globally.

7.5.4.6 Green initiatives

Given that ongoing R&D efforts are being conducted to develop lower energy processes which result in lower emissions, the introduction of a welding OEL has potential to significantly increase the funding of these technologies. As policy option 3 would introduce a legally binding limit, it is likely that investment in lower emission technologies would increase. This in turn may mean greater uptake of cleaner technologies in the future, which would reduce direct and indirect environmental impacts of welding fumes and particulate matter release. This relies on the assumption that R&D efforts are successful and can be substituted into all welding processes equally.

7.5.5 Summary of environmental impacts

Policy option three may result in highly varied environmental impacts depending on the level at which an EU OEL would be introduced. Should an OEL be implemented at a low level then higher numbers of discontinuations may occur which would have larger scale reductions in direct emissions of welding fumes. Conversely, if an OEL was introduced at a higher level then impacts would be more likely similar to those in section 6.5.3 where direct emissions may marginally increase depending on the efficiency of filters in ventilation systems.

When considering indirect impacts on environmental legislation and targets the above situation is again reflected. Under low OEL scenarios there is potential for high levels of disruption in civil engineering supply chains which would limit the availability of materials for 'green infrastructure' projects such as wind farms, electric vehicles, and energy efficient buildings. This could in turn cause increased dependence on globalised supply chains which would simply transfer welding fumes outside of the EU whilst also increasing the carbon footprint of green infrastructure projects. This however would still depend on the level an OEL would be introduced at. There is potential that the introduction of an OEL may increase the development speed of greener welding processes which use less energy and produce lower levels of emissions.

7.6 Other impacts

This chapter comprises the following sections:

- Section 7.6.1: Impacts on EU Strategic Goals;
- Section 7.6.2: Impacts on fundamental rights, including equality;
- Section 7.6.3: Impacts on digitalisation;
- Section 7.6.4: Contributions to the UN sustainable development goals; and
- Section 7.6.5: Summary of other impacts.

7.6.1 Impacts on EU Strategic Goals

The impacts on EU Strategic Goals are similar to those discussed in section 6.6.1. The introduction of a welding-specific OEL would arguably provide a clearer target for Member States and enterprises to achieve than policy option two (Annex I) (with no legal change); this would contribute towards the first priority of the Strategic Goals of protecting citizens and the third priority of building a fair Europe (with equal protection for all workers).

The impacts on the EU Commission priority areas for 2019-2024 are also similar to those listed in section 6.6.1, see Table 7-5 below.

Table 7-5 Impacts of a dust OEL (specific to welding) on the EU Commission priority areas for 2019-2024.

EU Commission Priority Areas 2019-2024	OELs impact (Yes/No)	Comment
A European Green Deal	No	See section 7.5.4.1
A Europe Fit for the Digital Age	No	See section 7.6.3
An Economy that Works for People	Possibly	A qualitative discussion of the impact on SMEs is provided in section 7.7.2; SMEs may need financial support to provide best practice RMMs to their workers. Low impact on international competition (see section 7.4.4.5)
A Stronger Europe in the World	Yes	The introduction of an EU welding fumes OEL will help to affirm the EU's reputation of delivering safe workplaces and respecting the fundamental rights of EU workforce.
Promoting our European Way of Life	Yes	The introduction of an EU Binding OEL will mean all Member States are subject to the same regulation of hazardous substances set out in the CMRD. EU OELs therefore support an equal approach to chemical risk management and a united Europe when dealing with external markets.
A New Push for European Democracy	No	The introduction of an EU dust OEL specific to welding does not impact the push for a maintained and renewed European democracy.

Source: Study team

7.6.2 Impacts on fundamental rights, including equality

The impacts on rights and equality are similar to those discussed in section 6.6.2, except again that the introduction of a welding-specific OEL would arguably provide a clearer target for Member States and enterprises to achieve than policy option two (Annex I) (with no legal change) to improve working conditions (Article 31.1). However, as discussed previously (section 7.3) a welding-specific OEL may have limited additional value for protecting workers from CMR substances using existing OELs for individual CMR substances in welding fumes.

7.6.3 Impacts on digitalisation

The impacts on digitalisation would be similar to the discussion in section 6.6.3.

7.6.4 Contributions to the UN sustainable development goals

The contributions to the UN sustainable development goals would be similar to those discussed in section 6.6.4.

7.6.5 Summary of other impacts

The summary of other impacts is the same as the summary in Table 6-40.

7.7 Distribution of impacts

Most of this section is not applicable to a qualitative assessment.

The impacts identified under the previous tasks will be broken down by stakeholder type and a systematic analysis of who will bear the costs and accrue the benefits will be provided.

This chapter comprises the following sections:

- Section 7.11.1: Businesses;
- Section 7.11.2: SMEs;
- Section 7.11.3: Workers;
- Section 7.11.4: Consumers;
- Section 7.11.5: Taxpayers/public authorities;
- Section 7.11.6: Specific Member States/regions; and
- Section 7.11.7: Summary of distribution of the impacts.

7.7.1 Businesses

This section is not applicable to a qualitative assessment.

7.7.2 SMEs

This section is not applicable to a qualitative assessment.

7.7.3 Workers

This section is not applicable to a qualitative assessment.

7.7.4 Consumers

This section is not applicable to a qualitative assessment.

7.7.5 Taxpayers/public authorities

This section is not applicable to a qualitative assessment.

7.7.6 Specific Member States/regions

As discussed in section 7.7.4, it is slightly more common for Member States to have a welding specific OEL than a non-specific generic dust limit, although sometimes from the available information it was impossible to categorise the dust limit into 'welding fumes-specific' or 'generic' (Czechia, Ireland, Spain). Six Member States with an OEL of some kind for welding fumes include: Austria, Belgium, Denmark, Latvia, Lithuania, Slovakia (Table 3-1). Six Member States with a generic dust limit include: Cyprus, Croatia, France, Germany, Ireland, Netherlands. In terms of non-EU countries, from the information available it is often unclear whether the limit value is specific to welding fumes or a generic dust limit (Table 3-1).

If correct, this means that 21 Member States would need to introduce a new welding fumes-specific OEL and up to 6 Member States may need to alter their legislation. The study team has heard anecdotal evidence that worker protection is better for welding in northern and western Europe than in southern and eastern Europe; this would indicate that the impact of introducing (and enforcing) a welding fumes specific OEL could be larger in southern and eastern Europe. This has not been substantiated, although the ECRHS II survey did find that cumulative exposure to welding fumes was higher in Southern compared with Northern Europe (Olsson and Kromhout, 2021).

No detailed analysis of direct impacts on Member States can be derived from this assessment. This is because the distribution of companies undertaking welding activities across EU Member States has been modelled based on Eurostat data and so may have a level of uncertainty relating to the true distribution. As such any analysis of impacts on specific Member States would pose a level of uncertainty and may lead to inaccurate conclusions.

7.7.7 Summary of distribution of the impacts

This section is largely not applicable to a qualitative assessment. The only key points of note are that:

- Potentially 21 Member States would need to introduce a new welding fumes-specific OEL and up to 6 Member States may need to alter their legislation; and

- The study team has heard anecdotal evidence that worker protection is better for welding in northern and western Europe than in southern and eastern Europe; this would indicate that the impact of introducing (and enforcing) a welding fumes specific OEL could be larger in southern and eastern Europe. This has not been substantiated, although the ECRHS II survey did find that cumulative exposure to welding fumes was higher in Southern than in Northern Europe (Olsson and Kromhout, 2021).

7.8 Summary of economic, social and environmental impacts

Environmental impacts are summarised in 7.5.

This chapter comprises the following sections:

- Section 7.8.1: Economic impacts;
- Section 7.8.2: Social impacts; and
- Section 7.8.3: Environmental impacts.

7.8.1 Economic impacts

This is not relevant for a qualitative assessment.

7.8.2 Social impacts

This is not relevant for a qualitative assessment.

7.8.3 Environmental impacts

A welding-specific OEL could have the following environmental impacts:

- Direct impacts on the environment through the increased release of particulate matter into the external environment from the increased use of extraction systems. However, the highly efficient filters (more than 99% effective) used in extraction systems are predicted to capture the majority of particulates;

- Indirect environmental impacts in terms of increased energy consumption from increased use of extraction systems, and therefore increased carbon emissions from the power sector; and

- Policy option two (Annex I) is unlikely to impact on EU environmental initiatives such as carbon neutrality, circular economy, energy efficiency or electric based mobility.

Please see section 7.5 for further details.

7.9 Limitations of this qualitative assessment

This qualitative assessment is severely hindered by not having any potential thresholds for a generic welding-specific dust limit to evaluate. The discussion is also limited by the information available on this topic. Welding fumes are highly heterogenous which makes any evaluation of how to regulate them complicated. The study team tried to ascertain whether there were any existing regulatory impact assessments (RIAs) that were undertaken before the existing national OELs for welding fumes or dust limits were introduced, but the WPC were unaware of any since RIAs are not mandatory (*pers comm*, meeting between RPA and WPC, 11 May 2023). These could have provided useful information to discuss in this qualitative assessment, and findings at a national level could have been extrapolated to the European level. However, the WPC explained that often OELs will be introduced at the national level based upon the scientific health evidence, without a full RIA.

8 QUALITATIVE IMPACT ASSESSMENT OF A COMPLEMENTARY NON-SPECIFIC GENERIC DUST METRIC (INHALABLE AND RESPIRABLE)

8.1 Introduction

A health-based generic dust limit could be introduced across all sectors and activities, for the inhalable and respirable fractions of dust respectively, in addition to policy option two (Annex I). This would ensure a harmonised level of protection for workers across sectors, not just across welding+ processes. Dust is a process generated substance generated by various activities, with associated health effects.

The sectors and groups of sectors that generate dust include:

- Extraction and processing of minerals, earths and raw materials;
- Ceramics and glass industry;
- Chemical, pharmaceutical, rubber and plastics industry;
- Wood, leather, paper, textile industry;
- Metal production, foundries;
- Metalworking and metal processing, machine and vehicle production;
- Repair, maintenance and workshop work;
- Electrical and precision engineering industry and trades;
- Electroplating, hot dip galvanising, surface coating;
- Services, transport, power generation, educational establishments;
- Agriculture, animal feed production;
- Food industry;
- Wholesale, retail, warehousing;
- Waste disposal, recycling; and
- Construction industry.

Source: DGUV, 2021.

Introducing an EU non-specific generic dust OEL would require an impact assessment across all sectors and activities which generate dust, but here the qualitative impact assessment focuses solely on welding activities. (Unless it was a health-based dust limit and then an impact assessment would not be required.)

8.2 Discussion of the benefits of a non-specific generic dust limit

In addition to the benefits of introducing a generic dust limit identified by ECHA, such as the necessary studies and resulting improvements in understanding of the health effects of dust (section 7.2), a further advantage would be that generic dust limits (respirable and inhalable) would be applied across all sectors/workers which would simplify the implementation according to ECHA (2022).

In terms of the presence of causative agents (CMR substances such as metals and metal compounds or certain gases), ECHA (2022) note that exactly the same adverse health effects can result from exposure both from welding and from other activities. This observation supports the application of the same limit values in all exposure settings.

Generic dust limits applied across the EU could in theory help towards harmonisation across the EU and towards the simplification of OELs. The EWA and IIW support these principles, and indeed consider them critical success factors for the regulation of welding (EWA, 2023; IIW, 2023). Harmonisation across the EU is useful to multinational enterprises that operate across national borders and helps to provide a level playing field of consistent protection of workers in different EU countries. The EWA recommend the simplification of OELs, based upon 'the most hazardous substance' or 'fewer singular elements to be controlled' and 'subsuming OELs where possible'. In theory applying generic dust limits to welding could be used as a way for fewer singular elements to be controlled in welding activities or even for OELs to be subsumed under these generic dust limits. Generic dust limits could provide simplification in terms of providing clear, understandable, measurable and communicable OEL values. However existing substance specific OELs would justifiably still be in force, unless the current policy was changed.

The DGUV agree that substances without defined OELs might also exhibit potential occupational exposure according to their deposition in different parts of the lung based upon particle size (DGUV, 2023a). Therefore, having a generic OEL for inhalable and respirable dust fractions could address this risk to some degree. In situations where specific metal components do not have consequences (because they are present at negligible quantities), it could make sense to have a generic non-specific dust EU OEL to protect workers from the health effects from particulates. The DGUV (2023a) and ECHA (2022) are not aware of any scientific data showing that specific substances act differently or have other hazardous properties depending on whether their origin is from welding fumes or generic dust generated from other occupational activities. Further to the above, it is technically feasible to measure occupational exposure to dust using wearable dust monitoring devices (DGUV, 2023a). I n Germany the measurement of relevant components in welding fumes (to ensure compliance with the existing national generic dust OELs) by wearing such devices is technically well established and validated.

As the welding of mild steel has been found to generate higher concentrations of welding fumes (0.6 times higher) than welding stainless steel (Kendzia *et al*, 2019), this supports the need for a generic OEL for inhalable and respirable dust in addition to OELs for CMR substances according to the DGUV (DGUV, *pers comm*, July 2023).

As an example, in Germany the generic dust limit is set for particles with low intrinsic toxicity (called GBS: Granuläre, biobeständige Stäube which in English translates to PSP: poorly soluble particles of low toxicity) (Fobig, *pers comm*, May 2023). This provides a clear distinction of how the generic dust limit should be applied. If the committees in Germany decide that a certain type of particle belong to that category, then the generic dust limit applies to these particles. The German dust limit is based on many toxicity studies on these PSP.

8.2.1 Summary of the key assessment framework

This is purely a qualitative assessment, with no attempt at quantification.

8.2.2 Improved welfare, assumptions and avoided cases of ill health

As for a welding-specific dust limit, a non-specific dust limit could help to create a level playing field but this time across sectors across Europe. Again, as limit values already exist for most metals relevant to welding work (Annex III of the CMRD), and are set at much lower levels than any threshold value that can be conceived to be set for inhalable and respirable dust; setting a generic non-specific dust limit may have limited additional value to using existing OELs for CMR substances.

As discussed in section 7.2.2, because it is not clear whether health effects observed in welders are due to exposure to poorly soluble, low toxicity dusts or something specific to welding (ECHA, 2022), it is hard to evaluate the health impact of introducing a non-specific dust limit. The causal mechanisms for health effects are not fully understood. If future toxicological studies show that there is a link between dust in general (from any activity) and health effects, as opposed to dust from welding in particular, then this would support the introduction of a non-specific dust limit.

8.2.3 Benefits to workers and families

For the above reasons (section 8.2), it is not possible to say whether there would be any benefits to workers and their families from introducing a generic, non-specific dust limit across the EU. If introducing a generic non-specific dust limit encourages enterprises that were not taking adequate measures to protect their workers, and results in improved worker protection, then this would represent a benefit to workers and their families as improved health outcomes would be expected for workers. The study team note that often an OEL is needed for enterprises to have a concrete threshold to work to achieve (from anecdotal evidence, study team).

A generic non-specific dust limit would have the added benefit of potentially improving worker protection, and therefore health outcomes, to workers and their families in all sectors undertaking processes that generate dust (beyond just welding).

In terms of the existing OELs, the non-specific dust limits (for the Respirable fraction in particular) are some of the tightest dust OELs currently in place in the EU (0.9 and 1 mg/m^3 in France and the Netherlands respectively for example) (Table 11-16). I f the same logic is applied in setting an EU non-specific dust limit as in these countries, perhaps it would be set at quite a tight threshold for the respirable fraction, for maximum health benefits, but this could result in negative impacts on competition.

8.2.4 Benefits to employers

Introducing an OEL would usually help employers to avoid costs due to insurance payments and absence from work, but as the benefits of introducing a generic, non-specific dust limit beyond the benefits of the existing substance specific OELs are unknown it is not possible to say whether employers would benefit. As above (section 7.2.3) if the dust OEL results in improved worker protection, in companies that were not previously using sufficient RMMs, then the above benefits for employers would ensue.

8.2.5 Benefits to public administrations

As for a welding-specific dust limit, it is difficult to say whether a generic, non-specific dust limit would result in avoided tax revenue losses, avoided administrative and legal costs. If the OEL resulted in improved worker protection in enterprises that were previously not using sufficient RMMs, then these benefits would ensue. An EU wide non-specific dust limit would help public administrations avoid the costs linked to the process of defining a national OEL (if they do not have one already).

8.2.6 Summary of the benefits

The benefits of a generic, non-specific OEL for dust are summarised in Table 8-1; they are potentially the same benefits as from policy option two (Annex I) and similar to a welding-specific dust limit as an OEL for dust would improve compliance. However, as stated above, since the causal links between dust and other components of welding fumes and health effects are not understood well it is difficult to distinguish them to be able to evaluate the health impact of a dust OEL. A s there are already substance specific OELs for most of the hazardous substances in welding fumes, set at tighter, more meaningful limits to address health effects than can be foreseen for a generic dust limit, a dust limit may have limited additional value.

Table 8-1 Potential benefits of a generic, non-specific OEL for dust.

Category		Benefits	Notes
Direct	Improved welfare	Reduced healthcare costs	Avoided cost of medical treatment, including hospitalisation, surgery, consultations, radiation therapy, chemotherapy/immunotherapy, etc. Avoided private direct and indirect medical costs and rehabilitation costs
		Reduced informal care costs[71]	Avoided opportunity cost of unpaid care (i.e. the monetary value of the working and/or leisure time that relatives or friends provide to those with ill health)
		Reduced cost for employers	E.g. avoided costs due to insurance payments and absence from work
		Safety	
		Direct economic benefits	

[71] A decision has been taken to include informal care costs in this analysis even though some elements of these costs may also have been included in individuals' willingness to pay values to avoid a future case of ill health. This decision may result in an overestimate of the benefits as generated by this study.

Category		Benefits	Notes
		Environment	See section 8.5, not monetised
	Improved market efficiency	Cost savings	Include higher economic productivity, improved allocation of resources, removal of regulatory or market failures or cost savings.
		Improved information	Includes improved information availability
		Wider range of products/services	Enhanced product and service variety and quality for end consumers
Indirect	Indirect compliance benefits	Reduced mortality – productivity loss.	Avoided costs to society due to premature death
		Reduced morbidity – lost working days.	Avoided earnings and output due to absence from work due to illness or treatment
		Other indirect benefits to workers and families	
		Indirect benefits to administrations	Avoided tax revenue losses Avoided administrative and legal costs Avoided costs linked to the process of defining a national OEL
	Wider economic benefits	including higher GDP, productivity enhancements, greater employment rates, improved job quality etc.	Employment may increase as a result of industry 'clean up' due to better perception of workplaces and increased acceptability of risks
	Other, non-monetary benefits	Protection of fundamental rights, social cohesion, reduced gender discrimination, international and national stability	

Source: Study team

8.3 *Discussion of the disadvantages of a non-specific generic dust limit*

Many of the same disadvantages discussed in section 7.3 would also apply to a non-specific EU generic dust limit:

- ECHA say that it should be complemented with monitoring the gaseous phase for relevant gases, as it would be difficult to define a generic gas exposure metric i.e. a substance specific approach to gases alongside a generic approach for particulate matter, even though particulate matter can contain some known specific carcinogens;
- There is low confidence in setting a generic dust limit because:

- Dust concentrations, particle sizes and substances present in the dust vary widely between workplaces; and

- The limit is likely to be set based upon an underestimation of the dust present (static dust sampling data rather than actual inhaled concentrations of dust which is better measured by personal sampling and tends to be higher).

The same potential risk applies as above for welding specific generic dust limits (section 7.3), that welding specific dust limits could be set below equivalent dust limits in other globally competitive regions which could result in welding workplaces and the associated value generated by them moving outside the EU, in which case neither employees or employers would benefit (EWA, 2023; IIW, 2023).

Again, depending upon the chosen limit value, there is a risk that if the limit was set too high for welding fumes this could result in insufficient safety precautions for exposed workers in the most hazardous working environments. Conversely, if the limit was set too low for welding fumes this could lead to unnecessary safety precautions in relatively safe working environments (if the threshold was set too low) (DGUV, 2023a).

8.3.1 The cost framework

This is purely a qualitative assessment without any attempt at quantification.

8.3.2 Direct adjustment costs to companies

-There would be some direct adjustment costs for companies if a generic non-specific dust limit was introduced; for companies that would need to introduce additional RMMs to achieve the limit value. The size of the adjustment costs would depend upon the limit level set. Some countries have welding-specific OELs but fewer countries have non-specific dust limits (Table 11-16). This means that the majority of Member States would have significant adjustment costs to introduce a new non-specific dust OEL across all sectors. This qualitative assessment focuses on the impact on sectors undertaking welding activities.

8.3.3 Indirect costs for companies

If the generic non-specific dust limit is set below equivalent dust limits in other globally competitive regions, or if non-specific dust limits do not exist at all in other such regions, then workplaces could move outside the EU.

8.3.4 Costs for public administrations

If a Member State does not already have an OEL, the cost of transposing an OEL into national legislation has in previous studies been assumed to be €50,000 per Member State with no existing OEL. If a Member State has an OEL, but it needs to be amended to align with the new EU OEL, the assumption is that the cost would be less than this.

8.3.5 Impact of transitional periods on costs

This policy option is being considered as a possible option for the future (in addition to policy option two (Annex I)), and no quantitative analysis has been undertaken.

8.3.6 Summary of costs of the measures [incl. previous Aggregated costs]

This is a qualitative assessment, so figures have not been provided.

8.4 Market effects

8.4.1 Overall impact

Overall, market impacts (in terms of the effect on the single market, R&D, competitiveness of EU businesses and employment) are strongly influenced by two key drivers, the extent to which costs are incurred to comply with the OEL and by the feasibility of meeting the required air concentrations. In extreme cases, companies will be forced out of business if they are unable to meet the OEL at a cost that maintains profitability.

Existing generic non-specific dust limits range in EU Member States from 0.9 (in France) to 1.25 mg/m^3 (in Germany) (for the Respirable fraction), and 1 (in the Netherlands) to 10 mg/m^3 (in Germany) (for the Inhalable fraction) (Table 11-16). Most Member States do not yet have a non-specific dust limit and would therefore incur costs in implementing one across sectors. Depending on the proposed limit for an EU generic non-specific dust limit, the impact is likely to be much lower in countries which already have a non-specific dust limit in place like France and Germany.

8.4.2 Research and innovation

Achieving compliance with a complementary generic non-specific dust limit may mean that enterprises divert funding away from research and innovation into investing in RMMs to achieve the dust limit. A table of average estimates of R&D budgets by sector and across small, medium and large enterprises is included above in Table 6-34 (and has therefore not been repeated here). As existing compliance is likely to be less in smaller enterprises than larger enterprises (interviews with key stakeholders, June-July 2023), smaller enterprises may need to divert a larger proportion of their R&D budget into investing in RMMs to achieve a new EU dust limit.

8.4.3 Single market

From the available information it was sometimes impossible to categorise existing dust limits into 'welding fumes-specific' or 'generic non-specific' (Czechia, Ireland, Spain). It appears that six Member States currently have a generic dust limit: Cyprus, Croatia, France, Germany, Ireland, Netherlands. If this is correct, then that would mean that 21 Member States would need to introduce a new generic non-specific dust limit. This would represent a fairly equal regulatory burden to introducing a welding fumes OEL, since six Member States already regulate welding fumes in some way (mostly via an OEL, but in the case of Denmark welding process-specific limit values).

Introducing a generic non-specific dust limit would help to create a level playing field across the EU.

In Germany a dust limit is now strictly enforced on construction sites, such that if the limit is exceeded, the construction site is closed down (*pers comm*, meeting between RPA and WPC, 11 May, 2023).

8.4.3.1 Competition

Table 8-2 below includes the initial screening of impacts on competition in order to focus the analysis on those impacts likely to be the most significant. The competition impacts of compliance with a new non-specific dust OEL are similar to the corresponding impacts of a welding-specific dust OEL (Table 7-3). The most significant impacts are further explored in the following paragraphs.

The answers in the table are the overall assessment following by a more sector specific considerations.

Table 8-2 Screening of competition impacts

Impacts	Key questions	Yes/No
Existing firms	Additional costs?	Yes
	Scale of costs significant?	Don't know
	Old firms affected more than new?	Possibly
	Location influences?	Member States with existing dust limits and compliance with them will need fewer improvements.
	Some firms will exit the market?	Don't know
	Are competitors limited in growth potential?	Yes, competitors will be limited by the shortage of welders in the EU
	Increased collusion likely?	Don't know
New entrants	Restrict entry?	Possibly
Prices	Increased prices for consumers	Potentially
Non-price impacts	Product quality/variety affected?	Probably not
	Impact on innovation	Innovation budgets may need to be diverted into investment in RMMs to achieve the new OEL; conversely innovative practices may be adopted to reduce worker exposure to dust.
Upstream and downstream market	Will OELs affect vertically integrated companies more or less than non-integrated ones?	Larger, vertically integrated companies will have more direct control over worker protection than non-integrated companies. They may already be in compliance with the new OEL and it will be easier for them to implement it. Smaller, non-integrated companies may find it harder and more costly to implement the new OEL, and without enforcement may be tempted to avoid changes in their practices.
	Will OELs encourage greater integration and market barriers?	Unknown
	Will OELs affect bargaining power of buyers or suppliers?	As there is growing awareness of working conditions in the supply chain (as part of the provenance of products), improvements in worker protection could potentially improve the bargaining power of suppliers; they could use this as a competitive advantage over suppliers in other parts of the world with weaker worker protection, despite possible increases in product prices.

Source: Study team.

8.4.3.2 Existing firms

In common with a welding-specific dust limit (and building on policy option two (Annex I)), compliance with a non-specific dust limit may sometimes be more difficult to reach for older facilities, as space is often more limited in older factory designs. Thus, making it more challenging or even impossible to install space-consuming RMM such as larger welfare facilities and/or ventilation systems needed for compliance. For a non-specific dust limit, the reach would be wider across all sectors that generate dust as part of their activities, and therefore the difficulty for older factories in achieving compliance is potentially much larger than for a welding-specific dust limit.

8.4.3.3 Firms leaving the market (discontinuations)

Based on the available data it is not possible to estimate the number of business discontinuations.

If the non-specific dust limit was set low, then some businesses potentially across multiple sectors may decide to cease operating if they consider the OEL not economically viable for them to achieve. As this dust limit would apply across sectors, the potential number of firms leaving the market could be significant.

8.4.3.4 New entrants

As for policy option two (Annex I) but perhaps to a greater extent, a new non-specific dust limit could focus the attention of new businesses across sectors on the need for compliance and the associated costs of compliance with this threshold limit. One-off (capital) costs of installing general ventilation and/or local exhaust ventilation systems and organisational costs could represent deterrents to new entrants. The extent and distribution of this deterrent effect across sectors or across small, medium and large enterprises is difficult to ascertain from the available information, but is likely to be larger than for a welding-specific dust limit as new entrants could be deterred across many sectors.

Significant capital expenditures are often incurred by new start-ups when entering the market. When entering the market companies are required to monitor exposure and so costs of running monitoring campaigns for start-ups cannot be attributed to the introduction of OELs. However, as limit values become lower more precise and more expensive monitoring techniques are required, potentially increasing the costs of the monitoring campaign and making entry to the market more challenging.

8.4.3.5 Consumers

As for policy option two (Annex I), enterprises which cannot pass on price increases to consumers may pursue compensating the compliance cost by reducing the product quality or reducing the product variety. A t the same time, such efforts can be risky, as a high degree of competition can provide a lot of market power to consumers. It is not possible to assess in specific detail which sectors are likely to pursue such efforts, as it would require primary data collection on consumer preference and their specific market power across sectors, which lies beyond the scope of this assessment.

8.4.3.6 Internal market

Introducing a harmonised generic non-specific dust limit across the EU would help to create a level playing field for enterprises across the internal market, as the gap between the lowest and highest worker exposure levels would decrease across all sectors generating dust during their activities. In addition, as mentioned above (section 8.2), the introduction of a dust limit would create a clear threshold for enterprises to reach, which could be argued is a clearer target than policy option two (Annex I) alone.

Introducing a non-specific dust limit could provide savings in terms of research and design cost across sectors, as common solutions can be adopted across facilities and sectors, as opposed to designing site-specific solutions to meet different OEL requirements.

8.4.4 Competitiveness of EU businesses

The introduction of a generic non-specific dust limit will have an impact on companies' cost competitiveness but will be more significant for the Member States, enterprises and/or sectors with lower existing compliance. As indicated previously, the increase in costs due to having to implement more or better RMMs represents the burden of compliance on companies. This would make those companies incurring these costs less competitive where they are competing with companies not generating dust and with any companies already compliant at this level.

The existence of non-EU non-specific dust limits is not fully understood at the time of writing, so the potential effect on competition between EU and non-EU countries cannot be discussed in great detail.

However, in principle, if the EU non-specific dust limit was set below the non-specific dust OELs in other non-EU countries (Table 6-40), this could lead to enterprises moving their operations to countries with weaker worker protection. Most of the countries that the EU welding community is in competition with (China, Japan, South Korea, India, US) already regulate exposure to welding fumes in some way (mostly through OELs), so an EU non-specific dust limit may have a limited effect on welding+ activities leaving the EU. However, the effect on other sectors that generate dust has not been evaluated and could be significant.

8.4.4.1 Sectors affected

For the same reasons as discussed in sections 6.4.4.1 and 7.4.4.1, the introduction of a dust limit is unlikely to have a significant impact on the competitiveness of the European sectors undertaking welding+ activities.

A non-specific dust limit could potentially have a significant impact on the competitiveness of European sectors undertaking other activities which generate dust (as listed in section 8.1), but this has not been evaluated here as this is beyond the scope of this impact assessment.

8.4.4.2 SME competitiveness

The same generalisations made for policy option two (Annex I) and a welding-specific dust limit apply for a non-specific dust limit, that larger enterprises are more likely to have stronger health and safety practices in place already, including using RMMs (interviews with key stakeholders, June-July 2023). Conversely, smaller enterprises are less likely to have sufficient RMMs in place, and therefore may need to invest in additional RMMs to comply with a non-specific dust limit. A chieving compliance also requires administrative effort and small companies may need to divert resources to achieve compliance. In combination, these effects could put smaller enterprises at a competitive disadvantage to larger enterprises.

8.4.4.3 Cost competitiveness

In common with and building on policy option two (Annex I), European enterprises across all sectors generating dust may need to increase their costs to cover the increased costs of compliance with a complementary EU non-specific dust limit. Depending on how low the non-specific dust limit is set, this could result in a significant number of price increases across sectors across the EU. In particular, smaller enterprises may need to do this.

8.4.4.4 Capacity to innovate

Again in common with a welding-specific dust limit, European enterprises may need to divert funding from research and innovation towards investment in RMMs to comply with a new EU non-specific dust limit, which could reduce their capacity to innovate. Conversely, innovative techniques and RMMs that can be used across sectors to reduce dust exposure may be developed that can be used across sites, with efficiencies of scale achieved. It is difficult to quantify the change in capacity to innovate as the available information is insufficient.

8.4.4.5 International competitiveness

Introduction of an EU non-specific dust limit could have a larger detrimental effect on international competitiveness than a welding-specific dust limit, as there seem to be only a limited number of countries with non-specific dust limits already in place and where they exist sometimes they are only guidelines (in the US and Canada) rather than mandatory limits (Table 11-16).

8.4.5 Employment

It has not been possible to estimate the number of discontinuations that would occur due to an unspecified welding-specific OEL. Therefore, the impacts on employment cannot be estimated.

8.4.6 Summary of market effects

It is difficult to discuss in much detail the market effects from implementing a generic non-specific dust limit, when no limit has been proposed. This makes it impossible to make a comparison with existing generic non-specific dust limits.

However, it was possible to make some generalisations:

- Most Member States (22 States[72]) do not yet have a non specific dust limit so would incur costs in implementing one across sectors, this is probably a slightly larger impact than introducing a welding-specific OEL as 7 Member States already have the latter in one form or another;
- Smaller enterprises may need to divert a larger proportion of their R&D budget into investing in RMMs to achieve a new EU generic dust limit;
- The capacity of enterprises to innovate could be impacted, but a new non-specific dust limit may drive innovation into innovative techniques and RMMs to reduce dust exposure;
- Smaller enterprises may consider passing on the additional cost to consumers in price increases, or decreasing their product quality or limiting the range of products;

[72] From the available information, sometimes the study team was not able to distinguish between generic dust limits and welding fumes specific OELs in Table 3-1.

- Smaller enterprises could be put at a competitive disadvantage to larger enterprises as a result of a generic non-specific dust limit, as they are less able to absorb the increased costs of RMMs;
- Introducing a generic non-specific dust limit would help to create a level playing field across the EU;
- Older facilities may find it more difficult to achieve a non-specific dust limit;
- It is not possible to estimate the number of discontinuations that would occur;
- New entrants may be deterred from entering the welding market by the cost of RMMs;
- The existence of non-EU non-specific dust limits is not fully understood, so it is not possible to discuss the effect on international competition in great detail;
- Most of the countries that the EU welding community is in competition with already regulate exposure to welding fumes in some way so a non-specific dust limit may have a limited effect on welding+ activities leaving the EU. However, the effect on international competition for other sectors that generate dust has not been evaluated and could be significant; and
- A non-specific dust limit would cover all sectors so the costs and benefits would be larger than a welding-specific OEL.

8.5 Environmental impacts

This chapter comprises the following sections:

- Section 8.5.1: Potential environmental impacts;
- Section 8.5.2: Current environmental exposure to the substance;
- Section 8.5.3: Direct impact on the environment;
- Section 8.5.4: Indirect impacts on the environmental and environmental legislation; and
- Section 8.5.4.1: Summary of environmental impacts.

8.5.1 Potential environmental impacts

The potential environmental impacts are the same as those discussed in section 6.5.1.

8.5.2 Current environmental exposure to the substance

See section 6.5.2.

8.5.3 Direct impact on the environment

The direct impacts to the environment as a result of policy option four (health based generic dust limit) will likely be the same as described for policy option three (section 7.5.3). Namely the environmental impacts will depend on the level at which a dust limit is introduced at. Lower dust limits are likely to indicate increased levels of process enclosure and discontinuations which will result in more significant reductions of welding fumes emissions, meanwhile higher dust limits will likely result in improvements to ventilation which may marginally increase environmental emissions (as described in sections 6.5.3 and 7.5.3).

An important distinction between policy options three and four is that a dust limit would apply to a far broader number of sectors than an OEL and so would likely have far broader environmental impacts. The level of these impacts cannot be accurately estimated in this report as different sectors may respond to the same level of a dust limit in different ways and so total change in emissions of environmental pollutants may vary significantly.

8.5.4 Indirect impacts on the environment and environmental legislation

8.5.4.1 EU Green Deal

In 2019, the European Commission announced the European Green Deal to encourage future policies to be developed in line with minimal adverse impacts on the environment and to support efforts to move to sustainable practices (European Commission, 2019). This section reviews the implementation of policy option three for welding fumes in the context of the key elements of the green deal. This is also in line with the approach described in chapter 36 of the better regulation toolbox.

Table 8-3 outlines the key elements put forward in the EU Green Deal and contains a short overview of the expected impact (positive or negative) of introducing the policy option three for welding fumes on the progress towards each of these elements. A short explanation is given to indicate the justification for the expected impact.

Table 8-3 Potential for OELs to impact benefits of the EU Green Deal

Elements of the EU Green Deal	Policy option impact (Yes/No)	Comment
Increasing the EU's climate ambition for 2030 and 2050	N/A	See section 9.4.2 on the European Climate Law
Supplying clean affordable and secure energy	Yes	Introduction of a generic dust limit could result in a loss of production of green infrastructure which would compromise the ability to deliver clean energy, electric mobility, efficient buildings. This may be more extreme than policy option three given more sectors may be impacted.
Building and renovating in an energy and resource efficient way	Yes	
Accelerating the shift to sustainable and smart mobility	Yes	
Mobilising industry for a clean and circular economy	Yes	Welding operations are likely involved in the recycling of metal

Elements of the EU Green Deal	Policy option impact (Yes/No)	Comment
		materials. Should welding be negatively impacted by introduction of a generic dust limit this could impact EU capacity for recycling and thus impacting circular economy.
Designing a fair, healthy and environmentally-friendly food system	Yes	The implementation of a generic dust limit may result in increased ventilation causing minor increases in the release of welding fumes to the environment. These may bioaccumulate in food chains and cause toxic effects in organisms. Conversely the OEL may result in closure of business which would reduce the environmental releases. This may be more pronounced than in policy option three.
Preserving and restoring ecosystems and biodiversity	Yes	
Zero pollution ambition for a toxic-free environment	Yes	

Source: Study team

8.5.4.2 European Climate Law

The European climate law was introduced in 2021 and sets out legally binding targets for emissions reductions proposed by the EU Green Deal. The main target proposed is to ensure that the European economy and society become climate neutral by 2050, with an intermediate goal to reduce greenhouse gas emissions 55% by 2030, compared to 1990 levels (EC, 2021d). It is therefore important that any implementation of policy option two (Annex I) for welding fumes should support the drive to climate neutrality and not contradict the objectives set out in this legislation.

See section 7.5.4.2 as it discusses how a dust limit will have the same impacts as an OEL. The dust limit may however impact more sectors outside of welded materials and so it is possible disruption may also occur in other primary material supply chains, further increasing the challenge of producing green infrastructure.

8.5.4.3 Waste management and disposal

A generic dust limit may seriously impact the waste sector as waste incineration activities often produce ash which is then landfilled (Zero Waste Europe, 2022). In the case of a generic dust limit the potential for exposure to this ash may result in significant changes to the processes and RMMs involved. The extent of these changes however cannot be quantified in this study. If incineration however is made more challenging via a dust limit this could have knock on impacts for the treatment of hazardous wastes and may relate to an increase/decrease in terms of environmental emissions (alike before this cannot be estimated without knowing industries' reaction to a generic dust limit).

8.5.4.4 Resource consumption and circular economy

See section 7.5.4.3 as the impacts on resource consumption and circular economy are the same as those for an introduced OEL.

8.5.4.5 Global impacts

See section 7.5.4.5 as the global impacts are the same as those for an introduced OEL.

8.5.4.6 Green initiatives

See section 7.5.4.6 as the impacts on green initiatives are the same as those for an introduced OEL.

8.5.5 Summary of environmental impacts

The introduction of health based generic dust limits would largely have the same impacts as outlined in section 7.5 relating to the introduction of a specific welding fumes OEL. This is based on the fact that impacts will be highly dependent on the level at which a dust limit is introduced. Low dust limit values may have large scale impacts on industry resulting in potential reductions of emissions of welding fumes but high disruption of supply chains and compromised ability to deliver green infrastructure projects. Meanwhile high dust limits may result in marginally increased emissions of welding fumes from the introduction of better ventilation. This increase however would likely not have a large change to current emission levels given the efficiency of filters used in ventilation systems. Under these higher levels disruption to the supply chains involving welding processes is less anticipated and so these have a better ability to ensure green infrastructure can be supplied to meet climate and other environmental legislation targets.

Under policy option four it is possible that the above impacts may be felt to a greater extent than in policy option three as generic dust limits would apply to a wider range of sectors than an OEL for welding fumes. This means impacts could extend further into industry and introduces a higher level of uncertainty in the environmental impacts. This uncertainty occurs as a result of the unknown response of each industry sector to different levels of generic dust limits that may be introduced.

8.6 Other impacts

This chapter comprises the following sections:

- Section 8.6.1: Impacts on EU Strategic Goals;
- Section 8.6.2: Impacts on fundamental rights, including equality;
- Section 8.6.3: Impacts on digitalisation;
- Section 8.6.4: Contributions to the UN sustainable development goals; and
- Section 8.6.5: Summary of other impacts.

8.6.1 Impacts on EU Strategic Goals

The impacts on EU Strategic Goals are similar to those discussed in sections 6.6.1 and 7.6.1. The introduction of a nonspecific dust limit would arguably provide a clearer target for Member States and enterprises to achieve than policy option two (Annex I) (with no legal change); this would contribute towards the first priority of the Strategic Goals of protecting citizens and the third priority of building a fair Europe (with equal protection for all workers).

The impacts on the EU Commission priority areas for 2019-2024 are also similar to those listed in sections 6.6.1 and 7.6.1, see Table 8-4 below.

Table 8-4 Impacts of a non specific limit on the EU Commission priority areas for 2019-2024.

EU Commission Priority Areas 2019-2024	OELs impact (Yes/No)	Comment
A European Green Deal	No	See section 8.5.4.1
A Europe Fit for the Digital Age	No	See section 8.6.3
An Economy that Works for People	Possibly	A qualitative discussion of the impact on SMEs is provided in section 8.7.2; SMEs may need financial support to provide best practice RMMs to their workers. Larger impact on international competition than a welding-specific dust OEL (see section 8.4.4.5)
A Stronger Europe in the World	Yes	The introduction of an EU non specific dust limit will help to affirm the EU's reputation of delivering safe workplaces and respecting the fundamental rights of EU workforce.
Promoting our European Way of Life	Yes	The introduction of an EU non specific dust limit will mean all Member States are subject to the same regulation of occupational hazards. A non specific dust limit would therefore support an equal approach to occupational hazards and a united Europe when dealing with external markets.
A New Push for European Democracy	No	The introduction of an EU non specific dust limit does not impact the push for a maintained and renewed European democracy.

Source: Study team

8.6.2 Impacts on fundamental rights, including equality

The impacts on rights and equality are similar to those discussed in section 6.6.2 and 7.6.2, except again that the introduction of a non-specific dust limit would arguably provide a clearer target for Member States and enterprises to achieve than policy option two (Annex I) (with no legal change) to improve working conditions (Article 31.1). However, as discussed previously (section 7.3) a generic non specific dust limit would have limited additional value for protecting workers from CMR substances using existing OELs for individual CMR substances in welding fumes.

8.6.3 Impacts on digitalisation

The impacts on digitalisation would be similar to the discussion in section 6.6.3.

8.6.4 Contributions to the UN sustainable development goals

The contributions to the UN sustainable development goals would be similar to those discussed in section 6.6.4.

8.6.5 Summary of other impacts

The summary of other impacts is the same as the summary in Table 6-40.

8.7 Distribution of impacts

Most of this section is not applicable to a qualitative assessment.

The impacts identified under the previous tasks will be broken down by stakeholder type and a systematic analysis of who will bear the costs and accrue the benefits will be provided.

This chapter comprises the following sections:

- Section 8.7.1: Businesses;
- Section 8.7.2: SMEs;
- Section 8.7.3: Workers;
- Section 8.7.4: Consumers;
- Section 8.7.5: Taxpayers/public authorities;
- Section 8.7.6: Specific Member States/regions; and
- Section 8.7.7: Summary of distribution of the impacts.

8.7.1 Businesses

This section is not applicable to a qualitative assessment.

8.7.2 SMEs

This section is not applicable to a qualitative assessment.

8.7.3 Workers

This section is not applicable to a qualitative assessment.

8.7.4 Consumers

This section is not applicable to a qualitative assessment.

8.7.5 Taxpayers/public authorities

This section is not applicable to a qualitative assessment.

8.7.6 Specific Member States/regions

As discussed in section 7.7.4, it is equally common for Member States to have a welding specific OEL or a non-specific generic dust limit, although sometimes from the available information it was impossible to categorise the dust limit into 'welding fumes-specific' or 'generic' (Czechia, Ireland, Spain). Six Member States with an OEL of some kind for welding fumes include: Austria, Belgium, Denmark, Latvia, Lithuania, Slovakia (Table 3-1). Six Member States with a generic non-specific dust limit include: Cyprus, Croatia, France, Germany, Ireland, Netherlands. In terms of non EU countries, from the information available it is often unclear whether the limit value is specific to welding fumes or a generic dust limit (Table 11-16).

If correct, this means that 21 Member States would need to introduce a new non-specific dust limit and up to 6 Member States may need to alter their legislation. The study team has heard anecdotal evidence that worker protection for welding is better for welding in northern and western Europe than in southern and eastern Europe; this would indicate that the impact of introducing (and enforcing) non specific dust limit (which would apply to welding and other dust generating activities) could be larger in southern and eastern Europe. This has not been substantiated, although the ECRHS II survey did find that cumulative exposure to welding fumes was higher in Southern compared with Northern Europe (Olsson and Kromhout, 2021).

No detailed analysis of direct impacts on Member States can be derived from this assessment. This is because the distribution of companies undertaking welding activities across EU Member States has been modelled based on Eurostat data and so may have a level of uncertainty relating to the true distribution. As such any analysis of impacts on specific Member States would pose a level of uncertainty and may lead to inaccurate conclusions.

8.7.7 Summary of distribution of the impacts

This section is largely not applicable to a qualitative assessment. The only key points of note are that:

- Potentially 21 Member States would need to introduce a non-specific dust limit and up to 6 Member States may need to alter their legislation; and

- The study team has heard anecdotal evidence that worker protection is better for welding in northern and western Europe than in southern and eastern Europe; this would indicate that the impact of introducing (and enforcing) a non-specific dust limit could be larger in southern and eastern Europe. This has not been substantiated, although the ECRHS II survey did find that cumulative exposure to welding fumes was higher in Southern than in Northern Europe (Olsson and Kromhout, 2021).

8.8 Summary of economic, social and environmental impacts

This section is largely not relevant to a qualitative assessment.

This chapter comprises the following sections:

- Section 8.8.1: Economic impacts;

- Section 8.8.2: Social impacts; and

- Section 8.8.3: Environmental impacts

8.8.1 Economic impacts

This is not relevant for a qualitative assessment.

8.8.2 Social impacts

This is not relevant for a qualitative assessment.

8.8.3 Environmental impacts

A generic dust limit could have the following environmental impacts:

- Direct impacts on the environment through the increased release of particulate matter into the external environment from the increased use of extraction systems. However, the highly efficient filters (more than 99% effective) used in extraction systems are predicted to capture the majority of particulates;
- Indirect environmental impacts in terms of increased energy consumption from increased use of extraction systems, and therefore increased carbon emissions from the power sector; and
- Policy option two (Annex I) is unlikely to impact on EU environmental initiatives such as carbon neutrality, circular economy, energy efficiency or electric based mobility.

For further details please see section 8.5.

8.9 Limitations of this qualitative assessment

This qualitative assessment is severely hindered by not having any potential thresholds for a generic non-specific dust limit to evaluate. The discussion is also limited by the information available on this topic. Welding fumes are highly heterogenous which makes any evaluation of how to regulate them complicated. The study team tried to ascertain whether there were any existing regulatory impact assessments (RIAs) that were undertaken before the existing national OELs for welding fumes or dust limits were introduced, but the WPC were unaware of any since RIAs are not mandatory (*pers comm*, meeting between RPA and WPC, 11 May 2023). These could have provided useful information to discuss in this qualitative assessment, and findings at a national level could have been extrapolated to the European level. However, the WPC explained that often OELs will be introduced at the national level based upon the scientific health evidence, without a full RIA.

9 IMPACT OF THE POLICY OPTIONS

This chapter comprises the following sections:

- Section 9.1: Cost-benefit assessment (CBA);
- Section 9.2: Multi-criteria analysis (MCA);
- Section 9.3: Practical implications of establishing an OEL;
- Section 9.4: Compliance with the subsidiarity and proportionality principles;
- Section 9.5: Highlighted issues; and
- Section 9.6: Summary for the option suggested by the ACSH.

This chapter summarises the estimates presented in the previous chapters by means of a Cost-benefit assessment (CBA), a Multi-criteria (MCA) analyses and analyses of effectiveness, efficiency and coherence of the policy options. All the costs and benefits presented in this chapter are Present value (PV) over 40 years and additional to the baseline option.

9.1 Cost-benefit assessment (CBA)

9.1.1 Overview of the benefits for the policy options

The benefits are only estimated for policy option two (Annex I), as part of the quantitative assessment, and not for the qualitative assessment of a welding fumes-specific OEL or generic non-specific dust limit.

The benefits (relative to the baseline) estimated in this report for policy option two (Annex I) are summarised in the table below. The benefits include the direct, the indirect and the intangible benefits as described in section 6.1.

Table 9-1 Overview of the benefits (PV cost savings due to reduced ill health and avoided costs) for policy option two (Annex I)

Impact	Stakeholders affected	Policy option two (Annex I)
Direct benefits – improved well-being - health		
Ill health avoided, incl. intangible costs (M1 to M2)	Workers & families	M1: € 1 000 million M2: € 510 million
Avoided costs	Companies	€ 4.7 million
Avoided costs	Public sector	€ 16 million
EU policy agenda	All	None identified
Direct benefits – improved well-being – environmental		
Environmental releases	All	None identified

Impact	Stakeholders affected	Policy option two (Annex I)
Direct benefits – market efficiency		
Level playing field	Companies	None identified
Indirect benefits		
Administrative simplification	Companies	None identified
Synergy	Companies	None identified
Corporate Social Responsibility	Companies	None identified
Avoided cost of setting OEL	Public sector	N/A
Notes: Numbers may not sum to total due to rounding.		

Source: Study team.

9.1.2 Overview of the costs for the policy options

The estimated direct and indirect costs for policy option two (Annex I) are presented in Table 9-2: these costs were not calculated for the qualitative assessment of a welding specific OEL or non-specific dust limit. The costs are for the present value (PV) over 40 years with a static discount rate of 3%.

Table 9-2 Overview of the costs (incremental to the baseline, PV over 40 years)

Impact	Stakeholders affected	Policy option two (Annex I)
Direct costs – compliance		
Risk management measures and dis-continuation costs (one-off and re-current)	Companies	€ 67-160 million
Monitoring (sampling and analysis)	Companies	N/A
Direct costs - administrative burdens		
Administrative burden	Companies	N/A
Direct costs – total		
Compliance, monitoring and adminis-trative burden costs per company	Companies	N/A
Direct costs - enforcement costs		
Transposition costs	Public sector	€ 2.7 million
Enforcement costs	Public sector	N/A
Monitoring costs	Public sector	N/A
Adjudication costs	Public sector	N/A

Impact	Stakeholders affected	Policy option two (Annex I)
Indirect costs – other		
Firms exiting the market - No. of company closures	Companies	None identified
Employment – Jobs lost	Workers & families	None identified
Employment – Social cost	Workers & families	None identified
International competitiveness	Companies	Negligible
Consumers	Consumers	Negligible
Internal market	Companies	Member States with better existing regulation of welding fumes and compliance with these regulations will need fewer improvements. Baseline level of compliance is not well understood. 13 Member States have welding fumes OELs or non-specific dust limits and include: AT, BE, CY, CZ, DK, FR, DE, IE, LV, LT, NL, SK, ES.
Specific MSs/regions - MSs that would have to change OELs	Public sector	The 14 Member States do not have welding fumes OELs or non-specific dust limits: BG, EE, FI[1], GR, HU, IT, LU, MT, PL, PT, RO, SI, SE. However, these countries may have other regulatory regimes to regulate exposure to welding fumes, for example in IT welding stainless steel is strictly regulated as these welding fumes are considered carcinogenic (Italian stakeholder, July 2023, *pers comm*).
Regulation	Companies	Policy option two (Annex I) may cause confusion to companies unless it is accompanied with a clear explanation.
Notes: Numbers may not sum to total due to rounding. *[1]Finland has a guideline of 0.1 mg/m³ for welding fumes (occupational health specialist, pers comm, July 2023).*		

Source: Study team.

9.1.3 Impact of different timescales for costs and benefits

9.1.4 CBA for the policy options

The overall costs and benefits of the policy options are shown in Table 9-3. The resulting benefit cost ratios are within a small range, but in all cases, benefits exceed costs. The study team interprets the small range of BCRs generated through different methods as validation that the cost and benefit figures used are likely to be reasonable estimates.

Feedback from six key stakeholders gave a range of answers as to the proportion of welders likely to need to purchase additional RMMs, from none to more than 50% of the welders that would improve practice as a result of policy option two (Annex I) (as discussed in section 6.3). This means that the below costs could be an underestimate. (The assumption was that some workers would use RMMs that they already have as a result of policy option two (Annex I), without additional expenditure, and stakeholders generally agreed that this was the case.) The same key stakeholders found it difficult to estimate the increase in RMM expenditure and benefits as a result of policy option two (Annex I), but one EU stakeholder and one national stakeholder thought the benefits could be greater than a 1% additional decrease in excess risk, estimating the improvement to be between 2-3% or 5% above the baseline respectively due to the associated awareness raising of the risks of exposure to welding fumes. Both stakeholders stressed the importance of a communication campaign to accompany the policy change. This means that the below benefits could be an underestimate. In summary there is a high level of uncertainty around these figures.

Table 9-3 Summary of monetised costs and benefits (3% static discount rate, additional to the baseline) based upon exposed workers (full time welders) and use of RMMs (% of welders needing to purchase additional RMMs = 50%).

Policy option	Policy option two (Annex I)
Total benefits M1	€1,000,000,000
Total benefits M2	€530,000,000
Total bottom up costs (BUC)	€160,000,000
Total top down costs (TDC)	€67,000,000
Benefit cost ratio M1 (BUC)	6.5
Benefit cost ratio M1 (TDC)	15
Benefit cost ratio M2 (BUC)	3.4
Benefit cost ratio M2 (TDC)	7.9

Notes: In all cases the increase in RMM expenditure was taken to be 1% and the increase in the rate of change in excess risk per year post year) and benefits from avoided ill health was taken to be 1%.

Numbers may not sum to total due to rounding.

Source: Study team.

9.2 Multi-criteria analysis (MCA)

Table 9-4 provides a multi-criteria analysis (MCA) to summarise both the monetised and qualitative impacts of the different policy options.

The MCA includes the monetised health benefits and the quantifying compliance costs. Other effects including market effects are described qualitatively.

For the future additional (complementary to policy option two (Annex I)) policy options of an OEL specific to welding fumes and a non-specific generic dust limit only a qualitative assessment is provided.

Table 9-4 Multi-criteria analysis (all impacts over 40 years and additional to the baseline) for the different policy options.

Impact	**Stakeholders affected**	**Policy option two (Annex I) Quantitative assessment (PV)**	**In addition to policy option two (Annex I), qualitative assessment only:**	
			OEL (inhalable and respirable dust) specific to welding fumes	**Non-specific generic dust metric (inhalable and respirable)**
Direct costs – compliance				
Risk management measures and discontinuation costs (one-off and recurrent)	Companies	€ 67 - 160 million	Out of scope	Out of scope
Monitoring (sampling and analysis)	Companies	None expected	Out of scope	Out of scope
Direct costs - administrative burdens				
Company cost of administration burden	Companies	N/A	Out of scope	Out of scope
Direct costs - total				
Compliance, monitoring and administration burden costs per company	Companies	€ 67 – 160 million	Out of scope	Out of scope
Direct costs - enforcement costs				
Transposition costs	Public sector	€ 2.7 million	€810,000 - 1,400,000	€810,000 - 1,400,000
Enforcement costs	Public sector	None	Out of scope	Out of scope
Monitoring costs	Public sector	None	Out of scope	Out of scope
Adjudication costs	Public sector	None	Out of scope	Out of scope
Indirect costs - other				
Firms exiting the market - No. of company closures	Companies	None predicted	None predicted	None predicted
Employment – Jobs lost	Workers & families	Not quantified. No legal change, awareness raising.	Not estimated	Not estimated
Employment – Social cost	Workers & families	Not estimated	Not estimated	Not estimated
International competitiveness	Companies	International competition is low for welding as welding often needs to be done *in situ* on site and cannot be exported. See box to right.	Most non-EU competitor countries already regulate welding fumes through dust limit or an OEL (not distinguishable from the available information): AU, CA, CN, IN, NO, KR, US. An exception is JP where employers measure and protect against exposure to Mn as a proxy for welding fumes. The lowest limit is 3 mg/m^3 (R) particles in the US or CA. The highest limit is 10 mg/m^3 (I) particles in the US or CA.	
Consumers	Consumers	None predicted.	Enterprises (especially smaller enterprises) may increase the price of their products to cover the increased costs of compliance.	

Impact	Stakeholders affected	Policy option two (Annex I) Quantitative assessment (PV)	In addition to policy option two (Annex I), qualitative assessment only:	
			OEL (inhalable and respirable dust) specific to welding fumes	Non-specific generic dust metric (inhalable and respirable)
Internal market Lowest to highest OEL	Companies	Not quantified.	Not quantified. The lowest (process-related) OEL for welding fumes is 0.5 mg/m^3 in DK, for 'electrode methods welding stainless steel'. The highest and most common OEL for welding fumes is 5 mg/m^3	Not quantified. The highest generic dust limit is 10 mg/m^3 (I) in Germany It was not possible to identify the full details of the limits for: CZ, IE or ES.
Specific MSs/regions - MSs that would have to change their policy or OELs	Public sector	Less compliance in E and S EU Member States according to anecdotal evidence heard by the study team.	8 Member States already have welding fumes OELs: AT, BE DK, FR, LV, LT, NL, SK.	6 Member States already have generic dust limits: CY, HR, FR, DE, IE, NL. It was not possible to categorise the limits in place in: CZ, IE or ES.
Regulation	Companies	Risk that the policy change creates confusion and company resources are wasted trying to understand what is needed.	OEL would impact on enterprises undertaking welding activities.	Generic dust limit would apply across sectors to all enterprises undertaking activities generating dust.
Direct benefits – improved well-being - health				
Reduced cases of cancer	Workers & families	1,618	Not quantified	Not quantified
Reduced fatalities	Workers & families	1,079	Not quantified.	Not quantified.
Reduced non-fatalities	Workers & families	270	Not quantified.	Not quantified.
Ill health avoided, incl. intangible costs (M1 to M2)	Workers & families	M1: €1 000 million M2: €510 million	Not quantified, but see above qualitative analysis.	Not quantified, but see above qualitative analysis.
Direct benefits – improved well-being - safety				
Avoided costs	Companies	€4.7 million	Not quantified	Not quantified
Avoided costs	Public sector	€16 million	Not quantified	Not quantified
EU policy agenda	All	Increasing the protection of workers health is main social benefit.		
Direct benefits – improved well-being - environmental				
Environmental releases	All	Not quantified	Not quantified	Not quantified
Direct benefits – market efficiency				

Impact	**Stakeholders affected**	**Policy option two (Annex I) Quantitative assessment (PV)**	**In addition to policy option two (Annex I), qualitative assessment only:**	
			OEL (inhalable and respirable dust) specific to welding fumes	**Non-specific generic dust metric (inhalable and respirable)**
Level playing field	Companies	Awareness raising may lead to an improved level playing field between and within Member States.	Clearer target than policy option two. Would contribute to level playing field across the EU 27.	Clearer target than policy option two. Would contribute to a level playing field across the EU 27.
Indirect benefits				
Administrative simplification	Companies	Not applicable	Not applicable, OEL would be in addition to existing substance specific OELs.	Not applicable, dust limit would be in addition to existing substance specific OELs.
Synergy	Companies			
Corporate Social Responsibility	Companies	Positive minor impact	Positive minor impact	Positive minor impact
Avoided cost of setting OEL (EU27)	Public sector	Not applicable	€1.4 – 2.7 million	€1.4 – 2.7 million
Other impacts				
Recycling – loss of business	Recycling companies	Not applicable. Circular economy principles in EU27 encourage recycling including recycling of metal products which will sometimes involve welding. This is not predicted to be exported, due to the subsidiarity principle - waste management including recycling should be undertaken by local and regional authorities.		
Impacts on fundamental rights	All	Not applicable		
Impacts on digitalisation	Companies	Not applicable		
Contributions to the UN sustainable development goals	All	Positive minor impact towards UN SDG 3: good health and wellbeing and UN SDG 8: Decent work & economic growth		
Notes: Numbers may not sum to total due to rounding.				

Source: Study team.

9.3 Practical implications of establishing an OEL

The following table highlights practical considerations for citizens/consumers, businesses and administrations which should be considered under the introduction of an EU OEL for welding fumes or a generic dust limit.

Table 9-5 Practical implications of establishing an OEL for welding fumes or a generic dust limit.

Citizens/Consumers	Businesses	Administrations
Citizens/consumers may experience quantified cost changes to products/services as businesses may pass on increased costs (due to compliance) to consumers. This is likely to be negligible though as the costs are small compared with the scale of the industries covered.	Businesses must comply with OSH legislated provisions (e.g. an OEL for welding fumes or generic dust limit) which would have the following practical implications: • installation and continued operation of necessary risk management measures (RMMs) required to meet the OEL. • implementation of a sampling strategy for airborne concentration measurements as part of business risk assessment processes and effectiveness checks of existing measures to meet the OEL or generic dust limit. • ensure that welding fumes are managed in line with the provisions of the national carcinogens and mutagens legislation. • ensure compliance with any other associated provisions in the legislation	Member States must transpose the amended Directive into national legislation: • assessment of the national scenario and potential impacts. • tripartite consultation of the proposal (workers, employers, authorities); • facilitate implementation of the national legislation by providing, among other measures, technical guidance to employers. These costs are minor in comparison to the overall costs of functioning incurred by the enforcement. Member States must also comply with the whole set of OSH national legislation provisions related to an OEL for welding fumes or generic dust limit.

Source: Study team.

9.4 Compliance with the subsidiarity and proportionality principles

Article 5.3 of the Treaty of Europe says "*Under the principle of subsidiarity, in areas which do not fall within its exclusive competence, the Union shall act only if and in so far as the objectives of the proposed action cannot be sufficiently achieved by the Member States, either at central level or at regional and local level, but can rather, by reason of the scale or effects of the proposed action, be better achieved at Union level*."

Whilst Member States can and do set their own limit values, the analysis and decision making are more efficient and effective if the process of setting limit values is undertaken at the Union level. The introduction of limit values at Union level also ensures that there is not divergence of risk within industry operating across the Union. For these reasons the introduction of EU wide limit values can be seen as compliant with the principle of subsidiary.

For control of exposure to CMR substances it has been established that the inclusion in the CMRD and the subsequent introduction of limit values is an appropriate method of controlling exposure.

The CMR substances present in welding fume are already covered by the CMRD, therefore the Member States have already agreed that setting limit values through the process managed by the Advisory Committee for Safety and Health at Work (ACSH), Working Party on Chemicals (WPC) and DG EMPL is the appropriate and proportionate manner. By definition, Member States are obliged under the CMRD to continually work to reduce the exposure to the CMR substances present in welding fume and this study assists the WPC and DG EMPL in specifying acceptable limit values. Given the structure and previous establishment of the above process, the introduction of EU wide limit values can be seen as compliant with the principle of proportionality.

Article 5.3 of the Treaty of Europe says "*Under the principle of proportionality, the content and form of Union action shall not exceed what is necessary to achieve the objectives of the Treaties*." It is often described as "*not using a sledgehammer to crack a nut*".

The CMR substances present in welding fumes are already covered by the CMRD and other hazardous substances present in welding fumes are already covered by the CAD, therefore the Member States have already agreed that setting limit values through the process managed by the Advisory Committee for Safety and Health at Work (ACSH), Working Party on Chemicals (WPC) and DG EMPL is the appropriate and proportionate manner. By definition, Member States are obliged under the CMRD and CAD to continually work to reduce the exposure to CMR and hazardous substances in welding fumes and this study assists the WPC and DG EMPL in developing the effectiveness of the CMRD and in specifying acceptable limit values.

9.5 Highlighted issues

Other issues to be considered in the decision-making process, organised by which policy options they relate to are summarised below.

9.5.1 For all policy options

9.5.1.1 Extent that welders are exposed to CMRs (section 5.1.1)

CMR substances in welding fumes are within the scope of the CMRD if they are classified as category 1A or 1B CMR under the CLP. However, ECHA (2022) argues that *"The majority (but not all) of the relevant substances are already covered by entries in Annex III".* If the remaining relevant substances were included in Annex III as a priority (and indeed the addition of cobalt compounds is being assessed in this same study), ECHA questions whether there would be any value in having welding fumes added to Annex I. The new OELs for chromium VI and nickel compounds (with a transition period ending on 17 January 2025) and proposed OEL for cobalt will probably address most of the remaining CMR substances in welding fumes (see section 3.3.8). Nickel compound exposure will decrease in parallel with chromium VI exposure as the same RMMs address both.

The crux of the discussion around regulation of welding fumes comes down to when CMR substances are present in welding fumes. In general, welding of high alloy steels (such as stainless steel with >5% nickel content) generates higher emissions of the alloys present (such as nickel compounds and chromium VI), and exposure to nickel compounds increases as the nickel compound content of the material welded increases, irrespective of the welding process used (Koppisch *et al*, 2022 in DGUV, *pers comm*, July 2023). This means that welders in sectors which typically weld stainless steel are at higher risk of exposure to CMRs (manufacture and installation/repair of medical equipment, pharmaceutical industry equipment, food industry equipment; manufacture and installation/repair pipes for the energy sector). However, CMR substances are still present in welding fumes when low alloy steels are welded. Exposure data in the German MEGA database shows that low alloy steels (<5% nickel content) if welded using a high emission welding process (such as MIG) can generate exposure levels of nickel compounds that are greater than the new OEL for nickel compounds so RMMs would be needed to reduce worker exposure to be compliant[73].

There is evidence that both welders of mild steel and stainless steel experience an excess risk for lung cancer (Honaryar *et al*, 2019, Sorensen *et al*, 2007 in ECHA, 2022). There is also evidence of the mechanistic carcinogenic potency from welding mild steel (Badding *et al*, 2014; Dierschke *et al*, 2017; Falcone *et al*, 2018; Leonard *et al*, 2019; Zeidler-Erdely *et al*, 2012 in DGUV, *pers comm*, July 2023). Of course, the working environment also impacts on exposure levels, so there would be a risk of exposure to CMR substances in welding fumes from welding mild steel in an enclosed space in the shipbuilding industry for example.

The study team interpret this to mean that due to these nuances and evidence, welding low alloy steel (mild steel) is not always associated with a low risk of exposure to CMRs, although some stakeholders would like this conclusion to be drawn. A key EU stakeholder concurs with this opinion (*pers comm*, July 2023).

This means that the fact that the majority of steel welded in the EU is mild steel/low alloy steel (93%[74] of metal welded by weight according to the EWA, March 2023*, pers comm*) rather than stainless steel does not reduce the need for risk assessments and mitigation of worker exposure to welding fumes.

This also means that although in many cases workers welding stainless steel/high alloy steel may be highly trained, certified, professional welders (key stakeholders, July 2023, *pers comm*), all welders should receive training in the risk of exposure to CMR substances and the need for using RMMs, and ideally worker protection should be enforced through inspections and meaningful penalties although this is beyond the scope of the policy change being discussed.

9.5.1.2 Emission rates from different welding processes (Section 4.1)

-Emission rates vary depending on the welding process being used (Table 2-4 and Table 3-46). This is one of the main reasons, amongst many other factors, that make it impossible to generalise about worker exposure levels or set an OEL specific to welding fumes that applies across different welding processes. The same welding processes are used across different sectors, so it is difficult to draw conclusions about which sectors have workers at higher risk of exposure to CMRs in welding fumes. Processes with higher emission rates (plasma cutting, arc spraying, flame spraying, laser cutting, laser welding, MAG) are of more concern than processes with lower emission rates such as TIG, SAW and gas welding. Indeed, in Denmark limit values have been set on a process-related basis rather than having an OEL for welding fumes applied to all processes (Table 11-16). A key stakeholder pointed out that emission rates from welding processes should be taken into account during policy decisions (national stakeholder, July 2023, *pers comm*).

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[73] According to exposure levels from the MEGA database, taken between 2010-2016 (data provided by the DGUV, *personal communication,* July 2023).

[74] Please note that there is a risk that quantifying the amount of welding based on the weight of metal being welded could distort the assessment of worker exposure. B y focusing solely on the weight of metal being welded, rather than the numbers of welders undertaking the activities, this could place too much emphasis on the sectors undertaking large scale welding; for example, where a relatively small number of welders are welding large pieces of metal such as steel beams in the construction sector.

9.5.1.3 Limited understanding of baseline (Section 4.11)

There is considerable uncertainty about the level of awareness of CMR substances in welding fumes and existing compliance with the CMRD across the EU27 for welding fumes with any certainty. No published literature was found which confirms the existing level of compliance in Member States, such as the findings of national labour inspections. Without undertaking a Europe-wide campaign of unannounced inspections of welding sites across sectors and different sized enterprises, the extent to which RMMs are currently being used to reduce worker exposure to welding fumes is unknown.

The study team has heard anecdotal evidence from stakeholders that in general worker protection is better in northern and western Europe than in southern and eastern Europe. This was not always corroborated by interviews with representatives of Member States though, with most people claiming that compliance with the CMRD is already good in their country. One stakeholder in an eastern European country did say that inadequate use of PPE has been identified as one of the main causes of professional diseases of workers in their metal industry. However, one stakeholder in a northern European country admitted that compliance was not perfect in their country either, with weaker worker protection in particular for migrant workers. The ECRHS II survey did find that cumulative exposure to welding fumes was lower in northern compared with southern Europe (Olson and Kromhout, 2021).

9.5.1.4 Future trends (Sections 4.4, 4.5, 4.6, 4.7)

There is a skills shortage of welders in Europe, which limits to some extent the growth in manual welding that can be undertaken across sectors and adds to the demand for immigration of welders from non-EU countries (such as the Philippines where awareness of best practice may be lower) and adds to the demand for increased automation of welding. This means that unless well trained by their employer, migrant workers may be at higher risk of exposure to welding fumes. Conversely, increased automation results in lower levels of worker exposure as automated processes are typically enclosed with built in extraction and limit the opportunities for worker exposure.

The skills shortage in welding is a limiting factor on the increasing demand for welding due to the Green Transition. The planned Green Transition has been accelerated in response to the Russian invasion of Ukraine, with a faster transition to renewables being undertaken (nuclear power, solar PV, wind turbines, hydrogen economy, electric cars) with associated investment in infrastructure requiring welding.

9.5.2 For policy option two (Annex I)

9.5.2.1 Underestimation of benefits (Section 6.1.7)

This study focused on the health benefits of avoided cases of lung cancer, which underestimates the full benefits of a policy change that results in reduced exposure to welding fumes, as other health effects are also associated with exposure to welding fumes (see section 2.1). Exposure to welding fumes has been associated with other types of cancer, such as cancer of the trachea and bronchus (Loomis *et al.*, 2022). Acute health effects include irritation to the throat and larger airways in the lungs, acute irritation-induced asthma, metal fumes fever and acute pneumonia (ECHA, 2022).

Further to the above, this study has only estimated the benefits of reducing exposure to full time workers in welding+ processes, not part time or occasional welders, or bystanders (non-welders exposed to welding fumes in the workplace). If exposure to welding fumes is reduced for all welders, the benefits would be greater. If exposure to welding fumes is reduced for bystanders too, then the benefits would be even greater. In some Member States with already good compliance, such as

Germany, addressing exposure by bystanders is one of their next objectives (German stakeholder, *pers comm*, July 2023).

There is considerable uncertainty about both the number of workers in welding+ processes and the number of potential bystanders in workplaces where welding+ activities are being undertaken.

9.5.2.2 Exception to BRG Toolbox #18 practice (Section 5.4)

While the inclusion of welding fumes in Annex I may focus the attention on welding and welders, the amendment of a Directive to increase awareness is not usual policy and, from an impact assessment perspective, brings the following problem: normally, in an impact assessment, either no assumptions on compliance are made, or better, 100% compliance is assumed; in other words, the (unstated) assumption is that if there was 100% compliance, these would be the costs, these would be the benefits. When defining policy options, there are considerations of enforceability but not rate of compliance.

The costs and benefits of policy option two (Annex I) equate to zero, because they relate to risk mitigation measures (RMMs) that companies should already be implementing.

The study team has estimated costs and benefits of additional companies applying already required RMMs, assuming that policy option two (Annex I) would result in increased awareness. But, in summary the costs and benefits of increasing awareness through policy option two (Annex I) can be quantified but raises the issue of whether they should be accounted for in the impact assessment, as they relate to RMMs that should be already implemented by companies.

9.5.2.3 Potential confusion (section 5.4)

The study team is also concerned that, in terms of clarity, the inclusion of welding fumes in Annex I, as in the current formulation, may work against it. In particular, the introduction of welding fumes in Annex I would require a clear definition of its scope. In the absence of such a clarification, this could create confusion about whether mutagenic and reprotoxic substances are also covered by this entry. The study team understands that additional text will be added to the Directive or Annex I, which should clarify the situation. However, the study team has no information about these potential changes and, thus, as the policy option stands, the inclusion of welding fumes containing CMR substances in Annex I may cause confusion.

The consultation of key stakeholders also showed that the inclusion of welding fumes in Annex I would require some clarifications about its implications: many do not understand that there is no legal difference and spent time trying to understand what has changed. At least eight key stakeholders (membership organisations and two major car manufacturers) out of fifteen stakeholders were clearly confused in various conversations during site visits, interviews and email exchanges.

It is not feasible for employers to measure for every CMR just in case they are present in welding fumes. Some German stakeholders identified a need to set a threshold for the content of CMRs intentionally present in welding materials, which if met would trigger occupational exposure monitoring. According to the German classification system for health hazards, hazard classes only apply if the alloys or cover/filler components for welding contain more than 5% carcinogenic substance (VBMG, 2007). For welding filler materials, safety data sheets (SDS) will contain harmonised classifications of substances so they can be used to check for the classification 1A or 1B for carcinogenicity, mutagenicity or reproductive effects. However, the threshold for notification of substances that are a CMR (category 1A or 1B under the CLP) and present in a mixture for inclusion in SDS is greater than or equal to 0.1% concentration (ECHA, 2020). If a substance is present below this threshold there is no obligation for the producer to list it on the SDS, and the user (welder) will not know it is present, but the situation may arise where such a substance may be picked up in occupational monitoring for a CMR substance with an established OEL.

9.5.2.4 Risk of stigmatising welding+ activities as 'carcinogenic'

Some stakeholders are concerned that policy option two (Annex I) could result in welding+ activities becoming stigmatised as 'carcinogenic' which could put potential workers off training as welders (section 6.1.5.2).

However, the study team point out that workers could actually be reassured by policy option two (Annex I) that welding is a well-regulated occupation and feel more confident in becoming welders.

The study team therefore believe that the messaging in the communication campaign for the policy change will be crucial.

9.5.2.5 Communications (Sections 5.4, 6.1.7, 6.4.2, 6.4.4, 6.4.4.5, and 6.7.2)

There is a recurrent message from ten key stakeholders that the success of the inclusion of welding fumes in Annex I, the avoidance of confusion, and the reduction of some of the potential risks to research funding, competitiveness, and SMEs depend upon a good communications strategy, communications campaign and associated training programme.

However, the study team understands that the communications about the inclusion of welding fumes in Annex I are likely to follow the Commission's usual method of communicating legislative changes, which is simply to add to the Directive's recitals, issue a press release and publish a page on the Commission's website. This is a much smaller scale than the communications strategy, campaign, and associated improvements to training that many key stakeholders indicated was necessary.

9.5.3 For complementary welding fumes OEL or generic non-specific dust limit

9.5.3.1 Welding fumes emissions

The above generalisation (section 9.5.1.1) about high alloy steels containing a higher content of CMRs does not necessarily correlate to the amounts of generic 'welding fumes' generated from welding high alloyed steels. Kendzia *et al.* (2019) found greater exposure levels of welding fumes (1.67 times higher) from welding mild steel (low alloyed steel) compared with stainless steel (high alloyed steel), for both the inhalable fraction and respirable fraction. This finding perhaps supports the need for a welding specific OEL. Since it is the particulate matter (dust) in 'welding fumes' that is of interest to this study, this finding is relevant to both the proposed welding fumes OEL and generic non-specific dust limit.

9.5.3.2 Limited use of a complementary welding specific OEL (Section 7.3) or non-specific dust limit (8.3)

Setting a dust limit (whether specific to welding fumes or not) would have limited additional value to using existing OELs for CMR substances. This is because dust limits are typically set at much higher levels (e.g. 5 mg/m^3) than OELs for individual CMR substances (e.g. the new OEL is 5 $\mu g/m^3$ for chromium VI, for nickel compounds it is 10 $\mu g/m^3$), and therefore cannot provide sufficient worker protection from the CMR substances that may be present, but can only provide protection from the general health effects from dust. It could be argued therefore that dust limits are useful for the CAD but not for the CMRD as they do not address CMR substances specifically.

9.5.3.3 Impact on avoided ill health

A generic dust limit could in theory have a larger impact on avoided ill health than a welding specific OEL, as the generic dust limit would apply across sectors and a larger number of workers that are occupationally exposed to dust.

9.5.3.4 Risk that welding will be exported to non-EU countries with lower health and safety standards

For either the welding specific OEL or the generic dust limit, there is a risk that welding (and other dust generating activities in the latter case) may be exported to non-EU countries with lower health and safety standards depending upon the limit set (section 7.4.4 and section 8.4.4).

Most of the countries that the EU welding community is in competition with (China, Japan, South Korea, India, US) already regulate exposure to welding fumes in some way (mostly through OELs), so an EU welding specific OEL or non-specific dust limit may have a limited effect on welding+ activities leaving the EU. However, the effect on other sectors that generate dust has not been evaluated and could be significant.

9.5.4 Strength of the evidence

For welding fumes there was limited data available on exposure distributions and on the number of companies with exposed workers. Therefore, exposure levels were estimated solely for workers, not at the company level. Section 5.1 of the report provides an outline of the definition of the problem. Estimated numbers of welders in Europe based on the literature were validated through interviews with six key stakeholders that represent a large number of welders across Europe (Section 5.1.1). The sectors with the largest numbers of workers (welders) exposed to welding fumes were identified from EUROSTAT data and broadly validated by other studies and during interviews with key stakeholders (Section 5.1.1). A discussion of the complexity of estimating welding processes that contain CMRs is included in section 5.1.2 of the report this includes:

- Calculation of excess risk;
- Assumption of a 1% per year downward trend in exposure levels due to improvements in RMMs;
- Size of the problem due to heterogeneity of welding fumes;
- Factors which affect the rate of emissions;
- Variations in exposure levels between countries, sectors and trades; and
- Need to consider the presence of ultrafine particles not just the total mass of particulates in terms of the resulting toxicity; the rationale for considering the risk of worker exposure to CMRs from welding of mild steel not just stainless steel.

Due to the lack of evidence for the baseline levels of worker exposure, the study team used interviews with six key stakeholders to ask them to provide definitions of welders at high risk of exposure to CMRs and at low risk of exposure to CMRs (Table 5-1, in section 5.1.3). The same six key stakeholders were asked about compliance with best practice RMMs for welding and their responses compared with the literature (see Section 5.1.3 and 5.1.4). These six stakeholders were asked to estimate the proportion of welders exposed to CMRs for welders at high risk of exposure to CMRs and for all welders (Section 5.1.4). A separate survey on the implementation of best practice was asked of welding stakeholders in five Member States (Croatia, Estonia, France, Netherlands and Slovenia) during June – July 2023 (section 5.1.4).

The evidence supporting and negating the inclusion of welding fumes in Annex I for several different aspects are discussed below.

9.5.4.1 Compliance with existing regulatory requirements of the CMRD

Where compliance is currently lacking, policy option 2 (Annex I) could help to raise awareness and therefore compliance with the regulatory requirements of the CMRD. In addition, there is no means of quantifying the extent to which policy option 2 could help improve compliance with the CMRD. The evidence base is weak regarding existing compliance, and the study team believes that the only way to understand the level of compliance with the CMRD would be for a campaign of unannounced inspections of workplaces across the EU (Section 5.2).

Supporting evidence that compliance is currently lacking was that:

- Compliance with best practice RMMs for welding is currently weaker in southern and eastern Europe (interviews with key stakeholders, June and July 2023). The ECRHS II survey partly validated this as the survey found that cumulative exposure to welding fumes was lower in northern Europe compared with southern Europe, but RMMs use is only one possible reason for this (Olsson and Kromhout, 2021) (Section 5.1.3).
- However, one Netherlands representative gave a surprisingly low estimate for best practice use of RMMs in the Netherlands (20%) and relatively high estimate for poor practice (20%) (Section 5.1.4).
- A recently obtained, report on inspections undertaken in the Netherlands from 2009-2015 (Inspectie SZW, 2016) found 217 infringements of the occupational health and safety risk of exposure to welding fumes (43% of all violations). The key reasons highlighted for these infringements was a lack of familiarity with the Working Conditions Catalogue for welding fumes and not obtaining advice from an improvement coach (Section 5.1.4).
- Smaller enterprises are less likely to have the resources to have a dedicated health and safety expert or team (interviews with key stakeholders, June and July 2023) (Section 5.1.3).
- There is less worker protection in the repair industry (interviews with key stakeholders, June – July 2023) (Section 5.1.3).

Negating evidence that compliance is already good was that:

- There is some evidence that compliance is better in western and northern Europe (Section 5.1.3).
- Larger enterprises are more likely to have the resources to have a dedicated health and safety expert or team (Section 5.1.3).

9.5.4.2 Lack of awareness by employers or workers regarding the health risk from exposure to welding fumes

A lack of awareness by employers or workers regarding the health risk from exposure to welding fumes could be remedied by policy option 2 (Annex I). However, again it is not possible to quantify the extent to which policy option 2 would improve the level of awareness.

Supporting evidence of a lack of awareness by employers or workers regarding the health risk from exposure to welding fumes:

- Some stakeholders believe that welding low alloy steel (mild steel) is associated with a low risk of exposure to CMRs, but this is not always the case. A key EU stakeholder concurs with this (Section 5.1.2).
- There is anecdotal evidence from the stakeholders interviewed (personal communication, June – July 2023) that the following groups of workers are at extra risk from exposure to CMRs in welding fumes, usually from lack of training and/or access to RMMs (Section 9.5.4.2):
  - Non-professional welders;
  - Part time or occasional welders;
  - Welders in SMEs; and
  - Migrant workers.
- One stakeholder from the Netherlands pointed out according to data from the national pension fund, one in five welders does not survive to retirement age due to health issues. Their opinion was that the situation would only improve if more control and enforcement measures were undertaken by the Labour Inspectorate because it was currently understaffed (Section 5.1.4).
- Quote from another interview with a stakeholder from the Netherlands: "Most welders underestimate the risks of inhaling welding fumes. The Netherlands Labour Authority (NLA) found that employers were still not providing sufficient information and instructions to their employees[75]. Welders (often less educated workers) are often loyal to their employer and point to their own autonomy (or: unwillingness) to use the right control measures. The employer does not adequately monitor the use of the measures. Employers also often wait too long to call in experts (occupational health and safety service or occupational hygienist) to support them in carrying out a (mandatory) good risk assessment and choosing the right control measures." (Section 5.1.4).

Negating evidence that there is already a good level of awareness by employers or workers regarding the health risk from exposure to welding fumes:

- Professional welders are already using RMMs when welding stainless steel (a European stakeholder and national stakeholder, *pers comm,* June 2023) (Section 4.1).
- Awareness is fairly good; few welders do not care about the risks from welding fumes (an EU level stakeholder) (Section 5.2).
- Awareness in Germany is good and improving (a national stakeholder) (Section 5.2).

9.5.4.3 Annex I would result in increased use of RMMs

Annex I could provide clarity that additional or improved use of existing RMMs are needed to minimise the risk of exposure to CMRs in welding fumes. However, there is some evidence that good practice measures are already in place in certain cases. In any case, it is hard to quantify the positive impact of awareness raising initiatives and to understand the timeframe of any impacts.

[75] Personal experience of the stakeholder, of a current, not yet published exploratory project in the Netherlands.

Supporting evidence that Annex I would result in increased use of RMMs is that:

- Although policy option two had not been fully defined before the questionnaire survey, companies estimated that they would need to invest in measures to comply with an Annex I entry for welding fumes, the most commonly stated estimates of initial investment cost being:
    - Small sized companies: 10 – 100k Euro
    - Medium sized companies: 10 – 100 k Euro
    - Large sized companies: >100 k Euro most commonly stated category
- Responses to the questionnaire survey, albeit an unrepresentative sample, suggest that many companies have yet to install RMMs to achieve the OELs coming into force in 2025 (see below comment regarding the new OEL for Cr(VI)). Only around 15% of respondents stated that they had invested in RMMs to achieve the new OELs (Section 4.1).
- There is also a lack of guidance for companies/workers on the use of RMMs (an EU level stakeholder) (Section 5.2).
- European stakeholders estimated that the policy change would result in an increase in the use of best practice RMMs by 5-10% by both welders at high risk and all welders, and a decrease in poor practice by 5-30% by welders at high risk (Section 6.1.7).
- Most of the interviewees in Croatia and Estonia thought policy option two (Annex I) would result in improvements in best or reasonable practice and reductions in poor practice (Section 6.1.7).
- One EU stakeholder predicted that policy option two (Annex I) would speed up the awareness of inappropriate welding practices, result in improvements in training, better management, improved habits (Section 6.1.7).
- An EU level stakeholder is of the opinion that if policy option two (Annex I) was implemented, the resulting communication campaign could reduce exposure by an additional 2 or 3% per year above baseline improvements (with their estimate of baseline improvements being more than 1-2% per year due to the trends for automation and use of welding processes generating less fumes) (Section 6.1.7).
- Another EU level stakeholder agreed that the reduction in exposure levels, as a result of policy option two (Annex I) accompanied by a communication campaign and training, could be as high as 5% per year (Section 6.1.7).
- A national stakeholder believes that the policy change may increase pressure on employers to ensure workers are using RMMs properly (Section 6.1.7).

Negating evidence that there is already good practice use of RMMs, or that practice will improve anyway due to existing initiatives is that:

- Some national OELs are tighter than the EU OELs for manganese. These countries are likely to already be applying good practice measures to protect workers from welding fumes more generally (Austria, Denmark, Germany and Hungary) (Section 3.2.7).
- Current voluntary industry initiatives providing guidance and training to welders include the BGHM 'welding fumes reduction program' in Germany (Linde, 2023) and the EWA technical committee are helping to improve awareness of which RMMs should be used in welding+ processes (Section 4.2).

- The REarc initiative by the DVS in Germany is developing innovative approaches and new technologies to reduce occupational exposure to arc welding fumes (DVS, 2023). Best practice may spread from the German initiatives to other countries (Section 4.2).
- Cultural/logistical barriers to using RMMs are not believed to be an issue in Germany (Section 5.2).
- CMR substances (classified as category 1a or 1b under the CLP) are already within the scope of the CMRD, policy option two does not constitute a legal change but rather an awareness raising activity (Section 5.4).
- The consultation of key stakeholders also showed policy option two (Annex I) would require some clarification about its implications: many do not understand that there is no legal difference and spent time trying to understand what has changed (Section 5.4).
- None of the national stakeholders interviewed in France, the Netherlands and Slovenia thought there would any resulting improvements in practice from policy option two (Section 6.1.7).
- One national stakeholder believes that policy option two (Annex I) would make no difference at all, zero costs in terms of increased expenditure on RMMs and zero benefits (Section 6.1.7).
- An EU level stakeholder estimated a small improvement as a result of policy option two (Annex I) and questioned how much the Annex I change would filter down to national enforcement. (Section 6.1.7).
- The most common response from the 40 representatives of Member State Authorities that responded to the questionnaire survey was that policy option two (Annex I) would have 'no impact' on costs for companies, costs for public authorities, competitiveness, SMEs, occupational health or the environment (Section 6.1.7).

9.5.4.4 Policy option 2 (Annex I) would result in better protection for workers

An important information gap is in the baseline use of RMMs across the EU27, across sectors and across small, medium and large enterprises. There is evidence both for and against whether policy option 2 (Annex I) would result in better protection for workers.

Supporting evidence that policy option 2 would result in better protection for workers:

- From interviews with national key stakeholders there was less of a distinction between high risk welders and welders in general in terms of access to and use of RMMs, and the proportion of welders applying poor practice was estimated to be higher in some cases than the estimate by EU stakeholders (Table 5-3, Section 5.1.4).
- One of the stakeholders pointed out that even if policy option two (Annex I) does not represent a legal change, it would be important for welders suffering personal damages, enabling them to sue the employer and hold the employer accountable for the health and income damage; and this may also have a preventative effect (Section 6.1.7).

Negating evidence that workers are already well protected, or will be well protected due to policy measures or that policy option two (Annex I) would not make any difference to worker protection:

- Only a small proportion of MSAs surveyed said that policy option two (Annex I) would have a moderate or significant impact on occupational health (12.6%). 72% thought that policy option two would have 'no impact' on occupational health (Section 3.6.3.4).

- From interviews with key EU stakeholders: high risk welders were believed to have slightly better access to and use of RMMs than welders in general (Table 5-2, Section 5.1.4).
- Additional RMMs will be needed to achieve the new OEL for Cr(VI) by January 2025 at 0.005 mg/m3 (instead of 0.025 mg/m3)– this will concurrently reduce exposure to welding fumes in general for the following welding processes which generate Cr(VI) air emissions; MMA, MIG/MAG/TIG, gas-shielded tubular cored arc welding (FCAW) and self-shielded tubular cores arc welding (FCAW) (Section 4.1).
- Arc welding processes for which Cr(VI) and nickel compounds are typically present are used across almost all sectors undertaking welding and may need additional RMMs if they have not already been installed during the current transition period (Table 3-19) (Section 4.1).

9.6 Summary for the option suggested by the ACSH

This study has been undertaken without considering transitional periods as the opinion of the ACSH had not been published at the time of writing. The ACSH published their opinion on 22 September 2023 (as summarised in section 1.2.4), that they strongly recommend that the Commission to adopt as soon as possible the below new entry into Annex I under Directive 2004/37/EC (ACSH, 2023):

"Work involving exposure to fumes from welding processes containing substances that meet the criteria for CMR category 1A/1B set out in Annex I to the CLP regulation."

They also identified the need for further measures to reduce the health effects of exposure to particulates coming from welding fumes or other sources including the establishment of a general dust limit under the CAD. Therefore, the combined costs and benefits for policy option two (Annex I) and for the non-specific generic dust metric would apply (see Cost Benefit Analysis in section 9.1 and multicriteria analysis in section 9.2).

The ACSH recommended that guidance be produced on how policy option two (Annex I) should be applied, and suggested that this would take at least 2 years to prepare. There is a lack of clarity in the ACHS opinion as to whether the above Annex I entry for welding should be made before or after guidance has been published.

10 REFERENCES

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11 ANNEXES

11.1 Annex 1 – Stakeholder consultation – synopsis report

This section provides a summary of the stakeholder consultation exercises undertaken as part of this study ('Study on collecting the most recent information on substances to analyse health, socio-economic and environmental impacts in connection with possible amendments of Directive 2004/37/EC on the protection of workers from the risks related to exposure to carcinogens, mutagens or reprotoxic substances at work').

11.1.1 Outline of consultation strategy

The primary aim of the consultation activities is to identify information not available via desk-based research. For example, although information on current OELs, STELs, BLVs and notations is available, there is limited information on the specific concrete risk management measures already in place, as well as those that would need to be implemented, should the proposed measures be introduced into the CMRD. There may also, for example, be complications regarding the specificities of different sites and environments in which workers may be exposed. Consultation activities therefore formed a valuable part of this study.

The consultation activities conducted to date have included:

- Targeted questionnaires, these included: substance specific questionnaires, Member State Authorities, OSH Experts, Trade Unions and a further short questionnaire for welding[76];
- Interviews;
- Site visits; and
- Conversations (these consisted of email exchanges and online calls).

The study team have consulted a range of organisations whose activities are relevant to welding as part of this study. Information collected via consultation included the sectors and processes in which the welding fumes are produced, the size of companies that would be impacted, estimates of numbers of workers exposed currently, current air concentrations of substances concerned (both 8-hour time weighted averages (8-h TWA) and 15-minute reference periods), current biological limit values, as well as risk management measures currently in place, and risk management measures that would need to be implemented should the limits be introduced and the associated costs.

Consultation activities have been conducted by those with expertise; substance experts (those writing the substance-specific reports) and national experts (with knowledge of the situation in their Member State and native language competence) conducted the interviews with stakeholders. The substance and national experts in turn were also supported by experts in cost-benefit analysis and consultation via a consortium led by RPA which has worked on all five previous OELs studies.

Any contact made with stakeholders was logged so that progress could be monitored, and interview guides have been prepared for those conducting interviews to ensure that the approach to collecting data was thorough and consistent. These guides include information clarifying the objectives of the study, the study approach and provide detailed information on the measures being assessed.

[76] Questionnaires for MSA, Trade Unions and the further welding questionnaire were often accompanied by interviews. The aim of these interviews was to fill in the questionnaire and this formed the basis of the interview questions.

They also include information on the role of the national experts and the specific data that needs to be collected via consultation, as well as the privacy statement and the confidentiality options.

The following important aspects of the consultation exercise should be mentioned:

- There has been no public consultation conducted as part of this work, although the survey has – through its submission strategy – aimed to reach out widely;
- The consultation focused on generating *evidence* to directly support the analyses. Views and opinions have also been provided and are presented here as well, but the approach towards this has not been as systematic; and
- Much of the evidence gathered is of a confidential nature and is thus not presented here, however it has been used to support the calculations and assessments that result from the analyses.

The table below summarises the stakeholder groups targeted and the tools, interests and strategies applied:

Table 11-1 Consultation tools and strategies

Stakeholder type	Interests represented	Main consultation tools	Strategy
EU Associations and REACH Consortia	Industry	Online interviews Email requests	Our previous work demonstrated that EU Associations are the best instrument for reaching out to manufacturers/users. Upon the study team's request, the EU associations thus forwarded the questionnaires to national associations and companies. Supplementary information e.g. on number of companies, numbers of workers exposed, market situation, etc. was collected through email requests and online interviews with the associations and REACH consortia and statistics from Eurostat.
Member State Authorities	Member State authorities	Questionnaires Online interviews	Member State authorities were contacted with a questionnaire and responses were followed up with online interviews, where possible. Experience from supporting the OELs 3, OELs 4 and OELs 5 studies demonstrated that this is the most effective way of collecting the specific information across all Member States.
Manufacturers/users	Industry	Questionnaires Online interviews Email requests	Based on the experience from OELs 3, OELs 4 and OELs 5, questionnaires for manufacturers/users were mainly distributed via EU associations. The EU associations forwarded the questionnaire directly to companies or forwarded it to national industry associations which then forwarded it to their member companies. This strategy was deemed the most sensible as experience from the previous OELs studies shows that only a few companies answer the questionnaire unless encouraged to do so by either their relevant EU association or their national industry associations. To increase the number of responses, questionnaires were refined and kept as short as possible, and focused on providing data on existing

Stakeholder type	Interests represented	Main consultation tools	Strategy
			RMMs as well as RMMs (and costs) needed to comply with the various reference limits (options). Questionnaire responses were then, where possible/ necessary, followed up by interviews and site visits. Some companies have been also contacted directly (i.e. not via the associations) by phone by national experts who encouraged and assisted the companies in filling out the questionnaire and/or undertook telephone interviews. This additional approach was selected to ensure that answers are provided by companies situated in as many Member States as possible.
National industry associations	Industry	Online interviews Email requests	National industry associations were primarily contacted via the EU associations. Some national associations were contacted directly by phone by national experts and interviewed to collect information supplementary to the information from EU associations, and identify relevant national companies to be approached by the national experts.
Trade Unions	Workers	Online interviews Email requests WPC	Based on previous experience, this study focused on obtaining a few more targeted telephone interviews and email correspondence, as well as collecting information from worker association representatives of the WPC.
Occupational Health & Safety Professionals	Contacted to obtain scientific information	Questionnaire Online interviews	Occupational health and safety professionals were contacted with a questionnaire. This is considered the most efficient way to collect specific information across all Member States.
Working Party on Chemicals (WPC)	Industry Workers Member State Authorities	Participation in workshop	The study team presented draft results to the Working Party on Chemicals in May 2023. Previously, this has proved to be an effective means of receiving feedback from representatives of industry, employers' associations, workers' organisations and Member State authorities.

Source: Analysis by RPA Ltd and COWI

Some stakeholders could not be reached. Substance experts wanted to contact specific national welding institutes, companies and trade unions. Efforts were made to contact these stakeholders but there was no response.

11.1.2 Documentation of formal consultation activity

The questionnaires for welding fumes by stakeholder group can be found in:

- Companies - welding fume (see Annex 3 of this report);
- Member State Authorities (see Annex 2 of the separate Methodological Note);
- Occupational Safety and Health Experts (see Annex 3 of the separate Methodological Note);

- Trade Unions (see Annex 4 of the separate Methodological Note); and
- Welding short interview guide (see Annex 11 of this report).

11.1.3 Methodologies and tools to process data

The online questionnaires for this report were gathered using EU Survey. EU Survey allows for full control over the creation and design of the questionnaire and allows translations to be edited through the website tools. Once completed, the survey data was exported from EU Survey into Excel and cleaned to ensure that only genuine responses were analysed. Any test answers or irrelevant responses were removed[77]. This was then provided to substance experts for their analysis to combine with information that had been obtained through internet research, interviews and other means.

A stakeholder log was also created to monitor and record contact with stakeholders. This included contact information, contact method, and survey completion.

Experts responsible for welding fumes were provided with all the information relevant for welding fumes (questionnaire responses, interview minutes, site visit reports, position papers, etc.). All information was analysed by the specific substance expert and, where considered robust and relevant, used as the basis for the substance-specific analyses in conjunction with information obtained via desk-based research.

11.1.4 Results of consultation activities

The consultation activities being conducted as part of this study are explained in greater detail in the subsections below.

11.1.5 Targeted online survey

The online targeted survey opened on 23 January 2023 and ran until 27 March 2023. The deadline was extended twice to allow for a broader range of stakeholders to respond and address low response rates for certain substances.

Stakeholders were initially contacted via email. The email provided an overview of the study and a link to the RPA webpage explaining the consultation activities, with links to each of the questionnaires, the privacy statement, and an introductory letter from the Commission. A link rather than an attachment was used to decrease the size of the email and reduce the number of emails automatically directed to junk folders. Questionnaires were created for welding fumes for companies, three for the different stakeholder groups and an additional welding questionnaire:

- Companies - welding fume (see Annex 3 of this report);
- Member State Authorities (see Annex 2 of the separate Methodological Note);
- Occupational Safety and Health Experts (see Annex 3 of the separate Methodological Note);
- Trade Unions (see Annex 4 of the separate Methodological Note); and
- Welding short interview guide (see Annex 11 of this report).

The questionnaires for companies were available as a link to EU Survey. The questionnaire for Member State authorities and occupational safety and health experts was available as a Word

[77] Two responses for welding fumes were removed as these were completed by industry associations rather than companies and were analysed separately.

document which could be downloaded and sent to the study team using the designated OELs 6 email address. Trade Unions and specific welding stakeholders were also contacted by national experts and invited to interview for the questionnaire.

The questionnaires aimed to collect information on processes during which worker exposure to the substances in question is likely to occur, risk management measures that are already in place, current exposure concentrations, risk management measures that would need to be implemented should the limit be lowered, and any other impacts that could result from the introduction of EU-level limits. A s mentioned above, the questionnaires were targeted, focusing on the evidence needed for the analyses. In that regard, particular focus was placed on risk management measures, as only limited information on these is available in the literature.

Translations of each of the substance questionnaires were available in German, French, Italian, Polish and Spanish and respondents also had the option to ask the study team for the questionnaire in a language of their choice. Translations were initially requested through EU Survey and were then checked and edited by the National Experts.

At the end of the questionnaire, respondents were given the opportunity to add any further comments and were asked if they were willing for a substance expert to ask potential follow-up questions and whether they would be willing to host a site visit. Follow-up interviews were very useful when there were gaps in a stakeholder's response and questions could be asked further to fill in missing information. Other consultation methods were used to probe further into respondents' answers and gain a more in-depth understanding of the topic and potential impacts.

National experts were used to contact MSAs for countries where the study team did not have a response from that country.

The Commission and the WPC were provided the opportunity to comment on the drafts of each questionnaire before they were launched, to ensure that they were relevant and user-friendly.

Some stakeholders however expressed difficulty in responding to the questionnaire due to the complexity of the study for welding fume. Discussions were held with key industry associations and these stakeholders were provided with the opportunity to respond to the questionnaire via interview, where explanation could be provided for each question. The study team also received responses from industry organisations.

It should also be noted that some industry associations had already carried out their own surveys or had contributed to discussions on the relevant occupational exposure limits prior to this study, which may have resulted in consultation fatigue for some substances.

Across the overall study of five substances, **691** stakeholders were invited to take part in the questionnaire. Many of the stakeholders contacted were relevant for multiple substances. However, the true number of stakeholders that were contacted is likely to be higher as many industry and EU associations were contacted and asked to distribute the survey to their members. Based on experience from previous studies, this has been a useful method to ensure a high response rate from companies. Efforts were also made during calls with industry associations to encourage their members to respond. Stakeholders were selected from the sectors that were identified as being relevant for welding fumes. The tables below provide a summary of the responses according to stakeholder type.

Table 11-2 Summary of numbers of stakeholders directly contacted by questionnaire type

Stakeholder type		**Number contacted**
Companies	Companies	15.91% (110 out of 691)
	Industry associations	61.07% (422 out of 691)
Member State Authorities		20.69% (143 out of 691)
Occupational Health and Safety Experts		2.32% (16 out of 691)
Trade Unions*		3 contacted
Welding (short interviews)*		20 contacted

*Source: Consultation. *These were accompanied by an interview*

Four reminders were sent out to stakeholders to prompt them to respond and update them on the extension to the survey deadline. Stakeholders that had completed the survey or indicated to the study team that the substance was not relevant to them were removed from the mailing list.

Table 11-3 Breakdown of number of stakeholders directly contacted by questionnaire type

Stakeholder type	**Number contacted**
Company	15.63% (108 out of 691)
Education and Training	0.14% (1 out 691)
Industry associations	59.62% (412 out of 691)
Laboratories	0.14% (1 out of 691)
Public authority	20.69% (143 out of 691)
NGO	1.45% (10 out of 691)
OSH Professional	2.32% (16 out of 691)
Trade Unions	0% (0 out of 691)

Source: Consultation.

The table below provides an overview of the number of responses received to the questionnaires from those contacted. This number includes the number of responses that were able to be analysed after the initial cleaning process. Most responses came from companies as this was the stakeholder group where there was the most engagement and requests for responses. At least one contact was approached for each Member State, however not all Member States provided a response to the targeted questionnaire. The study team used the national experts to conduct interviews with the Member State authorities that have not responded to the questionnaire, these were often accompanied by an interview based on the questions in the survey. National experts were also tasked with contacting and getting responses from trade unions.

Table 11-4 Responses per questionnaire for welding fumes

Stakeholder type	**Number of responses**
Companies	72.84% (59 out of 81)
Member State Authorities	17.28% (14 out of 81)

Stakeholder type	Number of responses
Occupational Health and Safety Experts	9.88% (8 out of 81)
Trade Unions*	2 responses
Welding (short questionnaire)*	12 responses
Total	**81**

*Source: Consultation. *These were accompanied by an interview and were undertaken in addition to the main questionnaires and thus are not included in the total number.*

A large number of responses were received for welding fumes that are produced across a wide variety of industries. 59 responses were received to the welding questionnaire. A breakdown of the questionnaire responses for welding fumes by company size is presented in below (Table 11-5).

Table 11-5 Number of responses submitted by companies, for the welding fumes questionnaire, by size of company

Company size (employees)	Welding Fumes
Micro (<10)	12
Small (10-49)	14
Medium (50-249)	12
Large (250<)	21
Total	**59**

Source: Consultation.

11.1.5.1 Online interviews

Online interviews were conducted with stakeholders whose activities are relevant to welding fumes. The aim of these interviews was to build upon the information provided in response to the questionnaires, to fill any information gaps. The study team aimed to obtain detailed information on processes, to pinpoint exactly where exposure is likely to occur, to investigate what types of risk management measures are already in place and how effective they are, as well as what risk management measures would be required if limits were lowered and other potential ramifications for the company, etc.

Interviews were obtained a variety of ways. At the end of the questionnaire, respondents were asked if they would be willing to take part in an interview. However, some online interviews were arranged through making direct contact with key industry associations.

Consultees were given the opportunity to respond in their native language. In cases where this was required, the interview was carried out by the national expert.

Each online interview lasted approximately one hour. At the end of the telephone interview, the study team ensured that the organisations/individuals were satisfied with the minutes of the interview. This either involved sending them the minutes by email and receiving confirmation or, if the interviewee was happy with this, a sign-off process at the end of the interview.

National experts and welding fumes experts conducted interviews with relevant stakeholders. Some of the interviews were based on the responses to the questionnaire. The meeting notes were shared with the company after the interview, and that occasion was also used to ensure mutual agreement on the level of confidentiality required.

A summary of the number of interviews carried out is presented in the table below. A total of 18 interviews were carried out: 12 short interviews by National Experts, and 6 interviews with key stakeholders.

Table 11-6 Breakdown of interviews per stakeholder type

Stakeholder type	Interviews conducted
Laboratories	0% (0 out of 18)
EU industry association	11.1% (2 out of 18)
Companies	5.56% (1 out of 18)
Member State Authorities	0% (0 out of 18)
Trade Unions	16.67% (3 out of 18)
Occupational health and safety experts	16.67% (3 out of 18)
Other	33.33% (9 out of 18)
Total	18

Source: Consultation

Notes: 'Other' includes training institutions and national trade associations.

11.1.5.2 Conversations

Email requests have also been used to collect information for the study. The purpose of email requests is similar to the interviews, with stakeholders being asked for further detail on their answers to the questionnaire, as well as making requests for additional information such as industry statistics.

For welding fumes, constructive conversations have been carried out via email with the following stakeholders:

- Deutscher Verband für Schweißtechnik (DVS);
- European Welding Association (EWA);
- European Welding Federation (EWF);
- International Institute of Welding (IIW);
- Arbo Advies Bureau Halm, Netherlands;
- Berufsgenossenschaft Holz und Metall (BGHM);
- Syndicat National de La Chaudronnerie, de La Tôlerie et de La Tuyauterie Industrielle (SNCT);
- European Construction Industry Federation (FIEC);
- The Welding Institute (TWI);
- Community of European Railway and Infrastructure Companies (CER);
- Vocational training centre, UK;

- Company, Germany;
- Company, Germany;
- Deutsche Gesetzliche Unfallversicherung (DGUV);
- Nederlands Instituut voor Lastechniek (NIL); and
- Netherlands working group on welding fume.

11.1.5.3 Site visits

Companies whose activities are likely to be affected by the potential modifications to the CMRD were also asked whether they would be willing to welcome members of the study team for a site visit. Companies to be visited were identified via the questionnaire or via contact established via industry associations.

The purpose of the site visits was to gain a more operational understanding of the risk management measures currently in place to protect against exposure to the substances concerned, as well as of the risk management measures that would be needed should the CMRD be modified.

Detailed notes from each site visit were drafted and sent back to the company to ensure that the information recorded is accurate. This process enabled the company to add more detail and information to the study, where possible, and to confirm the level of confidentiality accorded to the information.

Two site visits were undertaken during Spring and Summer 2023, once significant progress had been made with data collection. This ensured that site visits added more nuance to the data already collected and helped to fill remaining information gaps.

Table 11-7 Summary of site visits per substance and size of enterprise

Company size (enterprises)	Welding Fumes
Micro (< 10)	0
Small (10-49)	0
Medium (50-249)	0
Large (>250)	2
Total	2

Source: Consultation.

11.1.5.4 Consultation results by substance

Specific information obtained from the stakeholder consultation on exposure levels, exposed workforce, applied RMMs, costs of compliance with reference OELs, etc. is included in the substance-specific reports.

11.1.5.5 Summary of consultation statistics

The following tables provide breakdowns of the questionnaire responses, interviews and site visits carried out by company size, stakeholder type and substance.

The breakdown of questionnaire responses, interviews and site visits by company size are provided below. They show that the majority of the responses were received from large or medium-sized enterprises, with fewer responses from small and very small enterprises.

Table 11-8 Breakdown of questionnaire responses, interviews and site visits per company size for welding fumes (only for consulted companies and laboratories)

Company size (employees)	Questionnaire responses	Interviews	Site visits
Micro (<10)	20.34% (12 out of 59)	0 (0%)	0% (0 out of 2)
Small (10-49)	23.73% (14 out of 59)	0 (0%)	0% (0 out of 2)
Medium (50-249)	20.34% (12 out of 59)	0 (0%)	0% (0 out of 2)
Large (250<)	35.59% (21 out of 59)	0 (0%)	100% (2 out of 2)

Source: Consultation

For interviews with 6 key stakeholders, these included membership organisations which have a small structure but large influence, so company size would be misleading.

The breakdown of questionnaire responses, interviews and site visits for welding fumes are provided below.

Table 11-9 Breakdown of questionnaire responses, interviews and site visits per substance (all stakeholders; companies, Member State authorities, trade associations, OSH (Occupational Safety and Health) specialists) -

Substance	Questionnaire responses[78]	Interviews	Site visits
Welding fumes	26.82% (81 out of 302)	10.34% (6 out of 58)	22.22% (2 out of 9)
Welding (short interviews)	12 responses	n/a	n/a

Source: Consultation

The breakdown of questionnaire responses, interviews and site visits per Member State are provided below. These results show a high number of questionnaire responses were received from Germany. It is not clear why this country provided a high number of responses.

In the substance reports, the potential impact of the high number of responses from Germany is referred to if the study team thinks that the results could be biased by this. Germany in particular has already implemented regulations relating to welding. Overall, the unbalanced breakdown of responses by Member States is taken into account by the study team, and the information is balanced by data from other stakeholders and sources, to ensure that the conclusions are not believed to be unduly influenced by the responses from Germany.

[78] The questionnaire responses are higher here as the MSA and OSH questionnaire had substance specific sections. Where these have been completed, they have been added as one response.

Table 11-10 Breakdown of questionnaire responses, National Expert interviews, key stakeholder interviews and site visits per Member State (all stakeholders; companies, Member State authorities, trade associations, OSH (Occupational Safety and Health) specialists)

Country	Questionnaire responses	National Expert interviews	Key stakeholder interviews	Site visits[1]
Inside the EU				
Austria	2.47% (2 out of 81)	0% (0 out of 12)	0% (0 out of 6)	-
Belgium	2.47% (2 out of 81)	0% (0 out of 12)	0% (0 out of 6)	-
Bulgaria	0% (0 out of 81)	0% (0 out of 12)	0% (0 out of 6)	-
Croatia	0% (0 out of 81)	25% (3 out of 12)	0% (0 out of 6)	-
Cyprus	1.23% (1 out of 81)	0% (0 out of 12)	0% (0 out of 6)	-
Czechia	3.70% (3 out of 81)	0% (0 out of 12)	0% (0 out of 6)	-
Denmark	2.47% (2 out of 81)	0% (0 out of 12)	0% (0 out of 6)	-
Estonia	0% (0 out of 81)	33.3% (4 out of 12)	0% (0 out of 6)	-
Finland	2.47% (2 out of 81)	0% (0 out of 12)	0% (0 out of 6)	-
France	7.41% (6 out of 81)	8.3% (1 out of 12)	0% (0 out of 6)	-
Germany	43.21% (35 out of 81)	0% (0 out of 12)	16.6% (1 out of 6)	-
Greece	0% (0 out of 81)	0% (0 out of 12)	16.6% (1 out of 6)	-
Hungary	2.47% (2 out of 81)	0% (0 out of 12)	0% (0 out of 6)	-
Ireland	1.23% (1 out of 81)	0% (0 out of 12)	0% (0 out of 6)	-
Italy	6.17% (5 out of 81)	0% (0 out of 12)	16.6% (1 out of 6)	-
Latvia	1.23% (1 out of 81)	0% (0 out of 12)	0% (0 out of 6)	-
Lithuania	1.23% (1 out of 81)	0% (0 out of 12)	0% (0 out of 6)	-
Luxembourg	0% (0 out of 81)	0% (0 out of 12)	0% (0 out of 6)	-
Malta	0% (0 out of 81)	0% (0 out of 12)	0% (0 out of 6)	-
Netherlands	2.47% (2 out of 81)	25% (3 out of 12)	0% (0 out of 6)	-
Poland	2.47% (1 out of 81)	0% (0 out of 12)	0% (0 out of 6)	-
Portugal	1.23% (2 out of 81)	0% (0 out of 12)	0% (0 out of 6)	-
Romania	2.47% (2 out of 81)	0% (0 out of 12)	0% (0 out of 6)	-
Slovakia	1.23% (1 out of 81)	0% (0 out of 12)	0% (0 out of 6)	-
Slovenia	1.23% (1 out of 81)	8.3% (1 out of 12)	0% (0 out of 6)	-
Spain	0% (0 out of 81)	0% (0 out of 12)	0% (0 out of 6)	-

Country	Questionnaire responses	National Expert interviews	Key stakeholder interviews	Site visits[1]
Sweden	3.70% (3 out of 81)	0% (0 out of 12)	0% (0 out of 6)	-
Multiple MS	1.23% (1 out of 81)	0% (0 out of 12)	0% (0 out of 6)	
EU level	0% (0 out of 81)	0% (0 out of 12)	50% (3 out of 6)	-
Outside the EU				
Iceland	0% (0 out of 81)	0% (0 out of 12)	0% (0 out of 6)	-
Norway	1.23% (1 out of 81)	0% (0 out of 12)	0% (0 out of 6)	-
South Korea	0% (0 out of 81)	0% (0 out of 12)	0% (0 out of 6)	-
Switzerland	4.94% (4 out of 81)	0% (0 out of 12)	0% (0 out of 6)	-
UK	0% (0 out of 81)	0% (0 out of 12)	0% (0 out of 6)	-
US	0% (0 out of 81)	0% (0 out of 12)	0% (0 out of 6)	-
Total	**81**	**12**	**6**	**2**

Source: Consultation

Notes: In some cases, the input for location was given as several Member States or a list of companies for the same response. In order to not inflate the numbers presented, if this was given as an answer, it is recorded this under 'multiple Member States'. In other cases European level stakeholders were interviewed and have been counted as 'EU level'.

[1]Site visits have been carried out, but the location cannot be disclosed due to confidentiality and the small sample size.

11.1.6 How the information gathered has been taken into account

A large amount of information has been collected via consultation, particularly through means of the targeted online questionnaires, telephone interviews and email correspondence. Efforts have been made to contact a variety of relevant stakeholders in all of the Member States, for each of the relevant substances, from companies of varying sizes.

The information collected via consultation has enabled the study team to gain a more nuanced understanding of the likely impacts of modifying or introducing OELs, which could not have been obtained otherwise via desk-based research/literature reviews. Through the combination of desk-based research, questionnaire responses, interviews, and site visits, it has been possible to compile a significant amount of detailed information in relation to the potential impacts of introducing the proposed measures.

The table below summarises how the responses in each questionnaire section are used in each report. The majority of the analysis is undertaken and discussed in each of the substance specific reports.

Table 11-11 Questionnaire sections mapped to relevant section in each substance report

Questionnaires and sections	Report section
Companies	
B	Exposure concentrations Exposed workforce Current risk management measures (RMMs)
C	Lowest technically possible and economically feasible option
D	RMMs needed to achieve compliance
E	Voluntary industry initiatives
F	Other benefits
G	Impact of the implementation of other OELs
H	Other comments
Member State Authority	Existing national limits Costs for public administrations Costs Market effects Environmental impacts Indirect benefits Employment
Occupational Health & Safety Experts	Current risk management measures (RMMs) Existing national limits RMMs needed to achieve compliance
Trade Unions	Voluntary industry initiatives Exposed workforce Benefits
Welding	(Welding only- short interviews) Definition of the problem Benefits

Source: Study team

11.1.6.1 Information and issues raised by stakeholders

There were no reports received from stakeholders that had been prepared specifically for the purpose of providing information for this study on welding fumes.

11.2 Annex 2 Who is affected and how?

The below tables provide a summary of who is affected and how. Table 11-12 provides an overview of the benefits of policy option two. For policy option two, no OEL has been set, so there is no avoided cost of setting an OEL.

Table 11-12 Overview of benefits (total for all provisions) – preferred policy option two €millions

Description	Amount €millions
Direct benefits	
Workers & families - Reduced cases of ill health (Lung cancer)	1,618
Workers & families - Reduced fatalities	1,079
Workers & families - Reduced non-fatalities	270
Workers & families - Ill health avoided, incl. intangible costs (M1 to M2)	M1: 997.5 M2: 510
Companies - Avoided costs	4.7
Public sector - Avoided costs	16.4
Indirect benefits	
Public sector - Avoided cost of setting an OEL	N/A

Source: Study team

Notes: Benefits are PV discounted over 40 years

Table 11-13 and Table 11-14 give an overview of costs and apply the "one in, one out" approach for the preferred option. The costs are presented as present value costs discounted over 40 years and are not split between one-off and recurrent costs.

Table 11-13 Overview of costs – Preferred policy option two in €millions

	Businesses	**Administration**
Direct adjustment costs	€ 67-156 million	€ 2.7 million
Direct administrative costs	N/A	N/A
Direct regulatory fees and charges	N/A	None
Direct enforcement costs	None	None
Indirect costs	None predicted	N/A

Source: Study team

Notes: Costs are PV discounted over 40 years

Enforcement costs are not estimated as they are specific to Member States individual inspection regime.

Table 11-14 Application of the 'one in, one out' approach – Preferred policy option two €millions

	Total
Businesses	
New administrative burdens (INs)	N/A
Removed administrative burdens (OUTs)	€0
Net administrative burdens	N/A
Adjustment costs	€ 67 – 156 million
Total administrative burdens	€ 67 – 156 million

Source: Study team

Notes: recurrent costs are PV discounted over 40 years

Policy option two would help to contribute towards two Sustainable Development Goals as set out in Table 11-15.

Table 11-15 Overview of relevant Sustainable Development Goals for the preferred policy option two.

Relevant SDG	Expected progress towards the Goal
SDG 3 Good health and wellbeing	The preferred policy option achieves improved worker and family health outcomes.
SDG 8 Decent work & economic growth"	The preferred policy option achieves improved worker and family health outcomes.

Source: Study team

11.3 Annex 3 Questionnaire for companies – welding fumes

Questionnaire for companies: welding fume

Fields marked with * are mandatory.

Questionnaire for companies: welding fume

This survey is part of a study to support a possible amendment of Directive 2004/37/EC on the protection of workers from exposure to carcinogens, mutagens or reprotoxic substances at work (the Carcinogens, Mutagens or Reprotoxic substances Directive, **CMRD**). Specifically, the study assesses the impacts of establishing new limit values for some substances or introducing a substance into Annex I.

The substances being considered are:

- **Polycyclic aromatic hydrocarbons (PAH)**
- **Cobalt and inorganic cobalt compounds**
- **Isoprene**
- **1,4-dioxane**
- **Welding fume**

New OELs are proposed for the first four substances above under the CMRD. In addition, biological limit values (BLV) are proposed for PAH and 1,4-dioxane, and a 15-minute short-term exposure limit value (STEL) is proposed for 1,4-dioxane. 'Skin sensitisation' and 'respiratory sensitisation' notations are also proposed for cobalt and inorganic cobalt compounds, and 'skin' notations are proposed for isoprene, PAHs and 1,4-dioxane.

An amendment to include welding fume in Annex I of the CMRD is also being considered.

This questionnaire is intended for all companies where exposure to **welding+ fumes*** within the scope of the CMRD takes place.

The study is being undertaken by a consortium comprising RPA Risk & Policy Analysts (United Kingdom), RPA Europe (Italy), RPA Europe Prague (Czech Republic) COWI (Denmark), FoBiG Forschungs- und Beratungsinstitut Gefahrstoffe (Germany), EPRD (Poland) and Force Technology (Denmark) under a contract for the European Commission's Directorate-General for Employment, Social Affairs and Inclusion.

All responses to this questionnaire will be treated in the **strictest confidence** and will only be used for the purposes of this study. In preparing our report for the Commission (which, subsequently, may be published), care will be taken to ensure that specific responses cannot be linked to individual companies.

This questionnaire is intended for a **single facility.** If workers are exposed at multiple facilities, please complete the questionnaire several times or contact the study team.

It will take approximately 15–45 minutes to answer the questionnaire depending on data availability and detail.

The deadline for completion of the questionnaire is the 3 March 2023.

This questionnaire is available in English, French, German, Italian, Polish and Spanish. However, you are welcome to answer the questions in an official language of the European Union of your choice. If you prefer to be interviewed in your language or if you have questions about the survey, please contact: OELs6@rpaltd.co.uk

Abbreviations used in the questionnaire:

BLV - Biological Limit Value

CMRD - Carcinogens, Mutagens or Reprotoxic substances Directive 2004/37/EC

NACE - NACE Revision 2, statistical classification of economic activities in the European Community (See https://ec.europa.eu/eurostat/documents/3859598/5902521/KS-RA-07-015-EN.PDF, page 61 ff.)

OEL - The term Occupational Exposure Limit value (OEL) refers to the limit of the time-weighted average of the concentration in the air within the breathing zone of a worker, measured or calculated in relation to a reference period of eight hours (8-h TWA).

RMM - Risk Management Measure

STEL - A short-term exposure limit is like an OEL but involves a shorter reference period (usually 15 minutes). The aim of this value is to prevent adverse health effects caused by peaks in exposure that will not be controlled by the application of an 8-hour TWA limit.

8-hour TWA - 8-hour Time-Weighted Average, measured in parts per million (ppm) or milligrams per cubic metre (mg/m^3). The 8-hour TWA is an expression for the average exposure for a typical working day. It is calculated by summing up the concentrations (in ppm or mg/m^3) during different periods of a day (usually 8 hours). Each concentration is multiplied by its relevant duration and the total is divided by the entire length of the working day (usually 8 hours) such as in this example:

8h-TWA = (2 hours * 500 ppm + 5 hours * 100 ppm + 1 hours * 700 ppm) / (2 + 5 + 1 hours).

***welding+ fumes** is defined (by ECHA, 2022[1]) as fumes from the following activities:

- Fusion welding (gas welding, arc welding (MIG, MAG, SMAW, FCAW, SAW, ESW, SW), arc welding (TIG, PAW), beam welding,
- Soldering (soft soldering, hard soldering)
- Brazing (>450°C, Laser beam brazing, Brazing with an electric arc (MIG, TIG, plasma))
- Thermal cutting or gouging
- Thermal spraying
- Flame straightening

- Additive production processes

[1] ECHA, 2022. ECHA Scoping Study report for evaluation of limit values for welding fumes and fumes from other processes that generate fume in a similar way at the workplace. 17 November 2022, European Chemicals Agency, Helsinki, Finland. Available from: https://echa.europa.eu/documents/10162/7399806/report_welding_fumes_en.pdf/45d744a8-da00-7ebe-3890-0a4cded3bf7d

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A) About your company

Please complete a separate questionnaire for each facility.

A1) Please provide the following details about your company

* **Name of contact person**

* **Company**

* **Email address of contact person**

Telephone number of contact person

Please give the name and address (incl. country) of the facility for which you are completing this questionnaire

* **Country of facility**

- Austria
- Belgium
- Bulgaria
- Croatia
- Cyprus
- Czechia
- Denmark
- Estonia
- Finland
- France
- Germany
- Greece
- Hungary
- Ireland
- Italy
- Latvia
- Lithuania
- Luxembourg
- Malta
- Netherlands
- Poland
- Portugal
- Romania
- Slovak Republic
- Slovenia
- Spain
- Sweden
- Other

If other, please specify

A2) Please define the sector in which your company is active (if possible, using a NACE code)

- C24.2 Manufacture of tubes, pipes, hollow profiles and related fittings, of steel
- C25 Manufacture of fabricated metal products
- C26 Manufacture of computer, electronic and optical products
- C27 Manufacture of electrical equipment
- C28 Manufacture of machinery and equipment n.e.c.
- C29 Manufacture of motor vehicles, trailers and semi-trailers
- C30 Manufacture of other transport equipment
- C31 Manufacture of furniture
- C32 Other manufacturing
- C33 Repair and installation of machinery and equipment
- E38.31 Dismantling of wrecks

- F Construction
- G45.2 Repair of motor vehicles and motorcycles
- J61 Telecommunications
- O84.2 Provision of services to the public
- P85 Education
- Q86.2 Medical and dental practice activities
- R90 Creative, arts and entertainment activities
- S95 Repair of computers and personal and household goods
- Other

If other, please specify:

A3) What is the annual turnover in EUR at the facility for which you are filling out this questionnaire?

- < €2 million
- €2 – 10 million
- €10 – 50 million
- €50 – 100 million
- > €100 million

A4) How many workers are employed in your company at the facility for which you are filling out this questionnaire?

A5) What is the number of workers whose primary role is welding+?

A6) How many non welders are potentially exposed to welding+ fumes?

A7) How many welders work on high risk welding+ activities?

A8) Please specify which high risk welding+ processes are undertaken

A9) Do you currently have a health surveillance system in place for welding+ activities at this facility?

- ◯ Yes
- ◯ No

A9a) To which workers does the health surveillance system apply at the facility for which you are filling out this questionnaire? (Tick all that apply)

- ☐ All workers potentially exposed to welding+
- ☐ All welders
- ☐ For selected high risk welding+ process(es)

A9b) How many people are included in the health surveillance programme relating to welding+ activities?

A9c) Please provide further information about your health surveillance programme

---

A10) Which substances do you monitor for in air concentrations or biomonitoring from welding+ activities? Tick all that apply.

- ☐ Inhalable welding fumes
- ☐ Respirable welding fumes
- ☐ Welding fumes (generic)
- ☐ Particulate matter (dust)
- ☐ Carbon monoxide
- ☐ Nitrogen monoxide (NO)
- ☐ Nitrogen dioxide (NO2)
- ☐ Nitrogen oxides (NOx)
- ☐ Ozone
- ☐ Aluminium compounds (Al)
- ☐ Barium compounds (Ba)
- ☐ Cobalt compounds (Co)
- ☐ Chromium II or III compounds (Cr II/III)
- ☐ Chromium VI compounds (CrVI)
- ☐ Total chromium (Cr)
- ☐ Copper compounds (Cu)
- ☐ Iron compounds (Fe)
- ☐ Magnesium compounds (Mg)
- ☐ Manganese compounds (Mn)
- ☐ Nickel compounds (Ni)

- [ ] Vanadium compounds (V)
- [ ] Other, please specify:

Other, please specify

A11) What is the annual cost of monitoring all substances ticked for welding+ activities?

- ( ) < €10,000
- ( ) €10,000 - €100,000
- ( ) > € 100,000

A12) Have you any experience of workers having health issues resulting from occupational exposure to welding+ fume at the workplace? (e.g., lung cancer, kidney cancer)

A13) Have any workers left the company due to health issues associated with exposure to welding+ fume?

B) Information about current exposure at your facility

Airborne concentrations

B1) Please specify the most important processes* during which exposure to welding fume and its hazardous gases can occur. You can report on a maximum of four processes.

*The most important processes in this context are those for which exposure to welding fume and emissions of hazardous gases gives you the most concern. This could be because the process has low levels of exposure but affects many people. Or because the process has high levels of exposure but for short periods. Or alternatively, a process where it is very difficult or expensive to reduce exposure at all.

Process 1

- ( ) Submerged arc welding
- ( ) Gas fusion welding
- ( ) TIG
- ( ) Soft soldering
- ( ) Laser beam cutting (without additional materials)
- ( ) MIG/MAG (low-energy protective gas welding)
- ( ) Brazing
- ( ) MIG soldering
- ( ) Laser beam cutting (with additional materials)
- ( ) MIG (solid wire, nickel, nickel-based alloys)

- MAG (solid wire)
- MMA
- MAG (flux-cored arc welding with shielding gas)
- Laser beam cutting
- MAG (flux-cored arc welding *without* shielding gas)
- MIG (aluminium materials)
- Autogenous flame cutting
- Plasma cutting
- Arc spraying
- Flame spraying
- Flame straightening
- Additive production: 3D printing, using metal dust

Process 2

- Submerged arc welding
- Gas fusion welding
- TIG
- Soft soldering
- Laser beam cutting (without additional materials)
- MIG/MAG (low-energy protective gas welding)
- Brazing
- MIG soldering
- Laser beam cutting (with additional materials)
- MIG (solid wire, nickel, nickel-based alloys)
- MAG (solid wire)
- MMA
- MAG (flux-cored arc welding with shielding gas)
- Laser beam cutting
- MAG (flux-cored arc welding *without* shielding gas)
- MIG (aluminium materials)
- Autogenous flame cutting
- Plasma cutting
- Arc spraying
- Flame spraying
- Flame straightening
- Additive production: 3D printing, using metal dust

Process 3

- Submerged arc welding
- Gas fusion welding
- TIG
- Soft soldering
- Laser beam cutting (without additional materials)
- MIG/MAG (low-energy protective gas welding)
- Brazing
- MIG soldering
-

- Laser beam cutting (with additional materials)
- MIG (solid wire, nickel, nickel-based alloys)
- MAG (solid wire)
- MMA
- MAG (flux-cored arc welding with shielding gas)
- Laser beam cutting
- MAG (flux-cored arc welding *without* shielding gas)
- MIG (aluminium materials)
- Autogenous flame cutting
- Plasma cutting
- Arc spraying
- Flame spraying
- Flame straightening
- Additive production: 3D printing, using metal dust

Process 4

- Submerged arc welding
- Gas fusion welding
- TIG
- Soft soldering
- Laser beam cutting (without additional materials)
- MIG/MAG (low-energy protective gas welding)
- Brazing
- MIG soldering
- Laser beam cutting (with additional materials)
- MIG (solid wire, nickel, nickel-based alloys)
- MAG (solid wire)
- MMA
- MAG (flux-cored arc welding with shielding gas)
- Laser beam cutting
- MAG (flux-cored arc welding *without* shielding gas)
- MIG (aluminium materials)
- Autogenous flame cutting
- Plasma cutting
- Arc spraying
- Flame spraying
- Flame straightening
- Additive production: 3D printing, using metal dust

B2) Is this/are these welding process(es) physically separated from the rest of the workplace so that other workers are not exposed to welding fume?

	Yes	No
Process 1	○	○
Process 2	○	○
Process 3	○	○

Process 4	○	○

B3) Please provide the number of welders exposed at all exposure levels during a typical working day

	Number of workers exposed
Process 1	
Process 2	
Process 3	
Process 4	

B4) Please provide the number of other workers potentially exposed at all exposure levels during a typical working day

	Number of workers exposed
Process 1	
Process 2	
Process 3	
Process 4	

B5) Have you checked the distribution of welding fumes in terms of exposure to non welders?

	Yes	No
Process 1	○	○
Process 2	○	○
Process 3	○	○
Process 4	○	○

B6) If yes, then did this lead to additional RMMs being introduced to protect non welders?

	Yes	No
Process 1	○	○
Process 2	○	○
Process 3	○	○
Process 4	○	○

B7) Please provide data for airborne concentrations of welding fume without PPE from your most recent measurements of air exposure concentration (8-hour Time Weighted Averages) in mg/m³

	Process 1	Process 2	Process 3	Process 4
Lowest exposure level (value)				
Highest exposure level (value)				
Arithmetic mean exposure level (value)				
95th percentile level (value)				
Number of samples (n)				
Year of monitoring				
B8) Please confirm the unit for the data you have just entered	◯ µg welding fume/m³ ◯ mg welding fume/m³ ◯ µg welding fume/L ◯ mg welding fume/L ◯ ppm	◯ µg welding fume/m³ ◯ mg welding fume/m³ ◯ µg welding fume/L ◯ mg welding fume/L ◯ ppm	◯ µg welding fume/m³ ◯ mg welding fume/m³ ◯ µg welding fume/L ◯ mg welding fume/L ◯ ppm	◯ µg welding fume/m³ ◯ mg welding fume/m³ ◯ µg welding fume/L ◯ mg welding fume/L ◯ ppm
B9) Please select the sampling method followed	◯ Stationary sampling ◯ Personal sampling ◯ Personal sampling of inhalation air inside the RPE	◯ Stationary sampling ◯ Personal sampling ◯ Personal sampling of inhalation air inside the RPE	◯ Stationary sampling ◯ Personal sampling ◯ Personal sampling of inhalation air inside the RPE	◯ Stationary sampling ◯ Personal sampling ◯ Personal sampling of inhalation air inside the RPE
	◯	◯	◯	◯

B10) Are the workers wearing respiratory protective equipment (RPE) during the activity?	Yes No	Yes No	Yes No	Yes No
B11) Please indicate the standard/analytical method followed				
B12) If you have airborne concentration data other than 8-hour Time Weighted Averages for welding fume, please specify type of data and air exposure concentrations	[type of data, value]	[type of data, value]	[type of data, value]	[type of data, value]
B13) Please confirm the unit for the data in B12	µg/m3 welding fume mg/m3 welding fume µg/L welding fume mg/L welding fume ppm	µg/m3 welding fume mg/m3 welding fume µg/L welding fume mg/L welding fume ppm	µg/m3 welding fume mg/m3 welding fume µg/L welding fume mg/L welding fume ppm	µg/m3 welding fume mg/m3 welding fume µg/L welding fume mg/L welding fume ppm
B14) Please select the sampling method followed in B12	Stationary sampling Personal sampling Personal sampling of inhalation air inside the RPE	Stationary sampling Personal sampling Personal sampling of inhalation air inside the RPE	Stationary sampling Personal sampling Personal sampling of inhalation air inside the RPE	Stationary sampling Personal sampling Personal sampling of inhalation air inside the RPE

B15) If you have indicated below limit of quantification (LoQ) and/or limit of detection (LoD) in the responses above, what was the LOQ or LOD?

	Value	Unit
Limit of quantification		
Limit of detection		

B16) Could actions related to covid-19 have artificially altered exposure levels? For example, greater use of PPE.

- ○ Yes, reduced exposure
- ○ Yes, increased exposure
- ○ No change
- ○ Don't know

Please provide a short explanation for your answer to B16

B17) Does your company apply the formula for calculating an additive welding fume limit value as proposed by ISO 15011-4?* (see below formula)

* The formula for calculating an additive welding fume limit value as proposed by ISO 15011-4:

$$LV_{WF(A)} = \frac{100}{\sum_{1}^{n} \frac{i}{LV_i} + \frac{(100-\sum_{1}^{n} i)}{LV_{WF}}}$$

where

- $LV_{WF(A)}$ is the additive welding fume limit value in mg/m^3;
- LV_i is the limit value for the ith principal component of the welding fume;
- n the number of principal components of the welding fume;
- i is the proportion of the ith principal component of the welding fume, in % (mass fraction), as reported on the fume data sheet;
- LV_{WF} is the limit value, in mg/m^3, for welding fume containing only chemical agents of low to moderate toxicity, if such a limit has been set, or the limit value, in mg/m^3, for respirable fraction if no limit value for welding fume has been set.

The calculated additive welding fume limit value for the welding consumable in use shall be then compared with results from gravimetric measurements of personal exposure. The method requires to round additive welding fume limit value to the nearest 0.1 mg/m^3.

B18) Does your company use another method to calculate combined exposure? If so, please provide details

If you are happy to provide more detailed information about numbers of workers exposed, exposure levels and/or further activities, please email this to OELs6@rpaltd.co.uk

Risk Management Measures in place

B19) Which Risk Management Measures (RMMs) are in place to control exposure of the welding fume and hazardous gases in emissions from the different activities at this facility? Please tick all that you use

Substitution or discontinuation

	Process 1	Process 2	Process 3	Process 4
Partial substitution of welding or associated processes: TIG has lower emissions than MMA, MAG solid wire has lower emissions than MAG flux cored wire, automated welding with integrated extraction instead of conventional welding	☐	☐	☐	☐
Substitution of welding or associated processes with other joining processes such as gluing, folding or mechanical joining (screws, rivets)	☐	☐	☐	☐
Partial substitution of content base material and addition material such as low manganese materials	☐	☐	☐	☐
Substitution of content base material and addition material such as low manganese materials	☐	☐	☐	☐
Discontinuation of activity using welding or associated processes	☐	☐	☐	☐

Restructuring operations/processes

	Process 1	Process 2	Process 3	Process 4
Separate welding and associated processes with emissions from other activities in space or time	☐	☐	☐	☐
Temporary relocation of workers with health effects of welding fume	☐	☐	☐	☐
Permanent relocation of workers with health effects of welding fume	☐	☐	☐	☐
Reduced time spent on welding activity	☐	☐	☐	☐
Reduced number of workers exposed	☐	☐	☐	☐

Rotation of the workers exposed	☐	☐	☐	☐
Redesign of work processes	☐	☐	☐	☐

Ventilation and extraction

	Process 1	Process 2	Process 3	Process 4
Closed systems	☐	☐	☐	☐
Partially closed systems	☐	☐	☐	☐
Open hoods over equipment, tracking extraction elements or local extraction ventilation	☐	☐	☐	☐
Separate low volume or high volume spot extraction with mobile individual station separators	☐	☐	☐	☐
Welding torch-integrated extraction system	☐	☐	☐	☐
General ventilation	☐	☐	☐	☐
Regular maintenance of extraction equipment	☐	☐	☐	☐
Pressurised or sealed control cabs	☐	☐	☐	☐
Simple enclosed control cabs	☐	☐	☐	☐
Welding booth with a welding table and adjustable extraction element	☐	☐	☐	☐

PPE (Personal Protective Equipment)

	Process 1	Process 2	Process 3	Process 4
Gloves, goggles, coverall (for additive manufacturing with metal powders)	☐	☐	☐	☐
Welding helmets with a separate air supply	☐	☐	☐	☐
Powered air-purifying respirators	☐	☐	☐	☐
Fan-assisted welding helmets	☐	☐	☐	☐
Forced ventilation welding helmets	☐	☐	☐	☐
Half and full facemasks (negative pressure respirators)	☐	☐	☐	☐
Disposable respirators (FFP masks)	☐	☐	☐	☐
Face screens, face shields, visors	☐	☐	☐	☐

Organisational and hygiene measures

	Process 1	Process 2	Process 3	Process 4
Training and education of workers	☐	☐	☐	☐
Formal/external mask cleaning and filter changing regime	☐	☐	☐	☐
Regular check of effectiveness of protective measures	☐	☐	☐	☐
Blood monitoring	☐	☐	☐	☐
Continuous measurement of air concentrations to detect unusual exposures	☐	☐	☐	☐
Health surveillance in place for these process workers	☐	☐	☐	☐
Creating a culture of safety	☐	☐	☐	☐

Other measures

	Process 1	Process 2	Process 3	Process 4
Other (please specify)				

	Process 1	Process 2	Process 3	Process 4
B20) Have you already implemented Risk Management Measures in preparation for the new EU OELs which will be introduced in 2025 (For Cr VI, Ni)	Yes No	Yes No	Yes No	Yes No
B21) For which EU OELs?	Cr VI Ni	Cr VI Ni	Cr VI Ni	Cr VI Ni
B22) Have you already implemented Risk Management Measures for national OELs in your country, if so for which OELs?	Carbon monoxide NOx Ozone Welding fumes Al Ba Co Cr II/III CrVI Cu Fe Mg Mn Ni V	Carbon monoxide NOx Ozone Welding fumes Al Ba Co Cr II/III CrVI Cu Fe Mg Mn Ni V	Carbon monoxide NOx Ozone Welding fumes Al Ba Co Cr II/III CrVI Cu Fe Mg Mn Ni V	Carbon monoxide NOx Ozone Welding fumes Al Ba Co Cr II/III CrVI Cu Fe Mg Mn Ni V

B23) Could there be co-exposure from both welding fumes and any of the following substances or processes at this facility? Please tick all that apply.

	Select
Polycyclic aromatic hydrocarbons (PAH)	☐
Cobalt and inorganic cobalt compounds	☐
Isoprene	☐
1,4-dioxane	☐

B24) Is your company making any investments not directly related to exposure to welding fumes that are likely to lead to a reduction in exposure to welding fumes?

at most 1 answered row(s)

	Select
Investments are being made that will significantly reduce exposure to welding fume	☐
Investments are being made that may reduce exposure to welding fume	☐
No investments are planned that will reduce exposure to welding fume	☐
Don’t know	☐

B25) If any investments are being made in question B24, what are the investments for? Please tick all that apply.

	Select
Compliance with other OELs	☐
Improved risk management measures being implemented alongside other improvements to production facilities	☐
New or improved production facilities that will remove from or reduce exposure to worker	☐
Other, please specify	☐

Please specify the 'other OELs'

Other, please specify

B26) When will the reduction in worker exposure take effect?

at most 1 answered row(s)

	Select
By the end of 2024	☐
By the end of 2029	☐
By the end of 2034	☐

C) What are the lowest exposure levels that you could achieve

	Value	Unit
C1) What do you think is the lowest *technically possible* 8 hour TWA air concentration that can be achieved in this facility?		☐ µg/m³ welding fume ☐ mg/m³ welding fume ☐ µg/L welding fume ☐ mg/L welding fume ☐ ppm welding fume ☐ µg/m³ total dust (particulates) ☐ mg/m³ total dust (particulates) ☐ µg/L total dust (particulates) ☐ mg/L total dust (particulates) ☐ ppm total dust (particulates)
C2) What do you think is the lowest *economically feasible* 8 hour TWA air concentration that can be achieved in this facility?		☐ µg/m³ welding fume ☐ mg/m³ welding fume ☐ µg/L welding fume ☐ mg/L welding fume ☐ ppm welding fume ☐ µg/m³ total dust (particulates) ☐ mg/m³ total dust (particulates) ☐ µg/L total dust (particulates) ☐ mg/L total dust (particulates) ☐ ppm total dust (particulates)

C3) Any comments on above answers?

D) Cost of compliance with inclusion in Annex I of the CMRD

D1) If welding fume and associated activities were introduced to Annex I of the CMRD, what is your estimated range of the total initial investment likely to be incurred at this facility?	◯ None ◯ <10,000 Euro ◯ 10,000 – 100,000 Euro ◯ >100,000 Euro ◯ Don't know
D2) If welding fume and associated activities were introduced to Annex I of the CMRD, what is your estimated range for ongoing costs likely to be incurred each year at this facility?	◯ None ◯ <10,000 Euro ◯ 10,000 – 100,000 Euro ◯ >100,000 Euro ◯ Don't know

E) Is your company working towards voluntary industry targets?

Voluntary Industry Targets

	Response
E1) Is your company trying to meet voluntary industry targets? If yes, please specify the targets (concentration, units)	
E2) What are the main challenges in meeting the voluntary targets?	
E3) Have you made any assessment of the possible costs of meeting the voluntary targets? If yes, please provide information on costs and cost structure.	

F) Indirect benefits

F1) Do you think your company will benefit from any of these indirect benefits if welding fume is put into Annex I of the CMRD? Please tick all that apply.

	Select
Healthier staff	☐
Increased productivity of workers	☐
Improved public image	☐
Easier to recruit staff	☐
Easier to retain staff	☐
Reduced cost of recruitment	☐
Easier monitoring of exposure	☐
Savings because company currently has multiple locations in different Member States with different regulations or OELs	☐
Level playing field with EU competitors	☐
Other indirect benefits, please specify	☐
There will be no indirect benefits	☐

If other, please specify

G) Any other comments

G1) Do you have any other comments relevant to this study that you would like to make?

H) Further communication

H1) Please tick if you are happy for the study team to contact you for further clarification or discussion about your responses?

- ○ Yes
- ○ No

H2) Please tick if you would be willing to host a site visit for the study team at this facility. This can be carried out under a non-disclosure agreement.

- ○ Yes
- ○ No

H3) If you prefer this contact to be via a different email or phone number from those you provided at the start of the questionnaire, please provide the details here.

Thank you for your answers!

11.4 Annex 4 Overview of OELs and BLVs.

This annex includes tables to summarise:

- Current national OELs for welding fumes and dust limit values (Table 11-16);
- Existing Occupational Exposure Limits (OELs) in EU27 Member States and at EU level, for metals (and oxides) common in welding (Table 11-17);
- Metal compounds in urine in the general population (Table 11-18); and
- Metal compounds in blood in the general population (Table 11-19).

Table 11-16 Current national OELs for welding fumes and dust limit values (as in December 2022)

Country	OEL [mg/m³]	Specification of OEL
Austria [1,2,3]	5 (R)	- All welding types
Belgium [1,2,4, 45]	5 (I)	-Welding fumes (not specified) - Information according to reply of Member State authority (MSA) on questionnaire - Binding value according to reply of MSA on questionnaire
Bulgaria [5]	-	*- no value available*
Croatia [6]	-	*- no value available*
Cyprus [7, 46]	5(T)	-Total dust -Information according to reply of MSA on questionnaire -Binding value according to reply of MSA on questionnaire
Czechia [8]	5	- As total concentration, applies to solid particles
Denmark [2,9]	0.5 - 1.7 (T)	-Process-related limit values for several welding+ processes - Binding value according to reply of MSA on questionnaire - derived process-related limit values for several welding processes and used material based on experienced data. Electrode methods - stainless steel 0.5 mg/m³; TIG 1.1 mg/m³, MIG/MAG 1.6 mg/m³, Flame cutting 1.7 mg/m³, and Electrode methods - construction steel 1.7 mg/m³
Estonia [10]	-	*- no value available*
Finland [1,11]	-	*- no value was identified in official sources* 0.1 mg/m³ guideline target for welding fumes was provided by a Finnish occupational hygienist (*pers comm*,
France [1,2,12]	7 (I)[2, 12] 3.5 (R)[2, 12] 5[1,12]	From July 2023 onwards[2, 12]: 4 (I) 0.9 (R) Non-specific generic dust limit but applies to welding fumes, all particles -Binding value according to country-specific source
Germany [2, 13]	10 (I) 1.25 (R)	No limit value for welding fumes themselves. The upper limit is the general dust limit value for granular bio-resistant dusts with a mean density of 2.5 g/cm³ -Binding value according to country-specific source -In Germany, individual substances present in welding fumes and their respective OELs are used as limit values according to TRGS 528
Greece [14]	-	*- no value available*
Hungary [15]	-	*- no value available*

Country	OEL [mg/m³]	Specification of OEL
Ireland [1,2,16]	5 [1,2]	
Italy [17]	-	*- no value available*
Latvia [1,2,18]	4	- Welding spray - Binding value according to reply of MSA on questionnaire
Lithuania [19]	5 (I)	Welding aerosol -Information according to reply of MSA on questionnaire -Binding value according to reply of MSA on questionnaire
Luxembourg [20]	-	*- no value available*
Malta [21]	-	*- no value available*
Netherlands [2,22]	1 (I)	- Generic dust limit value, according to expert (Halmarboadvies, *pers comm*, August 2023) - applies to welding fumes occurring in multiple industries - Binding value according to reply of Member State authority on questionnaire
Poland [23]	-	*- no value available*
Portugal [24]	-	*- no value available*
Romania [25]	-	*- no value available*
Slovakia [26]	5	- Welding aerosol, applies to solid aerosol particles - Binding value according to reply of MSA on questionnaire
Slovenia [27]	-	*- no value available*
Spain [1,28]	5 [1]	
Sweden [29]	-	*- no value available*
European Union	-	*- no value available*
RAC	-	*- no value available*
Non-EU countries		
Australia [1,30]	5	Binding value according to the Final report for OEL/STEL deriving systems from 2018 (Available at: https://bit.ly/3PKDhbS, accessed on 05.07.2023). S tatus was not checked since 2018.
Brazil [31]	-	*- no value available*
Canada, Ontario [32]	many jurisdictions in Canada apply the US ACGIH guidelines for particles: 10 (I) 3 (R)	Particles (insoluble or poorly soluble) not otherwise specified (PNOS)
Canada, Québec[1,33]	5	-Welding fumes -Binding value according to the Final report for OEL/STEL deriving systems from 2018 (Available at: https://bit.ly/3PKDhbS, accessed on 05.07.2023). S tatus was not checked since 2018.
China [1]	4 (I)	-According to (country-specific source) unclear if value is binding or indicative
India [34]	5	- Binding value according to the Final report for OEL/STEL deriving systems from 2018 (Available at: https://bit.ly/3PKDhbS, accessed on 05.07.2023). S tatus was not checked since 2018.

Country	OEL [mg/m³]	Specification of OEL
Japan, MHLW [1,35]		Limit Value of welding fumes is not set, but employers of welders are obliged to measure the concentration of Mn in the air and select the respirator with the enough protection factor for Mn.
Japan, JOSH [36]	-	Carcinogenicity *- no value available*
Norway [1,2,37,47]	5 (T)	-Total dust -Information according to reply of Member State authority on questionnaire -Indicative value according to reply of Member State authority on questionnaire
Russia [38]	-	*- no value available*
South Korea [1]	5	-According to (country-specific source) unclear if value is binding or indicative
Switzerland [39]	-	*- no value available*
Turkey [40]	-	*- no value available*
United Kingdom [41]	-	*- no value available*
USA, ACGIH [42]	ACGIH guidelines: 10 (I) 3 (R)	Particles (insoluble or poorly soluble) not otherwise specified (PNOS)
USA, NIOSH [43,$$]	-	- For NIOSH recommended exposure limits (RELs), *"TWA" indicates a time-weighted average concentration for up to a 10-hour workday during a 40-hour workweek.*"; Online: https://www.cdc.gov/niosh/npg/pgintrod.html, assessed December 2022
USA, OSHA [44]	-	*- no value available*

Notes:
‡ In addition to (or instead of) OELs for welding fumes expressed as total dust, some national regimes refer to single substance OELs relevant for certain welding processes (e.g., chromium(VI), cobalt, nickel), which are not considered in this table.
RAC = Committee for Risk Assessment
MHLW = Ministry of Health, Labour and Welfare
JSOH = Japan Society for Occupational Health
ACGIH = American Conference of Governmental Industrial Hygienists
NIOSH = National Institute for Occupational Safety and Health
OSHA = Occupational Safety and Health Administration
(I) = inhalable fraction/aerosol
(R) = respirable fraction/aerosol
(T) = Total dust
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3: Austria (2021) Grenzwerteverordnung 2021 – GKV. Available at: https://www.ris.bka.gv.at/GeltendeFassung.wxe?Abfrage=Bundesnormen&Gesetzesnummer=20001418, accessed on 02.12.2022
4: Belgium (2021) List of limit values (Titel 1. – Chemische agentia. and Titel 2. – Kankerverwekkende, mutagene en reprotoxische agentia). Available at: https://werk.belgie.be/nl/themas/welzijn-op-het-werk/algemene-beginselen/codex-over-het-welzijn-op-het-werk, accessed on 02.12.2022
5: Bulgaria (2021) List of limit values and list of carcinogenic/mutagenic/reprotoxic substances. A vailable at: https://www.lex.bg/laws/ldoc/2135477597 and https://www.lex.bg/bg/mobile/ldoc/2135473243, accessed on 05.12.2022

Country	OEL [mg/m³]	Specification of OEL

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9: Denmark (2022) List of limit values. Available at: https://www.retsinformation.dk/eli/lta/2022/1054, accessed on 05.12.2022
10: Estonia (2022) List of limit values. Available at: https://www.riigiteataja.ee/aktilisa/1120/3202/2025/VV_30m_lisa.pdf#, accessed on 05.12.2022
11: Finland (2020) List of limit values. Available at: https://julkaisut.valtioneuvosto.fi/handle/10024/162457, accessed on 05.12.2022
12: France (2022) List of limit values. Available at: https://www.inrs.fr/media.html?refINRS=outil65, accessed on 05.12.2022
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17: Italy (2022) List of limit values and amendments. Available at: https://www.ispettorato.gov.it/it-it/strumenti-e-servizi/Documents/TU-81-08-Ed.-Agosto-2022.pdf, accessed on 06.12.2022
18: Latvia (2022) List of limit values. Available at: https://likumi.lv/doc.php?id=157382&from=off, accessed on 06.12.2022
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26: Slovakia (2020) List of limit values. Available at: https://www.epi.sk/zz/2006-355, accessed on 07.12.2022
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Country	OEL [mg/m³]	Specification of OEL
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Table 11-17 Existing Occupational Exposure Limits (OELs) in EU27 Member States and at EU level, for metals (and oxides) common in welding indicated as 8-h Time-Weighted Average (TWA) for welding fumes

Metal	OEL as TWA (8 hrs)		OEL as STEL (15 min)		Remarks
	EU value (range)[1] mg/m3	Countries	EU value (range)[1] mg/m	Countries	
Aluminium	(1-10) I and R	Austria, Belgium, Denmark, Finland, France, Germany, Hungary, Ireland, Latvia, Poland, Romania, Spain	(3-20) I and R	Austria, Denmark, Poland, Romania	OEL values for metal, metal oxide, fumes.
Barium	0.5 (0.5) I	EU wide	(0.5-4) I	Austria, Germany	OEL for Barium soluble compounds EU IOELV
Cobalt	(0.0005-0.5)	Austria, Belgium, Denmark, Finland, Germany[2], Hungary	(0.04-0.4) I	Austria, Denmark, Germany, Hungary, Romania	OELs values for cobalt and its

Metal	OEL as TWA (8 hrs)		OEL as STEL (15 min)		Remarks
	EU value (range)[1]mg/m3	Countries	EU value (range)[1] mg/m	Countries	
	I				compounds and cobalt oxides
Chromium metal and Cr (II) /(III)	2 (0.5-2) I	EU wide	(1 -2) I	Denmark, Germany, Hungary, Netherlands	Chromium Metal, Inorganic Chromium (II)Compounds and Inorganic Chromium (III)Compounds (insoluble)EU IOELV
Hexavalent Chromium (Cr(VI))	0.005 (0.001-0.1) I	EU wide	(0.008 - 0.2) I	Austria, France, Germany, Hungary	Chromium VI compounds EU BOELV
Copper	(0.01-0.2) I and R	Austria, Belgium, Denmark, Finland, France, Germany, Hungary, Ireland, Poland, Spain	(0.02-0.4)	Austria, Denmark, Germany, Hungary, Poland, Romania	OEL for Copper fumes
Iron	(2.5-6) I and R	Austria, Belgium, Denmark, Finland, Hungary, Ireland, Poland, Romania, Spain	(5-10)	Austria, Denmark, Ireland, Poland	OEL for iron (III) oxide fumes or respirable dust
Magnesium	(0.3 –10) I and R	Belgium, Denmark, France, Germany, Hungary, Ireland, Poland, Romania, Spain	(2.4 -24)	Denmark, Germany, Hungary, Romania	Magnesium oxide as Mg or MgO
Manganese	0.2 I (0.1-5) 0.05 R (0.02-0.05) I and R	EU wide	(1.6-20) I (0.1-0.16)	Austria, Denmark, Germany, Hungary	Manganese and inorganic compounds
Nickel compounds	0.1 (I) 0.006-0.1 I and R	EU wide	(0.048-2) I and R	Austria, Denmark. Germany, Hungary, Romania	Until 17 January 2025
	0.05 (I) 0.01(R)	EU wide			From 18 January 2025

Metal	OEL as TWA (8 hrs)		OEL as STEL (15 min)		Remarks
	EU value (range)[1] mg/m3	Countries	EU value (range)[1] mg/m	Countries	
Vanadium	(0.005-0.2) I and R	Austria, Belgium, Denmark, Finland, Germany, Hungary, Ireland, Netherlands, Poland, Romania, Spain	(0.005-0.25)	Austria, Denmark, Germany, Hungary, Netherlands	Vanadium, Vanadium oxide

Source: ECHA, 2022.
Notes:
(1) The range corresponds to the values implemented in the different EU MS.
(2) BOEL is set to 0.025 mg/m^3 for welding and similar processes and 0.01 mg/m^3 for other activities until 2025 I= Inhalable fraction R= Respirable fraction
(3) A binding tolerable level rather than an OEL is in place in Germany.

Table 11-18 Existing occupational BLVs and reference values for the general population (not occupationally exposed) for metal compounds in urine

Metal	Country/ Organisation	Metal in urine	Specifications
Aluminium	Germany	50 µg/g creatinine	BAT Sampling time: for long-term exposures: at the end of the shift after several shifts
	Finland	3 µmol/L (i.e. 80 µg/L)	BAL Sampling time: before the first shift after 2 days without exposure
	Germany	15 µg/g creatinine	BAR (general population) sampling time not relevant
Barium	Germany	10 µg/L	BAR (general population) sampling time not relevant
Cobalt	France	5 µg/g creatinine	VLB Sampling time: end of exposure week
	ACGIH	15 µg/L	VLB Sampling time: end of exposure week
	Germany	Range of values starting from value of 3 µg /l urine for an external concentration of 0.005 mg/m^3 in air	EKA value Sampling time: for long-term exposure: at the end of the shift after several shifts
	Finland	130 nmol/L (i.e 7.7 µg/L) e	BAL: end of exposure week
	Spain	15 µg/L	VLB

Metal	Country/ Organisation	Metal in urine	Specifications
			Sampling time: end of exposure week
Hexavalent Chromium(Cr(VI))	France	2.5 µg/L (1.8 µg/g creatinine)	VLB Sampling time: end of exposure week
	ACGIH	0.7 µg/L	VLB
	Finland	0.2 µmol/L (i.e. 10.4 µg/L) with a target of 0.01 µmol/L (i.e. 0.52 µg/L)	
	Spain	10 µg/L 25 µg/L	VLB Sampling time: beginning and end of exposure week (value refer to the difference between the two points) Sampling time: end of exposure week
	France	0.65 µg/L (0.54 µg/g creatinine)	VBR (general population)
Nickel compounds	Germany	Insoluble compounds Range of values from 15 µg Ni/L urine for an external concentration of 0.1 mg/m^3 in air	EKA value
	Germany	3 µg/L	BAR (general population)
	Finland	Soluble compound 0.2 µmol Ni/L urine (12 µg/L) Insoluble compound 0.1 µmol/L urine (6 µg/L)	BAL Sampling time: end of exposure week

Source: ECHA, 2022

Notes:

BAT: Biological tolerance value (for occupational exposure)

BAL: Biological Action Levels (for occupational exposure)

BAR: Background level of a substance which is present concurrently at a particular time in a reference population of persons of working age who are not occupationally exposed to this substance

VLB: Biological limit value (for occupational exposure)

VBR: valeurs biologiques de référence = biological limit values (general population)

Table 11-19 Overview of existing occupational BLVs and reference values for the general population (not occupationally exposed) for metal compounds in blood

Metal	Country	Metal in blood	Specifications
Cobalt	Spain	1 µg/L	VLB Sampling time: end of exposure week

Source: ECHA, 2022.

11.5 Annex 5 Relevant sectors

The sectors that were taken forward for analysis are summarised in Table 11-20.

Table 11-20 Analysed sectors with risk of exposure to welding fumes

NACE code	Short name for sector	Description of activities with exposure to welding fumes containing CMR substances
C24	Manufacture of basic metals	Welding processes, cutting during manufacture of steel tubes, pipes etc.
C25	Manufacture of fabricated metal products (excl. machinery & equipment)	Welding processes, cutting, coating (spraying)
C26	Manufacture of computer, electronic & optical products	Welding processes, soldering
C28	Manufacture of machinery & equipment	Welding, cutting, coating (spraying)
C29	Manufacture of motor vehicles, trailers & semi-trailers	Welding, cutting, coating (spraying)
C30	Manufacture of other transport equipment	Welding, cutting, coating (spraying)
C31	Manufacture of furniture	Welding, cutting, coating (spraying)
C32	Other manufacturing	Welding, cutting, coating (spraying)
C33	Repair & installation of machinery & equipment	Welding, soldering
E38	Waste collection, treatment & disposal, materials recovery	Cutting up metal products for materials recovery.
F41	Construction of buildings	Welding processes
F42	Civil engineering	Welding processes
F43	Specialised construction activities	Welding processes, soldering electronics or soldering pipework.
G45	Motor trade & repair	Welding processes: resistance spot welding

Source: Study team.

11.6 Annex 6 – consistency and synergies of enlarging the scope of the CMRD with other Union legislation

11.6.1 The CMRD

Since welding fumes+ are Process Generated Substances, the Commission is considering an entry to Annex I for welding fumes+ that contain carcinogenic, mutagenic or reprotoxic substances as explained below.

Employers have a number of obligations related to CMR substances (category 1A or 1B) present in welding fumes within the scope of the CMRD which include:

- The employer shall reduce the use of the CMR substances (in welding fume) at the place of work by replacing them, in so far as is technically possible, with substances, mixtures or process(es) which, under their conditions of use, are not dangerous or are less dangerous to workers' health or safety, as the case may be;

- Where it is not technically possible to replace the CMR substances, the employer shall ensure that the substances are, in so far as is technically possible, contained in a closed system;

- Where a closed system is not technically possible, the employer shall ensure that the level of exposure of workers to the CMR substances is reduced to as low a level as is technically possible; and

- Where it is not technically possible to use or manufacture a threshold reprotoxic substance in a closed system, the employer shall ensure that the risk related to the exposure of workers to that threshold reprotoxic substance is reduced to a minimum.

More detailed European guidance on how to apply the Hierarchy of Controls to welding fumes is included in Table 3-47 in section 3.8.1.

The minimum requirements for protecting workers that are exposed to carcinogens and mutagens are — for some substances — expressed by Occupational Exposure Limit (OELs). For each OEL, Member States (MS) are required to establish a corresponding national limit value (OEL), from which they can only deviate to a lower but not to a higher value. An OEL expresses the concentration for substances within the scope of the CMRD of the relevant substance in the air within the breathing zone of a worker in relation to a specified reference period as set out in Annex III to the CMRD. However, there are no legal proposals to set limit values for welding fumes.

Of importance for the current assessment, in the case of any activity likely to involve a risk of exposure to CMR substances in welding fume that are within the scope of the Directive, the nature, degree and duration of workers' exposure shall be determined in order to make it possible to assess any risk to the workers' health or safety and to lay down the measures to be taken. The assessment shall be renewed regularly and, in any event, when any change occurs in the conditions which may affect workers' exposure to the substances.

In order to determine the degree of exposure, it would typically be necessary to measure the workplace concentrations of CMR substances in welding fume. Measurements of workplace concentrations are not specifically linked to the assessment of compliance with an OEL. The assessment shall be renewed regularly, but the CMRD does not require regular monitoring if changes in the conditions which may affect workers' exposure to the substances do not occur.

11.6.2 REACH

The substances in welding fumes+ are process generated, produced during the welding process. There is no requirement for process generated substances to be registered under REACH. According to ECHA (2022) the base metals can be considered to be part of an article whilst the filler materials could be either articles or mixtures (alloys are special mixtures), and although covered by REACH are not subject to REACH registration. Some substances present in welding fumes+ may be registered for other uses, but the tonnage information has not been included in this report because it is not useful to this study. For instance, while it is possible to estimate the total registration tonnage of a substance like nickel, it is not possible to determine how much of this nickel is used for solders since information on specific uses is not provided in registration data.

11.6.3 Other relevant legislation

'Welding fumes+' as a group of Process Generated Substances, with highly complex and variable composition, do not have a harmonised classification and labelling for CMR effects under the CLP Regulation (ECHA, 2022). However, some of the constituents of welding fumes+ have a harmonised classification in Annex VI to the CLP Regulation (No 1272/2008) as carcinogenic, mutagenic or reprotoxic 1A or 1B and are therefore in the scope of the CMRD, as defined by Article 2 paragraph a(i).

Some of the metals used in welding+ processes (such as chromium or nickel in steel) may be classified as carcinogenic under the CLP Regulation, and their exposure needs to be controlled under the CMRD. Other metals (such as aluminium and copper) do not have such hazard classifications under the CLP, but exposure needs to be controlled under the Chemical Agents Directive (CAD) (98/24/EC). Employers have requirements, under the hierarchy of controls, to minimise worker exposure (as set out in section 1.1.1).

Safety and Occupational Health (OSH) is also covered under the UN Sustainable Development Goal number 8 with the objective "*Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all*" (UN, 2023a). Under this goal, Target 8.8 calls for the protection of labour rights and the promotion of "*safe and secure working environments for all workers, including migrant workers, in particular women migrants, and those in precarious employment*".

11.6.4 Summary of legal context

Different constituents of welding fumes are classified under the Chemical Agents Directive (CAD) (98/24/EC), Classification, Labelling and Packaging Regulation (CLP) (1272/2008) and CMRD (2004/37/EC), as summarised in Table 1-1. These three pieces of Secondary European legislation have been chosen as being most relevant to controlling worker's occupational exposure to the constituents of welding fumes as they are process generated substances rather than intentionally used substances. The CLP is critical in the classification of substances properties that lead to a hazardous classification and ensuring adequate risk management throughout the EU, CAD and CMRD are recognised as being the most pertinent pieces of legislation affecting exposure to chemical agents. REACH was not included here as welding fumes are process-generated substances rather than manufactured or imported substances. REACH includes regulatory obligations that the users of the substances used in welding processes would be required to implement including use of restricted substances (REACH Annex XVII) and those on the authorisation list (REACH Annex XIV).

11.7 Annex 7 RMMs used by sector as reported in the consultation.

In the below tables of RMMs used by sector (A1.1-A1.12), in order to save space, sector names and welding processes have been shortened as summarised in Table 3-13 and Table 3-7 respectively. Some sectors appear in the survey that are not expected to involve welding, see section 3.3.6.

Table 11-21 RMMs used by the Manufacture of paper and paperboard (C17.12) and Manufacture of basic pharmaceutical products and pharmaceutical preparations (C21) sectors.

RMM	C17.12 Paper (1)		C21 Pharmaceuticals (1)			
	MAG (solid wire)	MIG solder	MAG (flux)	MIG solder	MMA	TIG
Organisational and hygiene measures						

RMM	C17.12 Paper (1)		C21 Pharmaceuticals (1)			
	MAG (solid wire)	MIG solder	MAG (flux)	MIG solder	MMA	TIG
Blood monitoring			1	1	1	1
Culture of safety	1	1				
Health surveillance	1	1	1	1	1	1
Regular check of RMM effectiveness	1	1	1	1	1	1
Training and education	1	1				
PPE (Personal Protective Equipment						
Face screens, face shields, visors	1	1	1	1	1	1
Gloves, goggles, coverall	1	1	1	1	1	1
Restructuring operations/processes						
Reduced number of workers exposed	1	1				
Separate welding from other activities	1	1				
Ventilation and extraction						
General ventilation			1	1		1
Open hoods	1	1	1	1	1	1

Source: Stakeholder consultation 2023, 58 responses received.

Table A1.2 RMMs for the Manufacture of glass and glass products (C23.1) and the Manufacture of tubes, pipes, hollow profiles and related fittings of steel (C24.2) sectors.

RMM	C23.1 Glass (1)		C24.2 Tubes & pipes (1)
	F Spray	MAG (flux)	MIG (solid wire, Ni)
Organisational and hygiene measures			
Blood monitoring	1		
Culture of safety	1	1	1
Health surveillance	1		1
Regular check of RMM effectiveness	1		1
Training and education	1	1	1
PPE (Personal Protective Equipment)			
Disposable respirators (FFP masks)	1		
Face screens, face shields, visors	1	1	
Fan-assisted welding helmets			1
Forced ventilation welding helmets			1
Gloves, goggles, coverall	1	1	1

RMM	C23.1 Glass (1)		C24.2 Tubes & pipes (1)
	F Spray	MAG (flux)	MIG (solid wire, Ni)
Restructuring operations/processes			
Permanent relocation of workers with health effects of welding fumes			1
Redesign of work processes	1		1
Reduced number of workers exposed	1	1	1
Reduced time spent on welding activity	1	1	1
Rotation of the workers exposed			1
Separate welding and associated processes	1	1	
Temporary relocation of workers with health effects of welding fumes	1	1	1
Substitution with lower emission welding process	1	1	
Ventilation and extraction			
Closed systems			
General ventilation	1	1	1
Open hoods	1		1
Partially closed systems			1
Regular maintenance of extraction equipment	1		1
Separate low volume or high volume spot extraction	1		1
Welding booth with a welding table & adjustable extraction element		1	1

Source: Stakeholder consultation 2023, 58 responses received.

Table A1.3 RMMs for Aluminium production (C24.42) and Casting of iron (C24.51) sectors.

RMM	C24.42 Aluminium (2)			C24.51 Iron (2)			
	MIG (Al)	MIG/MAG	TIG	MIG/MAG	MMA	PC	TIG
Organisational and hygiene measures							
Blood monitoring				2	1	1	2
Culture of safety	1	1	2				
Health surveillance				2	1	1	2
Training and education	1	1	2	2	1	1	2

RMM	C24.42 Aluminium (2)			C24.51 Iron (2)			
	MIG (Al)	MIG/MAG	TIG	MIG/MAG	MMA	PC	TIG
PPE (Personal Protection Equipment)							
Disposable respirators (FFP masks)			1	2	1	1	2
Face screens, face shields, visors	1	1	2	2	1	1	2
Gloves, goggles, coverall	1	1	2	2	1	1	2
Restructuring operations/processes							
Reduced number of workers exposed		1					
Reduced time spent on welding activity	1		2	2	1	1	2
Rotation of the workers exposed	1		1				
Separate welding and associated processes	1	1		2	1	1	2
Ventilation and extraction							
General ventilation		1		2	1	1	2
Open hoods		1		2	1	1	2
Regular maintenance	1	1	1	2	1	1	2
Welding torch-integrated extraction system	1						

Source: Stakeholder consultation 2023, 58 responses received.

Table A1.4 RMMs used by the Manufacture of fabricated metal products sector (C25).

RMM	C25 Metal products (8)		
	3D printing	Auto flame cutting	Brazing
Organisational and hygiene measures			
Blood monitoring			1
Culture of safety			1
mask cleaning & filter changing			1
Training and education		1	2
PPE (Personal Protection Equipment)			
Disposable respirators (FFP masks)		1	3
Face screens, face shields, visors			2
Gloves, goggles, coverall		1	1

RMM	C25 Metal products (8)		
	3D printing	Auto flame cutting	Brazing
Half and full facemasks (negative pressure respirators)			1
Welding helmets with a separate air supply		2	2
Restructuring operations/processes			
Reduced number of workers exposed		1	
Reduced time spent on welding activity			1
Temporary relocation of workers with health effects of welding fumes			1
Partial substitution of content base material and addition material		1	
Substitution of welding+ processes with other joining processes (gluing, folding, screws, rivets etc)			1
Substitution with lower emission welding+ process	1		
Ventilation and extraction			
Closed systems	1	1	
General ventilation		2	1
Open hoods	1		1
Partially closed systems			1
Pressurised or sealed control cabs			
Regular maintenance of extraction equipment	1	1	1
Simple enclosed control cabs	1		
Welding booth with a welding table & adjustable extraction element	1		1

Source: Stakeholder consultation 2023, 58 responses received.

Table A1.5 RMMs used by the Manufacture of fabricated metal products sector (C25) continued.

RMM	C25 Metal products (8)						
	F spray	MAG (flux, shielding gas)	MAG (flux)	MAG (solid wire)	MIG (aluminium materials)	MIG (solid wire, Ni)	MIG solder
Organisational and hygiene measures							
Blood monitoring		1			1		
Culture of safety	1	2	1	4	1	1	1

RMM	C25 Metal products (8)						
	F spray	MAG (flux, shielding gas)	MAG (flux)	MAG (solid wire)	MIG (aluminium materials)	MIG (solid wire, Ni)	MIG solder
Mask cleaning & filter changing		1		3			
Health surveillance	1	2	1	3	1	2	
Regular check of RMM effectiveness	1	1	1	3		1	
Training and education	1	3	1	10	2	3	
PPE (Personal Protective Equipment)							
Disposable respirators (FFP masks)		1		4	7		
Face screens, face shields, visors	1	3	1	4		2	1
Fan-assisted welding helmets		1		2		1	
Forced ventilation welding helmets		1					
Gloves, goggles, coverall	1	1	1	7	1	2	1
Half and full facemasks (negative pressure respirators)				1			
Powered air-purifying respirators		1		1		1	
Welding helmets with a separate air supply		2		4		1	
Restructuring operations/processes							
Reduced time spent on welding activity				1			
Separate welding+ associated processes		1		2			1
Partial substitution of content base material and addition material		1					
Substitution with lower emission welding+ process				1	1		
Ventilation & extraction							
Closed systems		1		1	1		
General ventilation		2		8	2	2	1
Open hoods	1	2	1	7	2	1	
Partially closed systems	1	2	1	1		1	
Pressurised or sealed control cabs		1					
Regular maintenance of extraction equipment	1	3	1	4	2	3	

RMM	C25 Metal products (8)						
	F spray	MAG (flux, shielding gas)	MAG (flux)	MAG (solid wire)	MIG (aluminium materials)	MIG (solid wire, Ni)	MIG solder
Separate low volume or high volume spot extraction		2		2		1	
Simple enclosed control cabs		1			1		
Welding booth with a welding table and & adjustable extraction element	1		1	1	1	2	
Welding torch-integrated extraction system		1			1		

Source: Stakeholder consultation 2023, 58 responses received.

Table A1.6 RMMs used by the Manufacture of fabricated metal products sector (C25) continued.

RMM	C25 Manufacture of fabricated metal products (8)						
	MIG/MAG	MMA	Not specified	PC	Soft solder	SAW	TIG
Organisational and hygiene measures							
Blood monitoring	2			2		2	
Continuous measurement of air concentrations to detect unusual exposures							1
Culture of safety	2	2		5	1	4	4
Mask cleaning & filter changing	1	1		2		1	2
Health surveillance	2	2		2		1	3
Regular check of RMM effectiveness	1	2		2		2	1
Training and education	5	2		6		7	5
PPE (Personal Protective Equipment)							
Disposable respirators (FFP masks)	4	1		2		3	2
Face screens, face shields, visors	4	2	4	4	1	5	4
Fan-assisted welding helmets	1						1
Forced ventilation welding helmets							1
Gloves, goggles, coverall	2	1		4	1	6	3
Half and full facemasks (negative pressure respirators)	2			1		1	1
Powered air-purifying respirators	1					1	1
Welding helmets with a separate air supply	3	1		3		1	1

RMM	C25 Manufacture of fabricated metal products (8)						
	MIG/MAG	MMA	Not specified	PC	Soft solder	SAW	TIG
Restructuring operations/processes							
Permanent relocation of workers with health effects of welding fumes	1						
Reduced number of workers exposed				1		1	1
Reduced time spent on welding activity	1						1
Separate welding+ processes	1			1		2	2
Temporary relocation of workers with health effects of welding fumes				1		1	2
Substitution of content base material and addition material	1						
Substitution with lower emission welding+ process						1	
Ventilation & extraction							
Closed systems						7	1
General ventilation	4			6	1	7	5
Open hoods	3	2		3		7	2
Partially closed systems		1					
Regular maintenance of extraction equipment	3	2		4		2	3
Separate low volume or high volume spot extraction	1	1	4	1			2
Simple enclosed control cabs				1		1	
Welding booth with a welding table & adjustable extraction element	2	1					2
Welding torch-integrated extraction system	1						

Source: Stakeholder consultation 2023, 58 responses received.

Table A1.7 RMMs used by the Manufacture of other general-purpose machinery (C25.2) and Manufacture of other fabricated metal products (C25.99) sectors.

RMM	C25.2 Other machinery		C25.99 Other metal products (1)		
	MAG (solid wire)	SAW	LB cutting	MAG (solid wire)	TIG
Organisational and hygiene measures					
Continuous measurement of air concentrations to detect unusual exposures			1	1	1
Culture of safety	1	1	1	1	1

RMM	C25.2 Other machinery		C25.99 Other metal products (1)		
	MAG (solid wire)	SAW	LB cutting	MAG (solid wire)	TIG
Mask cleaning & filter changing	1	1			
Health surveillance			1	1	1
Regular check of RMM effectiveness			1	1	1
Training and education	1	1	1	1	1
PPE (Personal Protection Equipment)					
Face screens, face shields, visors				1	1
Forced ventilation welding helmets	1	1			
Gloves, goggles, coverall				1	1
Welding helmets with a separate air supply	1	1			
Restructuring operations/processes					
Redesign of work processes	1	1			
Separate welding and associated processes			1	1	1
Substitution or discontinuation					
Substitution of welding or associated processes with other joining processes (gluing, folding, screws, rivets)			1		
Substitution with a lower emission welding+ process			1		
Ventilation & extraction					
Closed systems			1		
General ventilation	1	1	1	1	1
Open hoods	1		1	1	1
Regular maintenance	1	1	1	1	1
Simple enclosed control cabs			1		
Welding booth with a welding table and adjustable extraction element			1		

Source: Stakeholder consultation 2023, 58 responses received.

Table A1.8 RMMs used by the Manufacture of machinery and equipment (C28) sector.

RMM	C28 Machinery & equipment (5)					
	Brazing	LB cutting (additional materials)	MAG (flux, shielding gas)	MAG (solid wire)	MIG (solid wire, Ni)	MIG/MAG
Organisational and hygiene measures						
Blood monitoring	1		1			1
Continuous measurement of air concentrations to detect unusual exposures	1	1			1	3
Culture of safety	2				1	3
Mask cleaning and filter changing	1	1			1	3
Health surveillance	2		1	1	1	3
Regular check of RMM effectiveness	2	1		1	1	4
Training and education of workers	2	1	1	1	1	4
PPE (Personal Protective Equipment)						
Disposable respirators (FFP masks)		1		1		1
Face screens, face shields, visors	2	1		1		3
Fan-assisted welding helmets					1	1
Gloves, goggles, coverall	2			1	1	3
Powered air-purifying respirators	1				1	2
Welding helmets with a separate air supply		1	1			1
Restructuring operations/processes						
Redesign of work processes				1		1
Rotation of the workers exposed				1		
Separate welding and associated processes	1				1	3
Substitution or discontinuation						
Partial substitution of content base material and addition material					1	
Substitution of welding or associated processes with other joining processes (gluing, folding, screws, rivets)				1		1
Substitution with a lower emission welding+ process						2
Ventilation & extraction						

RMM	C28 Machinery & equipment (5)					
	Brazing	LB cutting (additional materials)	MAG (flux, shielding gas)	MAG (solid wire)	MIG (solid wire, Ni)	MIG/MAG
Closed systems						1
General ventilation	2			1	1	3
Open hoods	1	1		1	1	4
Partially closed systems		1				2
Pressurised or sealed control cabs						
Regular maintenance	2			1	1	3
Separate low volume or high volume spot extraction			1			1
Welding booth with a welding table and adjustable extraction element	2			1	1	3
Welding torch-integrated extraction system			1	1		1

Source: Stakeholder consultation 2023, 58 responses received.

Table A1.9 RMMs used by the Manufacture of machinery and equipment (C28) continued, and by the Manufacture of motor vehicles, trailers and semi-trailers (C29) sectors.

RMM	C28 Machinery & equipment (5)			C29 Motor vehicles (2)		
	PC	SAW	TIG	Brazing	Gas fusion welding	LB cutting
Organisational & hygiene measures						
Blood monitoring	1		1	1		
Continuous measurement of air concentrations to detect unusual exposures	1	1	2		1	1
Culture of safety	1		3	2	1	1
Mask cleaning and filter changing	1	1	2	2		
Health surveillance	1		3	2	1	1
Regular check of RMM effectiveness	2	1	4	2	2	1
Training and education	2	1	5	2	2	1
PPE (Personal Protective Equipment)						
Disposable respirators (FFP masks)	1	1	1	2		
Face screens, face shields, visors	2	1	4	2	1	

RMM	C28 Machinery & equipment (5)			C29 Motor vehicles (2)		
	PC	SAW	TIG	Braz-ing	Gas fu-sion welding	LB cut-ting
Fan-assisted welding helmets			1	1		
Forced ventilation welding helmets					1	1
Gloves, goggles, coverall	1		4	2	2	1
Half and full facemasks (negative pressure respira-tors)				2		
Powered air-purifying respirators	1		2			
Welding helmets with a separate air supply	1	1		1	1	1
Restructuring operations/processes						
Redesign of work processes			1			
Reduced number of workers exposed					1	1
Rotation of the workers exposed			1			
Separate welding and associated processes with emissions from other activities in space or time	1		4	1	1	
Substitution or discontinuation						
Substitution of welding or associated processes with other joining processes (gluing, folding, screws, riv-ets)			2	1		
Substitution with lower emission welding+ process			2	1	1	
Ventilation and extraction						
Closed systems				1		
General ventilation	1		5	1	1	1
Open hoods	2	1	3	1	2	1
Partially closed systems	1	1	1	1		
Regular maintenance	1		3	2		
Separate low volume or high volume spot extraction			1	1		
Simple enclosed control cabs						
Welding booth with a welding table and adjustable extraction element	1		4	1		
Welding torch-integrated extraction system			1	1		

Source: Stakeholder consultation 2023, 58 responses received.

Table A1.10 RMMs used by the by the Manufacture of motor vehicles, trailers and semi-trailers (C29) sector (continued).

RMM	C29 Motor vehicles (2)						
	LB cutting	MIG (Al)	MIG (solid wire, Ni)	MIG solder	MIG/MAG	PC	SAW
Organisational and hygiene measures							
Blood monitoring		1	1		1		
Continuous measurement of air concentrations to detect unusual exposures					1	1	
Culture of safety	1	3	1	1	4	1	1
Mask cleaning and filter changing		2	1	1	2		
Organisation and hygiene measures							
Health surveillance in place for these process workers		3	1	1	4	1	1
Regular check of RMM effectiveness	1	3	1	1	4	1	2
Training and education	1	3	1	1	4	1	2
PPE (Personal Protective Equipment)							
Disposable respirators (FFP masks)		1	1		1	1	
Face screens, face shields, visors		2	1	1	2		1
Fan-assisted welding helmets		3	1	1	2		1
Forced ventilation welding helmets					1		
Gloves, goggles, coverall		3	1	1	4		2
Half and full facemasks (negative pressure respirators)		2	1	1	3		1
Powered air-purifying respirators		1			1		1
Welding helmets with a separate air supply		3	1	1	3		1
Restructuring operations/processes							
Redesign of work processes		2		1	1		
Reduced number of workers exposed			1		1	1	
Reduced time spent on welding activity			1				
Rotation of the workers exposed		1					
Separate welding and associated processes		2		1	1		2

RMM	C29 Motor vehicles (2)						
	LB cutting	MIG (Al)	MIG (solid wire, Ni)	MIG solder	MIG/MAG	PC	SAW
Substitution or discontinuation							
Substitution of welding or associated processes with other joining processes (gluing, folding, screws, rivets)		2	1	1	1		
Substitution with a lower emission welding+ process		2	1	1	2		
Ventilation and extraction							
Closed systems	1	2			1		
General ventilation		3	1	1	3	1	1
Open hoods		2	1	1	3	1	2
Partially closed systems		1					1
Regular maintenance	1	2		1	2		1
Separate low volume or high volume spot extraction		1			1		
Simple enclosed control cabs					1		
Welding booth with a welding table and adjustable extraction element		2	1	1	2		1
Welding torch-integrated extraction system		1	1		1		

Source: Stakeholder consultation 2023, 58 responses received.

Table A1.11 RMMs used by the by the Repair and installation of machinery and equipment (C33) sector.

RMM	C33 Equipment repair & installation (3)						
	Gas fusion welding	MAG (flux)	MAG (solid wire)	Not specified	PC	SAW	TIG
Organisational and hygiene measures							
Blood monitoring	1			1			1
Continuous measurement of air concentrations to detect unusual exposures				1			
Creating a culture of safety	1			2			1
Mask cleaning and filter changing	1			2			1
Health surveillance	1			2			1
Regular check of RMM effectiveness	1	1	1	1	1	1	1
Training and education	1	1	1	2	1	1	1
PPE (Personal Protection Equipment)							
Disposable respirators (FFP masks)	1			1			1
Face screens, face shields, visors	1			1			
Fan-assisted welding helmets		1	1		1	1	
Forced ventilation welding helmets				1			
Gloves, goggles, coverall	1			2			1
Half and full facemasks (negative pressure respirators)	1			2			1
Powered air-purifying respirators	1			2			
Welding helmets with a separate air supply	1			2			1
Restructuring operations/processes							
Permanent relocation of workers with health effects of welding fumes	1			1			1
Redesign of work processes							
Reduced number of workers exposed			1	1	1	1	
Reduced time spent on welding activity	1			1			1
Rotation of the workers exposed	1			1			1
Separate welding and associated processes with emissions from other activities in space or time	1	1	1	2	1	1	1
Substitution or discontinuation							
Partial substitution of content base material and addition material such as low manganese materials				1			
Substitution of content base material and addition material such as low manganese materials				1			
Substitution with lower emission welding+ process	1			1			1
Ventilation and extraction							
Closed systems				1			
General ventilation	1	1		2			1
Open hoods over equipment, tracking extraction elements or local extraction ventilation	1		1	2		1	1
Partially closed systems	1				1		1
Regular maintenance				2			
Separate low volume or high volume spot extraction				2			
Welding booth with a welding table and adjustable extraction element				1			

Source: Stakeholder consultation 2023, 58 responses received.

Table A1.12 RMMs used by the Repair of fabricated metal products (C33.11), Repair of motor vehicles and motorcycles (G45.2) and Education (P85) sectors.

RMM	C33.11 Metal products repair (1)	G45.2 Automotive repair (2)		P85 Education (1)			
	TIG	MIG solder	MIG/MAG	Brazing	Gas fusion welding	MIG/MAG	TIG
Organisational and hygiene measures							
Blood monitoring	1						
Culture of safety	1		1	1	1	1	1
Mask cleaning and filter changing	1		1				
Regular check of RMM effectiveness	1		1				
Training and education of workers	1		1				
PPE (Personal Protective Equipment)							
Face screens, face shields, visors	1	1	2				
Forced ventilation welding helmets			1				
Gloves, goggles, coverall	1		1	1	1	1	1
Half and full facemasks (negative pressure respirators)	1						
Welding helmets with a separate air supply	1						
Restructuring operations/processes							
Redesign of work processes			1				
Reduced number of workers exposed			1				
Rotation of the workers exposed			1				
Ventilation and extraction							
General ventilation		1	2	1	1	1	1
Partially closed systems				1	1	1	1
Regular maintenance of extraction equipment				1	1	1	1
Welding booth with a welding table and adjustable extraction element				1	1	1	1
Welding torch-integrated extraction system			1				

Source: Stakeholder consultation 2023, 59 responses received.

11.8 Annex 11 - Welding short interview questionnaire

Questionnaire for welding organisations

A consortium comprising RPA Risk & Policy Analysts (United Kingdom), RPA Europe (Italy), RPA Europe Prague (Czech Republic) COWI (Denmark), FoBiG Forschungs- und Beratungsinstitut Gefahrstoffe (Germany), EPRD (Poland) and Force Technology (Denmark) has been contracted by the European Commission's Directorate-General for Employment, Social Affairs and Inclusion to assess the impacts of establishing Occupational Exposure Limit values (OELs) or introducing a substance into Annex I into the Carcinogens, Mutagens and Reprotoxins Directive (CMRD).

This interview deals specifically with the proposed amendment to include welding+ fume into Annex I of the CMRD.

Many questions ask for rough estimates / guestimates to the best of your ability. We need your expert judgement.

All responses to this questionnaire will be treated in the strictest confidence and will only be used for the purposes of this study. In preparing our report for the Commission (which, subsequently, may be published), care will be taken to ensure that specific responses cannot be linked to individual companies.

The purpose of this interview is to collect data and information that will underpin the assessment.

A supporting letter from the European Commission is available here, together with the privacy statement here.

Welding+ fumes is defined (by ECHA, 2022)	Fumes from the following activities: Fusion welding (gas welding, arc welding (MIG, MAG, SMAW, FCAW, SAW, ESW, SW), arc welding (TIG, PAW), beam welding, Soldering (soft soldering, hard soldering) Brazing (>450°C, Laser beam brazing, Brazing with an electric arc (MIG, TIG, plasma)) Thermal cutting or gouging Thermal spraying Flame straightening Additive production processes

Publication privacy

- **Confidentiality status**

☐ Confidentiality Option A: free to quote any information in the minutes and attribute it to them

☐ Confidentiality Option B: use information in the minutes on an anonymous basis and in a way that cannot be linked to their company

☐ Confidentiality Option C: treat the information in the minutes as confidential and only use it to inform the study's findings and conclusions

Privacy

By checking this box, it is confirmed that the interviewee has read the Privacy Statement (in full) and agrees with the processing of their personal data for the purposes stated therein. They acknowledge that their views could be shared with the European Commission and published with information concerning the type of organisation that they represent, to which they hereby give their consent.

☐

- **Approval status**

☐ Minutes have been agreed during the interview and do not need further approval

☐ Draft minutes to be sent to interviewee for approval

A) About the organisation

A1) Please provide the following details	
• Name of interviewer	
• Name of interviewee(s)	
• Role of the interviewee(s)	
• Organisation	
• Type of organisation	☐ Welding institute or professional association ☐ Trade union for industry with significant number of welders such as metal working ☐ Welding training organisation ☐ Company employing a significant number of welders ☐ Other, please specify
• Number of welders represented as members, workers, students, etc (approx.)	
• Email address(es) of contact person(s)	
• Telephone number of contact person(s)	
• Country	

B) Main Interview Questions

1. Are you concerned about your employees', members', or students' exposure to welding+ fume? If yes, please explain why.

2. Have you run any campaigns to explain the risks of exposure to welding fume to your employees', members, or students? If yes, please give some details.

3. Are you aware of the Carcinogens, Mutagens and Reprotoxins Directive (CMRD)?
☐ Aware and confident that I understand it ☐ Aware ☐ Not aware

4. Are you aware that carcinogens, mutagens and reprotoxins (CMRs) might be present in welding fume?
☐ Aware and confident that I understand the implications of CMRs in welding fume ☐ Aware of CMRs in welding fume ☐ Not aware of CMRs being in welding fume

5. Approximately what is your estimate of the proportion of your employees, members or students that are aware of the Carcinogens, Mutagens and Reprotoxins Directive (CMRD)? – to the nearest 10%

6. Approximately what is your estimate of the proportion of your employees, members or students that are aware that carcinogens, mutagens and reprotoxins (CMRs) might be present in welding fume? – to the nearest 10%

7. Describe the part of the welding industry that you believe that you understand well. This could be on the basis of Member State, region, industry, company, welding process, welding emission rates, base or filler substances or any other variable

8. For this part of the welding industry, describe the situations that cause the highest exposure to carcinogens, mutagens and reprotoxins (CMRs) such as chromium VI, nickel compounds and cobalt

9. For this part of the welding industry, describe the situations that cause the lowest (or no) exposure to carcinogens, mutagens and reprotoxins (CMRs) such as chromium VI, nickel compounds and cobalt

10. How good is your employees', members', or students' (in the future) access to and use of risk management measures to protect them from welding fume containing carcinogens, mutagens and reprotoxins? Please give the percentage for each, summing to 100%.	
Best practice	
Reasonable practice	
Poor practice/none	
Total	100%

11. If welding fume containing carcinogens, mutagens and reprotoxins was brought into Annex I of the CMRD[79], how would the percentages in Q11 change? Please give your estimate of the future percentages for each, summing to 100%.	
Best practice	
Reasonable practice	
Poor practice/none	
Total	100%

12. Do you have any further comments?

[79] If a substance, mixture, or process is listed in Annex I of the CMRD, in Article 2 (a) (ii) of the CMRD the substance, mixture or process is defined as being carcinogenic. The proposal is to bring only welding fume containing CMRs into Annex I: this does not include welding fume that does not contain CMRs.

11.9 Annex 12 - Classification of welding processes

The diagram below displays the classification of welding processes according to the types of energy used (adapted from Health reference values - Work involving exposure to welding fumes to be included in the list of carcinogenic substances, mixtures and processes (ANSES, 2022)).

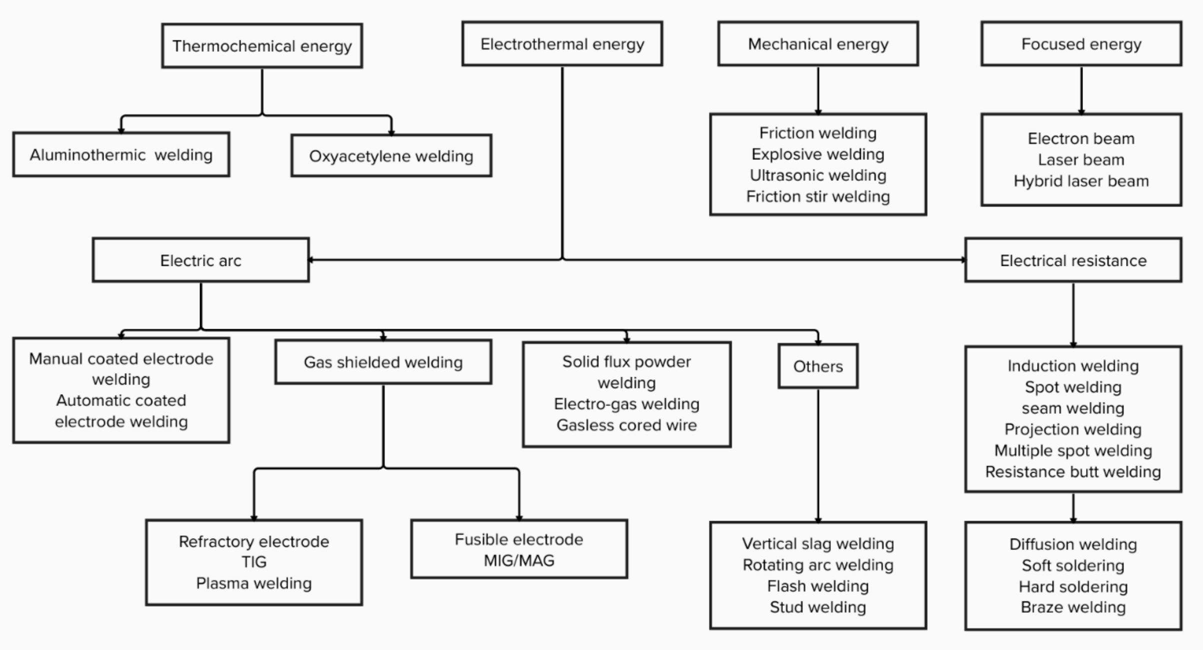

Table 11-22 Classification of welding processes by type of energy

Source: ANSES, 2022

11.10 Annex 13 - Description of welding processes

Table 11-23 Description of welding processes and estimated category of risk for worker exposure with rationale where possible.

Activity	Description	Estimated category of risk for worker exposure Rationale
A) Fusion welding	**Welding processes that rely on melting to join materials via gas, electric arc, laser or plasma**	
A1 Gas welding	Also known as oxyacetylene or oxyfuel welding. Oxygen and acetylene or other combustible gases such as hydrogen, methane or natural gas are burnt When mixed together in correct proportions in a hand-held torch or blowpipe, a flame is produced ~3,200 °C. The chemical action of the flame can be adjusted by changing the ratio of oxygen:acetylene Oxygen and acetylene is the only gas combination to produce a flame with enough heat to weld steel, since steel melts above 1,500 °C. Gases such as propane, hydrogen and coal gas can be used for joining lower melting point non-ferrous metals, for brazing and for silver soldering. Oxyacetylene equipment consists of oxygen and acetylene gases stored under pressure in steel cylinders and is portable and easy to use. The cylinders are fitted with regulators and flexible hoses leading to the blowpipe. The oxyacetylene flame can be adjusted to produce a soft, harsh or violent reaction on the surface of the material to be welded by varying the gas flows. Different sizes of 'swan neck' copper nozzles can be fitted to the blowpipe, for the desired intensity of flame for the activity. For fusion welding, a filler metal rod can be added when required.	Low emission rate (<1 mg/s)
B Arc welding	Uses an electric arc to create heat to melt and join metals. A power supply creates an electric arc between a consumable or non-consumable electrode and the base material using either direct (DC) or alternating (AC) currents. The arc temperature can range from 3,000 °C to above 20,000 °C (for a plasma arc) depending upon: • Voltage • Arc length • atmosphere The metals react chemically with oxygen and nitrogen in the air when heated to high temperatures by the arc, so a protecting shield gas or slag is used to minimse the contact of the molten metal with the air.	

Activity	Description	Estimated category of risk for worker exposure Rationale
	When the molten metals cool they solidify to form a metallurgical bond. There are two categories of arc welding: consumable and non-consumable electrode methods.	
B1 Arc welding: Consumable electrode methods		
B1-a Gas metal arc welding (GMAW)	Comprises: Metal Inert Gas (MIG) and Metal Active Gas (MAG) welding Uses heat created from an electric arc between a consumable metal electrode and a workpiece to create a weld pool to fuse them together to form a joint. The metal electrode is a small diameter wire fed continuously through the contact tip of the welding torch from a wire spool, at the same time a shielding gas is fed through the welding torch. MIG uses inert gases which do not react with the filler material or weld pool such as argon and helium mixes for welding of non-ferrous metals such as aluminium. MAG uses active shielding gases such as carbon dioxide or mixtures of argon, carbon dioxide and oxygen which can react with filler metal transferring across the arc and the weld pool, to alter the chemistry and/or resulting mechanical properties. MAG is the most widely-used welding process according to The Welding Institute.	High emission rates: 2-12 mg/s for MAG (solid wire) 6 to >25 mg/s for MAG (flux-cored arc welding with shielding gas) >25 mg/s mg/s for MAG (flux cored welding without shielding gas) 2-6 mg/s for MIG (solid wire, nickel, nickel-based alloys) 0.8 – 29 for MIG (aluminium materi-als) and MIG or MAG are commonly used processes across sectors. MIG/MAG hybrid welding (low-energy inert gas welding) is also used across sectors, with medium to high emission rates 1-4 mg/s.
B1-b Shielded Metal Arc Welding (SMAW) or Manual Metal Arc Welding (MMA or MMAW)	Flux shielded arc welding or stick welding is a process in which an arc is created between the metal rod (electrode flux coated) and the work piece, so that both the rod and the work piece surface melt to form a weld pool. Concurrent melting of the flux coating on the rod creates gas and slag which protects the weld pool from the surrounding atmosphere. Versatile process which can join ferrous and non-ferrous materials with a range of material thicknesses in all positions.	High emission rate for MMAW 2-22 mg/s
B1-c Flux Cored Arc Weld-ing (FCAW)	An alternative to SMAW	No emission rates listed in BAUA 2021

Activity	Description	Estimated category of risk for worker exposure Rationale
	Uses a continuously fed consumable flux cored electrode and a constant voltage power supply to create a constant arc length. Uses either a shielding gas or just the gas created by the flux to provide protection from contamination.	
B1-d Submerged Arc Welding (SAW)	Commonly used process with a continuously-fed consumable electrode A blanket of fusible flux is conductive once molten which provides a current path between the part and the electrode. The flux helps prevent spatter and sparks and suppresses fumes and ultraviolet radiation	Low emission rates <1 mg/s
B1-e Electro-Slag Welding (ESW)	Vertical process used to weld thick plates (>25 mm thick) in a single pass Relies on an electric arc which is extinguished on addition of flux The flux melts as the wire consumable is fed into the molten pool, creating a molten slag on top of the pool. As the molten slag resists the passage of the electric current, heat is generated to melt the wire and plate edges Two water-cooled copper shoes follow the process progression and prevent any molten slag from running off.	No emission rates listed in BAUA 2021
B1-f Arc Stud Welding (SW)	Similar to flash welding Joins a nut or fastener to another metal piece, usually with a flange with nubs that melt to create the join.	No emission rates listed in BAUA 2021
B2 Arc welding: Non-consumable Electrode Methods		
B2-a Tungsten Inert Gas Welding (TIG) or Gas Tungsten Arc Welding (GTAW)	Uses a non-consumable tungsten electrode to create the arc and an inert shielding gas to protect the weld and molten pool against atmospheric contamination.	Low emission rate <1 mg/s
B2-b Plasma Arc Welding (PAW)	Similar to TIG Uses an electric arc between a non-consumable electrode and an anode, placed within the body of the torch. The electric arc is used to ionise the gas in the torch to create the plasma; the plasma is then pushed through a fine bore hole in the anode to reach the base plate so that the plasma is separated from the shielding gas.	No emission rates listed in BAUA 2021

Activity	Description	Estimated category of risk for worker exposure Rationale
C Beam Welding		
C1 Laser beam welding	Uses a laser beam to join metals together to form a weld. As the laser is a concentrated heat source, laser welding can be carried out at high welding speeds of metres per minute in thin materials. In thicker materials, laser welding can produce narrow, deep welds between square-edged parts. Frequently used in high volume applications using automation, such as in the automotive industry. Two different modes: conduction limited welding and keyhole welding In conduction welding, using a low-power laser ~500 watts, the material gets heated above the metal's thawing point, but before it evaporates, to produce welds that do not require a high weld strength. Benefits of conduction welding include: aesthetics and a highly smooth finish. In keyhole welding, using high powered lasers (>105 watts/cm^2) the laser beam heats the metal to evaporate its contact surface and penetrate deep into the metal. This forms a keyhole inside which a kind of plasma is created temperatures greater than 10,000 K.	Low Despite medium to high emission rates, (1-2 mg/s for laser beam welding without filler and 2-5 mg/s for laser beam welding with additional material), laser beam welding is mostly automated avoiding worker exposure.
C2 Electron beam (EB) welding	Electrons are generated by an electron gun and accelerated to high speeds using electrical fields. The high speed stream of electrons is tightly focused using magnetic fields and applied to the materials to be joined. The beam of electrons creates kinetic heat as it impacts with workpieces making them melt and bond together. Performed in a vacuum environment as the presence of gas can cause the beam to scatter. Uses high voltages Heavily automated and computer controlled Specialised fixtures and computer numerical control (CNC) tables are used to move workpieces inside the welding vacuum chamber.	Low Heavily automated, closed system
C3 Resistance spot welding	A thermo-electric process where heat is generated at the interface of the parts to be joined by passing an electrical current through them at a precisely controlled time and under a controlled pressure (also called force). The name "resistance" spot welding derives from the fact that the resistance of the workpieces and electrodes are used in combination or contrast to generate the heat at their interface. Has a short process time	Low Automated in industrial settings When manual, resistance spot welding has low emissions due to low voltage

Activity	Description	Estimated category of risk for worker exposure Rationale
	No consumables Due to low voltage the operator safety is good Clean and environmentally friendly[80] In the industrial setting spot welding is automated Manual spot welding machines are used in most welding workshops Used in the following sectors: aerospace, automobile, rail, manufacturing, electronics, construction, batteries	
D Soldering	Although there are various types of solder on the market, based on different ratios of lead, tin and flux, there are three main categories of solder: Lead-based solder used in electronics. The most common mixture is 60:40 (tin:lead) blend with a melting point ~180-190°C. This is known as 'soft solder'. Tin is used for its lower melting point, while lead is used to inhibit the growth of tin whiskers. Lead-free solder used since the EU started restricting the inclusion of lead in consumer electronics. Tin whiskers can be avoided by using newer annealing techniques, incorporating SnAgCu alloy as a solder, and using conformal coatings. Lead-free solders usually have a higher melting point than conventional solder.Flux core solder comprises a spool of 'wire' with a reducing agent at the core. The flux is released during soldering and reduces metal at the point of contact to achieve a cleaner electrical connection and improved wetting properties of the solder. For electronics the flux is usually rosin, for metal mending and plumbing acid cores are used (but these should not be used on electronics). Solder fluxes have associated health impacts: Solder fluxes containing fluoride can produce hydrogen fluoride and boron trifluoride which can both cause eye, skin, nose and throat irritation. Hydrogen fluoride can cause pneumonitis. Boron trifluoride can lead to bronchitis and pulmonary oedema. Rosin core solders and rosin-based solder fluxes contain rosin from the resins of pine trees. Heated rosin creates a flux fumes called colophony which contains a mixture of particulates and gases. Colophony particles can be deposited in the lungs and can lead to lung damage and occupational asthma. Colophony gases include: acetone, methyl alcohol, methane, ethane, carbon monoxide, carbon dioxide and aliphatic aldehydes. Exposure to colophony gases can result in respiratory irritation and cancer.	
D1 Soft soldering	At temperatures of 90-450 °C For lead-free solder in the electronics industry, temperature range 210-230 °C Lowest liquidus temperatures for soldering, therefore least thermal stress on components, but does not make strong joints and is unsuitable for mechanical load-bearing applications Not suitable for high temperature uses as this type of solder loses strength and melts	Medium Despite a low emission rate of <1 mg/s, workers may be exposed due to lack of RMMs used by self-employed

[80] Pers comm, Force Technology by email February 2023.

Activity	Description	Estimated category of risk for worker exposure Rationale
	NB: Not expected to emit similar fumes to welding as the base materials is not melted at these lower temperatures	electricians, jewellery makers, musical instrument makers
D2 Hard (silver) soldering	Temperatures >450 °C For flame brazing, brass solders made of copper-zinc alloys are mainly used, containing silver additives ‘silver brazing alloys’ Used to solder precious and semi-precious metals such as gold, silver, brass, and copper in jewellery making/repair and musical instrument bodies manufacture/repair. Used by machinists and refrigeration technicians for its tensile strength but lower melting temperature than brazing.	Medium to high emission rate 1-4 mg/s Self-employed jewellers or musical instrument manufacturers/repairers are unlikely to be using RPE.
D3 Brazing	Uses a metal with a much higher melting point than those used in hard and soft soldering. The metal being bonded is heated, then the soldering metal is placed between the two pieces, which melts and acts as a bonding agent. In arc brazing (MIG, TIG, plasma brazing) and laser beam brazing, temperatures are 900 – 1100 °C and mainly wire-shaped copper-based alloys are used as filler material. Brazing is used in musical instrument manufacture on keywork and braces. Brazing is used to repair cast-iron objects and wrought-iron furniture by blacksmiths. NB: under REACH (Restriction Entry 23), cadmium is restricted from use in brazing fillers, with a derogation in place for its use in defence and aerospace applications and for safety reasons Cadmium-free brazing fillers are available for aerospace applications	Despite a medium to high emission rate of 1-4 mg/s, worker exposure is likely to be low as brazing will be undertaken in specialist facilities, and often automated and enclosed for example in automotive manufacturing. Self-employed or micro enterprise blacksmiths may not be using sufficient RPE (the former are not covered by the CMRD but the latter are).
D4 Thermal cutting or gouging	A generic term for welding processes that involve melting to cut a shape or remove unwanted metal. Used for the rapid removal of unwanted metal. Material is locally heated and the molten metal forcibly ejected often over relatively large distances, usually by blowing it away, and workers and equipment must be suitably protected from the material. In carbon arc gouging, the constituents of the molten metal to react strongly with air, and the air blast vapourises much of the molten metal into fine droplets, creating a fumes of metal vapour, carbon dust and metallic by-products at levels typically above allowed exposure levels in the workplace. Originally developed to remove defective welds in stainless steel armour plate on US warships where other methods of gouging were difficult to use.	Medium?? (carbon arc gouging) The fumes from carbon arc gouging typically contains welding fumes above the allowed exposure level, and could also contain other hazardous substances depending upon the base metal. However, as this is process is undertaken in specialist facilities RMMs should be in place.

Activity	Description	Estimated category of risk for worker exposure Rationale
	Now used for a wide range of applications in engineering industries such as the repair and maintenance of structures (to remove welds or metal to replace a worn or defective part or reweld it), removal of cracks and imperfections, removal of surplus metal (including for demolition). Cutting processes can be classified according to the source of energy used. Common cutting processes include: Flame cutting or oxygen-gas cutting which is a chemical reaction between pure oxygen and steel to form iron oxide; a type of rapid, controlled rusting. Can only be used to cut low-carbon steel and some low alloys. Arc-air gouging is an electric arc-cutting process. Metals are cut by melting using the heat of a carbon arc. Most commonly used to cut cast irons, copper alloys and stainless steel. Plasma cutting uses a welding arc to cut metal to create a clean profile. The majority of plasma cutting is undertaken using pre-programmed computer numerical control with the operator at a distance from the source of fumes. Laser cutting uses a focused laser beam, typically with an annular gas jet to create a fine cut. Laser cutting minimises wasted material and produces a high quality profile. Similar to plasma cutting, laser cutting is usually undertaken using pre-programmed computer numerical control with the operator at a distance from the source of fumes.	Low (plasma cutting, laser cutting) – except for aluminium applications which do create fumes Although both plasma cutting and laser beam cutting have high emission rates (of >25 mg/s and 9-25 mg/s respectively) Plasma cutting and laser cutting are typically automated with operators working at a distance and/or separated from the source of exposure. Also less molten metal vaporises than in carbon arc gouging, so less metallic vapour is produced and there is less reaction with the surrounding air. If air is used as the plasma gas, some reaction occurs but less than in carbon-arc gouging.
D5 Thermal spraying	A technology which improves or restores the surface of a solid material. An alternative to arc welded coatings, electroplating, physical and chemical vapour depositiong and ion implantation for engineering applications. Used to apply coatings to a wide range of materials and components, to provide resistance to wear, erosion, cavitation, corrosion, abrasion or heat. Used to provide electrical conductivity or insulation lubricity, high or low friction, sacrificial wear, chemical resistance and many other desirable surface properties. Can deposit coatings of almost any material as long as it melts or becomes plastic during spraying, including: metals, cermet coatings, ceramics and polymers in layers Used in engineering applications for example in the manufacturing of gas turbines, diesel engines, bearings, journals, pumps, compressors and oil field equipment, coating medical implants. Ideally thermal spraying should be automated and enclosed with extraction of fumes, reduction in noise levels and prevention of direct viewing of the spraying head. In certain circumstances, thermal spraying is undertaken manually, for example for certain components or low production levels.	Low (if automated and enclosed) With automation, enclosure and effective extraction workers can be protected from exposure. High (if manual) If manual, workers are exposed to noise, UV light and large amounts of dust and fumes containing fine particles – effective extraction is vital, respirators fitted with suitable filters is recommended where equipment cannot be enclosed. For example arc spraying and flame spraying both have emission rates >25 mg/s.

Activity	Description	Estimated category of risk for worker exposure Rationale
	Types of thermal spraying are usually classified according to the energy source used to melt the feedstock material, including: • Liquid spraying • Flame spraying (using gas combustion) • Detonation spraying (using gas combustion) • High velocity spraying (using gas combustion) • Cold kinetic spraying • Plasma spraying (electric discharge) • Arc spraying (electric discharge) • Laser spraying (energy from beams)	
D6 Flame straightening	An efficient, well-established method of correcting weld distortions without impairing the base material. Can be used on any materials suitable for welding such as: steel, nickel, copper, brass and aluminium. Different materials require different flame straightening temperatures for mild steel and copper 600-800 °C pure aluminium 150-450 °C The design of the torch should be chosen depending upon the workpiece thickness The flame setting should be set depending upon the material itself. Potentially hazardous fumes can be generated depending upon: the material being straightened, the fuel gas being used, the surface condition of the workpiece (presence of oil or paint). Flame straightening produces nitrogen oxides in particular. Workpieces should be prepared to prevent worker exposure from surface coatings	Lower if workpieces are prepared to remove surface coatings (requirement in Germany) Higher if oil or paint is present on the surface of workpieces.
D7 Additive production process (3D printing) with metal powders	A subset of 'additive manufacturing' technologies in which 3D objects are built one superfine layer at a time. Each successive layer bonds to the preceding layer of melted or partially melted material. Objects are digitally defined by computer-aided-design (CAD) software; the software guides the path of a nozzle or printhead as it precisely deposits material upon the preceding layer; or alternatively a laser or electron beam selectively melts or partially melts in a bed of powdered material. As the materials cool they fuse together to form a 3D object. Well studied metal powders for additive production include: titanium (for medical/dental industries), nickel and aluminium alloys (for aerospace and automotive industries).	Low Usually undertaken in a closed system. Industrial 3D printers using metal powders must encapsulate the build process in a sealed chamber that is oxygen free.

Activity	Description	Estimated category of risk for worker exposure Rationale
	Metal powders are costly, so there is interest in reusing any leftover metal powder – it can be used several times until it becomes unusable. Additive manufacturing is usually undertaken inside a 'construction unit' which is a closed system Key sectors using 3D printing include: automotive and aviation, mechanical and plant engineering, electronics, consumer goods and retail and wholesale trade, energy, logistics and transport (Kersting *et al*, 2017).	However, metal powder must be handled before and after the construction process which can lead to worker exposure to metal powder via airborne or inhalable dust particles.
Sources: BAUA (2021) and ECHA (2022).		

11.11 Annex 14 - Methodology for establishing Member States already defining welding fume as a process generated substance

11.11.1 Overview

Welding fumes are Process Generated Substances (PGS) generated during welding processes. The constituents of welding fumes are complex and highly heterogenous.

There were two parts to the investigation:

- Asking the Member State authorities directly; and
- Study team searches of Member State legislation.

The results of this investigation are included in section 3.1.5.

11.11.2 Member States' input

Twenty Member States responded to the online survey or were interviewed as part of the main consultation. These twenty individuals, together with the contact details held for the remaining seven Member States, were asked the following question by email in December 2023:

> "In your transposition of the CMRD, do you have any provision specifically for welding fumes?
>
> The European Commission is considering adding the following entry into Annex I of the CMRD (from the ACSH opinion of 22 September 2023)
>
> Work involving exposure to fumes from welding processes containing substances that meet the criteria for CMR category 1A/1B set out in Annex I to the CLP regulation.[1]
>
> > *[1] The limit values listed in annex III of this directive must be respected if a given welding process is related to an exposure to CMR substances. Most of the relevant hazardous substances for welding processes are already listed there (or are on the way to be listed)*
>
> Do you have any similar provisions within your legislation that transposes the CMRD?
>
> If you do, please could you provide a link to the document and indicate the relevant section/article/page?"

11.11.3 Study team searches

Up to three documents were identified in each Member State, depending upon how their legislation is presented. Some Member States combine them in one document, others have the limit value list in a separate document, and a few have the Annex I element of the CMRD in a further document. These are the transposition of the:

- CMRD;
- List of limit values; and
- Contents of Annex I of the CMRD.

The search started with the webpage named as the source of the limit values in Table 3-1 of the welding report. If this did not include the latest amendments to the CMRD, further searches based on the naming of the first document were made to see if a later version has been issued. If this webpage did not include all three components, more searches were made of the document to see if any pointers could be found to the other documents.

The element that proved the most difficult to locate was the transposition of Annex I of the CMRD. If this was not within the list of limit values or the transposition of the main body of the CMRD, the study team went to the Google site for the Member State (such as google.it for Italy) and searched for words like auramine, cupro-nickel mattes, or isopropyl alcohol, combined with carcinogen, all translated. Auramine, cupro-nickel mattes, or isopropyl alcohol were chosen because these three substances are only mentioned in Annex I of the CMRD: the other items in Annex I of the CMRD have an OEL or skin notation.

The study team looked for any use of the words "weld", "welding", "fume" and "smoke" in all documents to find any instances of the legislation defining welding as a process generated substance with associated restrictions. Initially, this was done in English translations, but if these were unavailable or an English search found nothing, it was repeated using translations.

Terms were translated using two methods:

- The translation of the CMRD into all languages[81]; and
- Google translate.

In the majority of cases, the only instances where the word "weld" occurred were associated to chromium VI in Annex III of the CMRD[82].

In some cases, only the first five or six items in Annex I of the CMRD were found: sometimes this reflected an old version of legislation, sometimes the Member State does not yet appear to have transposed the latest updates of the CMRD. Further searches were then made to try and find later versions of legislation which does include all eight items.

[81] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02004L0037-20220405

[82] Annex III of the CMRD has the following transitional measures for Chromium VI compounds: Limit value 0,010 mg/m^3 until 17 January 2025. Limit value: 0,025 mg/m^3 for welding or plasma cutting processes or similar work processes that generate fume until 17 January 2025

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