The Cost of Occupational Cancer in the EU-28

Final Report
prepared for

European Trade Union Institute (ETUI)

November 2017

FoBiG

RPA
Risk & Policy Analysts

The Cost of Occupational Cancer in the EU-28

November 2017

Final Report

Quality Assurance	
Project reference / title	J907 Occupational Cancer
Report status	Final Report
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Approved for issue by	Meg Postle
Date of issue	9th November 2017

Document Change Record			
Report	**Version**	**Date**	**Change details**
Progress report	V1	1st September 2016	
Draft final report	V2	28th February 2017	
Draft final report	V3	5th April 2017	
Final report	V4	4th May 2017	
Final report	V4.1	9th November 2017	Minor editorial changes

The authors would like to thank Dr Tony Musu, Dr Émilie Counil, and Dr Henning Wriedt for their guidance and comments; and Dr Lesley Rushton and Dr Jukka Takala for their comments/external review.

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Executive Summary

1. Aims of the study

It is estimated that there are approximately 1.3 million cancer deaths in the European Union (EU) every year, and past research suggests that 2-12% of cancer deaths may relate to occupational exposure to carcinogens. In order to establish an effective and efficient strategy for tackling this problem, a better understanding is required of the burden of occupational cancer and the associated key carcinogenic agents. Reliable quantification of the occupational cancer burden in the EU-28 is required for these purposes.

The aim of this study was to **estimate the economic burden of cancer incidence resulting from past occupational exposure to selected carcinogenic agents in the EU-28**, so as to assist the trade unions in refining their strategy and actions to tackle occupational cancer. The work involved estimating the current incidence of occupational cancer for the EU-28 and each Member State, and assessing the associated economic costs to workers, employers and governments. A key element of the study was a comprehensive consideration of gender-relevant aspects of occupational cancer.

2. Study approach

The approach to the study was separated into two different tasks, with the first involving quantification of the occupational burden of cancer. This work involved the following steps:

- Step 1: Selection of priority carcinogens/occupations for assessment;
- Step 2: Estimation of occupationally exposed populations;
- Step 3: Identification of the relative risks for the relevant carcinogens/occupations;
- Step 4: Derivation of the attributable fractions (AFs);
- Step 5: Estimation of the attributable numbers (ANs); and
- Step 6: Comparison with published AFs (ANs).

Placing an economic value on the costs to workers, employers and governments comprised the second task to the study. This involved the development of a cost framework describing the different cost components (direct, indirect and intangible) and who would bear each of the costs.

In order to address the uncertainty surrounding some of the data required for the assessment (numbers of workers exposed, relative risk, etc.) six scenarios were assessed for each carcinogen (three central scenarios and three further scenarios). The central estimates reflect the study team's judgement of the most reliable numbers of exposed workers and the most appropriate risk estimates for the exposure patterns experienced. The Central-core scenario is complemented with two further estimates (Central-high and Central-low) which provide a range that incorporates uncertainty regarding the relative risks in published literature. The Central-core estimate (and the accompanying low-high range) thus represents the most realistic estimate of the current cancer incidence due to past occupational exposure to the 25 agents considered in this study.

The central scenarios are complemented with a low scenario (lowest assumptions on incidence, exposed population and relative risk), a high scenario (highest assumptions on incidence, exposed population and relative risks), and a mid-point estimate (midpoints between the input data used for the high and the low scenarios).

3. Priority carcinogenic agents

It was not possible to look at all carcinogenic agents within the scope of this study. As a result, the agents to be considered had to be prioritised. In particular, the aim was to identify the top carcinogens in terms of their contribution to the overall incidence of occupational cancer, and their

gender relevance (in particular their contribution to the occupational cancer incidence for women, although agents specifically relevant to men were also identified) to ensure that the study is not skewed towards one of the two genders.

The starting point for this prioritisation was a review of existing studies that have assessed occupational exposure across a number of carcinogens and occupations. The results of the key meta-analyses were reviewed and their findings scored for prioritisation purposes based on the following attributes: relative risk and number of workers exposed; age of the underlying data; specificity; geographic scope; gender aspects; and scope in terms of the breadth of the carcinogenic agents examined.

The outcome of this prioritisation process was the identification of the 25 carcinogenic agents to be examined in more detail in this study, as listed in Table 1. These included chemical agents, process-generated substances such as wood dust and diesel exhaust, and occupational agents such as shift work and work in the rubber industry.

Table 1: Final selection of the 25 carcinogenic agents	
Diesel exhaust	Solar radiation
Silica	Environmental tobacco smoke (ETS)
Asbestos	Epichlorohydrine
Formaldehyde	Tetrachloroethylene
Benzene	Shift work
Mineral oils	Dioxins
Cd and Cd compounds	Inorganic acid mists containing sulphuric acid
Wood dust	Rubber manufacturing industry
Arsenic	Ionising radiation
Vinyl chloride	Cr(VI) compounds
Ethylene oxide	Aromatic amines
PAHs (from coal tars and pitches)	Cytostatic drugs
Occupation as a welder	

Although it is possible that the 25 agents account for the majority of occupational cancer incidence, this is by no means certain, and it is highly likely that the inclusion of additional agents in the assessment would have increased the estimated attributable fractions (AFs) and attributable numbers (ANs). For example, although organic solvents were not included in the core assessment due to significant uncertainties associated with the input data, an additional assessment is provided to show that their inclusion would increase the estimated AFs.

4. Occupationally exposed populations

The proportion of workers exposed to the relevant carcinogenic agents over the reference period for the analysis (1966-2005 for cancers with 10-50 year latency and 1996-2015 for cancers with 0-20 year latency) was estimated. Developing estimates for the EU-28 required extrapolating from existing data sources (e.g. CAREX, SUMER, ASA, etc.) and combining these extrapolations with estimated long-term trends and staff turnover ratios. These estimates were derived for the low, high, mid-point and central[1] estimate scenarios, with a summary of the results presented below.

Table 2: Exposed population (adjusted for natural mortality) as % of the current working population					
Carcinogen	Reference period	Low	High	Midpoint	Central
01 DEE	1966-2005	4.9%	8.9%	6.4%	6.7%
02 Silica	1966-2005	2.1%	6.3%	4.6%	4.1%

[1] Please note that the exposed populations under the Central-core, Central-low, and Central-high scenarios are identical.

Table 2: Exposed population (adjusted for natural mortality) as % of the current working population					
Carcinogen	**Reference period**	**Low**	**High**	**Midpoint**	**Central**
03 Asbestos	1966-2005	0.2%	2.0%	1.2%	1.7%
04 Formaldehyde	1966-2005	1.1%	4.1%	1.9%	1.6%
	1996-2015	0.8%	2.3%	1.4%	1.1%
05 Benzene	1996-2015	0.1%	2.2%	0.7%	0.3%
06 Mineral oils	1966-2005	4.4%	11.4%	7.8%	11.1%
07 Cd and Cd compounds	1966-2005	0.1%	0.4%	0.3%	0.4%
08 Wood dust	1966-2005	3.1%	5.6%	4.0%	4.5%
09 Arsenic	1966-2005	0.3%	0.3%	0.3%	0.3%
10 Vinyl chloride	1966-2005	0.01%	0.1%	0.1%	0.1%
11 Ethylene oxide	1996-2005	0.002%	0.04%	0.02%	0.04%
12 PAHs	1966-2005	0.005%	1.3%	0.7%	0.9%
	1996-2015	0.004%	1.1%	0.6%	1.1%
13 Occupation as a welder	1966-2005	0.4%	6.7%	3.2%	4.3%
14 Solar radiation	1966-2005	9.7%	12.8%	11.3%	12.8%
15 ETS	1966-2005	2.3%	14.5%	10%	14.5%
16 Epichlorohydrine	1966-2005	0.1%	0.1%	0.1%	0.1%
17 Tetrachloroethylene	1966-2005	0.1%	0.6%	0.4%	0.4%
	1996-2015	0.1%	0.4%	0.4%	0.2%
18 Shift work	1966-2005	6.6%	20%	13.2%	20%
19 Dioxins	1966-2005	0.1%	4.6%	2.3%	2.3%
20 Inorganic acid mists	1966-2005	0.4%	0.8%	0.6%	0.6%
21 Rubber manufacturing	1966-2005	0.1%	0.5%	0.3%	0.3%
	1996-2015	0.1%	0.3%	0.2%	0.2%
	1966-2005 Women	0.01%	0.1%	0.05%	0.04%
	1966-2005 Men	0.1%	1.0%	0.5%	0.5%
22 Ionising radiation	1966-2005	0.2%	2.0%	0.8%	0.5%
	1996-2015	0.1%	1.1%	0.6%	0.3%
	1966-2005 Women	0.1%	0.5%	0.2%	0.1%
	1966-2005 Men	0.3%	3.4%	1.5%	0.9%
23 Cr(VI) compounds	1966-2005	0.5%	1.7%	0.9%	0.8%
24 Aromatic amines	1966-2005	0.3%	0.9%	0.6%	0.5%
25 Cytostatic drugs	1966-2005 Women	0.7%	3.1%	1.5%	0.8%
	1996-2015	0.3%	1.1%	0.6%	0.3%

5. Relative risk

Information was then taken from the published literature on the relative cancer risk for workers exposed to the various carcinogenic agents. These relative risk estimates were taken from both meta-analyses and individual cohort studies. To the extent possible, the cancer sites for which risk estimates have been identified were based on those listed in IARC (2016)[2]. For some of the carcinogenic agents, it was not possible to source occupational risk estimates for all of the cancer sites, leading to a gap in our analysis. In other cases, additional sites to those listed in IARC were taken into account, in particular where these sites were identified as being relevant when

[2] IARC (2016): List of classifications by cancer sites with sufficient or limited evidence in humans, available at https://monographs.iarc.fr/ENG/Classification/Table4.pdf

establishing harmonised classifications for the substances under Regulation (CE) 1272/2008 on classification, labelling and packaging of substances and mixtures (as the relevant EU legislation).

In total, estimates have been developed for 23 cancer sites across the 25 carcinogenic agents (see Table 2-9 in the main report).

6. Attributable fractions (AFs) and attributable numbers (ANs)

The Attributable Fraction (AF) is the proportion of cancer cases that would not have occurred in the absence of occupational exposure, and it has been estimated for each of the 25 carcinogenic agents and sites based on relative risks and the estimates of the exposed population. Levin's equation has been used for the calculation of the AFs:

$$AF = Pr(E)(RR-1)/\{1+Pr(E)(RR-1)\}$$

where RR=relative risk and Pr(E)=proportion of the 'at risk' population with a history of occupational exposure to the carcinogen.

The detailed results are summarised in Section 2.5 of the report, with Table 3 below setting out the overall AFs calculated for the three central scenarios.

Table 3: Incidence AFs for all cancer sites across the 25 carcinogenic agents (reference year: 2015)

Scenario	Central-low	Central-core	Central-high
Overall AF – Both genders	6%	8%	12%
Overall AF – Women	3%	5%	7%
Overall AF - Men	6%	10%	15%

The AF derived under the CENTRAL scenario is 8%. When the 95% CI in the relative risk estimates is taken as a basis for the estimation, the central estimate is a range between 6% and 12%. These estimates are positioned closer to the higher estimates in the published literature and provide further support for studies that have estimated the overall AF for occupational cancer at 8% or above. It should be noted that the AFs estimated in this study are for cancer incidence rather than mortality and they relate to the 25 specific carcinogenic agents and do not capture cancer incidence resulting from all occupational carcinogens.

An important finding of this study is that, by including a specific gender focus on carcinogenic agents for women, this study has found a higher AF for occupational exposure of female workers than previous studies. This is, in particular, due to the shift work, ionising radiation and cytostatic drugs within the scope of this study. The central estimates found by this study are compared with other published studies in Figure 1.

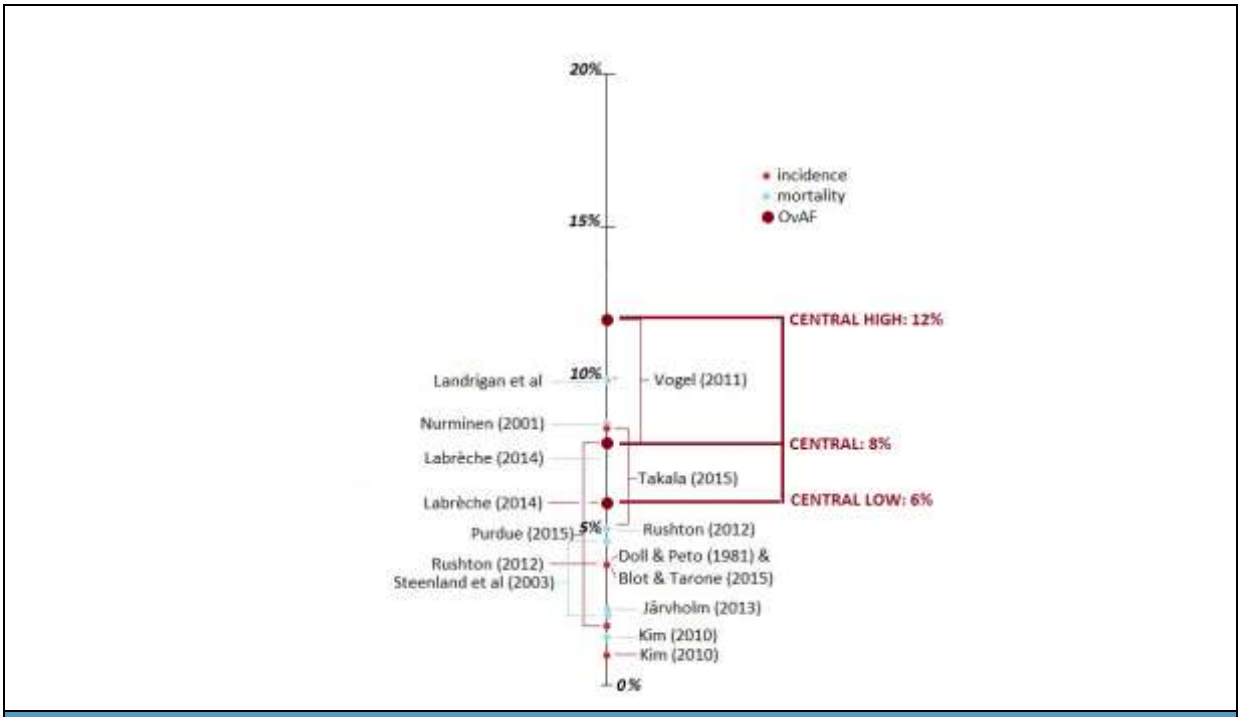

Figure 1: Central scenarios - overall AFs compared with published estimates

The calculated AFs were applied to national cancer incidence data from two Europe-wide cancer incidence registries (EUREG and EUCAN) and other sources to generate the numbers of occupational cancers in EU Member States.[3] This provides estimates of the Attributable Numbers (ANs) of cancer registrations stemming from occupational exposures. Using data from EUCAN and other sources, it is estimated that each year around 190,000 cancer registrations are attributable to past occupational exposure to the 25 agents considered in this study (Central Low-Central High: 125,000-275,000). A breakdown by cancer site is provided in Figure 2.

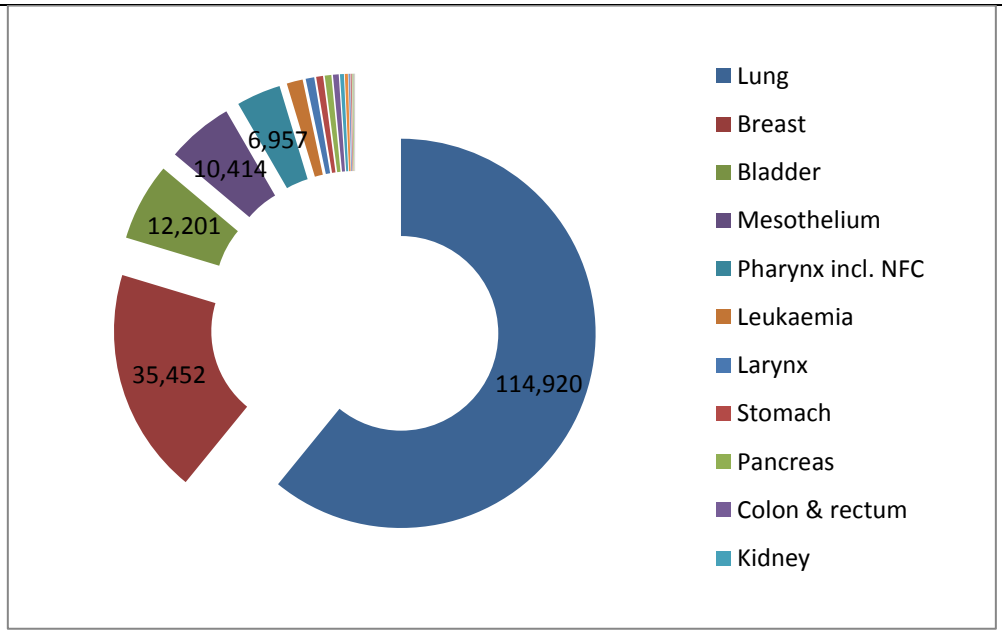

Figure 2: Central-core scenario – contribution of cancer sites to the overall AN

[3] In addition, lung cancer incidence attributable to asbestos exposure was estimated using mesothelioma incidence as a proxy.

7. The economic burden of occupational cancer

The first step in estimating the annual economic burden of occupational cancer in the EU28 was the development of a cost framework describing the different cost components (direct, indirect and intangible/human) and who would bear the costs. It is important to note that for the purposes of this study, this framework is constrained to the assessment of those costs that comprise true "economic" or social costs, and excludes financial impacts that essentially reflect transfers between different groups in society.

From this perspective, the economic costs of cancer can be divided into:

- **Direct costs:** These are the medical costs associated with the treatment of cancer and the non-medical costs that arise directly as a result of cancer. Direct medical costs are those associated with the treatment and services patients receive, including the cost of hospitalisation, surgery, physician visits, radiation therapy and chemotherapy/ immunotherapy.
- **Indirect costs:** These are the monetary losses associated with the time spent receiving medical care, including productivity losses due to time spent away from work or other usual activities and lost productivity due to premature death.
- **Intangible or human costs:** These include the non-financial 'human' losses associated with cancer, e.g. reduced quality of life, pain, suffering, anxiety and grief.

The total costs for the different scenarios are summarised below, indicating that the total cost of cancer registrations recorded in a given year and caused by past occupational exposure to carcinogenic agents is between €270 and €610 billion when both the full costs of mortality and morbidity (as defined for this study) are taken into account. If the human costs associated with morbidity effects are removed from the assessment (i.e. the WTP value of €410,000), then the present value costs fall to between €250 and €570 billion. These ranges reflect the three central scenarios (Central-core, Central-high, Central-low) and whether cancer incidence data are built around the EUCAN or EUREG registry.

Both of these sets of estimates are primarily driven by valuation of the human costs. Excluding the VSL (€4 million) and VCM estimates decreases the costs to between €4 and €10 billion, driven primarily by healthcare costs (both formal and informal).

Table 4: Summary of the total present value costs of annual occupational cancer registrations

Scenario	Source of data for calculation of AN	Total present value costs of 2015 cancer registrations (VSL and VCM) (€ billion)	Total present value costs of 2015 cancer registrations (VSL only) (€ billion)
Central-core	EUREG+GCO+UK	348	327
	EUCAN+UK	436	409
Central-low	EUREG+GCO+UK	267	253
	EUCAN+UK	295	279
Central-high	EUREG+GCO+UK	493	458
	EUCAN+UK	613	572

Note: These present value estimates represent the costs associated with cancer registrations recorded in a single year, with the associated costs possibly spread over a number of years.

These cost figures are significant, and equate to between roughly 1.8% and 4.1% of EU GDP (based on 2015 Eurostat data) for the estimates including both the VSL and VCM valuations of the human

costs of cancer. Removing the figure for VCM from the estimates, reduces this slightly to between 1.7% and 3.9% of EU GDP.

The costs in the table above are also of a similar order of magnitude to those estimated recently in RIVM (2016).[4] RIVM (2016) concluded that the total societal cost of work-related cancer is at least in the order of magnitude of €334 billion (range: €242-440 billion), the largest component of which is the welfare loss associated with cancer morbidity and mortality (€329 billion).

These figures compare to those produced by Luengo-Fernandez et al (2013) on the per annum total costs of cancer in the EU, which they estimated €126 billion for 2009, with health care accounting for €51.0 billion (40%). It is important to note that this figure covers occupational and non-occupational cancers. In addition, it reflects the costs associated with cancer in a given year, rather than the present value costs of the cancer registrations predicted for 2015, as developed by this study. Furthermore, the costs estimated by Luengo-Fernandez et al do not include any allowance for intangible costs. Assuming that around 8% of the costs in Luengo-Fernandez et al (2013) are caused by occupational cancer suggests that the costs of occupational cancer in 2009 were around €10 billion. This compares to around €14 billion calculated for the Central-core scenario in this study when all intangible costs are excluded from the analysis.

It should, however, be noted that a different methodology was used in RIVM (2016) and Luengo-Fernandez et al (2013), with this study estimating the costs of annual cancer registrations incurred over several years rather than the costs incurred in a single year due to new registrations and the ongoing treatment of past registrations.

8. Distribution of the costs

In addition to the magnitude of the costs, also of interest is the distribution of these to different groups within society. Table 5 provides this for the Central-core scenario and EUCAN estimates.

Table 5: Distribution of costs across different types (€ billion), Central-core/ EUCAN+UK

Type of cost	Group bearing the cost	Total present value costs	Share of total costs
Healthcare	Government/taxpayers	6	1.3%
Lost working days	Worker/ family	0.4	0.1%
Informal care	Worker/ family	1	0.3%
VSL	Worker/ family	394	90.3%
VCM	Worker/ family	35	8%
TOTAL		436	

HSE (2016), because it was examining costs for a single country, was able to develop estimates of the costs borne by employers.[5] For the UK, they estimated that around 3% of total costs to society were borne by employers, with this equating to a cost of roughly €17 per worker per annum. Multiplying it across the EU-28 worker population (aged 15 to 64) gives a total figure of €4.13 billion in costs to employers associated with the costs of production disturbance, sickness payments due to worker absence and legal obligations with regard to employers' liability insurance. This figure does of

[4] RIVM (2016): Work related cancer in the European Union, available at http://rivm.nl/en/Documents_and_publications/Scientific/Reports/2016/mei/Work_related_cancer_in_the_European_Union_Size_impact_and_options_for_further_prevention

[5] UK HSE (2016): Costs to Britain of Work Related Cancer, Research Report 1074, available at: http://www.hse.gov.uk/research/rrhtm/rr1074.htm

course reflect requirements in the UK which may be more or less onerous than those that apply in other Member States. However, it provides an indication of significance of these costs.

They are only a small percentage of the total costs with this type of finding being attributed to the nature of cancer as an occupational disease. Many of the cancers considered here have latency periods of between 10 and 50 years. As a result, most individuals diagnosed with occupational exposure-related cancer (estimated at over 70%) will have left work by the time they are diagnosed, or may have changed jobs. The relevant employer during the period of exposure will not therefore bear the costs of disruption from sickness absence, paying sick pay, etc. As noted by the UK HSE, this estimate is also an under-estimate as it fails to capture some costs to employers that may be significant, such as those associated with the loss of expertise, and reductions in productivity of those returning to work after successful cancer treatment. Reputational damage (which can impact on sales and recruitment) is also not included.

9. Sensitivity analysis

Sensitivity analysis was undertaken to test key uncertain assumptions. This focused on testing assumptions regarding the intangible costs of cancer within the economic analysis.

As noted above, the total cost of cancer registrations recorded in a given year and caused by past occupational exposure to carcinogenic agents has been estimated to be between €270 and €610 billion, with this figure being driven by the assumed value of a statistical life. The VSL of €4 million is higher than the VSL which would apply to a non-cancer fatality. For example, ECHA's guidance on SEA[6] provides a central value of around €1.33 million when up-dated to 2015 prices. Adopting this figure significantly reduces the estimated total present value costs of cancer registrations, as can be seen from Table 6.

Table 6: Summary of economic costs – sensitivity analysis on the VSL

Scenario	Source of data for calculation of AN	Total cost of annual cancer registrations (€ billion) VSL: €4 million	Total cost of annual cancer registrations (€ billion) VSL: €1.33 million
Central-core	EUREG+GCO+UK	348	134
	EUCAN	436	167

10. Limitations of the analysis

Calculated attributable fractions (AFs), attributable cancer cases (ANs), associated costs and country specific breakdown derived in this project are inevitably subject to considerable uncertainties, as are estimates of the costs associated with a cancer registration. The study has attempted to provide *ranges* for the estimates (High, Low, Central-core, Central-high, Central-low, Mid-point). However, these ranges reflect only parts of the variability and uncertainty, where "true" numbers may spread over an even larger range. As a result, the central estimate should only be regarded as a qualified *order of magnitude* figure instead of an exact number.

More generally, it is important that the limitations of the analysis presented here are recognised. Importantly, gender differences in cancer attributable to occupation could only partly be addressed. This analysis focused on the gender-specific exposure profiles, whereas the intrinsic different biological potency of the carcinogenic agents, leading to gender discrepancies, was not (or only marginally) addressed.

[6] Based on environmental pollution willingness to pay values.

There are some parameters which may *increase* the overall estimated AF:

- If selection were not restricted to 25 carcinogenic agents;
- If selection were not limited to only a few cancer sites and risk quantifications (as "relative risk"), which were restricted to the most relevant ones according to IARC plus some additional - not necessarily representative - information sources;
- If many suspected carcinogens, 'possible' carcinogens, and carcinogens found to only be carcinogenic in animal studies, were examined, including those with high production tonnages;
- Moreover, no extended and systematic supplemental assessment could be performed from different starting points apart from the 'carcinogenic agents'. Starting from 'cancers attributed to occupations' and 'occupations and carcinogenic agents attributed to cancer sites' could have provided a more complete coverage of some carcinogenic impacts.

There are some parameters which may *decrease* the overall estimated AF:

- Relative risks may often be quantified at elevated exposure levels and risks at lower exposures may be associated with a significantly lower cancer risk. Because a realistic exposure concentration was not modelled and the exposure level associated with the RR was not explicitly taken into account and because some non-genotoxic carcinogens (but even genotoxic carcinogens) may be associated with a sublinear exposure risk relationship or even a threshold type of carcinogenicity, these elements may contribute to an overestimation of the final overall AF; and
- Because some suspected carcinogens were included as if they were confirmed carcinogens (e.g., tetrachloroethylene or shift work), new data may disprove suspicion and lead to lower estimated carcinogenic impact.

There are some parameters leading to significant uncertainties, even though the direction (higher or lower estimate) could not be clearly determined:

- Not all of the carcinogenic agents are well-defined, which leads to significant uncertainties on all subsequent input figures (cancer sites, RR, AF, exposure, AN, and costs), notably for mineral oils;
- Only epidemiological data were used for risk quantification. The large pool of "additional risk" data from experimental animals may have been more appropriate for some substances and may lead to quantitative changes; and
- A more exhaustive search for epidemiological data including meta-analyses would have improved the reliability of the finally adopted RRs, but was not feasible within the framework of this project.

The overall result of cancer incidence attributed to occupation is not far away from other similar assessments. This provides some confidence in the overall result, although the above-mentioned uncertainties are acknowledged.

11. Conclusion

In conclusion, occupational cancer is associated with a significant economic burden. It is therefore essential that these costs are reduced and additional efforts in terms of prevention policies should be viewed through the prism of the substantial costs that could be avoided.

1 Introduction

1.1 Background and aims of the study

It is estimated that there are approximately 1.3 million cancer deaths in the European Union (EU) every year. Even more people are diagnosed with cancer resulting in reduced quality of life, healthcare costs and economic costs due to absence from work. In 2008, 2.45 million people were diagnosed with cancer in the then 27 countries of the EU. The overall cost of cancer in the EU was estimated to be €126 billion in 2009, with health care accounting for €51 billion (40%). Productivity losses because of early death have been estimated to cost €42.6 billion and lost working days €9.43 billion. Informal care was estimated to cost €23.2 billion[7].

Past research suggests that between 2-12% of cancer deaths are related to occupational exposure to carcinogens; for some types of cancer, such as lung or bladder cancer, this figure is thought to be in excess of 10% (Vogel, 2011[8]). This proportion is even higher for asbestos-induced mesothelioma, with the attributable fraction in excess of 90% (Rushton et al, 2011; Steenland, 2011[9]).

A full and accurate understanding of the burden of occupational cancer is a prerequisite for an effective and comprehensive strategy to tackle the problem. Reliable quantification of the occupational cancer burden in the EU-28 is thus required for policy makers to ensure that the problem is addressed effectively and efficiently. The objective of this study is thus to **estimate the current economic burden of past occupational exposure to selected carcinogenic agents in the EU-28**, with the aim being to assist the trade unions in refining their strategy and actions to tackle occupational cancer.

The specific objectives of the study involve:

- estimating the current incidence of occupational cancer for the EU-28 and each EU Member State (Work Package 1); and
- assessing the associated economic costs in the EU-28, and their distribution between workers, employers and governments (Work Package 2).

A key element of the study was a comprehensive consideration of gender-relevant aspects of occupational cancer.

1.2 Structure of this report

The report has been organised as follows:

- **Section 2** sets out the results for occupational cancer incidence in the EU2-8 and in each Member State (Work Package 1); and

[7] Luengo-Fernandez et al (2013): Economic burden of cancer across the European Union: a population-based cost analysis, available at http://dx.doi.org/10.1016/S1470-2045(13)70442-X

[8] Vogel (2011): Occupational cancer, available at https://www.etui.org/content/download/7515/71981/file/Occupational+cancer++the+main+challenge+for+the+new+Community+Strategy.pdf

[9] Steenland (2011): Attributable fraction, available at http://www.occupationalcancer.ca/wp-content/uploads/2011/03/Steenland.pdf

- **Section 3** provides the results of the economic analysis, setting out the economic costs of occupational cancer.

This report is complemented with the following annexes:

- **Annex 1** provides a detailed overview of the analysis carried out for each of the 25 carcinogenic agents considered in this study;
- **Annex 2** sets out the Attributable Fractions (AFs) , Attributable Numbers (ANs), and the costs estimated in this study for each Member State;
- **Annex 3** provides a summary of the cancer incidence data extracted from EUCAN and EUREG;
- **Annex 4** provides the estimated AFs for each cancer site, disaggregated by gender; and
- **Annex 5** provides additional information for the prioritisation of the key carcinogens, gender shares in the exposed workforce, a more detailed assessment of the limitations of the study and additional data for Task 2 (costs).

2 WP 1: Occupational cancer incidence in the EU-28

2.1 Overview of the approach

The approach to WP 1 (**Occupational cancer incidence in the EU28**) involved the following steps:

- Step 1: Selection of priority carcinogens/occupations for assessment;
- Step 2: Estimation of occupationally exposed populations;
- Step 3: Identification of the Relative Risks for the relevant carcinogens/occupations;
- Step 4: Derivation of the attributable fractions (AFs);
- Step 5: Estimation of the attributable numbers (ANs);
- Step 6: Comparison with published AFs (ANs); and
- Step 7: Limitations of the analysis.

The approach to WP1 is based on the Attributable Fraction (AF) approach. The Attributable Fraction (AF) is the proportion of cancer cases that would not have occurred in the absence of occupational exposure, and it has been estimated for each of the 25 carcinogenic agents and sites based on the relative risks in published literature and the estimates of the workforce exposed to these agents over the relevant reference period preceding the year for which the costs associated with occupational cancer incidence are calculated (2015). Due to the long latency periods for some of the relevant carcinogens (up to 50 years), estimates of occupationally exposed populations dating back to 1966 were required for most of the 25 carcinogenic agents considered in this study.

The uncertainty regarding some of the data inputs (numbers of workers exposed, relative risk, etc.) has been dealt with by means of constructing six scenarios for each carcinogen:

- **Low:** this scenario models the lowest cancer incidence that can be estimated on the basis of the various input data, relying on the lowest estimate of the exposed population over the reference period (which is estimated by combining a point estimate for a specific year with an estimated rate of growth/decline[10]) and the lowest identified relative risk (set at 1 where this was below 1);

- **High:** the high scenario models the highest cancer incidence that can be estimated on the basis of the identified input data, i.e. the highest estimate of the exposed population over the relevant reference period the highest relative risk;

- **Mid-point:** this scenario is based on midpoints between the input data used for the high and the low scenarios;

- **Central-core:** this scenario reflects the study team's judgement of the most realistic input data. As a result, some of the assumptions used to model this scenario are taken from the high scenario, whilst others are identical to the low scenario. The relative risks used to estimate the central scenario have been chosen based on the criteria set out in Section 2.4.

[10] Please note that the exposed population over the whole reference period can be higher for a declining population than constant population, i.e. in some instances a high rate of decline extrapolated over a historical period produces a higher estimate of the exposed population than the assumption of no annual change.

- **Central-high and Central-low:** The Central-core scenario is complemented with two further estimates (Central-high and Central-low) which provide a range that incorporates uncertainty regarding the relative risks in published literature. The Central-high and Central-low scenarios are thus based on the 95% (or 90%) CI for the relative risks used for the Central-core scenario.

The methodology used for the different steps and the results of the assessment are set out below.

2.2 WP1-Step 1: Prioritisation of key carcinogens

2.2.1 Introduction

The very large number of potential occupational carcinogens means that a detailed one-by-one examination of all potentially relevant carcinogens is not possible within the scope of the study. However, the relatively large contribution of a limited number of carcinogens and occupations to the overall occupational cancer incidence (as estimated in Rushton et al, 2010) [11] suggests that a focus on a limited number of key occupational carcinogens may provide a good balance between comprehensiveness and analytical detail. The assessment in Rushton et al (2010) suggests that the top 15 occupational carcinogens may have accounted for around 96% of occupationally relevant cancer registrations in the UK in 2004.

The aim of WP1-Step 1 is thus to select the carcinogenic agents for which occupational cancer incidence is estimated in this study.

The selection of the top carcinogens is carried out using the following criteria:

- their contribution to the overall incidence numbers for occupational carcinogens and/or the size of the exposed workforce, drawing on data in existing literature;
- their gender relevance: this study has sought to ensure that sufficient attention is given to gender specific exposures, in particular carcinogenic agents that predominantly affect women. For this reason, the carcinogenic agents selected for the assessment in this study comprise those that are relevant to both genders and those predominantly relevant to women or men only; and
- expert judgement based on discussions with ETUI and broader expertise of the study team.

The prioritisation exercise primarily focuses on IARC Group 1 and 2A carcinogens (factors that are carcinogenic and probably carcinogenic to humans). Due to the fact that Group 2B (factors that are possibly carcinogenic to humans) comprises a very large number of entries, it was not been possible to consider the vast majority of them within the prioritisation exercise. In addition, limited human data are available for Group 2B carcinogens.

2.2.2 Priority carcinogens identified from existing literature

The starting point for the prioritisation exercise was a review of recent studies that have compared and ranked occupational exposure across a large number of carcinogens and occupations, which was complemented by around 80 recent (post-2005) papers focussing on specific carcinogens. The purpose of this review as to identify the most important occupational carcinogens in terms of the number of workers exposed and/or their contribution to overall occupational cancer incidence, and to determine which carcinogens have a specific gender significance.

[11] Rushton et al (2010): Occupation and cancer in Britain, available at: http://www.ncbi.nlm.nih.gov/pubmed/20424618

Since the underlying methodologies and geographical focuses differ, the different studies often provide varying rankings for the same carcinogen. For example, considering the exposed workforce, benzene was ranked the No. 1 carcinogen in RIVM (2015) but the 48th most important carcinogen in France in SUMER (2010). The diversity of approaches and data sources that underpin the existing research presents a significant complication for attempts to draw conclusions on the basis of combining the results of the different studies.

The results of the following studies are summarised in the table below: CAREX (2010)[12], Rushton et al (2010)[13], RIVM (2015)[14], SUMER (2010) and Wriedt (2015).

Table 2-1: The most significant occupational carcinogens (IARC Groups 1 and 2A)

Carcinogenic agent	Rushton et al (2010)	CAREX (2010)	RIVM(2015)*	SUMER (2010)	Wriedt (2015)**
Asbestos	Rank 1	Rank 9	Top 70	Rank 36	Relevant
Shift work	Rank 2				
Mineral oils	Rank 3		Rank 76	Rank 7	
Solar radiation	Rank 4	Rank 1			
Silica	Rank 5	Rank 3	Top 70	Rank 11	Relevant
Diesel exhaust emissions	Rank 6	Rank 4	Top 70	Rank 1	Relevant
PAHs (from coal tars and pitches)	Rank 7	Rank 12***			Relevant
Occupation as a painter	Rank 8			Rank 14 and 38	
Dioxins	Rank 9				
Environmental tobacco smoke (ETS)	Rank 10	Rank 2			
Radon	Rank 11	Rank 5			
Welding fumes	Rank 12		Top 70	Rank 4	
Tetrachloroethylene	Rank 13	Rank 14			
Arsenic	Rank 14	Rank 23	Top 70	Rank 27	Relevant
Inorganic acid mists containing sulphuric acid	Rank 15	Rank 16			
Benzene	Rank 31	Rank 8	Top 10	Rank 48	Relevant
Formaldehyde	Rank 26	Rank 11	Top 10	Rank 19	Relevant
1,3-butadiene	Rank 33	Rank 35	Top 10		Relevant
Vinyl chloride	Rank 32	Rank 33	Top 10		Relevant
Ethylene oxide	Rank 35	Rank 31	Top 10		Relevant
Epichlorohydrine		Rank 30	Top 10		Relevant
Cd and Cd compounds	Rank 29	Rank 22	Top 10	Rank 47	Relevant
Acrylamide	Rank 34	Rank 36	Top 10		Relevant
Isopropyl alcohol manufacture				Rank 2	
Rubber manufacturing			Top 70	Rank 3 and 9	
Wood dust		Rank 6	Top 70	Rank 8	Relevant
Petroleum refining			Top 70	Rank 10	

Notes:*for the purposes of this table classed as either Top 70 or Top 10. Top 70 includes Top 10. **Classed as 'relevant for a BOELV under the CMD' and 'potentially relevant for a BOELV' and 'relevance unclear'. ***Excludes ETS.

[12] CAREX (2010): Carcinogenic exposure information for the European Union, available at: http://www.ttl.fi/en/chemical_safety/carex/countries/pages/default.aspx

[13] Rushton et al (2010): Occupation and cancer in Britain, available at: http://www.ncbi.nlm.nih.gov/pubmed/20424618

[14] RIVM (2015): Identifying prevalent carcinogens at the workplace in Europe, available at http://www.rivm.nl/bibliotheek/rapporten/2015-0107.pdf

The studies summarised in the table above had different aims and relied on diverse datasets and methodologies. Whilst Rushton et al (2010) considered all IARC occupational carcinogens classified (by the end of 2008) as Group 1 and 2A in terms of their contribution to cancer incidence, RIVM (2015), SUMER (2010) and Wriedt (2016) focussed on chemical agents and the numbers of workers exposed to them. Combining the results of these studies into a single analytical framework is therefore difficult. For example, is a chemical substance identified as belonging to the Top 70 carcinogens in Europe by RIVM (2015) largely based on the numbers of workers exposed, and for which it is not possible to determine whether it is the 11th or 70th most important carcinogen, more or less important than welding fumes identified as the 12th most important cause of occupational cancer in the UK by Rushton et al (2010)?

Each of these studies is characterised by a different set of advantages and disadvantages. Examples of advantages and disadvantages of RIVM (2015) are discussed below.

RIVM (2015) prioritised 70 substances on the basis of the number of workers exposed as recorded in nine national exposure databases. Differentiation within the list of the top 70 substances was not possible due to data limitations, with the study only differentiating between the top 70 and the rest. The key advantage of RIVM (2015) is that it draws on a number of national databases thus offering a wider geographical coverage than Rushton et al (2010) or SUMER (2010). Unlike Rushton et al (2010), RIVM (2015) and SUMER (2010) only take into account the number of workers exposed and not the relative risk[15]. Furthermore, the results of RIVM (2015) are primarily driven by data availability rather than holistic hazard considerations. In addition, some of the substances in the national exposure databases may have been subject to regulatory action or are currently considered for regulatory action.

This study combines the results of the above studies using a simple scoring system that attaches a certain weight to each source based on its key attributes and relevance, including whether it is risk based, age of the underlying data, specificity, and its scope in terms of the countries and agents covered. Admittedly, combining such incongruent sources into a single analytical framework entails a certain degree of arbitrariness. The impact of this is minimised by means of clearly setting out the methodology for combining the results of these studies – the details of the scoring system are given in Annex 5.

2.2.3 Gender aspects and expert judgement

The review of the relevant studies (see above) has been complemented by consideration of gender aspects and study team judgement based on discussions within the study team and/or with ETUI which sought to include/exclude carcinogens that have been highlighted in policy discussions or that have been subject to regulatory action.

A comprehensive coverage of gender-specific carcinogens is crucial since research into the gender dimension of cancer risk is sparse and it is believed that this may have led to an underestimation of female occupational cancer incidence. For example, breast cancer, the leading cause of cancer mortality among women, has not been studied as much in terms of occupational hazards as lung or bladder cancer among men (Vogel, 2011), although some epidemiological research exists for breast cancer, e.g. in relation to shift/night work.

A number of studies that provide information on the gender relevance of the carcinogens identified in the table above are summarised in Annex 5. Some of these studies provide data on the numbers

[15] Some information on worker protection is available in one of the national databases, i.e. the SUMER study in France.

of male and female workers exposed (e.g. SUMER 2010), others provide information in relation to cancer incidence (Rushton et al 2010) whilst other have highlighted specific issues, e.g. shift/night work and breast cancer. These studies have been taken into account in the final selection of the 25 carcinogenic agents to be examined in more detail in this study by means of study team discussions. The conclusions in terms of gender relevance were typically guided by the proportion of occupationally exposed populations that are women (>20% typically triggered the conclusion that the carcinogen is relevant to women).

2.2.4 Selection of the 25 carcinogenic agents for further examination

The table below sets out the final selection of the top 25 carcinogenic agents to be examined in more detail in this study. The starting point was the 25 carcinogens that have received the highest scores from the review of the five studies (see above). These were complemented by four additional carcinogens that were either requested by ETUI (CrVI) or are suspected to be particularly relevant to female workers (ionising radiation, aromatic amines and cytostatic drugs). This necessitated the removal of four carcinogens from the list of the top 25 scorers from the five studies. Due to past or potential future regulatory action radon, 1,3-butadiene and acrylamide have been removed from the list. Occupation as a painter has not been taken forward due to the potential for overlap with other carcinogens (e.g. CrVI).

Table 2-2: Final selection of top 25 carcinogenic agents

Carcinogenic agent	Score (5 studies)	Gender relevance (male and/or female)	Study team judgement/ discussions with ETUI	Selected?
Diesel exhaust	44	Include – Men		Yes 1
Silica	41	Include – Men		Yes 2
Asbestos	37	Include – Men		Yes 3
Formaldehyde	36	Include – Women		Yes 4
Benzene	35	Include – Men		Yes 5
Mineral oils	31	Include - Men		Yes 6
Cd and Cd compounds	30	Include – Men & women		Yes 7
Wood dust	28	Include – Men		Yes 8
Arsenic	27	Include – Men & women		Yes 9
1,3-Butadiene	27		Exclude	No 1
Vinyl chloride	27	Include – Men & women	Include	Yes 10
Ethylene oxide	27	Include – Women	Include	Yes 11
Acrylamide	27		Exclude	No 2
PAHs (from coal tars and pitches)	26	Include – Men & women		Yes 12
Occupation as a welder	26	Include – Men	Include	Yes 13
Solar radiation	24	Include – Men & women		Yes 14
Environmental tobacco smoke (ETS)	24	Include – Women		Yes 15
Occupation as a painter	23	Include	Exclude	No 3
Epichlorohydrine	22	Include – Women		Yes 16
Radon	19	Include	Exclude	No 4

Table 2-2: Final selection of top 25 carcinogenic agents				
Carcinogenic agent	**Score (5 studies)**	**Gender relevance (male and/or female)**	**Study team judgement/ discussions with ETUI**	**Selected?**
Tetrachloroethylene	19	Include – Women		Yes 17
Shift work	16	Include – Women		Yes 18
Dioxins	16	Include – Women		Yes 19
Inorganic acid mists containing sulphuric acid	16	Include – Women		Yes 20
Rubber manufacturing industry	15	Include – Men		Yes 21
Ionising radiation		Include – Men & women	Include	Yes 22
Cr(VI) compounds		Include – Men & women	Include	Yes 23
Aromatic amines		Include – Men & women		Yes 24
Cytostatic drugs		Include – Women		Yes 25
Organic solvents		Include - Women		No 5

2.3 WP1-Step 2: Occupationally exposed populations

2.3.1 Introduction

There are a number of sources that provide data on occupational exposure to carcinogens, including national registers, exposure measurement databases and exposure information systems. However, these sources as they stand do not provide a sufficient basis for the analysis in this report (which, as explained below, requires data for 1966-2005 and/or 1996-2015), with the key reasons being that:

- much of the existing data are **outdated**, e.g. CAREX data are available for 1990-93 and 1997, although more recent data are available for some Member States (e.g. SUMER 2010 for France);
- the data often represent a **snapshot in time** and are only available for one or a few years; however, most cancers have very long latency periods that require extensive data on historical populations;
- the data collected at the national level are frequently **not publicly available**. For example, national databases of workers exposed to specific carcinogenic agents such as the SIREP (Italy) and EDPB (Belgium) and the CM register (Poland) are either confidential or not available free of charge;
- the existing datasets typically **do not cover EU-28** and the data are more detailed and reliable for only a few countries; and
- the different data sources are characterised by **different methodologies, coverage, and scope**.

2.3.2 Summary of the approach to WP1-Step 2

Overview

The exposed populations have been estimated by extrapolating from existing data sources (e.g. CAREX, SUMER, ASA, etc.) and combining these extrapolations with the estimated long-term trends to derive the occupationally exposed populations for the time periods appropriate for the relevant cancer site(s).

The reference year

The reference year for the cost calculations is 2015. The reasons for selecting 2015 as the reference year include:

- the need to capture the current burden of past occupational exposure and 2015 was the most recent full year that could be feasibly assessed (the key part of this study was carried out in 2016);
- the possibility to take into account the most recent economic evaluations and epidemiological studies; and
- although cancer incidence rates are not available for 2015, data are not available across all Member States for a single year, with the implication being that it is not possible to select a single reference year for cancer incidence. The most recent cancer incidence data have therefore been takes as the basis for calculations, although these are for different years in different Member States (typically for a year between 2006 and 2012).

Latency/reference periods (RPs)

By way of simplification, the approach taken in Rushton et al (2012) has been adopted for the purposes of this study and all solid tumours are expected to have a latency of 10-50 years and haematopoietic neoplasms are expected to have a latency of 0-20 years. These translate into reference periods (RPs) of 1966-2005 and 1996-2015.

Long-term trends

The long-term trends in terms of annual change to the exposed population have been established for each carcinogenic agent using the following methodology:

- where data were available from a single source for multiple years, these have been used to estimate the long-term trend expressed as the annual rate of change in the exposed population; this included, for example, comparing the number of workers exposed in Finland in 2005 and 2012 (Finnish register of occupational exposure ASA) and in France in 2003 and 2010 (SUMER), as well as similar data in other studies;

- the annual rate of growth or decline estimated from the numbers of workers exposed to specific carcinogens over time in France (SUMER) and/or Finland (ASA) has been applied to the remaining Member States;

- where a more abrupt change is expected to have occurred, e.g. as a result of a restriction on the use of asbestos or a smoking ban, the year that the measure was introduced in each Member State was taken into account and the rate of decline in that Member State was adjusted accordingly; and

- where no trend data were available from SUMER, ASA or another source but a decline is expected to have occurred, a generic rate of decline of 3% has been applied[16].

The annual estimates of the exposed populations and the rates of change used for the different scenarios are summarised below. The estimates of the exposed populations in the table below are extrapolations from published sources, i.e. annual estimates for the year assessed in the relevant study, and, as a result, do not represent the lowest or highest annual estimates over the whole reference period, since these also depend on the annual rate of change applied. For a more detailed overview of the assumptions underpinning the estimations for each carcinogen, please refer to Annex 1.

Table 2-3: Summary of the scenarios (exposed populations and annual rate of change)

Carcinogen	Parameter	Low	High	Midpoint	Central
01 DEE	Annual exposed population (EU-28)	4.4 million in 1990-93 or 1997	8.1 million in 2010	6.3 million in 2010	6.1 million in 2010
	Rate of change (per annum)	1%	0%	0.5%	0%
02 Silica	Annual exposed population (EU-28)	2.2 million (assumed in 2007)	6.6 million (assumed in 2006)	4.4 million (assumed in 2007)	3.85 million (assumed in 2002)
	Rate of change (per annum)	1.3%	-0.5%	0.4%	0.4%
03 Asbestos	Annual exposed population (EU-28)	180,000 (2005)	1.76 million (1994)	970,000 (2000)	1.76 million (1994)
	Rate of change (per annum)	-0.8% -1.6% following a restriction	-3.7% -7.4% following a restriction	-2.2% -4.4% following a restriction	-2.2% -4.4% following a restriction
04 Formaldehyde	Annual exposed population (EU-28)	990,000 (2006)	2.2 million (2012)	1.6 million (assumed 2009)	1.4 million (1993/1997)
	Rate of change (per annum)	0%	-3%	-1.5%	0%
05 Benzene	Annual exposed population (EU-28)	140,000 (2006)	1.6 million (early to mid-1990s)	900,000 (assumed in 2005)	380,000 (2003-2010)
	Rate of change (per annum)	-3.5%	+3.5%	0%	0%
06 Mineral oils	Annual exposed population (EU-28)	4 million (early 1990s[17])	10 million (1994)	7 million (assumed 1994)	1994: 9.7 million 2003: 8.4 million 2010: 5.5 million
	Rate of change (per annum)	0%	+2.8%	+1.4%	-3.5%

[16] This value has recently been used in RPA's Impact Assessment work in the chemicals sector. This assumption is based on expert judgement and is supported by recent trends in the chemicals sector. The number of EU-based companies in NACE C20 has been declining by 3% per annum and employment in NACE C20 has been declining at a rate of 1-2% per annum.

[17] For the purposes of this assessment, the reference year is 1994.

Table 2-3: Summary of the scenarios (exposed populations and annual rate of change)					
Carcinogen	**Parameter**	**Low**	**High**	**Midpoint**	**Central**
07 Cd and Cd compounds	Annual exposed population (EU-28)	90,000 (2005)	440,000 (2010)	270,000 (2007)	310,000 (1990s)
	Rate of change (per annum)	+2.5%	-0.6%	+1.2%	0%
08 Wood dust	Annual exposed population (EU-28)	2.8 million (2010)	6 million (2006)	4.4 million (assumed 2008)	4.1 million (assumed 2000)
	Rate of change (per annum)	0%	-0.4%	-0.2%	0%
09 Arsenic	Annual exposed population (EU-28)	250,000 in 1990-93 or 1997	250,000 in 1990-93 or 1997	250,000 in 1990-93 or 1997	250,000 in 1990-93 or 1997
	Rate of change (per annum)	+6%	-4%	+2%	0%
10 Vinyl chloride	Annual exposed population (EU-28)	6,500 (2010) (NHL 4,300)	50,000-60,000 in early 1990s (NHL 30,000-40,000)	27,000 (assumed in 2002) (NHL 18,000)	20,000 (assumed in 2006)
	Rate of change (per annum)	0%	-10%	-5%	-5%
11 Ethylene oxide	Annual exposed population (EU-28)	2,500 (2014)	50,000 (early to mid-1990s)	26,250 (assumed in 2004)	50,000 (early to mid-1990s)
	Rate of change (per annum)	0%	0%	-7.75%	0%
12 PAHs	Annual exposed population (EU-28)	5,000 (2005) 8,000 (2014)	1.2 million (assumed in 1994)	600,000 (assumed in 1996)	700,000 (assumed in 1994)
	Rate of change (per annum)	4.8%	0%	2.4%	4.8%
13 Occupation as a welder	Annual exposed population (EU-28)	430,000 (2005 and 2014)	6.1 million (assumed in 2002)	3.36 million (assumed in 2003)	4.2 million (assumed in 2003)
	Rate of change (per annum)	3.2%	0%	1.6%	0.9%
14 Solar radiation	Annual exposed population (EU-28)	8.8 million (assumed 2004)	14 million (early to mid-1990s)	11.4 million (assumed 2000)	14 million (early to mid-1990s)
	Rate of change (per annum)	0%	-2%	-1%	-2%
15 Environmental tobacco smoke	Annual exposed population (EU-28)	1.1 million in 2005	10.2 million (early to mid-1990s)	5.7million (assumed 2000)	10.2 million (early to mid-1990s)
	Rate of change (per annum)	Pre-smoking ban: -3% Post-smoking ban: -22% Partial smoking ban: -12.5%	Pre-smoking ban: -3% Post-smoking ban: -22% Partial smoking ban: -12.5%	Pre-smoking ban: -3% Post-smoking ban: -22% Partial smoking ban: -12.5%	Pre-smoking ban: -3% Post-smoking ban: -22% Partial smoking ban: -12.5%
16 Epichloro-	Annual exposed population (EU-	54,000 in 1990-93 or 1997	54,000 in 1990-93 or 1997	54,000 in 1990-93 or 1997	54,000 in 1990-93 or

Table 2-3: Summary of the scenarios (exposed populations and annual rate of change)					
Carcinogen	**Parameter**	**Low**	**High**	**Midpoint**	**Central**
hydrine	28)				1997
	Rate of change (per annum)	-2%	-3.5%	-2.75%	-2%
17 Tetrachloro ethylene	Annual exposed population (EU-28)	220,000 (2010)	1.1 million (assumed in 1994)	660,000 (assumed in 2002)	690,000 (assumed in 1994)
	Rate of change (per annum)	0%	-6%	-3%	-6%
18 Shift work	Annual exposed population (EU-28)	3 million (assumed 2004)	9 million (annual average over 1966-2005)	6 million (assumed 2004)	9 million (annual average over 1966-2005)
	Rate of change (per annum)	0%	-5% p.a.to +6 p.a., depending on the Member State	0%	-5% p.a.to +6 p.a., depending on the MS
19 Dioxins	Annual exposed population (EU-28)	6,000 (2005) 1,500 (2014)	4.2 million (assumed in 1994)	2.1 million (assumed in 2002)	2.1 million (assumed in 2002)
	Rate of change (per annum)	-14%	0%	0%	0%
20 Inorganic acid mists	Annual exposed population (EU-28)	390,000 (2004)	840,000 (early to mid-1990s)	615,000 (assumed in 2000)	615,000 (assumed in 2000)
	Rate of change (per annum)	0%	-3%	-1.5%	-1.5%
21 Rubber manufacturi ng industry	Annual exposed population (EU-28)	125,000 (2010)	408,000 (assumed in 2003)	267,000 (assumed in 2007)	260,000 (assumed in 1999)
	Rate of change (per annum)	4.7%	-2.7%	1%	0%
22 Ionising radiation	Annual exposed population (EU-28)	170,000 (2006)	1.3 million (2006)	720,000 (assumed in 2006)	460,000 (assumed in 1994)
	Rate of change (per annum)	0%	-3%	-1.5%	-3%
23 Cr (VI) compounds	Annual exposed population (EU-28)	420,000 (1994)	1.22 million (assumed in 2003)	820,000 (assumed in 1999)	750,000 (assumed in 2010)
	Rate of change (per annum)	+2.5%	-0.9%	+0.8%	0%
24 Aromatic amines	Annual exposed population (EU-28)	300,000 (1994)	820,000 (assumed in 2003)	560,000 (assumed in 1999)	562,500 (assumed in 2004)
	Rate of change (per annum)	0%	3.7%	1.85%	3.7%
25 Cytostatic drugs	Annual exposed population (EU-28)	Women and men: 375,000 Women: 337,000 (2010)	Women and men: 1.1 million Women: 820,000 (assumed 2012)	Women and men: 740,000 Women: 580,000 (assumed 2011)	Women and men: 420,000 Women: 380,000 (2010)
	Rate of change (per annum)	0%	-3%	-1.5%	0%

Staff turnover ratio

A generic staff turnover ratio of 10% was applied to the annual data in order to estimate the total exposed populations over the whole reference period. This appears to be broadly in line with the turnover ratios extracted from the Eurostat database and takes into account the possibility that some of the turnover is between companies within the same sector rather than between sectors:

- Agriculture, hunting and forestry; fishing: 9% male and 10% female;
- Mining and quarrying; manufacturing; electricity, gas and water: 9% male and 14% female;
- Construction: 13% male and 16% female; and
- Service industries: 11% male and 15% female.

Calculation of the PrE

The proportion of the population at risk of being diagnosed with cancer in the target year that has ever been occupationally exposed to each carcinogen (hereinafter referred to as PrE) has been estimated as follows:

$$PrE = N_e / N_p$$

where

PrE: the proportion of population at risk of being diagnosed with occupational cancer in 2015 that had been exposed to the relevant carcinogen (i.e. ever employed during the RP, exposed to the relevant carcinogen, and surviving to 2015);

N_e: number of people occupationally exposed to the carcinogen during the RP and surviving to 2015; and

N_p: number of people at risk of being diagnosed with cancer and employed during the RP, i.e. ever employed during the RP and in a high risk age cohort.

The number of people occupationally exposed to the carcinogen during the RP and surviving to 2015 $\mathbf{N_e}$ has been calculated by estimating the proportion of the occupationally exposed population in each year surviving to 2015 by applying Eurostat age distribution data for the relevant year and the average life expectancy[18] data for the relevant decade, also obtained from Eurostat. These estimates have been derived for each carcinogen and scenario individually since they also depend on the specific values of the rate of change of the occupationally exposed cohort.

In any given year, only a certain proportion of population is at risk of developing cancer due to past occupational exposure. The population at risk ($\mathbf{N_p}$) thus excludes those that have not worked during the RP (for RP 1966-2005 anyone younger than 25 and, for RP 1996-2015, anyone under the age of 15, as well as those that were of working age 15-64 during the RP but never worked). In addition, those aged 84 and over are expected not to have worked during RP 1996-2015. The long-term unemployment rate (over 12 months) as well as general unemployment rates vary widely between countries[19] and 10% is taken as a proxy for the proportion of people that have been inactive during the RP. Although this is higher than unemployment rates in many countries, please note that

[18] Exposed workforce has eliminated over 80 year olds (average life expectancy), although these are present in the incidence data and population that has ever worked during the RP. This is due to the use of an average life expectancy value and is expected to be compensated by the inclusion the cohort whose statistical life expectancy is below 80.

[19] See https://data.oecd.org/unemp/long-term-unemployment-rate.htm#indicator-chart

published unemployment rates may not include inactivity due to long-term sickness[20]. Using Eurostat data for population by age group (2015) and the 10% proxy for inactivity suggests that 28% (RP 1996-2015) or 37% (RP 1966-2005) should be excluded from N_p (Method A).

As an alternative to the approach set out above, age-specific cancer incidence rates have been examined (Method B). It is clear that the age cohort with a significantly increased risk of developing cancer is that aged 40 and over. Age specific incidence rates for all cancer sites excluding NMSC (C00-97 excl. C44) provided by Cancer Research UK for 2012-2014[21] show that on average 96% of cancers occur in people aged 40 and over (95.7% overall, 96.6% men, 94.7% women) and 50% occur in age groups over 70. At the same time, the age groups over 40 accounted for only 53% of EU-28 population in 2015.

The relevant rates that could be used to adjust the 2015 EU-28 population to derive the N_p are summarised below. It is, however, recognised that the use of a single estimate does not account for differences between the different cancer sites. For example, the age of diagnosis of breast cancer and leukaemia[22] is below the average for all cancer sites[23].

The core assessment in the study relies on Method A. Method B is only used for sensitivity analysis.

Table 2-4: Estimation of Np - population adjustment factor

Method	Cancer site	Age cut-off	Basis	Population adjustment factor 1966-2005	Population adjustment factor 1996-2015
A	All	66-05: <25 96-15: <15 & >85	Eurostat & inactivity estimate	0.63	0.72
B	All except NMSC	40	96% in Cancer Research UK	0.53	

Sources: Population data from Eurostat, Age cut-offs for specific cancer sites from http://www.cancerresearchuk.org/health-professional/cancer-statistics/incidence/age#heading-Zero

2.3.3 Exposed populations – the results

The exposed populations (over the relevant exposure period) estimated using the methodology set out above are summarised below for the EU-28. The first table provides the estimates without adjusting for natural mortality whilst the second table provides the exposed populations surviving until 2015.

[20] See https://www.theguardian.com/uk/2001/sep/05/socialsciences.research

[21] See http://www.cancerresearchuk.org/health-professional/cancer-statistics/incidence/age#heading-Zero

[22] See http://www.cancerresearchuk.org/health-professional/cancer-statistics/statistics-by-cancer-type/leukaemia/incidence#heading-One

[23] See http://www.cancerresearchuk.org/health-professional/cancer-statistics/statistics-by-cancer-type/breast-cancer/incidence-invasive#heading-One

Table 2-5: Numbers ever exposed over the relevant reference period (million workers) by carcinogen					
Carcinogen	**Reference period**	**Low**	**High**	**Midpoint**	**Central**
01 DEE	1966-2005	21	40	28	30
02 Silica	1966-2005	8.7	36.5	20.1	18.1
03 Asbestos	1966-2005	1.1	43*	22*	11.4
04 Formaldehyde	1966-2005	4.9	28.1	12	6.9
	1996-2015	2.9	8.6	5.1	4.1
05 Benzene	1996-2015	0.5	8.2	2.6	1.1
06 Mineral oils	1966-2005	19.6	45.3	32.5	79.4
07 Cd and Cd compounds	1966-2005	0.3	2.6	1.1	1.6
08 Wood dust	1966-2005	13.7	32.4	22.7	20.1
09 Arsenic	1966-2005	1.1	2.2	1.1	1.2
10 Vinyl chloride	1966-2005	0.03	1.08	0.43	0.4
11 Ethylene oxide	1996-2005	0.007	0.15	0.08	0.15
12 PAHs	1966-2005	0.013	5.88	2.60	3.19
	1996-2015	0.018	3.4	2.36	4.18
13 Occupation as a welder	1966-2005	1.4	29.9	13.4	18.3
14 Solar radiation	1966-2005	43.1	82.1	67.4	82.1
15 ETS	1966-2005	11.8	74.0	51.1	74.0
16 Epichlorohydrine	1966-2005	0.3	0.4	0.4	0.3
17 Tetrachloroethylene	1966-2005	1.1	13.0	6.3	8.8
	1996-2015	0.2	0.8	0.7	0.5
18 Shift work	1966-2005	14.7	44.5	29.4	44.5
19 Dioxins	1966-2005	1.7	20.6	10.3	10.3
20 Inorganic acid mists	1966-2005	1.9	5.9	4.0	4.0
21 Rubber manufacturing	1966-2005	0.3	3.7	1.3	1.3
	1996-2015	0.35	1.2	0.8	0.75
	1966-2005 Women	0.02	0.3	0.1	0.1
	1966-2005 Men	0.25	3.4	1.2	1.2
22 Ionising radiation	1966-2005	0.8	13.5	5.1	3.5
	1996-2015	0.5	4.1	1.1	1.0
	1966-2005 Women	0.1	1.9	0.7	0.4
	1966-2005 Men	0.7	11.6	4.4	3.0
23 Cr(VI) compounds	1966-2005	1.9	7.3	3.7	3.7
24 Aromatic amines	1966-2005	1.36	4.02	2.34	1.75
25 Cytostatic drugs	1966-2005 Women	1.7	10.5	4.6	1.9
	1996-2015	1.1	4.3	2.4	1.2
*Estimates refer to the number of people alive in 2007 with a history of occupational exposure to asbestos. Source: Santé Publique France (2016): Estimation de parts de cancers attribuables à certaines expositions professionnelles en France, available at http://invs.santepubliquefrance.fr/Publications-et-outils/Rapports-et-syntheses/Travail-et-sante/2016/Estimation-de-parts-de-cancers-attribuables-a-certaines-expositions-professionnelles-en-France					

The MID-POINT and CENTRAL estimates of the exposed workforce over the relevant reference period are compared below with the estimated derived by the IOM in 2011[24]. When the annual data

[24] See http://ec.europa.eu/social/BlobServlet?docId=10150&langId=en. The figure for silica was taken from the IOM report for silica: http://ec.europa.eu/social/BlobServlet?docId=10161&langId=en

in IOM (2011) are converted to the whole reference period by applying a factor of five, most estimates are of the same order of magnitude as the estimates derived in this study.

Table 2-6: Comparison of numbers ever exposed with results from IOM 2011 (million workers, not taking into account life expectancy)				
Carcinogen	**Midpoint**	**Central**	**IOM annual**	**IOM annual*5**
01 DEE	28	30	3.6	18
02 Silica	20.1	18.1	5.3	26.5
06 Mineral oils & 12 PAHs	35.1	82.6	8	40
08 Wood dust	22.7	20.1	3	15
10 Vinyl chloride	0.43	0.4	0.019	0.095
11 Ethylene oxide	0.08	0.15	0.016	0.08
21 Rubber manufacturing	1.3	1.3	0.23	1.15
23 Cr(VI) compounds	3.7	3.7	0.92	4.6
Notes: The estimates presented in this table for the Mid-point and Central scenarios do not take into account natural mortality and thus represent the number of ever exposed workers over the relevant reference period, not the number of ever exposed workers surviving in 2015. Due to difficulties of classification of mineral oils and PAHs, mineral oils and PAHs have been grouped in this table, resulting in a significantly greater degree of consistency between this study and the IOM reports than would be the case if they were presented separately.				

The table below provides the occupationally exposed populations surviving until 2015. Please see Annex 1 for a split by Member State.

Table 2-7: Workers exposed over the relevant reference period and surviving until 2015 (million workers)					
Carcinogen	**Reference period**	**Low**	**High**	**Midpoint**	**Central**
01 DEE	1966-2005	15.6	28.6	20.5	21.5
02 Silica	1966-2005	6.6	20.2	14.7	13.3
03 Asbestos	1966-2005	0.6	43*	22*	5.6
04 Formaldehyde	1966-2005	3.5	13	6.2	5
	1996-2015	2.8	8.2	4.9	4.1
05 Benzene	1996-2015	0.4	8.1	2.6	1.1
06 Mineral oils	1966-2005	14.1	36.6	24.9	35.5
07 Cd and Cd compounds	1966-2005	0.2	1.4	0.8	1.1
08 Wood dust	1966-2005	9.8	18.1	12.8	14.5
09 Arsenic	1966-2005	0.9	1	0.9	0.9
10 Vinyl chloride	1966-2005	0.02	0.3	0.2	0.2
11 Ethylene oxide	1996-2005	0.007	0.2	0.08	0.2
12 PAHs	1966-2005	0.01	4.2	2.1	2.7
	1996-2015	0.02	4.2	2.4	4.2
13 Occupation as a welder	1966-2005	1.1	21.5	10.4	13.7
14 Solar radiation	1966-2005	31.1	40.9	36	40.9
15 ETS	1966-2005	11.8	74	51.1	74
16 Epichlorohydrine	1966-2005	0.2	0.2	0.2	0.2
17 Tetrachloroethylene	1966-2005	0.8	4.9	2.9	3.3
18 Shift work	1966-2005	10.6	32.1	21.2	32.1
19 Dioxins	1966-2005	0.4	14.8	7.4	7.4
20 Inorganic acid mists	1966-2005	1.4	2.5	2.1	2.1
21 Rubber manufacturing	1966-2005	0.2	1.8	0.9	0.9
	1996-2015	0.4	1.2	0.8	0.8
	1966-2005 W	0.02	0.2	0.07	0.07
	1966-2005 M	0.2	1.6	0.9	0.9

Table 2-7: Workers exposed over the relevant reference period and surviving until 2015 (million workers)					
Carcinogen	**Reference period**	**Low**	**High**	**Midpoint**	**Central**
22 Ionising radiation	1966-2005	0.6	6.3	2.7	1.6
	1996-2015	0.5	4	2.1	1
	1966-2005 W	0.1	0.9	0.4	0.2
	1966-2005 M	0.5	5.4	2.3	1.4
23 Cr(VI) compounds	1966-2005	1.5	5.5	2.8	2.7
24 Aromatic amines	1966-2005	1	2.9	1.8	1.5
25 Cytostatic drugs	1966-2005 W	1.2	4.9	2.4	1.3
	1996-2015	1.1	4.1	2.4	1.2
*Estimates refer to the number of people alive in 2007 with a history of occupational exposure to asbestos. Source: Santé Publique France (2016): Estimation de parts de cancers attribuables à certaines expositions professionnelles en France, available at http://invs.santepubliquefrance.fr/Publications-et-outils/Rapports-et-syntheses/Travail-et-sante/2016/Estimation-de-parts-de-cancers-attribuables-a-certaines-expositions-professionnelles-en-France					

2.3.4 PrE – the results

The number of workers exposed to each carcinogenic agent over the relevant reference period expressed as share of the target population is summarised below.

Table 2-8: Exposed population (adjusted for natural mortality) as % of the at risk population					
Carcinogen	**Reference period**	**Low**	**High**	**Midpoint**	**Central**
01 DEE	1966-2005	4.9%	8.9%	6.4%	6.7%
02 Silica	1966-2005	2.1%	6.3%	4.6%	4.1%
03 Asbestos	1966-2005	0.2%	13.4%	6.9%	1.7%
04 Formaldehyde	1966-2005	1.1%	4.1%	1.9%	1.6%
	1996-2015	0.8%	2.3%	1.4%	1.1%
05 Benzene	1996-2015	0.1%	2.2%	0.7%	0.3%
06 Mineral oils	1966-2005	4.4%	11.4%	7.8%	11.1%
07 Cd and Cd compounds	1966-2005	0.1%	0.4%	0.3%	0.4%
08 Wood dust	1966-2005	3.1%	5.6%	4.0%	4.5%
09 Arsenic	1966-2005	0.3%	0.3%	0.3%	0.3%
10 Vinyl chloride	1966-2005	0%	0.1%	0.1%	0.1%
11 Ethylene oxide	1996-2005	0%	0%	0%	0%
12 PAHs	1966-2005	0%	1.3%	0.7%	0.9%
	1996-2015	0%	1.1%	0.6%	1.1%
13 Occupation as a welder	1966-2005	0.4%	6.7%	3.2%	4.3%
14 Solar radiation	1966-2005	9.7%	12.8%	11.3%	12.8%
15 ETS	1966-2005	2.3%	14.5%	10%	14.5%
16 Epichlorohydrine	1966-2005	0.1%	0.1%	0.1%	0.1%
17 Tetrachloroethylene	1966-2005	0.1%	0.6%	0.4%	0.4%
	1996-2015	0.1%	0.4%	0.4%	0.2%
18 Shift **work**	1966-2005 Women	6.6%	20%	13.2%	20%
19 Dioxins	1966-2005	0.1%	4.6%	2.3%	2.3%
20 Inorganic acid mists	1966-2005	0.4%	0.8%	0.6%	0.6%
21 Rubber manufacturing	1966-2005	0.1%	0.5%	0.3%	0.3%
	1996-2015	0.1%	0.3%	0.2%	0.2%
	1966-2005 Women	0%	0.1%	0%	0%
	1966-2005 Men	0.1%	1.0%	0.5%	0.5%

Table 2-8: Exposed population (adjusted for natural mortality) as % of the at risk population					
Carcinogen	**Reference period**	**Low**	**High**	**Midpoint**	**Central**
22 Ionising radiation	1966-2005	0.2%	2.0%	0.8%	0.5%
	1996-2015	0.1%	1.1%	0.6%	0.3%
	1966-2005 Women	0.1%	0.5%	0.2%	0.1%
	1966-2005 Men	0.3%	3.4%	1.5%	0.9%
23 Cr(VI) compounds	1966-2005	0.5%	1.7%	0.9%	0.8%
24 Aromatic amines	1966-2005	0.3%	0.9%	0.6%	0.5%
25 Cytostatic drugs	1966-2005 Women	0.7%	3.1%	1.5%	0.8%
	1996-2015	0.3%	1.1%	0.6%	0.3%

2.4 WP1-Step 3: Relative risk

The aim of WP1-Step 3 was to collect estimates of relative cancer risk for workers exposed to each of the 25 carcinogenic agents. It should be noted that it was not possible to carry out a comprehensive literature review within the time and budget available for this study and it is likely that additional efforts would identify more relative risk estimates – the significance of this limitation is assessed under WP1-Step 7.

This exercise was not restricted to cancer sites identified as relevant by IARC and data have been collected for all cancer sites for which relative risk estimates could be identified from published literature within the time and budget available for this study. This approach means that this study is not constrained by IARC classifications. The IARC inclusion of carcinogens, whether confirmed or probable, is based on an administrative procedure with decisions being considered only when a reasonable number of studies become available and budgetary and time limitations allow the decision procedure to take place. It may take a number of years following the publication of new findings before a classification decision is taken. Unlike in IARC (2016), no weight of evidence criteria have been established in this study and the sole criterion for the inclusion of a cancer site in this study is the availability of a relative risk estimate for occupational exposure.

For example, the IARC monograph for silica[25] concludes that the evidence for cancers other than lung cancer is too sparse for evaluation but notes that Elci et al (2002) have reported an OR of 1.8 (95% CI: 1.3-2.3) for Turkish workers exposed to crystalline silica dust. The Elci et al (2002) OR has, however, been used to estimate the AF for silica and laryngeal cancer in this study.

Conversely, where a cancer site identified in IARC (2016) as relevant to a carcinogen is not assessed in this study, this is because a relative risk estimate for occupational exposure could not be identified. For example, the IARC Monograph for arsenic[26] has identified several cancer sites as relevant due to contaminated drinking water rather than occupational exposure.

The cancer sites for which risk estimates have been identified are summarised below and are compared with the cancer sites listed in IARC (2016)[27].

[25] See https://monographs.iarc.fr/ENG/Monographs/vol100C/mono100C-14.pdf
[26] See http://monographs.iarc.fr/ENG/Monographs/vol100C/mono100C-6.pdf
[27] IARC (2016): List of classifications by cancer sites with sufficient or limited evidence in humans, available at https://monographs.iarc.fr/ENG/Classification/Table4.pdf

Table 2-9: Comparison of the cancer sites considered in this study and in IARC (2016)			
Carcinogen	**Cancer sites for which AF is estimated in this study**	**IARC (2016)**	**Additional sites from other studies**
01 DEE	Bladder Lung	Bladder Lung	
02 Silica	Larynx Lung	 Lung	
03 Asbestos	Pharynx Stomach Colon And Rectum Larynx Lung Mesothelium (Pleura and Peritoneum) Ovary	Pharynx Stomach Colon And Rectum Larynx Lung Mesothelium (Pleura and Peritoneum) Ovary	
04 Formaldehyde	Leukaemia NFC SNC Lung Brain	Leukaemia and/or lymphoma Nasopharynx Nasal cavity and paranasal sinus	 Lung Brain
05 Benzene	Leukaemia	Leukaemia	 NHL Multiple myeloma
06 Mineral oils	Bladder Lung NMSC	 Skin cancer (other malignant neoplasms)	Bladder Lung
07 Cd and Cd compounds	Lung Kidney	Lung Kidney Prostate	
08 Wood dust	NFC SNC	NFC SNC	
09 Arsenic	Lung	Lung Skin (malignant neoplasms other than melanoma) Bladder Kidney Liver and bile duct Prostate	
10 Vinyl chloride	Liver NHL	Liver	 NHL
11 Ethylene oxide	Lymphoma Leukaemia	Lymphoma Leukaemia Breast	
12 PAHs	Bladder Lung NMSC Stomach Kidney Mesothelioma Pancreas Lymphoma and		Bladder Lung NMSC Stomach Kidney Mesothelioma Pancreas Lymphoma and

Table 2-9: Comparison of the cancer sites considered in this study and in IARC (2016)			
Carcinogen	**Cancer sites for which AF is estimated in this study**	**IARC (2016)**	**Additional sites from other studies**
	Leukaemia		Leukaemia
13 Occupation as a welder	Lung Ocular melanoma	Lung Ocular melanoma	
14 Solar radiation	NMSC	Eye Lip Skin (melanoma) Skin (other malignant neoplasms)	Eye Lip Skin (melanoma)
15 Environmental tobacco smoke	Lung	Larynx Pharynx Lung	
16 Epichlorohydrine	CNS Lung	CNS Lung	
17 Tetrachloroethylene	Bladder Cervix NHL Oesophagus Pancreas	Bladder	Cervix NHL Oesophagus Pancreas
18 Shift work	Breast	Breast	
19 Dioxins	Lung	Lung Soft tissue Leukaemia and/or lymphoma Multiple of unspecified sites – all cancer sites (combines)	
20 Inorganic acid mists	Larynx Lung	Larynx Lung	
21 Rubber manufacturing industry	Bladder Leukaemia Lymphoma Larynx Stomach Lung	Bladder Leukaemia Stomach Lung	Lymphoma Larynx
22 Ionising radiation	Bone Bladder Breast Brain Malignant melanoma Leukaemia Liver Lung Thyroid	Bone Bladder Breast Brain Malignant melanoma Leukaemia Liver Lung Thyroid Salivary gland Oesophagus Stomach Pancreas Bone Ovary Prostate Kidney	

Table 2-9: Comparison of the cancer sites considered in this study and in IARC (2016)			
Carcinogen	**Cancer sites for which AF is estimated in this study**	**IARC (2016)**	**Additional sites from other studies**
		Multiple sites (unspecified) Digestive tract (unspecified) Soft tissue	
23 Cr (VI) compounds	Lung	Lung Nasal cavity and paranasal sinus	
24 Aromatic amines	Bladder	Bladder	
25 Cytostatic drugs	Leukaemia Breast cancer	Leukaemia	

Relative risk estimates have been taken from both meta-analyses and individual cohort studies. A detailed overview of the studies used to estimate the relative risks for each carcinogen is provided in Annex 1.

Similar to the approach taken in the Occupational Cancer in the UK study, different types of Relative Risks (RRs, ORs, PMRs, SIRs, SMRs, HRs) have been used interchangeably. In the approach to the Occupational Cancer in the UK study, Hutchings (2007)[28] notes that

> *Odds ratios (ORs) from case-control studies, standardised mortality ratios (SMRs) from cohort studies or proportional mortality ratios (PMRs), were all used as RR estimates in the calculation of AF. In the case of ORs however, the 'rare disease' assumption (that the probability of disease was very small) needed to be satisfied.*

As a result, the available risk estimates have been used for the purposes of this subtask regardless of the fact that they express different measures of risk. The 'rare disease' assumption has not been examined for ORs.

The relative risks set out below have been used to calculate the AFs for the 25 carcinogenic agents under the different scenarios. The LOW scenario is based on the lowest identified relative risks whilst the HIGH scenario reflects the highest identified relative risks. The criteria used for the selection of the relative risks for the CENTRAL scenarios are set out in the table that follows.

It should be noted that the relative risks under the LOW and HIGH scenarios may not be realistic representations of the real risks and these scenarios have been modelled purely for the reason of providing a lower and the upped bound for the assessment, i.e. to provide a further check on the central AFs. In particular, some of the relative risks used under the LOW and HIGH scenarios are based on studies of specific industries or worker groups and may not be representative of the whole exposed populations. For example, the lung cancer OR used for DEE under the HIGH scenario is based on a study of miners who have a high diesel exposure but it is applied to the whole workforce exposed to DEE. Similar issues are evident in the HIGH relative risks for silica and benzene.

A further limitation of the study is that a single relative risk estimate is applied to the whole exposed population under each scenario and a distribution of the population over different exposure levels is not estimated.

[28] Hutchings (2007): The burden of occupational cancer in Great Britain, available at http://www.hse.gov.uk/research/rrpdf/rr595meth.pdf

Table 2-10: Summary of the scenarios (relative risk)				
Carcinogen	**Low**	**High**	**Midpoint**	**Central-core**
01 DEE	Lung RR=1.15 Bladder RR=1.24	Lung OR=3.2 Bladder RR=1.24	Lung 2.7 Bladder RR=1.24	Lung RR=1.47 Bladder RR=1.24
02 Silica	Lung: RR=1 Laryngeal cancer: OR=1.39	Lung: RR = 2.8 Laryngeal cancer: OR=1.5	Lung: RR=1.9 Laryngeal cancer: OR=1.445	Lung: RR=1.41 Laryngeal cancer: OR=1.5
03 Asbestos	Pharynx: OR=1.41 Stomach: RR=1.11 Colon and rectum: RR=1.15 Larynx: 1 Ovary: SIR=1 Lung: Meso*2	Pharynx: HR=2.2 Stomach: HR=4.59 Colon and rectum: SMR=2.00 Larynx: RR=2.02 Ovary: RR=2.61 Lung: Meso*10	Pharynx: 1.8 Stomach: 2.85 Colon and rectum: 1.58 Larynx: 1.51 Ovary: 1.8 Lung: Meso*6	Pharynx: HR=2.2 Stomach: RR/SMR=1.16 Colon and rectum: RR=1.15 Larynx: RR=1.37 Ovary: SMR=1.77 Lung: Meso*2
04 Formaldehyde	Leukaemia: RR=1 NFC: RR=1 SNC: OR=1 Lung: RR=1 Brain: RR=1	Leukaemia: RR=1.4 NFC: RR=2.1 SNC: OR=2.8 Lung: RR=1.18 Brain: RR=1.56	Leukaemia: RR=1.2 NFC: RR=1.55 SNC: OR=1.9 Lung: RR=1.09 Brain: RR=1.28	Leukaemia: RR=1.4 NFC: RR=2.1 SNC: OR=2.8 Lung: RR=1.18 Brain: RR=1.56
05 Benzene	Leukaemia: OR=1.004	Leukaemia: OR=3.6	Leukaemia: OR=2.3	Leukaemia: *=2.13
06 Mineral oils	Bladder: OR=1 Lung: RR=1 NMSC: RR=1	Bladder: OR=2.6 Lung: RR=2.3 NMSC: RR=1.21	Bladder: OR=1.8 Lung: RR=1.7 NMSC: RR=1.1	Bladder: OR=1.7 Lung: RR=1.9 NMSC: RR=1.21
07 Cd and Cd compounds	Lung: OR=1.19 Kidney: 1.77	Lung: OR=1.54 Kidney: OR=2.5	Lung: OR=1.37 Kidney: 2.14	Lung: OR=1.19 Kidney: OR=1.4
08 Wood dust	NFC: RR= 1.7 SNC: OR=1.4	NFC: 2.4 SNC: RR=5.91	NFC: 1.74 SNC: 3.93	NFC: 2.4 SNC: RR=1.61
09 Arsenic	Lung: SMR=1.2	Lung: OR=4.4	Lung: 2.8	Lung: OR=1.65
10 Vinyl chloride	Liver: RR=1.89 NHL: SIR=4.06	Liver: RR=9.57 NHL: SIR=4.06	Liver: RR=5.73 NHL: SIR=4.06	Liver: SMR=2.4 NHL: SIR=4.06
11 Ethylene oxide	Lymphoma: OR=1.3 Leukaemia: 1.08	Lymphoma: OR=1.3 Leukaemia: 2.29	Lymphoma: OR=1.3 Leukaemia: 1.685	Lymphoma: OR=1.3 Leukaemia: 2.29
12 PAHs	Bladder: SMR=1 Lung: SMR=1 NMSC: RR=1.74 Stomach: SIR=1.95 Kidney: SIR=1.99 Mesothelioma: SIR=2.41 Pancreas: SMR= 2.41 Lymphoma and Leukaemia: SMR=2.03	Bladder: SMR=2.09 Lung: SIR=1.99 NMSC: RR=1.74 Stomach: SIR=1.95 Kidney: SIR=1.99 Mesothelioma: SIR=2.41 Pancreas: SMR= 2.41 Lymphoma and Leukaemia: SMR=2.03	Bladder: SMR=1.55 Lung: SIR=1.5 NMSC: RR=1.74 Stomach: SIR=1.95 Kidney: SIR=1.99 Mesothelioma: SIR=2.41 Pancreas: SMR= 2.41 Lymphoma and Leukaemia: SMR=2.03	Bladder: RR=1.49 Lung: RR=1.12 NMSC: RR=1.74 Stomach: SIR=1.95 Kidney: RR=1.23 Mesothelioma: SIR=2.41 Pancreas: SMR= 2.41 Lymphoma and Leukaemia: SMR=2.03
13 Occupation as a welder	Lung: RR=1.1 Melanoma of the eye: RR=2.05	Lung: RR=1.36 Melanoma of the eye: RR=2.05	Lung: RR=1.23 Melanoma of the eye: RR=2.05	Lung: RR=1.36 Melanoma of the eye: RR=2.05
14 Solar radiation	NMSC RR=1.15	NMSC OR=1.77	NMSC 1.46	NMSC OR=1.77
15 Environmental tobacco smoke	Lung RR=1.15	Lung RR=2.01	Lung RR=1.63	Lung RR=1.24
16 Epichlorohydrine	CNS OR=1	CNS OR=4.2	CNS OR=2.6	CNS OR=4.2

Table 2-10: Summary of the scenarios (relative risk)				
Carcinogen	**Low**	**High**	**Midpoint**	**Central-core**
	Lung OR=1	Lung OR=1.7	Lung OR=1.4	Lung OR=1.7
17 Tetrachloroethylene	Bladder: RR=1.44 Cervical: RR=1.09 NHL: RR=1.29 Oesophagus: RR=2.47 Pancreas: RR=1.27	Bladder: RR=1.44 Cervical: RR=1.95 NHL: RR=1.29 Oesophagus: RR=2.47 Pancreas: RR=1.27	Bladder: RR=1.44 Cervical: RR=1.52 NHL: RR=1.29 Oesophagus: RR=2.47 Pancreas: RR=1.27	Bladder: RR=1.44 Cervical: RR=1.2 NHL: SMR=1.39 Oesophagus: RR=2.47 Pancreas: RR=1.27
18 Shift work	Breast RR=1	Breast RR=4.3	Breast RR=2.62	Breast RR=1.51
19 Dioxins	Lung: RR=1.1	Lung: RR=1.5	Lung: RR=1.25	Lung: RR=1.5
20 Inorganic acid mists	Larynx: RR=4.28 Lung: RR=1.36	Larynx: RR=4.28 Lung: RR=1.36	Larynx: RR=4.28 Lung: RR=1.36	Larynx: RR=4.28 Lung: RR=1.36
21 Rubber manufacturing industry	Bladder: SMR=1.15 Leukaemia: 1.03 Lymphoma: SMR=1.02 Larynx: RR=1.19 Stomach: SMR=1 Lung-males: RR=1.29 Lung-females: RR=1.15	Bladder: RR=8.25 Leukaemia: 1.70 Lymphoma: SMR=1.02 Larynx: RR=1.19 Stomach: RR=3.5 Lung-males: RR=2.3 Lung-females: RR=2.9	Bladder: RR=4.7 Leukaemia: 1.37 Lymphoma: SMR=1.02 Larynx: RR=1.19 Stomach: RR=2.25 Lung-males: RR=1.8 Lung-females: RR=1.9	Bladder: SIR=2.87 Leukaemia: SMR=1.5 Lymphoma: SMR=1.02 Larynx: RR=1.19 Stomach: SMR=1.83 Lung-males: RR=2.3 Lung-females: RR=2.9
22 Ionising radiation	Bone: RR=1.03 Bladder: SIR=1 Breast: SIR=1.4 Brain: SIR=1.68 Malignant melanoma: SMR=1.78 Leukaemia: SIR=1 Liver: SIR =1 Lung: SIR=1 Thyroid: SIR=1.39	Bone: RR=7.6 Bladder: SIR=1 Breast: SIR=1.4 Brain: SIR=1.68 Malignant melanoma: SMR=1.78 Leukaemia: RR=2.4 Liver: RR=1.8 Lung: RR=2.77 Thyroid: OR=2.1	Bone: RR=4.3 Bladder: SIR=1 Breast: SIR=1.4 Brain: SIR=1.68 Malignant melanoma: SMR=1.78 Leukaemia: RR=1.7 Liver: RR=1.4 Lung: RR=1.88 Thyroid: OR=1.75	Bone: RR=1.03 Bladder: SIR=1 Breast: SIR=1.4 Brain: SIR=1.68 Malignant melanoma: SIR=2.15 Leukaemia: *=1.11 Liver: RR=1.01 Lung: Men RR=1.05, Women RR=1.021 Thyroid: RR=1.09
23 Cr(VI) compounds	Lung: RR=1 SNC: RR=3.34	Lung: SMR=1.44 SNC: PMR=5.18	Lung: RR=1.22 SNC: *=4.26	Lung: OR=1.25 SNC: RR=3.34
24 Aromatic amines	Bladder: RR=1	Bladder: OR=3.3	Bladder: RR=2.15	Bladder: RR/SRR=1.3
25 Cytostatic drugs	Breast: OR=1.65 Leukaemia: RR=10.65	Breast: OR=1.65 Leukaemia: RR=10.65	Breast: OR=1.65 Leukaemia: RR=10.65	Breast: OR=1.65 Leukaemia: RR=10.65
Note: Where a measure of the relative risk (RR, SMR, etc.) is not specified, this means that it was either not given in the relevant study, two different measures of relative risk (e.g. and OR and an RR) were combined into a mid-point value, or it was estimated from another measure (e.g. ERR per dose). Studies cited in Rushton et al (2012) assumed to be RR, unless established otherwise.				

The criteria for the selection of the risk estimates for the CENTRAL scenarios (Central-core and 95% CI for Central-low and Central-high) have been as follows in terms of priority given to different studies:

1. Meta-analyses, IARC monographs also given some precedence
2. Most recent studies
3. Studies adopted by other burden of disease studies and/or IARC

4. Studies with the largest population/broadest cohorts and/or cohorts in the EU or comparable countries
5. Studies used for one or more other carcinogenic agents
6. ORs or RRs were chosen in preference to a SMR given our approach is not focused only on mortality

Table 2-11: The CENTRAL scenarios – Relative risks				
Carcinogen	**Central-core: relative risk**	**Central-low and central-high 95% CI (unless specified otherwise)**	**Source**	**Reasons for selection**
01 DEE	Lung RR=1.47	1.29-1.67	Lipsett & Campleman (1999), cited in IOM (2011) & Rushton et al (2012)	1,3,5
	Bladder RR=1.24	1.01-1.41	Boffetta & Silverman (2001), cited in IOM (2011) and Rushton et al (2012)	1,3,5
02 Silica	Lung: RR=1.41	1.18-1.67	Peluchi (2006), cited in Sante Publique France (2016)	1, 2, 6
	Laryngeal cancer: OR=1.5	1.2-1.9	Elci et al (2002), cited in Sante Publique France (2016)	4
03 Asbestos	Pharynx: HR=2.2	1.08-4.49	Offermans et al (2014)	2, 4
	Stomach: SMR=1.15, RR=1.17	SMR: 1.03-1.27 RR: 1.04-1.28	Forunato & Rushton (2012) IOM (2006)	1,2 5,6
	Colon and rectum: RR=1.15	1.01-1.31	IOM (2006)	1,6
	Larynx: RR[b]=1.37	1.17-1.6	Forunato & Rushton (2012), cited in Rushton et al (2012)	1, 3, 5, 6
	Ovary: SMR=1.77	1.37-2.28	Camargo et al (2011)	1,2
04 Formaldehyde	Leukaemia: RR=1.4	n/a	Rushton & Hutchings (2007) and Rushton & Hutchings (2007a)	5
	NFC: SMR=2.1	1.05-4.21	Hauptmann et al (2004), cited in Slack (2012)	3
	SNC: OR=2.8	1.8-4.3	Hansen & Lassen (2011)	2
	Lung: RR=1.18	1.12-1.2	Siew et al (2012)	2,4
	Brain: RR=1.56	n/a	Bosetti et al (2008)	1
05 Benzene	Leukaemia: *=2.13 (average of 1.64 for low exposure and 2.62 for high exposure)	Low exposure: 1.13-2.39 High exposure: 1.57-4.39	Khalade et al (2010)	1,2,4
06 Mineral oils	Bladder: OR=1.7	1.1-2.5	Colt et al (2014)	4
	Lung: RR=1.9	1.1-3.3	Ronneberg et al (1988)	4**
	NMSC: OR=1.21	0.48-3.06	IOM (2011), from Mitropoulos & Norman (2005)	1
07 Cd and Cd compounds	Lung: OR/*=1.19	0.09-1.29	t'Mannetje A et al (2003) Verougstraete et al	1,4,5

Table 2-11: The CENTRAL scenarios – Relative risks				
Carcinogen	**Central-core: relative risk**	**Central-low and central-high 95% CI (unless specified otherwise)**	**Source**	**Reasons for selection**
			(2003), cited in Rushton et al (2012)	
	Kidney: OR=1.4	0.69-2.85	Boffetta et al (2011)	2
08 Wood dust	NFC: SMR=2.4	1.10-4.50	Demers et al (1995), cited in Rushton et al (2012)	3, 4, 5
	SNC: RR=1.61	1.10-2.37	Binazzi et al (2015)	1,2, 5
09 Arsenic	Lung: OR=1.65	1.05-2.58	t'Mannetje et al (2003)	4,6
10 Vinyl chloride	Liver: SMR=2.40	1.80-3.14	Ward et al (2001)	2
	NHL: SIR=4.06	1.64-10.0	Budroni et al (2010)	***
11 Ethylene oxide	Lymphoma: OR=1.3	0.7-2.1	Kiran et al (2012)	***
	Leukaemia: SMR=2.29	0.64-6.02	Coggon et al (2004), cited in IOM (2011) and Rushton et al (2012)	2, 3
12 PAHs	Bladder: RR=1.49	n/a	Bosetti et al (2006)	1
	Lung: RR=1.12	n/a	Bosetti et al (2006)	1
	NMSC: RR=1.74	1.07-2.65	Partanen & Boffetta (1994)	***
	Stomach: SIR=1.95	1.16-3.29	Sim et al (2009)	***
	Kidney: RR=1.23	n/a	Bosetti et al (2006)	1
	Mesothelioma: SIR=2.41	1.00-5.78	Sim et al (2009)	***
	Pancreas: SMR= 2.41	1.11-5.23	Carta et al (2004)	***
	Lymphoma and Leukaemia: SMR=2.03	1.03-4.00	Carta et al (2004)	***
13 Occupation as a welder	Lung: OR=1.36	1.00-1.86	t'Mannetje et al (2012)	4
	Melanoma of the eye: RR=2.05	1.20-3.51	Shah et al (2005), cited in Rushton et al (2012)	***
14 Solar radiation	NMSC OR=1.77	1.40-2.22	Fartasch et al (2012)	1, 2
15 Environmental tobacco smoke	Lung: RR=1.24	1.18-1.29	Stayner et al (2007)	2
16 Epichlorohydrine	CNS: OR=4.2	0.7-26.0	Barbone et al (1994)	***
	Lung: OR=1.7	0.7-2.6	Barbone et al (1994), cited in IOM (2011)	***
17 Tetrachloroethylene	Bladder: RR=1.44	1.07-1.93	Lynge et al (2006)	***
	Cervical: RR=1.2	0.6-2.2	Lunge et al (2006)	2,4
	NHL: SMR=1.39	0.56-2.86	Ruder et al (2001), cited in Rushton et al (2012)	***
	Oesophagus: SMR=2.47	1.35-4.14	Ruder et al (2001), cited in Rushton et al (2012)	***
	Pancreas: RR=1.27	0.7-2.0	Lynge et al (2006)	***
18 Shift work	Breast RR=1.51	1.36-1.68	Megdal et al (2005)	1,3
19 Dioxins	Lung: RR=1.5	n/a	IARC (2012)	1
20 Inorganic acid mists	Larynx: RR[b]=4.28	2.13-8.58	Steenland & Beaumont (1989), cited in Rushton et al (2012)	***
	Lung: RR[b]=1.36	0.97-1.94	Steenland & Beaumont	***

Table 2-11: The CENTRAL scenarios – Relative risks				
Carcinogen	**Central-core: relative risk**	**Central-low and central-high 95% CI (unless specified otherwise)**	**Source**	**Reasons for selection**
			(1989), cited in Rushton et al (2012)	
21 Rubber manufacturing industry	Bladder: SIR=2.87	2.02-3.96	Carreon et al (2014)	6
	Leukaemia: SMR=1.5	1.0-2.1	IARC (2012)	1
	Lymphoma: SMR=1.02	0.86-1.21	Alder et al (2006)	***
	Larynx: SMR=1.19	0.82-1.62	Sorahan et al (1989), cited in Rushton et al (2012)	***
	Stomach: SMR=1.83	1.23-2.72	Boniol et al (2016)	2
	Lung: Men RR=2.3 Women RR=2.9	Men: 1.0-5.0 Women: 1.0-8.2	IARC (2012)	1
22 Ionising radiation	Bone: RR=1.03	n/a[a]	UNSCEAR (2006), cited in Rushton et al (2012)	2,3
	Bladder: SIR=1 (0.36)	0.12-0.82	Band et al (2006)	****
	Breast: SIR=1.4	1.19-1.65	Buja et al (2006)	***
	Brain: SIR=1.68	0.66-3.62	Zeeb et al (2002)	***
	Malignant melanoma: SIR=2.15	1.56-2.88	Buja et al (2007)	1, 6
	Leukaemia: *=1.11	90%CI: 1.04-1.18	UNSCEAR (2006), cited in Rushton et al (2012)	2,3
	Liver: RR[b]=1.01	n/a[a]	UNSCEAR (2006), cited in Rushton et al (2012)	2,3
	Lung: Men RR[b]=1.05 Women RR[b]=1.021	n/a[a]	UNSCEAR (2006), cited in Rushton et al (2012)	2,3
	Thyroid: RR[b]=1.09	n/a[a]	UNSCEAR (2006), cited in Rushton et al (2012)	
23 Cr(VI) compounds	Lung: OR=1.25	0.95-1.65	t'Mannetje et al (2011)	2,4
	SNC: RR=3.34	0.4-10.5	IOM (2011)	3,5
24 Aromatic amines	Bladder: RR/SRR=1.30	1.15-1.4	Harling et al (2010) Takkouche et al (2009)	1, 2
25 Cytostatic drugs	Breast: OR=1.65	0.53-5.17	Gunnarsdottir et al (1997)	***
	Leukaemia: RR=10.65	1.29-38.5	Skov et al (1992)	***

Notes:
*not specified whether RR, OR, SMR, SIR
** broadly consistent with Friesen et al (2012) and Acquavella et al (1993)
*** only a single study available
**** <1, set at 1
****Estimated from ERR per dose

[a] Confidence Intervals not estimated for cancers attributed to ionizing radiation in UNSCEAR (2008)
[b] Studies cited in Rushton et al (2012) assumed to be RR, unless established otherwise.

2.5 WP1-Step 4: Attributable fractions (AFs)

An Attributable Fraction (AF) is the proportion of cancer cases that can be attributed to occupational exposures to a carcinogen; in other words, it is the proportion that would not have occurred in the absence of occupational exposure. These AFs have been estimated for each of the 25 carcinogens.

2.5.1 Summary of the methodology

Levin's equation

Levin's equation has been used for the calculation of the AFs. This equation is summarised in Rushton et al (2010)[29] as follows:

$$AF = Pr(E)(RR-1)/\{1+Pr(E)(RR-1)\}$$

where RR=relative risk and Pr(E)=proportion of the population exposed.

The total AF for each cancer site has been calculated using the formula provided in Hutchings (2007)[30] for combining AFs in cases where exposed populations overlap but are independent and risks are assumed to be multiplicative:

$$AF_{overall} = 1-(1-AF_1)\times(1-AF_2)\times\ldots\times(1-AF_n)$$

The AF for each cancer site has been applied to cancer incidence data under WP1-Step 5 and the sum of the resulting Attributable Numbers (ANs) was combined with total cancer incidence to calculate the Overall Attributable Fraction (OvAF) across the 25 carcinogenic agents and all the relevant cancer sites.

AFs for women and men

Three different AFs have been calculated for each carcinogen, one for each gender and another one for the whole exposed workforce. This necessitated the estimation of the shares of women and men within the exposed workforce. The key sources for this were the SUMER and ASA databases. Where different data were given for different countries and years, an average has been used.

The shares for each gender are summarised below for each carcinogen.

Table 2-12: % of MEN and WOMEN in occupationally exposed populations

Carcinogen	% of exposed workers (MEN)	% of exposed workers (WOMEN)
01 DEE	95%	5%
02 Silica	93%	7%
03 Asbestos	96%	4%
04 Formaldehyde	45%	55%
05 Benzene	90%	10%
06 Mineral oils	96%	4%
07 Cd and Cd compounds	84%	16%
08 Wood dust	92%	8%
09 Arsenic	88%	12%

[29] Rushton et al (2012): Occupational cancer burden in GB, available at http://www.nature.com/bjc/journal/v102/n9/full/6605637a.html

[30] Hutchings (2007): The burden of occupational cancer in Great Britain, available at http://www.hse.gov.uk/research/rrpdf/rr595meth.pdf

Table 2-12: % of MEN and WOMEN in occupationally exposed populations		
Carcinogen	**% of exposed workers (MEN)**	**% of exposed workers (WOMEN)**
10 Vinyl chloride	85%	15%
11 Ethylene oxide	45%	55%
12 PAHs	86%	14%
13 Occupation as a welder	97%	3%
14 Solar radiation	82%	18%
15 ETS	36%	64%
16 Epichlorohydrine	77%	23%
17 Tetrachloroethylene	63%	37%
18 Shift work	0%	100%
19 Dioxins	56%	44%
20 Inorganic acid mists	50%	50%
21 Rubber manufacturing	95%	5%
22 Ionising radiation	50%	50%
23 Cr(VI) compounds	89%	11%
24 Aromatic amines	52%	48%
25 Cytostatic drugs	15%	85%

2.5.2 The results (AFs for cancer incidence)

The AFs per cancer site are given below for each of the scenarios. The AFs for each carcinogen and cancer site are given overleaf for the three central scenarios (Central-low, Central-core, and Central-high).

Table 2-13: AFs per cancer site across the 25 carcinogenic agents (reference year: 2015) EUCAN (EUREG)							
Cancer site	**No. of agents***	**Low**	**Central-low**	**Central-core**	**Central-high**	**High**	**Midpoint**
Bladder	7	1.2%	2.0%	9.8%	18.1%	23.3%	9.3%
Bone	1	0.004%	0.01%	0.01%	0.01%	6.1%	1.9%
Brain	2	0.1%	0.9%	1.2%	2.1%	3.5%	1.1%
Breast	3	0.5%	6.7%	9.8%	15%	41.1%	18.5%
Cervix	1	0.01%	0%	0.05%	0.3%	0.4%	0.2%
CNS	1	0.0%	0%	0.2%	1.2%	0.2%	0.1%
Colon & rectum	1	0.03%	0.02%	0.3%	0.5%	11.8%	3.8%
Eye	1	0.4%	0.8%	4.3%	9.7%	6.6%	3.3%
Kidney	2	0.06%	0.2%	0.7%	0.8%	1.9%	0.9%
Larynx	4	2.2%	1.8%	4.7%	9.2%	17%	7.3%
Leukaemia	6	2.8%	0.7%	4.0%	12.5%	17%	7.4%
Liver & bile duct	2	0.01%	0.05%	0.1%	0.1%	2.4%	0.6%
Lung**	16	7.9% (14.2%)	27.1% (46.3%)	36.8% (53.5%)	47.6% (61.5%)	65% (81.7%)	39.6% (54.1%)
Lymphoma	2	0.002%	0%	0.02%	0.09%	0.02%	0.01%
Lymphoma &leukaemia	1	0.01%	0.03%	1.2%	3.3%	1.0%	0.7%
Malignant melanoma	1	0.1%	0.3%	0.6%	0.9%	1.5%	0.6%
Mesotheliu m	2	95.0%	95.0%	95.1%	95.2%	95.1%	95.0%
NHL	2	0.04%	0.02%	0.3%	1.1%	0.4%	0.2%
NMSC	3	1.4%	4.9%	11.6%	30.5%	11.9%	6.1%

Table 2-13: AFs per cancer site across the 25 carcinogenic agents (reference year: 2015) EUCAN (EUREG)							
Cancer site	**No. of agents***	**Low**	**Central-low**	**Central-core**	**Central-high**	**High**	**Midpoint**
Oesophagus	1	0.1%	0.1%	0.6%	1.3%	0.9%	0.5%
Ovary	1	0%	0.05%	0.1%	0.2%	1.8%	0.5%
Pancreas	2	0.03%	0.1%	1.3%	3.9%	2%	1%
Pharynx incl. NFC	3	2.2%	0.7%	9.4%	22.5%	23.6%	8.9%
SNC	3	2.3%	1.7%	7.1%	17%	31.9%	14.5%
Stomach	3	0.02%	0.3%	1.3%	2.9%	34.3%	12.1%
Thyroid	1	0.1%	0.04%	0.04%	0.04%	2.1%	0.6%
Note: *Number of carcinogenic agents included in the AF; **Since lung cancer AF is estimated from mesothelioma incidence, the AF also depends on the total number of cancer registrations. As a result, the AFs differ depending on whether EUCAN or EUREG (see Section 2.6) is used as the basis for the estimation of the AFs. The first value presented is based on EUCAN and the number in parentheses is based on EUREG.							

Table 2-14: AFs per cancer site (Central-low)																								
Carcinogen	Bladder	Bone	Brain	Breast	Cervix	CNS	Colon & rectum	Eye	Kidney	Larynx	Leukaemia	Liver & bile duct	Lung	Lymphoma	Lymphoma and leukaemia	Malignant melanoma	Mesothelium	NHL	NMSC	Oesophagus	Ovary	Pancreas	Pharynx incl. NFC	Sinonasal (SNC)	Stomach	Thyroid
Diesel exhaust	0.07 %												1.9%													
Silica										0.8%			0.7%													
Asbestos							0.02 %			0.3%			21.6 % (42.3 5%)				95%				0.05 %		0.1%		0.1%	
Formalde hyde			0.9%								0.4%		0.2%										0.1%	1.2%		
Benzene											0.1%															
Mineral oils	1.1%												1.1%						0%							
Cd and Cd compoun ds									0%				0%													
Wood dust																							0.4%	0.4%		
Arsenic													0.01 %													
Vinyl chloride												0.04 %						0.02 %								
Ethylene oxide											0%			0%												
PAHs	0.4%								0.2%				0.1%		0.03 %		0%		0.1%			0.09 %			0.1%	
Occupatio n as a welder								0.8%					0%													
Solar radiation																			4.9%							
ETS													1.9%													
Epichloro hydrine						0%							0%													
Tetrachlor oethylene	0.03 %				0%													0%		0.14 %		0%				
Shift work				6.7%																						
Dioxins													1.1%													

Table 2-14: AFs per cancer site (Central-low)																								
Carcinogen	Bladder	Bone	Brain	Breast	Cervix	CNS	Colon & rectum	Eye	Kidney	Larynx	Leukaemia	Liver & bile duct	Lung	Lymphoma	Lymphoma and leukaemia	Malignant melanoma	Mesothelium	NHL	NMSC	Oesophagus	Ovary	Pancreas	Pharynx incl. NFC	Sinonasal (SNC)	Stomach	Thyroid
Inorganic acid mists										0.7%			0%													
Rubber manufacturing	0.3%									0%	0%		0%	0%											0.1%	
Ionising radiation	0%	0.01 %	0%	0.03 %							0.01 %	0%	0.02 %			0.3%										0.04 %
Cr(VI) compounds													0%											0.00 %		
Aromatic amines	0.07 %																									
Cytostatic drugs				0%							0.1%															
OvAF	***2%***	***0.01 %***	***0.9%***	***6.7%***	***0%***	***0%***	***0.02 %***	***0.8%***	***0.2%***	***1.8%***	***0.7%***	***0.05 %***	***27.1 % (46.3 3%)***	***0%***	***0.03 %***	***0.3%***	***95%***	***0.02 %***	***4.9%***	***0.14 %***	***0.05 %***	***0.09 %***	***0.7%***	***1.7%***	***0.3%***	***0.04 %***

Table 2-15: AFs per cancer site (Central-core)																								
Carcinogen	Bladder	Bone	Brain	Breast	Cervix	CNS	Colon & rectum	Eye	Kidney	Larynx	Leukaemia	Liver & bile duct	Lung	Lymphoma	Lymphoma and leukaemia	Malignant melanoma	Mesothelium	NHL	NMSC	Oesophagus	Ovary	Pancreas	Pharynx incl. NFC	Sinonasal (SNC)	Stomach	Thyroid
Diesel exhaust	1.6%												3.1%													
Silica										2%			1.7%													
Asbestos							0.3%			0.6%			21.6 % (42.3 5%)				95%				0.1%		2.1%		0.3%	
Formaldehyde			0.9%								0.4%		0.3%										1.7%	2.7%		
Benzene											0.3%															

Table 2-15: AFs per cancer site (Central-core)																									
Carcinogen	Bladder	Bone	Brain	Breast	Cervix	CNS	Colon & rectum	Eye	Kidney	Larynx	Leukaemia	Liver & bile duct	Lung	Lymphoma	Lymphoma and leukaemia	Malignant melanoma	Mesothelium	NHL	NMSC	Oesophagus	Ovary	Pancreas	Pharynx incl. NFC	Sinonasal (SNC)	Stomach	Thyroid
Mineral oils	7.2%												9.1%						2.3%							
Cd and Cd compounds									0.5%				0.2%													
Wood dust																							5.9%	2.7%		
Arsenic													0.2%													
Vinyl chloride												0.1%						0.1%								
Ethylene oxide											0.1%			0.01 %												
PAHs	0.4%								0.2%				0.1%		1.2%		1.2%		0.6%			1.2%			0.8%	
Occupation as a welder								4.3%					1.5%													
Solar radiation																			9%							
ETS													2.5%													
Epichlorohydrine						0.2%							0.03 %													
Tetrachloroethylene	0.2%				0.05 %													0.2%		0.6%		0.1%				
Shift work				9.3%																						
Dioxins													1.1%													
Inorganic acid mists										2.1%			0.2%													
Rubber manufacturing	0.5%									0.1%	0.1%		0.7%	0.004 %											0.2%	
Ionising radiation	0%	0.01 %	0.3%	0.1%							0.03 %	0.005 %	0.02 %			0.6%										0.04 %
Cr(VI) compounds													0.2%											1.9%		
Aromatic amines	0.1%																									

Table 2-15: AFs per cancer site (Central-core)																								
Carcinogen	Bladder	Bone	Brain	Breast	Cervix	CNS	Colon & rectum	Eye	Kidney	Larynx	Leukaemia	Liver & bile duct	Lung	Lymphoma	Lymphoma and leukaemia	Malignant melanoma	Mesothelium	NHL	NMSC	Oesophagus	Ovary	Pancreas	Pharynx incl. NFC	Sinonasal (SNC)	Stomach	Thyroid
Cytostatic drugs				0.5%							3.1%															
OvAF	***9.8%***	***0.01 %***	***1.2%***	***9.8%***	***0.05 %***	***0.2%***	***0.3%***	***4.3%***	***0.7%***	***4.7%***	***4%***	***0.1%***	***36.8 % (53.47)***	***0.02 %***	***1.2%***	***0.6%***	***95.1 %***	***0.3%***	***11.6 %***	***0.6%***	***0.1%***	***1.3%***	***9.4%***	***7.1%***	***1.3%***	***0.04 %***

Table 2-16: AFs per cancer site (Central-high)																										
Carcinogen	Bladder	Bone	Brain	Breast	Cervix	CNS	Colon & rectum	Eye	Kidney	Larynx	Leukaemia	Liver & bile duct	Lung	Lymphoma	Lymphoma and leukaemia	Malignant melanoma	Mesothelium	NHL	NMSC	Oesophagus	Ovary	Pancreas	Pharynx incl. NFC	Sinonasal (SNC)	Stomach	Thyroid
Diesel exhaust	2.7%												4.3%													
Silica										3.6%			2.7%													
Asbestos							0.5%			1%			21.6 %				95%				0.2%		5.8%		0.5%	
Formaldehyde			0.9%								0.4%		0.3%										4.8%	4.9%		
Benzene											0.7%															
Mineral oils	14.3 %												20.3 %						18.6 %							
Cd and Cd compounds									0.6%				0.1%													
Wood dust																							13.6 %	5.8%		
Arsenic													0.4%													
Vinyl chloride												0.1%						0.3%								
Ethylene oxide											0.2%			0.04 %												
PAHs	0.4%								0.2%				0.1%		3.3%		3.9%		1.4%			3.5%			1.9%	

Table 2-16: AFs per cancer site (Central-high)																									
Carcinogen	Bladder	Bone	Brain	Breast	Cervix	CNS	Colon & rectum	Eye	Kidney	Larynx	Leukaemia	Liver & bile duct	Lung	Lymphoma	Lymphoma and leukaemia	Malignant melanoma	Mesothelium	NHL	NMSC	Oesophagus	Ovary	Pancreas	Pharynx incl. NFC	Sinonasal (SNC)	Stomach	Thyroid
Occupation as a welder								9.7%					3.5%													
Solar radiation																			13.5 %							
ETS													3%													
Epichlorohydrine						1.2%							0.1%													
Tetrachloroethylene	0.4%				0.3%													0.8%		1.3%		0.4%				
Shift work				12%																						
Dioxins													1.1%													
Inorganic acid mists										4.7%			0.6%													
Rubber manufacturing	0.8%									0.2%	0.2%		0.4%	0.04 %											0.5%	
Ionising radiation	0%	0.01 %	1.3%	0.1%							0.05 %	0%	0.0%			0.9%										0.04 %
Cr(VI) compounds													0.5%											7.3%		
Aromatic amines	0.2%																									
Cytostatic drugs				3.4%							11%															
OvAF	***18.1 %***	***0.01 %***	***2.1%***	***15.0 %***	***0.3%***	***1.2%***	***0.5%***	***9.7%***	***0.8%***	***9.2%***	***12.5 %***	***0.1%***	***47.6 %***	***0.1%***	***3.3%***	***0.9%***	***95.2 %***	***1.1%***	***30.5 %***	***1.3%***	***0.2%***	***3.9%***	***22.5 %***	***17%***	***2.9%***	***0.04 %***

The Overall AFs (OvAFs) for the 25 carcinogens derived for the different scenarios are summarised below. A more detailed presentation of the AFs and OvAFs (including a breakdown by gender) is provided in Annex 4.

Table 2-17: Incidence OvAFs for all cancer sites across the 25 carcinogenic agents (reference year: 2015)			
Scenario	**Central-low**	**Central-core**	**Central-high**
Core assessment			
Overall AF Both genders	6%	8%	12%
Overall AF (OvAF) Women	3%	5%	7%
Overall AF (OvAF) Men	6%	10%	15%
Sensitivity analysis –excl. shift-work			
Overall AF Both genders	5%	7%	10%
Overall AF (OvAF) Women	1%	2%	4%

As shown in the table above, the estimates derived under the Central scenarios range from 6% to 12% with the core estimate being 8%. It should be noted that the AFs estimated in this study are for cancer incidence rather than mortality and they relate to the 25 specific carcinogenic agents and do not capture cancer incidence resulting from all occupational carcinogens.

The OvAFs estimated under the Low and High scenarios range from 2% to 20%, with the mid-point estimate being 10%. However, the Low and High scenarios may not be realistic representations of the real extent of occupational cancer[31] and they have been modelled purely for the reason of providing a lower and the upped bound for the assessment. However, they provide a further check on the central AFs estimated in this study. In particular, it is noted that the Mid-point scenario (OvAF: 10%) is positioned very close to the Central-core estimate.

Due to the importance of shift-work to the OvAF for women, the OvAFs are also presented above for a scenario whereby shift-work is excluded from the analysis. This confirms that approximately one half of the female occupational cancer incidence estimated in this study is linked to shift-work.

2.6 WP1-Step 5: Attributable numbers (ANs)

Under WP1-Step 5, the calculated AFs were applied to cancer incidence data to generate the numbers of occupational cancers in EU Member States, the so-called attributable numbers (ANs).

This involved collating data from EUREG (complemented by GCO Cancer Today and UK data) and EUCAN registries and applying cancer site specific AFs to these data. Both EUREG and EUCAN have been used for this step. Although EUCAN provides more recent (and more internally consistent) data, EUREG is more detailed in terms of the cancer sites covered. In addition, mesothelioma incidence has been estimated on the basis of the most recent data on the number of registrations in the UK and incorporated into the EUREG dataset.

[31] In particular, some of the relative risks used under the LOW and HIGH scenarios are based on studies of specific industries or worker groups and may not be representative of the whole exposed populations. For example, the lung cancer OR used for DEE under the HIGH scenario is based on a study of miners who have a high diesel exposure but it is applied to the whole workforce exposed to DEE.

2.6.1 EUREG & GCO: summary of cancer incidence data

Data on cancer incidence broken down by site are available for the majority of EU Member States from the EUREG database.[32] For Member States where data are missing or partial, additional data have been derived from the Global Cancer Observatory (GCO) Cancer Today dataset.[33]

Mesothelioma incidence across the EU has been estimated by extrapolating the UK data over the EU because the UK appears to have the most comprehensive dataset on mesothelioma incidence. The UK data suggest that there are currently around 40 cases of mesothelioma per year per million inhabitants whilst data for other countries[34] suggest a similar or lower order of magnitude. A review of mesothelioma incidence data carried out by Bianchi & Bianchi (2014)[35] shows that the highest incidence rates are reported for United Kingdom, the Netherlands, Malta, and Belgium whilst lower incidence/mortality rates are reported for Central Europe. It is, however expected that this may reflect a lack of reliable data collection rather than lower incidence of mesothelioma per se. For this reason, the use of UK data for extrapolation to the EU-28 is seen as appropriate. The UK data have been extrapolated to the other EU Member States using per capita incidence rates provided in Bianchi & Bianchi (2014). Where not data on national incidence was available, the average of all available national rates was applied.

The EU-28 totals per cancer site are presented in the following table.

Table 2-18: Cancer incidence data and estimates (EU-28) – EUREG, Cancer Today, UK registrations

Cancer site	Data available?	Annual registrations
Bladder	Yes	52,499
Bone	Yes	2,920
Brain	No	
Breast	Yes	196,119
Cervix	Yes	17,474
CNS	Yes	21,578
Colon & rectum	Colon + rectum	190,398
Eye	Yes	2,512
Kidney	Yes	45,428
Larynx	Yes	13,522
Leukaemia	Yes	32,047
Liver & bile duct	Liver	22,998
Lung	Yes	159,732
Lymphoma	HL+NHL+MM	68,454
Malignant melanoma	Yes	45,551
Mesothelium	Derived	10,955

[32] See EUREG, accessed at: http://eco.iarc.fr/EUREG/AnalysisT.aspx on 6th September 2016.

[33] See Cancer Today (IARC), accessed at: http://gco.iarc.fr/today/online-analysis-multi-bars?mode=cancer&mode_population=continents&population=40&sex=0&cancer=29&type=0&statistic=0&prevalence=0&color_palette=default on 6th September 2016.

[34] For example, see http://www.google.co.uk/url?sa=t&rct=j&q=&esrc=s&source=web&cd=9&cad=rja&uact=8&sqi=2&ved=0ahUKEwjYzYvv6p7SAhULBcAKHZ7uD3wQFghSMAg&url=http%3A%2F%2Fec.europa.eu%2Fsocial%2FBlobServlet%3FdocId%3D11280%26langId%3Den&usg=AFQjCNGeTbkYFSLDPsFMLj2Pt0zXRiDj3Q&bvm=bv.147448319,d.d24

[35] Bianchi & Bianchi (2014): Global mesothelioma epidemic: Trend and features, Indian J Occup Environ Med 2014;18:82-8, available at http://www.ijoem.com/text.asp?2014/18/2/82/146897

Table 2-18: Cancer incidence data and estimates (EU-28) – EUREG, Cancer Today, UK registrations		
Cancer site	**Data available?**	**Annual registrations**
NMSC	Other skin	212,273
Oesophagus	Yes	21,032
Ovary	Yes	24,726
Pancreas	Yes	40,323
Pharynx (incl. NFC)	Yes	13,825
Sinonasal (SNC)	Nose & sinuses	2,239
Stomach	Yes	47,879
Thyroid	Yes	18,906
All exc. NMSC/other skin	Yes	1,380,439
All incl. NMSC/other skin	Yes	1,595,612
Sources: EUREG, Cancer Today, UK mesothelioma registrations. Note: Annual registrations are totals of national data for the most recent year available in the relevant Member State (typically 2006 to 2012).		

2.6.2 EUCAN: summary of methodology and cancer incidence data

The key advantage of EUCAN is that it provides a consistent source of data across the EU Member States for key cancer sites, broken down by gender, as well as data not only on incidence but also on mortality and prevalence. The data are also more recent than those in EUREG with 2012 data generally being available. The key disadvantage of EUCAN is the fact that specific data are not available for some relevant cancer sites (bone, eye, other skin, nose & sinuses).

The EU-28 totals for incidence per cancer site are presented in the following table. More detailed results by Member State are presented in Annex 3.

Table 2-19: Cancer incidence data and estimates (EU-28) - EUCAN		
Cancer site	**Data available?**	**Total cases**
Bladder	Yes	124,188
Bone	No	
Brain	Brain & CNS	21,568*
Breast	Yes	361,608
Cervix	Yes	33,679
CNS	Brain & CNS	21,568*
Colon & rectum	Large bowel	345,346
Eye	No	
Kidney	Kidney, including renal pelvis & ureter	85,215
Larynx	Yes	28,336
Leukaemia	Yes	62,678
Liver & bile duct	Liver & intraheptic bile ducts	51,785
Lung	Lung incl. trachea & bronchus	312,645
Lymphoma	NL+NHL+Multiple myeloma	125,385
Malignant melanoma	Yes	82,749
Mesothelium	Derived	10,955
NHL	Yes	79,312
NMSC	No	

Table 2-19: Cancer incidence data and estimates (EU-28) - EUCAN		
Cancer site	**Data available?**	**Total cases**
Oesophagus	Yes	34,777
Ovary	Yes	44,577
Pancreas	Yes	79,331
Pharynx incl. NFC	Lip, oral cavity, pharynx	73,699
Sinonasal (SNC)	No	
Stomach	Yes	81,592
Thyroid	Yes	37,440
All exc. NMSC/ other skin	Yes	2,635,222
*Sources: EUCAN Note: * Only total available, brain & CNS assumed 50%-50%. Note: Annual registrations are totals of national data for the most recent year available in the relevant Member State (typically 2012).*		

The EUCAN incidence data broken down between men and women are given below.

Table 2-20: Cancer incidence data and estimates (EU-28) – EUCAN – MEN and WOMEN			
Cancer site	**Data available?**	**Total cases**	
		MEN	**WOMEN**
Bladder	Yes	97,193	26,995
Brain	Brain & CNS	11,715	9,854
Breast	Yes	0	361,608
Cervix	Yes	0	33,679
CNS	Brain & CNS	11,715	9,854
Colon & rectum	Large bowel	193,426	151,920
Kidney	Kidney, including renal pelvis & ureter	54,281	30,934
Larynx	Yes	25,195	3,141
Leukaemia	Yes	36,201	26,477
Liver & bile duct	Liver & intraheptic bile ducts	35,893	15,892
Lung	Lung incl trachea & bronchus	213,663	98,982
Lymphoma	NL+NHL+Multiple myeloma	67,280	19,368
Malignant melanoma	Yes	39,880	42,869
Mesothelioma	Derived	9,202	1,753
NHL	Yes	42,499	36,813
Oesophagus	Yes	26,189	8,588
Ovary	Yes	0	44,577
Pancreas	Yes	39,436	39,895
Pharynx incl. NFC	Lip, oral cavity, pharynx	53,884	19,815
Stomach	Yes	50,521	31,071
Thyroid	Yes	9,722	27,718
All exc. NMSC/ other skin		1,429,715	1,205,507
*Sources: EUCAN Note: * Only total available, brain & CNS assumed 50%-50%. Note: Annual registrations are totals of national data for the most recent year available in the relevant Member State (typically 2012). The male/female split for mesothelioma incidence estimated on the basis of UK data, see http://www.cancerresearchuk.org/health-professional/cancer-statistics/statistics-by-cancer-type/mesothelioma/incidence#heading-Zero*			

2.6.3 The results (ANs)

The attributable numbers (ANs) calculated by combining the AFs presented in Section 2.5 with the cancer incidence data given above are summarised below for the three central scenarios.

Table 2-21: Attributable numbers (cancer incidence - both genders)						
Scenario	Central-low		Central-core		Central-high	
Site	AN EUCAN	AN EUREG	AN EUCAN	AN EUREG	AN EUCAN	AN EUREG
Bladder	2,430	1,027	12,201	5,158	22,433	9,483
Bone		0		0		0
Brain	187		260		463	
Breast	24,403	13,235	35,452	19,228	54,293	29,446
Cervix	0	0	16	8	94	49
CNS	0	0	34	34	266	266
Colon & rectum	60	33	904	498	1,863	1,027
Eye		21		108		244
Kidney	167	89	615	328	718	383
Larynx	520	248	1,342	640	2,612	1,246
Leukaemia	410	210	2,518	1,288	7,805	3,990
Liver & bile duct	24	10	39	17	59	26
Lung	84,577	74,010	114,920	85,415	148,886	98,182
Lymphoma	0	0	20	11	109	60
Lymphoma and leukaemia	0		0		0	
Malignant melanoma	231	127	473	260	770	424
Mesothelium	10,407	10,407	10,414	10,414	10,429	10,429
NHL	17	0	209	0	841	0
NMSC		10,437		24,589		64,834
Oesophagus	50	30	208	126	442	267
Ovary	24	13	50	28	83	46
Pancreas	75	38	1,031	524	3,080	1,566
Pharynx incl. NFC	491	92	6,957	1,305	16,591	3,112
SNC		38		160		380
Stomach	215	126	1,074	630	2,340	1,373
Thyroid	17	8	17	8	17	8
All excl. NMSC/ other skin	124,305	99,765	188,754	126,189	274,193	162,007
All incl. NMSC/ other skin		110,202		150,778		226,841

A breakdown of the ANs (based on EUCAN) by cancer site is provided in the following figure.

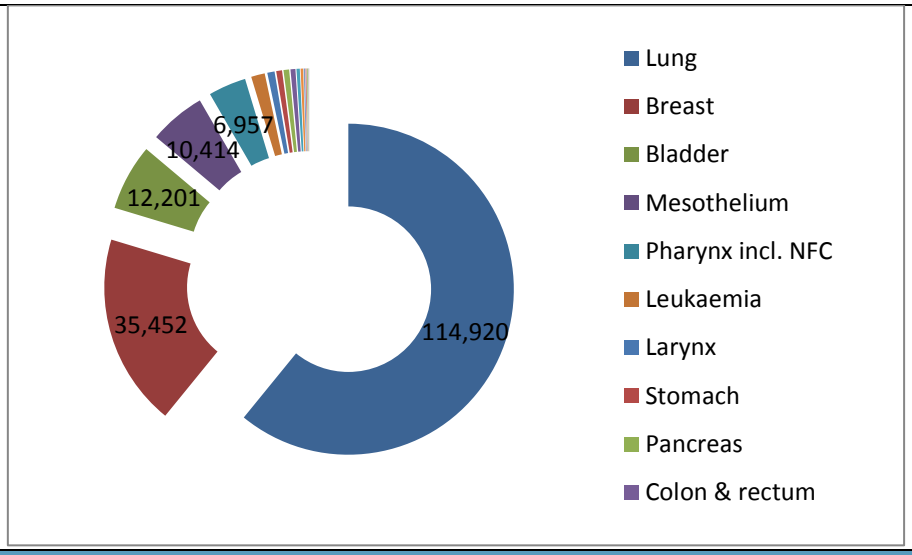

Figure 2-1: Central scenario (core scenario only) – contribution of cancer sites to the overall AN

The AN data broken down between men and women are given below.

Table 2-22: Attributable numbers (cancer incidence) for women and men, central scenarios

Scenario	Central-low		Central-core		Central-high	
Site	**Women**	**Men**	**Women**	**Men**	**Women**	**Men**
Bladder	100	3,490	393	17,064	739	29,682
Bone	n/a	n/a	n/a	n/a	n/a	n/a
Brain	93	93	126	132	219	243
Breast	24,403	0	35,452	0	54,293	0
Cervix	0	0	16	0	94	0
CNS	0	0	7	29	57	221
Colon & rectum	2	65	33	968	68	1,991
Eye	n/a	n/a	n/a	n/a	n/a	n/a
Kidney	17	182	70	658	83	767
Larynx	27	701	76	1,750	165	3,246
Leukaemia	179	229	1,520	803	4,795	2,116
Liver & bile duct	3	27	4	45	6	68
Lung	14,374	71,982	16,474	103,014	19,065	134,640
Lymphoma	0	0	3	12	10	81
Lymphoma and leukaemia	n/a	n/a	n/a	n/a	n/a	n/a
Malignant melanoma	120	111	245	228	399	371
Mesothelium	1,665	8,742	1,666	8,751	1,666	8,772
NHL	4	23	125	328	560	1,331
NMSC	n/a	n/a	n/a	n/a	n/a	n/a
Oesophagus	23	120	94	495	199	1,035
Ovary	24	0	50	0	83	0
Pancreas	11	63	218	934	704	2,781
Pharynx incl. NFC	33	625	591	8,203	1,580	18,156
SNC	n/a	n/a	n/a	n/a	n/a	n/a
Stomach	16	240	87	1,182	201	2,535
Thyroid	12	4	12	4	12	4
All excl. NMSC/ other skin	***41,106***	***86,697***	***57,262***	***144,601***	***84,998***	***208,041***

2.7 WP1-Step 6: Comparison with published AFs

WP1-Step 6 involves comparing the AFs calculated in this study with other estimates collected from published literature. This serves both as a discussion of the results of this study and as a check of the significance of the remaining data gaps.

The published AFs (both incidence and mortality) identified by the study team are summarised below.

Table 2-23: Occupational cancer estimates of selected countries

Reference	Country	Occupational cancer AF (%)	Notes
Labreche et al (2016)[36]	Canada	Incidence: 5 (men 9.1 women 2.7) Deaths: 7.6 (men 11.8 women 2.8)	
Purdue et al (2015)[37]	United States and others	2-8 (all cancers) 3-14 (men) 1-2(women)	Literature review
Blot & Tarone (2015)[38]	USA	Blot & Tarone (2015) support Doll & Peto (1981), i.e. 4%	
Takala (2015)[39]	-	5.3-8.4	
Labrèche et al (2014)[40]	Canada- Quebec	6 (incidence) 7.6 (cancer deaths)	
Järvholm et al (2013)[41]	Sweden	2.6 (cancer deaths)	
Rushton et al (2012)	Great Britain	5.3 (cancer deaths) 8.2 (cancer deaths men) 2.3 (cancer deaths women) 4 (cancer registrations) 2.2 (registrations women) 5.7 (registrations men)	Based on IARC Group1 and Group 2A carcinogens
Wild et al (2012)[42]	France	Overall: 52-56 (males) (range 41-67 and 32-66)	
Vogel (2011)[43]	-	8-12	
Boffetta et al (2010)[44]	France	2.7 (incidence, male) 0.3 (incidence, female)	Exposure data based on 1994 surveys; relative risks

[36] Labreche et al (2016) But other than mesothelioma? An estimate of the proportion of work-related cancers in Quebec, In: Current Oncology Vol. 23, No.2, April 2016.

[37] Purdue et al (2015): The proportion of cancer attributable to occupational exposures, Ann Epidemiol. 2015 March ; 25(3)

[38] Blot WJ and Tarone RE (2015): Doll and Peto's Quantitative Estimates of Cancer Risks: Holding Generally True for 35 Years. JNCI J Natl Cancer Inst, 107(4), djv044.

[39] Takala J et al (2015): Eliminating occupational cancer in Europe and globally. ETUI

[40] Labrèche F et al (2014): Estimating the Number of Cases of Occupational Cancer in Quebec. IRSST.

[41] Järvholm B et al (2013): Mortality attributable to occupational exposure in Sweden. Scand J Work Environ Health, 39(1), pp 106-111.

[42] Wild P et al (2012): Occupational risk factors have to be considered in the definition of high-risk lung cancer populations, British Journal of Cancer, 106, 1346-1352, available at: http://www.nature.com/bjc/journal/v106/n7/full/bjc201275a.html

[43] Vogel L (2011): Occupational cancer: the main challenge for the new Community Strategy, available at: http://www.etui.org/content/download/7515/71981/file/Occupational+cancer++the+main+challenge+for+the+new+Community+Strategy.pdf

[44] Boffetta P et al (2010): An estimate of cancers attributable to occupational exposures in France. J Occup Environ Med, 52(4), pp 399-406.

Table 2-23: Occupational cancer estimates of selected countries			
Reference	**Country**	**Occupational cancer AF (%)**	**Notes**
		4.0 (cancer deaths, men) 0.6 (cancer deaths, women)	from meta-analyses and pooled analyses
Kim et al (2010)[45]	South Korea	1.1 (incidence) 1.7 (cancer deaths)	Only took account of 9 of the 23 Group 1 carcinogens
ACSS (2006)	Australia	13.8 (cancer deaths, males) 2.2 (cancer deaths, females)	
Pearce et al (2004) in ASCC (2006)	New Zealand	5-9 (cancer deaths, men) 0.5-2 (cancer deaths, women)	Applies to men and women over 30 years old
Steenland et al (2003)[46]	USA	2.4-4.8 (cancer deaths) 0.8-1.0 (cancer deaths, females) 3.3-7.3 (cancer deaths, males)	Uses conservative estimates
Nurminen & Karjalainen (2001)[47]	Finland	8.4 (cancer deaths) 13.8 (cancer deaths, males) 2.2 (cancer deaths, females)	Data limitations; discrepancies in underlying studies
Dreyer et al (1997)[48]	Nordic countries	3 (cancers, male) 0.1 (cancers, female)	Projected to 2000
Doll & Peto (1981)	USA	4 (cancer deaths)	

The table above shows that the published AFs range from 2% to 12%, possibly reflecting differences in how, where, and when these estimates were derived and differences with regard to incidence or mortality.

An estimate of 2-8% (3-14% in men and 1-2% in women) for occupational cancer has been given by Purdue (2015). Doll & Peto (1981) estimated 4% of cancer deaths. Although more recently supported by Blot & Tarone (2015), the AF produced by Doll & Peto is considered by many to be an underestimate due to the increasing number of carcinogens being identified and recognised by IARC (Takala, 2015).[49] Vogel (2011)[50] notes that recent studies estimate that between 8% and 12% all cancers can be attributed to exposure to carcinogens at work.

Under the central assessment, the estimates derived in this study range from 6% to 12% with the core estimate being 8%. These estimates are positioned closer to the higher estimates in the published literature and provide further support for studies that have estimated the overall AF for occupational cancer at 8% or above. It should be noted that the AFs estimated in this study are for cancer incidence rather than mortality.

The OvAFs estimated under the Low and High scenarios range from 2% to 20%, with the mid-point estimate being 10%. However, the Low and High scenarios may not be realistic representations of the real extent of occupational cancer and they have been modelled purely for the reason of

[45] Kim EA et al (2010): Occupational Burden of Cancer in Korea. Safety and Health at Work, 1, pp 61-68.

[46] Steenland K et al (2003): Dying for work: The magnitude of US mortality from selected causes of death associated with occupation. Am J Ind Med, 43(5), pp 461-482.

[47] Nurminen M and Karjalainen A (2001): Epidemiologic estimate of the proportion of fatalities related to occupational factors in Finland. Scand J Work Environ Health, 27(3), pp 161-213.

[48] Dreyer L et al (1997): Avoidable cancers in the Nordic Countries. Occupation. APMIS Suppl., 76, pp 68-79.

[49] Takala J et al (2015): Eliminating occupational cancer in Europe and globally

[50] Vogel L (2011): Occupational cancer: the main challenge for the new Community Strategy, available at: http://www.etui.org/content/download/7515/71981/file/Occupational+cancer++the+main+challenge+for+the+new+Community+Strategy.pdf

providing a lower and the upped bound for the assessment. However, they provide a further check on the central AFs estimated in this study. In particular, it is noted that the Mid-point scenario (OvAF: 10%) is positioned very close to the Central-core estimate.

Since the 25 carcinogens examined in this study do not account for the entire incidence of occupational cancer, comparisons between the OvAFs derived in this study for the 25 carcinogens and OvAFs derived in other studies should take into account the possibility that those produced here may be underestimates. In particular, although some carcinogens not considered in this study result in a small number of cancers when each is considered in isolation, when considered together they may contribute a large number to overall occupational cancer incidence. The focus on selected carcinogens is therefore one of the limitations of this study.

The OvAFs found by this study are compared with the published studies in Figure 2-2.

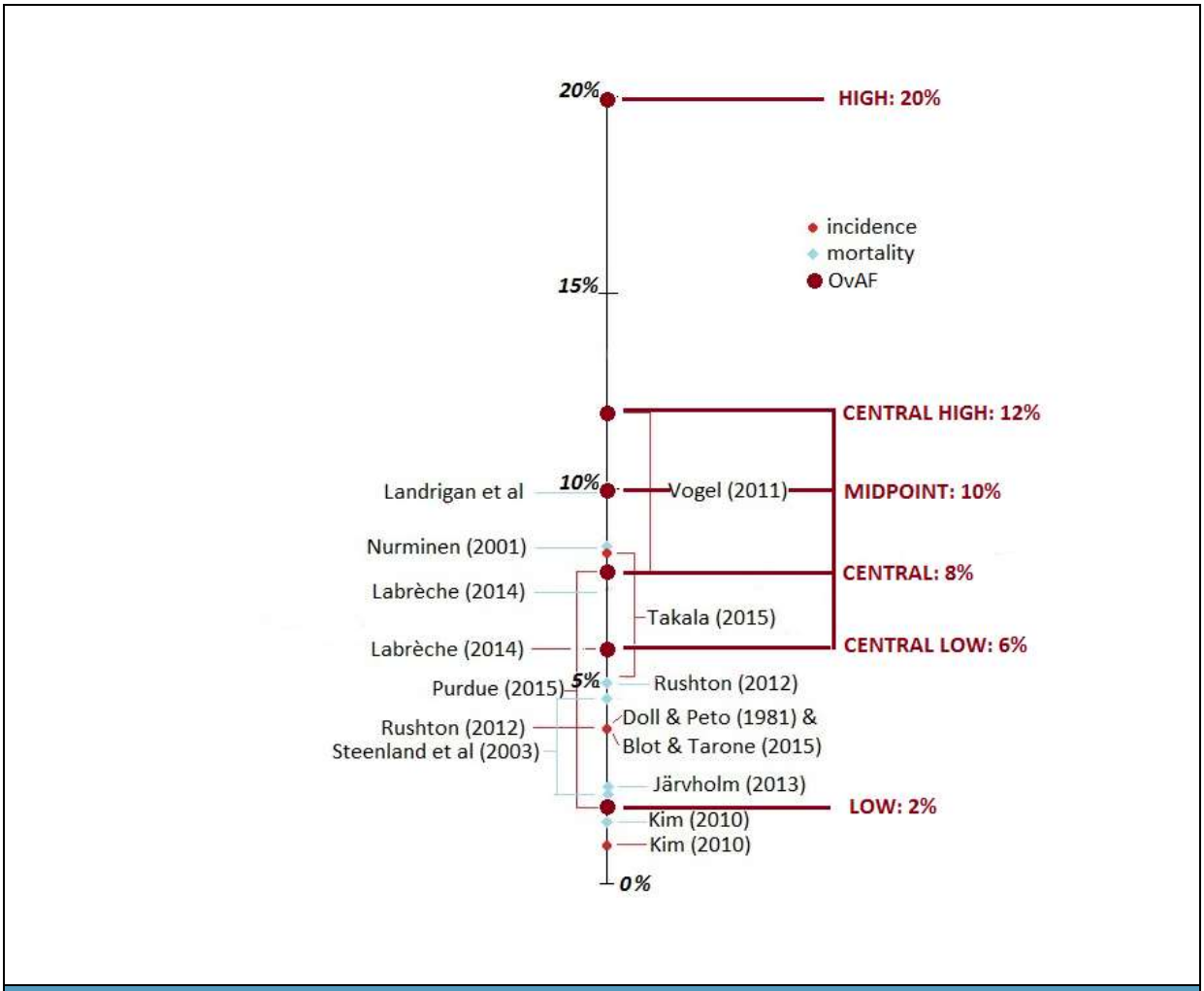

Figure 2-2: Comparison of the OvAFs derived in this study with published literature

An important finding of this study is that, by including a specific gender focus on carcinogenic agents for women, this study has found a higher AF for occupational exposure of female workers than previous studies (5% versus 0.3%-3%). This is, in particular, due to the shift work, ionising radiation and cytostatic drugs within the scope of this study.

The difference between the OvAFs calculated in this study for women and men is 5% versus 10% under the Central-core scenario (i.e. by a factor of 2). By contrast, the incidence OvAFs in the studies

in Table 2-28 are lower for women than men by a factor of between 2.6 and 30. To a large degree, this may be a consequence of the fact that this study set out to ensure that occupational carcinogens relevant to women receive sufficient attention and has made efforts to prioritise them under WP-Step 1. However, in light of the ANs calculated under WP1-Step 5 and, consequently, the OvAFs for women, it appears that female occupational cancer may have been underestimated in past research.

In addition, the ANs estimated in this study can be compared with data for occupational cancer deaths published by the Global Burden of Disease study. This comparison is provided in the following table for lung cancer deaths for 25 EU countries, showing that lung cancer fatality estimated under the Central-core scenario in this study is approximately 40% higher than that estimated in the GBD study.

Table 2-24: Comparison between lung cancer mortality estimated in this study and in the GBD

Member State	Mortality under Central-core scenario (80% of incidence)	Mortality due to occupational risks in GBD study (2015)
Austria	1,114	697
Belgium	2,258	2,366
Bulgaria	1,218	246
Croatia	870	514
Cyprus	98	56
Czech Republic	1,930	578
Denmark	1,249	766
Finland	778	539
France	11,452	8,083
Germany	13,406	11,531
Greece	1,898	1,170
Hungary	2,294	559
Ireland	514	290
Italy	10,422	9,825
Luxembourg	85	44
Malta	42	45
Netherlands	4,149	3,987
Poland	5,400	2,326
Portugal	1,479	394
Romania	3,485	568
Slovakia	842	188
Slovenia	387	163
Spain	7,707	3,437
Sweden	1,111	681
United Kingdom	16,805	15,026

Note: GBD data for deaths in 2015 due to tracheal, bronchus, and lung cancer, occupational risks only.
Source: Global Burden of Disease Study 2015. Global Burden of Disease Study 2015 (GBD 2015) Results. Seattle, United States: Institute for Health Metrics and Evaluation (IHME), 2016. Available from http://ghdx.healthdata.org/gbd-results-tool

2.8 WP1-Step 7: Limitations of the analysis

The key limitations relate to the following:

- Focus on suspected or confirmed carcinogenic agents, including issues regarding the definition of what is covered by specific agents and reliance on experimental animal data rather than epidemiological data;

- Selection of the relative risks for the purposes of the analysis, particularly as it has not been possible to undertake an exhaustive literature review and estimates can vary significantly across studies and over time;
- Exposure patterns, including the potential for threshold effects and the need for relative risks to correspond to real exposure levels in the workplace;
- The framework for the analysis, i.e. whether the starting point is a carcinogenic agent, tumour site, or a specific occupation;
- Gender differences with regard to occupational cancer;
- Focussing on the selected 25 carcinogenic agents, with those selected not including many high tonnage chemicals which have been registered under REACH, leading to a potentially significant underestimate of the total occupational burden of cancer (also see Section 2.8.7 which shows how the inclusion of another carcinogenic factor impacts on the overall results, focussing on the example of organic solvents);
- The method used for the estimation of the reference population for the calculation of the AFs; and
- The relative risks used for the low and high scenarios.

2.8.1 Focus on suspected or confirmed carcinogenic agents

Regulatory classification is an important consideration for the designation of substances as contributors to carcinogenic risk at the workplace. The IARC[51] and the CLP (EC, 2008)[52] classifications of the 25 carcinogenic agents selected for detailed assessment in this study are summarised in Annex 4. However, these classifications were derived for specific purposes and may not fully and consistently capture the real cancer potential of these agents. Different regulatory bodies may have different scientific perspectives and discussions on classifications may have been carried out at different points in time (and thus be based on different information). In addition, the definitions of the specific agents used may have differed.

The prioritisation phase of this study (WP1-Step 1) predominantly focused on IARC Group 1 and 2A carcinogens (carcinogenic and probably carcinogenic to humans). Due to the fact that Group 2B (possibly carcinogenic to humans) comprises a very large number of entries, it was not possible to consider the vast majority of these agents within the prioritisation exercise. In addition, limited human data and other information are available for Group 2B carcinogens. There is a number of high tonnage carcinogens in IARC Group 2 or CLP Carc. 2 but these are often not considered in published literature because they are only 'suspected' carcinogens by one or the other classification.

The 25 agents considered in this study include some that are classed as 'suspected carcinogens' rather than 'probable or known carcinogens. The implication for this study is that, should the carcinogenic property of these agents not be confirmed, this would reduce the overall AFs across the 25 agents estimated in this study.

In conclusion, classification is a significant factor of uncertainty. For example, shift work is currently not classified as a human carcinogen. In addition, conclusions drawn for tetrachloroethylene (CLP Carc. 2), mineral oils, aromatic amines, cytostatic drugs, inorganic mists and organic solvents should be considered more uncertain because of the definitional issues (e.g. mineral oils encompass a heterogeneous group of compounds with varying classifications).

[51] See http://monographs.iarc.fr/ENG/Classification/latest_classif.php

[52] EC, European Commission (2008): Regulation (EC) No 1272/2008 of the European Parliament and of the Council of 16 December 2008 on classification, labelling and packaging of substances and mixtures, amending and repealing Directives 67/548/EEC and 1999/45/EC, and amending Regulation (EC) No 1907/2006, Official Journal of the European Union, L 353, 1-1355

2.8.2 Cancer risk estimates from experimental animal data or from epidemiological data

This report only uses relative risk estimates from epidemiological studies. Whilst this is a widely accepted procedure, it gives rise to further uncertainty in the AFs estimated in this study. Agents classified as Carc. 1B (CLP) have been mainly evaluated based on experimental animal data for classification purposes. If there were adequate epidemiological data, these agents could have potentially been assigned Carc. 1A (CLP).

2.8.3 Selection of relative risks

As indicated above, this report uses relative risks (e.g., SMR, RR, OR, etc.) to calculate the AFs. However, these relative risk estimates may differ in quality and validation. Within the framework of this report it was not possible to perform an exhaustive search for all relevant studies with relative risk quantifications or to perform meta-analyses. It is emphasised in this report that incidence relative risks from meta-analyses are preferred but those are not always available or suffer from substantial study heterogeneity or sometimes are outdated. There are examples, where this uncertainty is limited or negligible. There are others, where the selection of the RR contributes significantly to the overall uncertainty.

By way of example, for shift work**,** breast cancer is just one of various cancer sites associated with respective occupations. Bhatti et al (2013) found a significantly elevated risk of *ovarian cancer* for shift workers. Similarly, *endometrial cancer* was increased according to Viswanthan et al. (2009). Rao et al. (2015) report a significantly elevated risk in *prostate* cancer from eight epidemiological studies on shift work and Wang et al (2015) performed a meta-analysis on *colorectal cancer* with significant odds ratio.

2.8.4 Exposure patterns

Substances with a non-genotoxic mode of action (MoA) are often regarded as threshold carcinogens (and tend to be classified only as suspected carcinogens). The European Scientific Committee on Occupational Exposure Limits (SCOEL) often describes carcinogens as having “a practical threshold”, if factors other than genotoxicity are significantly contributing to the carcinogenic MoA. Overall, genotoxicity was indicated for only for 38% (n=105) of 278 carcinogenic chemicals tested within the National Toxicology Program (NTP) of the United States (Kardekar et al., 2012)[53]. This indicates that many carcinogens in the workplace should be considered non-genotoxic or with only partial contributions of genotoxicity to the carcinogenic MoA. For these (frequently occurring) carcinogens with a sublinear exposure risk relationship or a threshold, there will be significant uncertainties in calculations of the attributed risk as the robustness of the AFs estimated in this study hinges on the exposure levels corresponding to the relative risks used.

2.8.5 Different starting points: ‘carcinogenic agents’ or ‘tumour sites’ or ‘cancer profiles for specific occupations’

Most of the 25 carcinogenic agents considered in this report are chemical substances but some are occupations/activities. However, it is important to recognise that:

- not all relevant cancer risks associated with the top 25 carcinogenic agents are covered;

[53] Kardekar et al (2012): Gender differences, Toxicologic Pathology, available at http://www.ncbi.nlm.nih.gov/pubmed/22585941;

- taking 'tumour sites' as a starting point (instead of carcinogenic agents) may increase respective associations; and
- taking 'cancer profiles for specific occupations' as a starting point may increase respective associations.

From the 25 agents considered here, only shift work, **ionising radiation** and **cytostatic drugs** contribute to occupational breast cancer risk. However, 216 chemicals have been identified from experimental animal studies as causing **mammary tumours** (Brophy et al, 2012). This indicates that occupational conditions with influence on breast cancer incidence are not fully covered by the selected 25 carcinogenic agents.

With additional resources, this analysis could be extended to other cancer sites and lead to additional numbers of workers with elevated risk. The implication is that the true occupational burden of cancer is greater than the overall AFs estimated in this study.

2.8.6 Gender differences of occupational cancer

With respect to gender differences in occupational cancer in general but also with respect to this study:

a) The relevance of sex-specific cancer may be underestimated because of insufficient studies with female cohorts, e.g. there are other studies highlighting ovarian cancer for female welders (Pukkala et al, 2009) and linking shift work to endometrial cancer (Viswanathan and Schernhammer, 2009). In addition, an increased risk for male reproductive organs was not quantified for any of the 25 carcinogenic agents which demonstrates another uncertainty of this assessment.

b) Significant disparities also exist for other than reproductive organ sites, with these referred to as being "enigmatic sex disparities" (Edgren et al, 2012). Some of these may reflect some endocrine influences on cancer occurrence which is an area that has not yet been studied in sufficient detail (Del Pup et al, 2015).

c) Due to resource limitations, it has not been possible to reflect gender differences across all cancer sites, with a single relative risk figure applied to both males and females. This is a simplification and leads to uncertainty. This simplification should be noted when gender specific AFs are discussed.

d) This report mainly addresses exposure related differences in cancer attributable to men or women. Biases in gender-linked reporting on exposure may contribute to uncertainty.

2.8.7 Organic solvents (carcinogenic agent no. 26)

Section 2.2 of the report provides a detailed description of the process by which the 25 carcinogenic agents, used in this study, were chosen. It is possible that these 25 agents may cover the majority of occupational cancer but this is not certain.

Although organic solvents were not included in the core assessment due to significant uncertainties associated with the input data, an additional assessment is provided here to show that the inclusion of additional agents has the potential to impact on the estimated AFs for each cancer site, and the overall AF for occupational cancer.

The assumptions used for estimating the AFs for organic solvents are given in Annex 1.

The AFs for organic solvents by scenario and cancer site are given below.

Table 2-25: AFs per cancer site (High, Low, Central and Mid-point scenarios)			
Carcinogen	**Breast**	**Liver & bile duct**	**NHL**
26 Organic solvents (HIGH)	30.0%	24.1%	8.4%
26 Organic solvents (LOW)	0.1%	1.8%	0.3%
26 Organic solvents (CENTRAL-CORE)	0.5%	3.2%	0.6%
26 Organic solvents (MID-POINT)	7.3%	10.2%	2.5%

2.8.8 Use of different population adjustment factors

OvAF: Population adjustment factor = 0.63 for 1966-2005 and 0.72 for 1996-2015

As regards the HIGH scenario for both genders, the inclusion of organic solvents among the list of top carcinogenic agents increases the overall attributable fraction by 7.14%. The increase is mainly caused by large attributable fractions for organic solvents-induced breast and liver cancers (29.97% and 24.05%, respectively). Moreover, breast cancer applies to women only, which coincides with the 6.93% increase in women's overall attributable fraction under the HIGH scenario compared to the 6.80% increase in men's attributable fraction. For all remaining scenarios, the increase in overall attributable fractions is of lesser magnitude, i.e. between 0.38% and 3.66%.

Table 2-26: AFs per cancer site across the 25 and 26 carcinogenic agents				
Attributable fractions	**High**	**Low**	**Central**	**Mid-point**
Across 26 carcinogenic agents (including organic solvents)				
Overall AF (OvAF) - BOTH	22.18%	1.68%	7.31%	10.68%
Overall AF (OvAF) - WOMEN	21.93%	0.78%	4.91%	9.52%
Overall AF (OvAF) - MEN	23.33%	2.66%	10.27%	12.83%
Across 25 carcinogenic agents (without organic solvents)				
Overall AF (OvAF) - BOTH	15.04%	1.17%	5.53%	7.39%
Overall AF (OvAF) - WOMEN	15.00%	0.40%	3.85%	6.78%
Overall AF (OvAF) - MEN	16.53%	1.97%	8.20%	9.17%

OvAF: Population adjustment factor = 0.53 for both time periods

The overall attributable fraction under the HIGH scenario for both genders has increased by 2.96%. Women's and men's overall attributable fraction under the HIGH scenario has increased by 6.12% and 1.23% respectively. For all other scenarios, the increase fluctuates between 0.04% and 1.79%.

Table 2-27: AFs per cancer site across the 25 and 26 carcinogenic agents				
Attributable fractions	**High**	**Low**	**Central**	**Mid-point**
Across 26 carcinogenic agents (including organic solvents)				
Overall AF (OvAF) - BOTH	23.89%	1.77%	8.01%	11.76%
Overall AF (OvAF) - WOMEN	23.32%	0.86%	5.56%	10.53%
Overall AF (OvAF) - MEN	25.15%	2.79%	11.13%	14.01%
Across 25 carcinogenic agents (without organic solvents)				
Overall AF (OvAF) - BOTH	20.93%	1.71%	7.87%	10.69%
Overall AF (OvAF) - WOMEN	18.20%	0.82%	5.40%	8.74%
Overall AF (OvAF) - MEN	23.92%	2.65%	10.97%	13.52%

2.8.9 The relative risks under the Low and High scenarios

It should be noted that the relative risks under the LOW and HIGH scenarios may not be realistic representations of the real risks and these scenarios have been modelled purely for the reason of providing a lower and the upped bound for the assessment, i.e. to provide a further check on the central AFs. In particular, some of the relative risks used under the LOW and HIGH scenarios are based on studies of specific industries or worker groups and may not be representative of the whole exposed populations. For example, the lung cancer OR used for DEE under the HIGH scenario is based on a study of miners who have a high diesel exposure but it is applied to the whole workforce exposed to DEE. Similar issues are evident in the HIGH relative risks for silica and benzene.

3 WP 2: The economic burden of occupational cancer

3.1 Overview of the approach

WP2 comprised the following steps:

- Step 1: Cost framework;
- Step 2: Literature review;
- Step 3: Estimates at MS level and EU level; and
- Step 4: Sensitivity analysis.

3.2 WP2-Step 1: Cost framework

The first step in estimating the annual economic burden of occupational cancer in the EU28 was the development of a cost framework describing the different cost components (direct, indirect and intangible/human) and who would bear the costs. It is important to note that for the purposes of this study, this framework is constrained to the assessment of those costs that comprise true "economic" or social costs, and excluding financial impacts that essentially reflect transfers between different groups in society.

From this perspective, the economic costs of cancer can be divided into:

- **Direct costs:** These are the medical costs associated with the treatment of cancer and the non-medical costs that arise directly as a result of cancer. Direct medical costs are those associated with the treatment and services patients receive, including the cost of hospitalisation, surgery, physician visits, radiation therapy and chemotherapy/ immunotherapy.

- **Indirect costs:** These are the monetary losses associated with the time spent receiving medical care, including productivity losses due to time spent away from work or other usual activities and lost productivity due to premature death.

- **Intangible or human costs:** These include the non-financial 'human' losses associated with cancer, e.g. reduced quality of life, pain, suffering, anxiety and grief.

Depending on the structure of national health care provision, the direct costs may be borne fully or partially by the government (tax payers). Direct medical costs associated with cancer vary significantly by cancer type and also vary over time. Indeed, it has been noted that cancer costs are highest in the initial period following diagnosis and, among patients who die from their disease, at the end of life; they are lowest in the period between the initial and end of life periods, following a "u-shaped" curve (Yaboriff et al., 2012)[54]. Individuals may also incur direct costs which are not linked to medical services, for example, the costs of transport to attend appointments (which may be borne by patients or their relatives/friends) and costs such as additional childcare or cleaning services.

[54] Yabroff KR et al. (2012): Economic burden of cancer in the US: Estimates, projections and future research, Cancer Epidemiology Biomarkers & Prevention, 20 (20) pp 2006-2014, available at: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3191884/

Indirect costs may be incurred by the patient but also by their family/friends, for example, through providing unpaid care. Employers might also bear costs indirectly through: loss of output; payments related to sick leave; administrative costs related to a worker's absence; additional recruitment costs; loss of experience/expertise; overtime working; compensation payments (although this may be covered by some form of employer's liability insurance); and insurance premiums. Depending on the national structure of social security provision, the government (tax payers) may also bear the costs of any disability/social security payments and will also suffer losses through foregone tax receipts (although there may also be savings in relation to future pension and other payments).

An illustrative cost framework describing the different cost components by cost bearer is shown in the table below, building on the cost framework developed by the UK Health and Safety Executive for their recent work on the Costs to Britain of Work-Related Cancer (2016)[55]. This framework is illustrated here as it has been recommended as a model of good practice by EU OSHA.[56]

From a **societal perspective**, the total costs of occupational cancer are the sum of the costs (-) listed below for the different cost bearers, minus any payments received which are identified in the table as (+).

Within the resources available for this study, it has not been possible to apply the full cost framework set out in Table 3-1. Instead, a more partial analysis has been carried out. However, care has been taken to ensure that the most significant components of cost have been taken into account. The costs explicitly considered here include:

- Direct medical costs and non-medical costs (i.e., out-of pocket expenses);
- Indirect costs linked to lost earnings or lost output (but not including the costs of responding to the loss of output); and
- Intangible or human costs linked to an individual's willingness to pay to avoid a case of disease.

A review of the literature suggests that these cost components account for over 90% of the estimated economic costs of cancer. As a result, although the approach adopted here provides only a partial analysis of the economic costs of occupational cancers, it should provide a good indication of the order of magnitude of such costs.

It is important to note though that the costs that underestimated within this analysis are the costs to employers associated with workplace cancers, and in particular the costs associated with employers' liability insurance and the administrative costs faced by employers. The recent UK HSE study found that these comprised around 3% of the total costs to society; although this is only a small percentage, as will become clear the actual magnitude of these costs is significant in money terms if this 3% figure is assumed to apply across the EU-28.

Exposure to some of the agents considered here may also result in occupational diseases other than cancer. Such impacts have not been taken into account in this analysis, with this leading to an underestimate of the impacts of exposure to the carcinogenic agents considered here.

[55] UK HSE (2016): Costs to Britain of Work Related Cancer, Research Report 1074, available at: http://www.hse.gov.uk/research/rrhtm/rr1074.htm

[56] See https://osha.europa.eu/en/publications/reports/estimating-the-costs-of-accidents-and-ill-health-at-work/view

Table 3-1: Cost framework describing the different cost components by cost bearer			
Cost component	**Cost bearer**		
	Worker/their family	**Employer**	**Government/taxpayer**
DIRECT	**(-) Out of pocket expenses** including funeral expenses (for fatal cancers), prescription charges, additional travel and living costs, home modifications	**(-) Corporate private health insurance premiums**	**(-) Medical treatment and rehabilitation costs**, including hospitalizations, surgery, physician visits, radiation therapy and chemotherapy/immunotherapy
	(-) Premiums for private medical insurance		**(+) Treatment and rehabilitation covered by private health insurance**
INDIRECT	(-) **Loss of earnings due to absence from work** (both short term absence whilst undergoing treatment but also absence in the future, e.g. due to reduced working hours or permanent withdrawal from work.	(-) **Loss of output due to workplace absence**, together with costs from loss of experience/expertise and costs of overtime working, etc.	
		(-) Recruitment and induction costs. The employer may recruit temporary or permanent replacement staff and supply them with suitable induction support.	
	(-) Loss of state pension income		(+) **Savings in state pensions not paid** State pension income that is no longer paid to individuals represents a saving to the public purse.
	(-) **Informal care costs,** reflecting the opportunity cost of unpaid care		
	(+) Receipt of payments related to sick leave, where applicable	**(-) Payments related to sick leave**	**(-) State payments**, where applicable.
	(+) State benefit receipts, where applicable.		**(-) State benefit payments**, where applicable.
	(+) Income tax and national insurance (NI) savings. The loss of gross income results in individuals 'saving' on their income tax and national insurance payments.	**(-) Work reorganisation.** Employers may reorganise work to cover the absent employee's duties; this reorganisation incurs managerial/supervisory time.	**(-) Loss of tax and national insurance (NI) receipts**
Intangible (human) costs	**(-) A monetary value of the impact on quality of life of affected workers**		
Administration	**(-) Administration of insurance, compensation**	**(-) Administration of sick pay, insurance and**	**(-) Administration of benefits claims**

Table 3-1: Cost framework describing the different cost components by cost bearer			
Cost component	**Cost bearer**		
	Worker/their family	**Employer**	**Government/taxpayer**
and legal costs	**and benefit claims**	**compensation claims**	
	(-) Insurance company profit margin Individuals can have life insurance products to protect their income in the event of death. The cost of insurance to the individual is the net difference between premiums paid and payments received.	**(-) Investigation / prosecution – internal costs + legal costs.** Cost to employers of management time for dealing with investigations/prosecutions and the arising legal costs.	**(-) Government investigation / prosecution – internal costs, in terms of the** internal costs borne by the government for investigating work-related cancers.
	(+) Compensation from employers' liability insurance	(-) **Employers' liability insurance costs,** but only the element of this related to	
		(-) Fines paid. The cost of any fines paid by employers due to breach of health and safety regulations	**(+) Fines received, where these are** the cost of any fines received by government due to breach of health and safety regulations (equal and opposite to that paid by employers)

Key

(-)	Cells shaded grey indicate money outflows
(+)	Cells shaded green indicate money inflows

Adapted from HSE (2015)

3.3 WP2-Step 2: Relevant cost estimates / economic values

3.3.1 Introduction

A brief discussion is provided below on the key findings of the literature review carried out to identify relevant estimates of the costs per registration case for the different cost components. As the intangible or human cost component is the most significant driver of the economic costs, this is discussed first, followed by estimates for the direct and indirect costs of a cancer registration.

3.3.2 Intangible or human costs

Mortality

In terms of the intangible impacts of a case of cancer on an individual, the costs of a cancer mortality are generally measured in one of the following two ways:

- through the value of statistical life (VOSL); or
- the value of a life year lost (VOLY).

A recent study led by the Charles University in Prague (Alberini & Scasny, 2014)[57] and undertaken for ECHA found a value of a statistical life for the avoidance of a death by cancer to be around €5 million (2014 prices). This figure is higher than the figure recommended in the European Commission's Better Regulation Toolbox (Tool #27), which refers to values developed by the OECD (with a range between €1.7 million and €5.1 million (converted from 2005-USD$), with a base value of €3.4 million.

These figures are both higher than those quoted in the European Chemicals Agency's (ECHA) original guidance on Socio-Economic Analysis (SEA) within the context of the chemical regulation. ECHA's guidance on SEA provides two figures for the value of statistical life[58], a central value of €1,052,000 (2003 prices) and a sensitivity value of €2,258,000 (2003 prices).

The figure found by Alberini & Scasny (2014) is also higher than those recommended in the European Commission's Better Regulation Toolbox. Tool #27 refers to values developed by the OECD and which range between €1.7 million and €5.1 million (converted from 2005-USD$), with a base value of €3.4 million.

The UK HSE applies a figure of £1.2 million as the value of preventing a fatality (i.e. VOSL) in its 2016 study on the Costs to Britain of Workplace Cancers. This figure of £1.2 million includes a downward adjustment to reflect only the human costs of a death; this adjustment includes removal of lost consumption from the willingness to pay value underlying the VPF figure to avoid double counting.

In addition, no adjustments are made to this figure to account for the fact that people may be willing to pay more to reduce their risk of dying from cancer than to reduce their risk of a death from other illnesses or from a road traffic accident, since the death from cancer may be preceded by a long period of serious illness. The authors argue that there may be a countervailing effect in terms of people placing a lower valuation on the avoidance of death because of latency effects. The end

[57] Alberini and Scasny (2014): Stated-preference study to examine the economic value of benefits of selected adverse human health due to exposure to chemicals in the European Union, Part III: Carcinogens, FD7. Final report, Service contract No. ECHA/2011/123

[58] Based on environmental pollution willingness to pay values.

impact is therefore uncertain and there is insufficient evidence to make any adjustment. (Note, UIK HSE also argue against the use of a value of a life year lost instead of a VOLY on ethical grounds, indicating that it would not be appropriate to assign a lower value to the mortality of a 70 year old compared to a younger individual.)

This study uses a VSL of €4 million as an approximate midpoint between the value of €3.4 million and the higher values of around €5 million found by Alberini & Scasny (2014). Note that it is assumed that these VOSL estimates include a component related to lost output/earnings, with this having implications for how lost earnings are accounted for in this analysis.

Note that no additional valuation of an individual's willingness to pay is included here in relation to the avoidance of ill-health (morbidity effects) prior to the cancer registration. It is not clear that this would not lead to double counting with the VSLs being used to value avoidance of a fatal cancer.

Morbidity

Starting with willingness to pay studies, the available literature offers a broad range of estimates for willingness to pay to avoid a non-fatal cancer. Estimates range from a low of €16,000 (1999 prices) to a high of €1,950,000 (1999 prices) depending on the type of cancer. ECHA's SEA guidance reports a value of €400,000 (2003 prices) for calculating the costs associated with morbidity for non-fatal cancers, but the origin of this estimate is not referenced and no details on the figure and what is included within the estimate are provided.

The most recent and relevant willingness to pay study is that carried out by Alberini & Scasny (2014) and undertaken for ECHA in the context of REACH. This study found a figure of €396,000 (2014 prices). Whilst a recent NeRSAP workshop organised by ECHA, criticised the use of this value due to methodological concerns[59], there are methodological issues associated with most of the other values reported above.

For the purposes of this study, we have therefore taken a value of €400,000 per non-fatal cancer registration to reflect the intangible or human costs. As for mortality, no additional valuation of an individual's willingness to pay is included here in relation to the avoidance of ill-health prior to the cancer registration. In addition, this figure may include a component related to lost output/earnings, with this having implications for how lost earnings are accounted for in this analysis. However, this is not clear.

Alternative approaches

Others have adopted an alternative approach to placing an economic value on morbidity effects. The UK HSE (2016) uses DALYs for this purpose, and quantifies morbidity for both fatal and non-fatal cancers in terms of years of life lost and years of life lived with a disability (with only the latter applied to non-fatal cancers).

The resulting figures suggest intangible or human costs related to morbidity and a fatal cancer of around £44,700 and of around £43,700 for a non-fatal cancer registration (present value estimate). Adding £44,700 to the figure of £1.2 million assumed for the human costs of a fatality, results in a much smaller estimate than the £4 million assumed here; similarly the figure of £43,700 is significantly lower than the figure of €400,000 assumed here.

[59] http://echa.europa.eu/support/socio-economic-analysis-in-reach/network-of-reach-sea-and-analysis-of-alternatives-practitioners

3.3.3 Healthcare costs

A range of studies have been identified that provide estimates of the costs of medical treatment for cancer patients (as shown below). Note that the average medical costs shown in the table below are annual figures and apply to patients over the period of time that they continue to be treated.

Table 3-2: Examples of estimates of medical treatment costs			
Study	**Year for prices**	**Average direct costs in original units (per annum)**	**Direct costs in € 2014**
Lung cancer			
Leal (2012)	2012	£9,071	€ 11,141
Gomez et al (2012)	2008	€8,261	€ 8,833
Braud et al (2003)	2001	€12,518	€ 15,170
Dedes et al (2004)	1999	CHF 20,102	€ 18,182[1]
Intestinal cancer (colon, colorectal and rectal cancer taken as proxies)			
York Health Economics Consortium (2007)	2004	£8,808	€ 13,197
York Health Economics Consortium (2007)	2004	£12,037	€ 18,035

Luengo-Fernandez et al (2013) also provide average unit costs (in 2009 prices) for the health care costs associated with GP visits, outpatient visits, A&E visits and inpatient days for 27 of the 28 EU MS (data are not included for Croatia). These are summarised below by cancer site, with more detailed data by MS given in Annex 5.

Table 3-3: Estimates of the annual cost per patient of cancer				
Mortality rate after 5 years	**Cancer**	**Health care**	**Informal care**	**Total cost per case (€)**
22%	Prostate	€ 4,027	€ 1,390	€ 5,417
80%	Lung	€ 6,952	€ 6,278	€ 13,230
24%	Breast	€ 4,378	€ 2,086	€ 6,464
44%	Colorectal	€ 5,037	€ 2,567	€ 7,604
47%	All cancers	€ 6,047	€ 2,753	€ 8,800
Source: Luengo-Fernandez, R. et al (2013): Economic burden of cancer across the European Union: a population-based cost analysis; Lancet Oncology; 14: 1165–74, published online October 14: http://dx.doi.org/10.1016/S1470-2045(13)70442-X				

The cost figures presented in the above tables correlate well with the average per case lifetime treatment cost estimated in the UK HSE study of £8,200, which is considered to reflect the top 90% of occupational cancers.

Note that these costs are assumed to apply to all cancer registrations in the analysis presented here, regardless of whether or not the cancer is fatal or non-fatal. Where data are not available for a particular cancer, the all cancers figure is adopted.

The above table also includes estimates of informal care costs, which are considered further below.

3.3.4 Non-medical direct costs

Non-medical direct costs for cancer include the costs associated with travel to appointments and parking; telephone calls; housekeeping and laundry services; childcare; clothing; meals, snacks, supplements and hotel stays.

A recent study in the UK (Macmillan, 2012)[60] found that more than half (54%) of people living with cancer experienced higher day-to-day living costs, such as heating the home or paying for help with the home or garden and that, on average, these costs added up to an extra €70 a month for those affected. Over a third (37%) of people incurred costs for clothing, specialised equipment and home modifications, with those affected spending, on average, €80 a month.

No separate cost estimate has been included in this analysis to account for these costs for several reasons. The first is the inability to link these costs to specific cancer types in order to create an average cost which reflects the carcinogenic agents considered here. In addition, these costs are UK specific and may or may not also be relevant to other EU member states. There may also be double-counting between these figures and informal care costs (see below), given that a significant proportion relates to "help around the home or garden".

This assumption may result in the analysis provided here underestimating the direct costs of both fatal and non-fatal cancers, and across all cancer registrations the costs could be significant.

3.3.5 Informal care costs

Informal care costs can be calculated as the '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 cancer). Estimates of these costs were developed by Luengo-Fernandez et al (2013) in their study on the costs of cancer in the EU, with these reported in Table 3-3 above. As can be seen from Table 3-3, these costs can equate to a significant percentage of the direct health care costs associated with more formal medical treatment activities.

A decision has been taken to include informal care costs in this analysis even though some element of these costs may also have been included in individuals' willingness to pay values to avoid a future case of a fatal or non-fatal cancer. It is considered less likely that these are fully captured in the willingness to pay estimates in terms of the contribution of carers both in and out of employment. This decision may result in an overestimate of the costs of a cancer registration as generated by this study.

These costs are assumed to apply to all cancer registrations in the analysis presented here, regardless of whether or not the cancer is fatal or non-fatal.

3.3.6 Lost working days

Individuals will incur costs associated with their inability to work in terms of a loss of earnings, including losses linked to days of for treatment as well as days off due to illness. Luengo-Fernandez et al (2013) developed estimate of the magnitude of such costs by member state in terms of an average cost per fatal or non-fatal cancer. These included what are referred to as "productivity losses" due to early death and then lost working days due to morbidity effects. Across all cancers, an average figure of €5,047 is given for productivity losses and €1,118 for the costs associated with lost working days due to morbidity effects (with these based on lost wages as the measure of lost output).

There are difficulties in including the type of estimates generated by Luengo-Fernandez et al (2013) for lost working days within the analysis carried out here due to the potential for double counting.

[60] Macmillan (2012): Cancer's hidden price tag, Revealing the costs behind the illness, available at: http://www.macmillan.org.uk/Documents/GetInvolved/Campaigns/Costofcancer/Cancers-Hidden-Price-Tag-report-England.pdf

As discussed above, it is not clear whether the figures adopted in this study to reflect the intangible or human costs of cancer mortality and morbidity (i.e. €4 million and €400,000 respectively) also include an element related to the loss of income. If they do, then to include a separate cost item to reflect lost income would result in a double-counting of impacts.

Given the magnitude of the willingness to pay value adopted here for cancer mortality, the decision has been taken not to include an additional element for lost income for mortality effects. However, due to uncertainty as to what may be captured by the value adopted here for cancer morbidity, lost income due to lost working days is considered within this analysis.

This inclusion may result in an overestimation of the economic costs associated with cancer morbidity. However, the exclusion of lost output for cancer mortalities may also lead to an underestimation if these are not fully accounted for within the value of a statistical life figure used here to reflect the intangible or human costs of a cancer.

In estimating lost income associated with cancer morbidity, it is important to recognise that most occupational cancers will arise after individuals have ended their working life due to latency effects. For example, the UK HSE study estimated that around 70% of cancers will occur in individuals aged around 70 or over. This age distribution is also relevant for this study and for the carcinogens considered here. As a result, lost income due to lost working days is only assumed to apply to 30% of non-fatal cancer cases. Note that a similar pro rata adjustment would have to be made to any similar losses linked to cancer mortality, reducing the degree to which the exclusion of such costs here will result in an underestimate.

It is important to note that no account is taken here of the economic impacts to employers in responding to either the short or longer term absence of an employee (see also Table 3-1). This will result in an underestimation of the impacts of lost working days on employers associated with the need to reorganise work or hire new staff. In addition, costs to employers in relation to for example sickness benefits and insurance contributions are not included within this analysis due to the difficulties in undertaking such an analysis covering the EU-28 within the scope of this study. Similarly, the impacts on government finances are not considered here.

3.4 WP2-Step 3: Estimates at MS and EU level

3.4.1 Estimated costs

The direct estimation of the costs is based on the following equation:

Present value of a cancer case = discount factor x [(probability of death x VSL) +(probability of survival x cost of illness)]

Where: cost of illness = health care + informal care + lost earnings + VCM

The resulting estimates are not the "annual costs" of a cancer registration but reflect the present value (covering a 5 year period) of a cancer registration in 2015 due to past working practices leading to exposures to the 25 carcinogenic agents. The five year period embodied within the estimates allows for costs associated with treatment prior to mortality or survival to be taken into account.

The equation above requires the following data:

- Occupational cancer incidence;

- Data on survivability of the cancer in question, in terms of both the likelihood that an individual survives and the associated length of time;
- Data on the on medical costs for a particular type of cancer; and
- Data on the value of lost earnings and on the costs of informal care.

The total costs for the different scenarios are summarised below, indicating that the total cost of cancer registrations recorded in a given year and caused by past occupational exposure to carcinogenic agents is between €270 and €610 billion when both the full costs of mortality and morbidity (as defined for this study) are taken into account. If the human costs associated with morbidity effects are removed from the assessment (i.e. the WTP value of €410,000), then the present value costs fall to between €250 and €570 billion. These ranges reflect the three central scenarios (Central-core, Central-high, Central-low) and whether cancer incidence data are built around the EUCAN or EUREG registry.

Both of these sets of estimates are primarily driven by valuation of the human costs. Excluding the VSL (€4 million) and VCM estimates decreases the costs to between €4 and €10 billion, driven primarily by healthcare costs (both formal and informal).

Table 3-4: Summary of the total present value costs of annual occupational cancer registrations

Scenario	Source of data for calculation of AN	Total present value costs of 2015 cancer registrations (VSL and VCM) (€ billion)	Total present value costs of 2015 cancer registrations (VSL only) (€ billion)
Central-core	EUREG+GCO+UK	348	327
	EUCAN+UK	436	409
Central-low	EUREG+GCO+UK	267	253
	EUCAN+UK	295	279
Central-high	EUREG+GCO+UK	493	458
	EUCAN+UK	613	572

Note: These present value estimates represent the costs associated with cancer registrations recorded in a single year, with the associated costs possibly spread over a number of years.

These cost figures are significant, and equate to between roughly 1.8% and 4.1% of EU GDP (based on 2015 Eurostat data) for the estimates including both the VSL and VCM valuations of the human costs of cancer. Removing the figure for VCM from the estimates, reduces this slightly to between 1.7% and 3.9% of EU GDP. The vast majority of these costs relate to mortality. Non-fatal cancer cases account for 6% of the overall costs under the three central scenarios.

The costs in the table above are also of a similar order of magnitude to those estimated recently in RIVM (2016).[61] RIVM (2016) concluded that the total societal cost of work-related cancer is at least in the order of magnitude of €334 billion (range: €242-440 billion), the largest component of which is the welfare loss associated with cancer morbidity and mortality (€329 billion).

These figures compare to those produced by Luengo-Fernandez et al (2013) on the per annum total costs of cancer in the EU, which they estimated €126 billion for 2009, with health care accounting for €51.0 billion (40%). It is important to note that this figure covers occupational and non-occupational cancers. In addition, it reflects the costs associated with cancer in a given year, rather than the present value costs of the cancer registrations predicted for 2015, as developed by this study.

[61] RIVM (2016): Work related cancer in the European Union, available at http://rivm.nl/en/Documents_and_publications/Scientific/Reports/2016/mei/Work_related_cancer_in_the_European_Union_Size_impact_and_options_for_further_prevention

Furthermore, the costs developed by Luengo-Fernandez et al do not include any allowance for intangible costs.

Assuming that around 8% of the costs in Luengo-Fernandez et al (2013) are caused by occupational cancer suggests that the costs of occupational cancer in 2009 were around €10 billion. This compares to around €14 billion calculated for the Central-core scenario in this study when all intangible costs are excluded from the analysis.

The costs also show reasonable convergence with the UK HSE's estimates, even though there are some significant differences in the underlying assumptions on the value of avoiding a fatal and non-fatal case of cancer as discussed above. The UK study found total costs of £12.3 billion for cancer registrations in 2010. Just over 93% of these, or £11.4 billion, are attributed to the human costs of cancer. Given that the UK accounts for around 15-16% of EU GDP, these figures show reasonable convergence with the EU-wide estimates developed here.

3.4.2 Distribution of the costs

In addition to the magnitude of the costs, also of interest is the distribution of these to different groups within society. Table 3-5 provides this for the Central-core scenario, and for estimates incorporating both the VSL and VCM.

Table 3-5: Distribution of costs across different types (€ billion)

Scenario/ Source of data for calculation of AN	Type of cost	Group bearing the cost	Total present value costs	Share of total costs
Central-core EUREG+GCO+UK	Healthcare	Government/taxpayers	5	1.4%
	Lost working days	Worker/ family	0.3	0.1%
	Informal care	Worker/ family	1	0.3%
	VSL	Worker/ family	311	89.3%
	VCM	Worker/ family	31	8.9%
	TOTAL		348	
Central-core/ EUCAN+UK	Healthcare	Government/taxpayers	6	1.3%
	Lost working days	Worker/ family	0.4	0.1%
	Informal care	Worker/ family	1	0.3%
	VSL	Worker/ family	394	90.3%
	VCM	Worker/ family	35	8%
	TOTAL		436	

As can be seen from Table 3-5, because the analysis undertaken here has not been able to capture the costs incurred by employers, there is no component within the estimates to reflect the magnitude of the costs that they incur due to the occupational burden of cancer.

The UK HSE study, because it was examining costs for a single country, was able to develop estimates of the costs borne by employers. For the UK, they estimated that around 3% of total costs to society were borne by employers, with the total equating to around £461 million per annum. This in turn equates to a cost of roughly £14.40 per worker per annum. Converting this figure to Euros[62] and multiplying it across the EU-28 worker population (aged 15 to 64) gives a total figure of €4.13 billion in costs to employers associated with the costs of production disturbance, sickness payments due to worker absence and legal obligations with regard to employers' liability insurance. This figure

[62] An exchange range of £1 = €1.2 has been used for these purposes.

does of course reflect requirements in the UK which may be more or less onerous than those that apply in other member states. However, it provides an indication of significance of these costs.

They are only a small percentage of the total costs with this type of finding being attributed to the nature of cancer as an occupational disease. Many of the cancers considered here have latency periods of between 10 and 50 years. As a result, most individuals diagnosed with occupational exposure-related cancer (estimated at over 70%) will have left work by the time they are diagnosed, or may have changed jobs. The relevant employer during the period of exposure will not therefore bear the costs of disruption from sickness absence, paying sick pay, etc. As noted by the UK HSE, the figure of £461 million is also an under-estimate as it fails to capture some costs to employers that may be significant, such as those associated with the loss of expertise, and reductions in productivity of those returning to work after successful cancer treatment. Reputational damage (which can impact on sales and recruitment) is also not included.

3.5 WP2-Step 4: Sensitivity analysis

The key parameters that are subject to uncertainty include:

- The AF for occupational cancer; and
- The treatment of intangible costs in the economic analysis.

Uncertainty regarding the AFs estimated in this study is dealt with by means of the different scenarios constructed under WP1, which show the spread of the costs, depending on the assumptions used for the analysis. This section therefore focuses on the remaining source of uncertainty, i.e. the treatment of intangible costs.

It should also be noted that the analysis in this study focuses exclusively on cancer and non-cancer health endpoints associated with occupational exposure to some of the 25 carcinogens have not been monetised in this study.

As noted above, the total cost of cancer registrations recorded in a given year and caused by past occupational exposure to carcinogenic agents has been estimated to be between €270 and €610 billion, with this figure being driven by the assumed value of a statistical life (€4 million above). The VSL of €4 million is based on studies that have applied multiple adjustments to account for the fact that cancer is a particularly severe illness, as well as cancer specific valuation work. It is much higher though than the valuations that have been recommended in other guidance, as well as that applied in the recent UK HSE study. At the EU level, for example, ECHA's guidance on SEA[63] provides a central value of €1,052,000 (2003 prices). Using a figure updated to €2015 (€1.33 million) and adopting this as part of our assessment, illustrates the importance of this assumption to the costs estimated above – see Table 3-6.

[63] Based on environmental pollution willingness to pay values.

Table 3-6: Summary of economic costs – sensitivity analysis on the VSL			
Scenario	**Source of data for calculation of AN**	**Total cost of annual cancer registrations (€ billion) VSL: €4 million**	**Total cost of annual cancer registrations (€ billion) VSL: €1.33 million**
Central-core	EUREG+GCO+UK	348	134
	EUCAN	436	167

As can be seen from Table 3-6, the costs (excluding valuation also of the human costs of morbidity using the VCM) fall significantly from €348 to €436 under the Central-core scenario, to between €134 and €167 million.

However, it must be stressed that adopting this lower value would result in the failure to account for cost components explicitly left out of the main assessment due to concerns over double counting. In particular, it would fail to account for lost output associated with cancer fatalities as well as non-medical costs incurred by individuals. Both of these have been assumed to be incorporated into the willingness to pay value of €4 million per prevented fatality. The failure to account for lost output (i.e. productivity losses) in particular would result in a significant underestimation of costs being borne by workers.

4 Annex 1: Methodology and AFs for the 26 carcinogens

4.1 DEE

4.1.1 Methodology/assumptions

Summary of the relevant cancer endpoints and exposure period(s)

The relevant cancer endpoints include **lung** and **bladder** cancer (IARC, 2016[64]; Rushton et al 2012[65]).

All (100%) cancer sites for which DEE was identified in IARC (2016) as a carcinogenic for humans with sufficient or limited evidence are therefore considered in this study.

Hu et al (1994)[66] have estimated the latency of lung cancer at over 50 years, although the minimum latency periods for different types of lung cancer have been estimated to be significantly less (Howard, 2013[67]). Nadler & Zurbenko (2014)[68] have estimated the typical latency period at 25 years for gallbladder and 14 years for lung and bronchus cancer. Should the estimated latency be shorter than the 40 year period taken as a basis for calculations for this study, this runs the risk of overestimating the attributable fractions for lung and bladder cancer.

The typical latency for both cancer endpoints is modelled to be between 10 and 50 years. The relevant exposure period is thus defined as 1966-2005.

Exposed population

The starting point for estimating the occupationally exposed population is the CAREX database, with further estimates being available from national databases for Finland and France. These estimates are summarised below.

Table 4-1: Published data – workforce exposed to Diesel engine exhaust fumes

Study	Country	Year/period	No. of exposed workers	% of exposed workforce	Notes
Carex	EU15	1990-1993 (mean)	2,968,999		
	France	1990-1993 (mean)	410,499		
	Finland	1990-1993 (mean)	38,490		
	UK	1990-1993 (mean)	473,062		

[64] IARC (2016): List of classifications by cancer sites with sufficient or limited evidence in humans, available at https://monographs.iarc.fr/ENG/Classification/Table4.pdf

[65] Rushton et al (2012): Occupational cancer in the UK – overview report, available at http://www.hse.gov.uk/research/rrpdf/rr931.pdf

[66] Hu et al (1994): Estimation of latency period of lung cancer, available at http://www.ncbi.nlm.nih.gov/pubmed/8033741

[67] Howard (2013): Minimum Latency & Types or Categories of Cancer, available at https://www.cdc.gov/wtc/pdfs/wtchpminlatcancer2013-05-01.pdf

[68] Nadler & Zurbenko (2014): Estimating Cancer Latency Times Using a Weibull Model, available at https://www.hindawi.com/archive/2014/746769/tab2/

Table 4-1: Published data – workforce exposed to Diesel engine exhaust fumes					
Study	**Country**	**Year/period**	**No. of exposed workers**	**% of exposed workforce**	**Notes**
SUMER	France	2003	727,500 (699,300 men and 28,200 women)	4.2% (7% men and 0.4% women)	
		2010	798,000 (754,300 men and 43,600 women)	3.7% (6.4% men and 0.4% women)	
FinJem	Finland	2006	45,000		Use of diesel engines, transportation, mines.
Rushton	UK	Published 2004-2005 Estimate for a 50 year period	2,063,271 (1,632,804 men; 452,017 women) over a 50 year period		Based on Carex

The national estimates for France suggest a higher exposed population in the EU-28 than the CAREX estimates (the CAREX data suggest an exposed population of around 4.4 million in the early 1990s). The FinJem estimate for Finland is of a similar order of magnitude as the CAREX estimate. The relevant extrapolations are summarised in the table below.

Table 4-2: Occupationally exposed population in the EU-28 extrapolated from national data	
Estimate and method of extrapolation	**Exposed population in the EU-28 and year**
A: France 2010 total exposed population, extrapolated based on population	6.1 million in 2010
B: France 2010 % of workforce, extrapolated based on workforce data[69]	8.1 million in 2010
C: Finland 2006 total exposed population, extrapolated based on population	4.2 million in 2006

The CAREX estimate (4.4 million in the early 1990s) is therefore taken as the basis for the LOW scenario while the extrapolation of the French estimate that relies on workforce data (see B in the table above) is used for the HIGH scenario. The CENTRAL scenario is based on the population-based extrapolation of the French data (A in the table above).

Rate of change

Comparing the number of workers exposed in France in 2003 and 2010 (SUMER) suggests an annual rate of increase of around 1%. However, applying this rate of change over 1966-2005 runs the risk of underestimating the risks to workers at the beginning of the assessment period. For this reason, two scenarios for the annual rate of change have been modelled:

- no change; and
- an annual increase of 1% throughout the EU.

[69] According to Eurostat, the total number of people in employment or self-employment in the EU-28 was 220 million in 2015.

A generic staff turnover factor of 10% per annum has been used.

Relative risk

The relative risk estimates identified through literature review are summarised below.

Table 4-3: Literature review of relative risk		
Study & summary of data/methodology	**Cancer site**	**Relative risk**
IOM (2011). Literature review and meta-analysis	Bladder	RR=1.24 (95% CI: 1.10-1.41)
Lipsett & Campleman (1999), cited in IOM (2011) & Rushton et al (2012)	Lung	RR=1.47 (95% CI: 1.29, 1.67)
Menvielle et al 2016.	Lung	OR=1.34 (95% CI: 1.17, 1.53)
Olssen et al (2011). Pooled case-control study in Europe and Canada	Lung	OR=1.31 (95% CI: 1.19-1.43)
Rushton L et al (2012) from Boffetta & Silverman (2001)	Bladder	RR=1.24 (95% CI: 1.01, 1.41)
Silverman et al (2012). Case-control study of miners	Lung	OR=3.20 (95% CI: 1.33,7.69) for highest exposure
Tsoi and Tse 2012. Review and meta-analysis of professional drivers	Lung	RR=1.22 (95% CI: 1.09-1.36) for all professional drivers
Villeneuve et al (2011).	Lung	OR=1.68 (95% CI: 1.03-2.74) for large-cell carcinoma
Sources: Attfield MD et al (2012): The Diesel Exhaust in Miners Study: A Cohort Mortality Study with Emphasis on Lung Cancer. J Natl Cancer Inst 104: 869-883. Canadian men. Environ Res 111: 727-735. Cancer and Diesel Exhaust. J Natl Cancer Inst 104: 855-868 IOM (2011): Diesel Engine Exhaust Emissions. Available at *ec.europa.eu/social/BlobServlet?docId=10166&langId=en* Menvielle G, et al (2016): Quantifying the mediating effects of smoking and occupational exposures in the Olsson A et al (2011): Exposure to Diesel Motor Exhaust and Lung Cancer Risk in a Pooled Analysis from Case-Control Studies in Europe and Canada. Am J Respir Crit Care Med; 183: 941-948. relation between education and lung cancer: the ICARE study. Eur J Epidemiology Rushton L et al (2012): The burden of occupational cancer in Great Britain. Available at http://www.hse.gov.uk/research/rrpdf/rr931.pdf Silverman DT et al (2012): The Diesel Exhaust in Miners Study: A Nested Case – Control Study of Lung Villeneuve PJ et al (2011): Occupational exposure to diesel and gasoline emissions and lung cancer in		

The highest and lowest risk estimates are summarised below.

Table 4-4: Summary of relative risk – exposure to diesel exhaust		
Cancer site	**Lowest**	**Highest**
Lung	RR=1.15	OR=3.20
Bladder	RR=1.24	RR=1.24

Summary of the scenarios

The assumptions underpinning the different estimates are summarised below. Please note that the estimates of the exposed population are point estimates for a specific year and do not represent the

lowest and highest annual estimates over the whole assessment period since these also depend on the annual rate of change.

Table 4-5: Summary of the scenarios (DEE)				
Aspect/scenario	**Low**	**High**	**Midpoint**	**Central**
Exposed population (EU-28) - point	4.4 million in 1990-93 or 1997	8.1 million in 2010	6.3 million in 2010	6.1 million in 2010
Relevant cancer sites	Lung, bladder (2 of 2)	Lung, bladder (2 of 2)	Lung, bladder (2 of 2)	Lung, bladder (2 of 2)
Relative risk	Lung RR=1.15 Bladder RR=1.24	Lung OR=3.2 Bladder RR=1.24	Lung 2.7 Bladder RR=1.24	Lung RR=1.47 Bladder RR=1.24
Change (p.a.)	1%	0%	0.5%	0%

4.1.2 The results

Summary of the occupationally exposed population (surviving to 2015)

The total number of workers in the EU-28 exposed to DEE between 1966 and 2005 and surviving to 2015 has been estimated to be between 15 and 28 million.

Table 4-6: Occupationally exposed population surviving to 2015 (DEE)		
Scenario	**No. of workers exposed 1966-2005 & surviving to 2015 (million)**	**% of current & at risk population**
Low	15	4.9%
High	28	8.9%
Midpoint	20	6.4%
Central	21	6.7%

The break-down of these figures by Member State is provided below. The minimum and maximum values across all scenarios are presented for each Member State.

Table 4-7: Occupationally exposed population surviving to 2015 by Member State (DEE, 1966-2005)				
Member State	**Number of workers exposed over the period and surviving to 2015**		**% of current & at risk population**	
	Min	**Max**	**Min**	**Max**
Austria	287,885	482,094	5.3%	8.9%
Belgium	243,417	632,865	3.4%	8.9%
Bulgaria	290,854	404,854	6.4%	8.9%
Croatia	170,635	237,516	6.4%	8.9%
Cyprus	22,485	47,612	4.2%	8.9%
Czech Republic	425,578	592,383	6.4%	8.9%
Denmark	228,562	318,147	6.4%	8.9%
Estonia	53,035	73,822	6.4%	8.9%
Finland	139,731	307,581	4.1%	8.9%
France	1,490,244	3,733,366	3.6%	8.9%
Germany	2,691,678	4,564,321	5.3%	8.9%
Greece	285,147	610,357	4.2%	8.9%
Hungary	398,008	554,007	6.4%	8.9%
Ireland	76,509	260,205	2.6%	8.9%
Italy	2,005,736	3,417,477	5.2%	8.9%
Latvia	70,399	111,644	5.6%	8.9%
Lithuania	117,972	164,212	6.4%	8.9%

Table 4-7: Occupationally exposed population surviving to 2015 by Member State (DEE, 1966-2005)				
Member State	Number of workers exposed over the period and surviving to 2015		% of current & at risk population	
	Min	Max	Min	Max
Luxembourg	15,952	31,645	4.5%	8.9%
Malta	13,839	24,135	5.1%	8.9%
Netherlands	395,466	950,033	3.7%	8.9%
Poland	1,534,820	2,136,393	6.4%	8.9%
Portugal	265,653	583,195	4.1%	8.9%
Romania	802,457	1,116,980	6.4%	8.9%
Slovakia	218,936	304,748	6.4%	8.9%
Slovenia	83,307	115,959	6.4%	8.9%
Spain	995,874	2,611,049	3.4%	8.9%
Sweden	292,695	547,924	4.8%	8.9%
UK	1,717,368	3,646,799	4.2%	8.9%
Total	***15,626,756***	***28,581,323***	***4.9%***	***8.9%***

AFs per Member State

Table 4-8: Overall attributable fractions across all industries by Member State (DEE)						
Cancer site/ scenario	Lung			Bladder		
	C-Low	C-Core	C-High	C-Low	C-Core	C-High
Austria	1.9%	3.1%	4.3%	0.1%	1.6%	2.7%
Belgium	1.9%	3.1%	4.3%	0.1%	1.6%	2.7%
Bulgaria	1.9%	3.1%	4.3%	0.1%	1.6%	2.7%
Croatia	1.9%	3.1%	4.3%	0.1%	1.6%	2.7%
Cyprus	1.9%	3.1%	4.3%	0.1%	1.6%	2.7%
Czech Republic	1.9%	3.1%	4.3%	0.1%	1.6%	2.7%
Denmark	1.9%	3.1%	4.3%	0.1%	1.6%	2.7%
Estonia	1.9%	3.1%	4.3%	0.1%	1.6%	2.7%
Finland	1.9%	3.1%	4.3%	0.1%	1.6%	2.7%
France	1.9%	3.1%	4.3%	0.1%	1.6%	2.7%
Germany	1.9%	3.1%	4.3%	0.1%	1.6%	2.7%
Greece	1.9%	3.1%	4.3%	0.1%	1.6%	2.7%
Hungary	1.9%	3.1%	4.3%	0.1%	1.6%	2.7%
Ireland	1.9%	3.1%	4.3%	0.1%	1.6%	2.7%
Italy	1.9%	3.1%	4.3%	0.1%	1.6%	2.7%
Latvia	1.9%	3.1%	4.3%	0.1%	1.6%	2.7%
Lithuania	1.9%	3.1%	4.3%	0.1%	1.6%	2.7%
Luxembourg	1.9%	3.1%	4.3%	0.1%	1.6%	2.7%
Malta	1.9%	3.1%	4.3%	0.1%	1.6%	2.7%
Netherlands	1.9%	3.1%	4.3%	0.1%	1.6%	2.7%
Poland	1.9%	3.1%	4.3%	0.1%	1.6%	2.7%
Portugal	1.9%	3.1%	4.3%	0.1%	1.6%	2.7%
Romania	1.9%	3.1%	4.3%	0.1%	1.6%	2.7%
Slovakia	1.9%	3.1%	4.3%	0.1%	1.6%	2.7%
Slovenia	1.9%	3.1%	4.3%	0.1%	1.6%	2.7%
Spain	1.9%	3.1%	4.3%	0.1%	1.6%	2.7%
Sweden	1.9%	3.1%	4.3%	0.1%	1.6%	2.7%
UK	1.9%	3.1%	4.3%	0.1%	1.6%	2.7%
EU-28	***1.9%***	***3.1%***	***4.3%***	***0.1%***	***1.6%***	***2.7%***

4.2 Silica

4.2.1 Methodology/assumptions

Summary of the relevant cancer endpoints and exposure period(s)

The relevant cancer endpoints and latency periods are (IARC, 2016[70]; Santé Publique France 2016[71]):

- Lung cancer, latency 10-50 years, 1966-2005; and
- Laryngeal cancer, 10-50 years, 1966-2005.

Only one cancer site (lung) was identified in IARC (2016) as relevant to silica. As a result, more cancer sites are covered in this report than those that were identified as relevant in IARC (2016).

Exposed population

The starting point for estimating the occupationally exposed population is the CAREX database, with further estimates being available for France from SUMER (2003 and 2010), for Finland from FinJem (2006), for the Czech Republic from Regex (2009-2016), and for the UK from Rushton et al (2012), although the data in Ruston are based on CAREX. These estimates are summarised below.

Table 4-9: Published data – workforce exposed to silica

Study	Country	Year/period	No. of exposed workers	% of exposed workforce	Notes
Carex	EU15	1990-1993 (mean)	3,089,054		
	France	1990-1993 (mean)	108,164		
	Czech Republic	1997	170,603		
	Finland	1990-1993 (mean)	82,550		
	UK	1990-1993 (mean)	589,929		
SUMER	France	2003	269,000 (254,100 men and 14,900 women)	1.5% (2.5% men and 0.2% women)	
		2010	294,900 (279,200 men and 15,600 women)	1.4% (2.4% men and 0.2% women)	
FinJem	Finland	2006	70,000		Exposure to Quartz dust. Construction work, mining,

[70] IARC (2016): List of classifications by cancer sites with sufficient or limited evidence in humans, available at https://monographs.iarc.fr/ENG/Classification/Table4.pdf

[71] Santé Publique France (2016): Estimation de parts de cancers attribuables à certaines expositions professionnelles en France, available at: http://invs.santepubliquefrance.fr/Publications-et-outils/Rapports-et-syntheses/Travail-et-sante/2016/Estimation-de-parts-de-cancers-attribuables-a-certaines-expositions-professionnelles-en-France

Table 4-9: Published data – workforce exposed to silica					
Study	**Country**	**Year/period**	**No. of exposed workers**	**% of exposed workforce**	**Notes**
					quarries etc.
Regex	Czech Republic	2009-2016	219		
Rushton	UK	Published in 2004-2005, refers to ever exposed workers	2,781,429 (2,525,118 men; 256,311 women)		Based on Carex

Extrapolations to the EU-28 are summarised below. No extrapolations have been carried out on the basis of the Regex data for the Czech Republic; it is assumed that these are outliers.

Table 4-10: Occupationally exposed population in the EU-28 (silica)	
Estimate and method of extrapolation	**Exposed population in the EU-28**
A: CAREX early to mid-1990s	4.9 million
B: France 2003 exposed workers extrapolated on the basis of population	2.1 million
C: France 2003 share (1.5%) applied to current EU workforce	3.1 million
D: France 2010 exposed workers extrapolated on the basis of population	2.3 million
E: France 2010 share (1.4%) applied to current EU workforce	3.0 million
F: Finland 2006 exposed workers extrapolated on the basis of population	6.6 million
H: UK ever exposed workers extrapolated on the basis of population (converted to an annual estimate)	4.4 million

Estimates B and D in the table above (2.1 million in 2003 and 2.3 million in 2010) form the basis for the LOW scenario while estimate F is used for the HIGH scenario (6.6 million in 2006). The CENTRAL scenario is based on an extrapolation of the average of the Rushton, Sumer (2003 and 2010) and CAREX data (estimates A, C, E and H).

Rate of change

Comparing the number of workers exposed in France in 2003 and 2010 (SUMER) suggests an annual increase of around 1.3% as well as an annual decrease in exposed workforce of around 0.5%. The following scenarios are modelled:

- no change; and
- an annual increase of 1.3%.
- an annual decrease of 0.5%

A generic staff turnover factor of 10% per annum has been used.

Relative risk

The relative risk estimates identified through literature review are summarised below.

Table 4-11: Literature review of relative risk		
Study & summary of data/methodology	**Cancer site**	**Relative risk**
Guida (2013), cited in Santé Publique France (2016)	Lung	OR: 1.35 (95% CI [1.03 – 1.77])
Pelucchi (2006), cited in Santé Publique France (2016)	Lung	RR: 1.41 (95% CI [1.18-1.70])
Checkoway et al (1997)	Lung	RR: 1.06 (95% CI [1.01-1.11])
Hnizdo & Sluis-Cremer (1991)	Lung	RR: 1.02 (95% CI [1.01-1.04])
Carta et al (2001)	Lung	<5.0 g-hr/m^3: RR: 1.55 (95% CI [0.59-2.57]) 5.1-10.0: RR: 1.25 (95% CI [0.73-2.15]) >10.0: RR : 1.35 (95% CI [0.73-2.51])
Brown & Rushton (2005)	Lung	<0.13 mg-yr/m^3: RR: 1.0 0.13-<0.40: RR: 1.24 (95% CI [0.66-2.34]) 0.40-<1.0: RR : 1.42 (95% CI [0.76-2.67]) >=1.00: RR : 0.88 (95% CI [0.45-1.73])
Sogl et al (2012)	Lung	15 mg/m^3: RR: 1.24 (95% CI [0.98-1.49])
Poinen-Rughooputh et al (2016). Meta-analysis of epidemiological studies	Lung	Pooled SMR: 2.32 (95% CI: 1.91-2.81) for silicotics; Pooled SMR: 1.78 (95% CI: 1.04-2.96) for non-silicotics; Pooled SIR: 2.49 (95% CI: 1.87-3.33) for silicotics; Pooled SIR: 1.18 (95% CI: 0.86-1.62) for non-silicotics
Pelucchi et al (2006). Systematic review of epidemiological literature	Lung	Pooled RR: 1.34 for cohort studies; Pooled RR: 1.41 for case-control studies
Lacourt et al (2015). Two case-control studies of construction workers in Montreal	Lung	OR: 1.7 (95% CI: 1.0-3.0) for substantially exposed; OR: 1.2 (95% CI: 0.9-1.5) for ever exposed
Kachuri et al (2014). Population based case-control study	Lung	OR: 1.67 (95% CI: 1.21,2.24) for >30 years exposure OR: 1.81 (95% CI: 1.34, 2.42) for high cumulative exposure; OR: 1.20 (95% CI: 1.00, 1.43) for ever exposed
Ore mining		
Carta et al (2001)	Lung	Cumulative total dust exposures: ≤10 (g-hr/m^3) RR = 1.0, >10 RR = 1.30 (95% CI 0.71-2.68), linear continuous RR = 1.003 (NS)
Chen and Chen (2002)	Lung	Cumulative total dust exposures: Unadjusted for silicosis: <0.1 (mg-yr/m^3) RR = 1.0, 0.1–14.9 RR = 2.1 (95% CI 1.1 to 3.8), 50–119.9 RR = 1.7 (95% CI 0.9 to 3.1),

Table 4-11: Literature review of relative risk		
Study & summary of data/methodology	**Cancer site**	**Relative risk**
		≥120 RR = 2.8 (95% CI 1.6-5.0)
Chen at al (2007)	Lung	Cumulative silica dust exposures: 0 (mg-yr/m^3) RR = 1.0, 0.1–1.1 RR = 1.40 (95% CI 0.81 – 2.43), 1.1–2.6 RR = 1.54 (95% CI 0.90– 2.63), 2.6–5.4 RR = 1.30 (95% CI 0.7 – 2.24), 5.4–10.1 RR = 1.18 (95% CI 0.68– 2.06)
Reid and Sluis-Cremer (1996)	Lung	Cumulative dust exposure up to 5 years before death of case: Continuous RR = 1.19 (95% CI 0.97– 1.70)
Hnizdo & Sluis-Cremer (1991)	Lung	Cumulative mixed dust exposure: Continuous exposure RR = 1.02 (95% CI 1.01–1.04)
Ceramics		
Ulm et al (1999)	Lung	Cumulative silica dust exposures: *Ceramics* ≤ 2.88 (mg-yr/m^3) RR = 1.00 > 2.88 RR = 1.05 (95% CI 0.59–1.86) *All* < 1.56 (mg-yr/m^3) RR = 1.00 1.56–2.88 RR = 0.95 (95% CI 0.48 – 1.53) 2.89–4.68 RR = 0.92 (95% CI 0.44 – 1.61) > 4.68 RR = 1.04 (95% CI 0.53 – 1.89)
Chen et al (2007)	Lung	Cumulative silica dust exposures: 0 (mg-yr/m^3) 1.0 0.1–1.1 RR = 1.4 (95% CI 0.81 – 2.43) 1.1–2.6 RR = 1.54 (95% CI 0.90 – 2.63) 2.6–5.4 RR = 1.30 (95% CI 0.75 – 2.24) 5.4–10.1 RR = 1.18 (95% CI 0.68 – 2.06)
Stone quarries		
Ulm et al (1999)	Lung	Cumulative silica dust exposures: < 1.56 (mg-yr/m^3) RR = 1.00 1.56–2.88 RR = 0.95 (95% CI 0.48 – 1.53) 2.89–4.68 RR = 0.92 (95% CI 0.44 – 1.61) > 4.68 RR = 1.04 (95% CI 0.53 – 1.89)
Sand and gravel		
McDonald et al (2005)	Lung	Cumulative silica dust exposures: ≤ 700 (µg-yr/m^3) RR = 1.00

Table 4-11: Literature review of relative risk		
Study & summary of data/methodology	**Cancer site**	**Relative risk**
		> 700–≥ 1 800 RR = 1.10 > 1 800–≥ 4 500 RR = 1.77 > 4 500 2.64 (trend P = 0.06)
Other		
Steenland et al (2001)	Lung	Cumulative silica dust exposure: Unlagged < 0.04 (mg-yr/m^3) RR = 1.0 0.04–2.0 RR = 1.0 (0.85–1.3) 2.0–5.4 RR = 1.3 (1.1–1.7) 5.4–12.8 RR = 1.5 (1.2–1.9) ≥ 12.8 RR = 1.6 (1.3–2.1)
Diatomaceous earth		
Checkoway et al (1997)	Lung	Continuous silica dust exposure: RR = 1.06 (95% CI 1.01–1.11)
Elci et al. (2002). From Santé Publique France (2016)	Laryngeal cancer	OR 1.5 (95% CI [1.2 – 1.9])
Chen et al. (2012). From Santé Publique France (2016)	Laryngeal cancer	OR 1.39 (95% CI [1.17 – 1.67])

Sources:

Santé Publique France (2016): Estimation de parts de cancers attribuables à certaines expositions professionnelles en France, available at: http://invs.santepubliquefrance.fr/Publications-et-outils/Rapports-et-syntheses/Travail-et-sante/2016/Estimation-de-parts-de-cancers-attribuables-a-certaines-expositions-professionnelles-en-France

Checkoway et al (1997): Dose-Response Associations of Silica with Nonmalignant Respiratory Disease and Lung Cancer Mortality in the Diatomaceous Earth Industry, *American Journal of Epidemiology*, vol. 145, No. 8, pp. 680-688

Hnizdo E, Sluis-Cremer GK. (1991) Silica exposure, silicosis, and lung cancer: a mortality study of South African gold miners. Br J Ind Med; 48: 53–60.

Carta et al. (2001): Mortality from lung cancer among silicotic patients in Sardinia: an update study with 10 more years of follow up, available at: http://oem.bmj.com/content/58/12/786.full

Brown & Rushton (2005): Mortality in the UK Industrial Silica Sand Industry: 2. A Retrospective Cohort Study, available at: https://www.jstor.org/stable/27732554?seq=1#page_scan_tab_contents

Sogl et al (2012): Quantitative relationship between silica exposure and lung cancer mortality in German uranium miners, 1946–2003, available at: http://www.nature.com/bjc/journal/v107/n7/full/bjc2012374a.html

McCormic ZD et al (2010): Occupational silica exposure as a risk factor for scleroderma: a meta-analysis, available at: https://www.ncbi.nlm.nih.gov/pubmed/20047060

Lacourt A et al (2015): Lung cancer risk among workers in the construction industry: results from two case-control studies in Montreal. BMC Public Health, 15:941

Kachuri L et al (2014): Occupational exposure to crystalline silica and the risk of lung cancer in Canadian men. International Journal of Cancer, 135, pp 138-148

Pelucchi C et al (2006): Occupational silica exposure and lung cancer risk: a review of epidemiological studies 1996-2005. Annals of Oncology, 17, pp 1039-1050.

Poinen-Rughooputh S et al (2016): Occupational exposure to silica dust and risk of lung cancer: an updated meta-analysis of epidemiological studies. BMC Public Health, 16:1137.

Chen and Chen (2002): Nested case-control study of lung cancer in four Chinese tin mines. Occup Environ Med. 2002;59:113-118, available at http://oem.bmj.com/content/59/2/113.full

Chen et al (2007): Effects of work related confounders on the association between silica exposure and lung cancer: a nested case-control study among Chinese miners and pottery workers. Int Arch Occup Environ Health. 2007;80:320-326, available at https://www.researchgate.net/publication/6890281_Effects_of_work_related_confounders_on_the_association_between_silica_exposure_and_lung_cancer_A_nested_case-control_study_among_Chinese_miners_and_pottery_workers

McDonald et al (2005): Mortality from Lung and Kidney Disease in a Cohort of North American Industrial Sand

Table 4-11: Literature review of relative risk		
Study & summary of data/methodology	**Cancer site**	**Relative risk**
Workers: An Update. Ann Occup Hyg. 2005;49(5):367-373 https://academic.oup.com/annweh/article/49/5/367/194509/Mortality-from-Lung-and-Kidney-Disease-in-a-Cohort Reid and Sluis-Cremer (1996): Mortality of white South African gold miners. Occup Environ Med. 1996;53:11-16, available at https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1128398/ Steenland et al (2001): Pooled Exposure-Response Analyses and Risk Assessment for Lung Cancer in 10 Cohorts of Silica-Exposed Workers: An IARC Multicentre Study. Cancer Causes & Control 2001; 12(9):773-784, abstract available at https://www.jstor.org/stable/3553765?seq=1#page_scan_tab_contents Ulm et al (1999): Silica dust and lung cancer in the German stone, quarrying, and ceramics industries: results of a case-control study. Thorax. 1999 Apr; 54(4): 347–351, available at https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1745453/		

The lowest and highest relative risks identified through literature are summarised below.

Table 4-12: Summary of relative risk – exposure to silica		
Cancer site	**Lowest**	**Highest**
Lung	RR=1	RR = 2.8
Laryngeal cancer	OR=1.39	OR=1.5

Summary of the scenarios

The assumptions underpinning the different estimates are summarised below. Please note that the estimates of the exposed population are point estimates for a specific year and do not represent the lowest and highest annual estimates over the whole assessment period since these also depend on the annual rate of change.

Table 4-13: Summary of the scenarios (silica)				
Aspect/scenario	**Low**	**High**	**Midpoint**	**Central**
Exposed population (EU-28) - point	2.2 million (assumed in 2007)	6.6 million (assumed in 2006)	4.4 million (assumed in 2007)	3.85 million (assumed in 2002)
Relevant cancer sites	Lung and Laryngeal cancer (1 more than IARC 2016)	Lung and Laryngeal cancer (1 more than IARC 2016)	Lung and Laryngeal cancer (1 more than IARC 2016)	Lung and Laryngeal cancer (1 more than IARC 2016)
Relative risk	Lung: RR=1 Laryngeal cancer: OR=1.39	Lung: RR = 2.8 Laryngeal cancer: OR=1.5	Lung: RR=1.9 Laryngeal cancer: OR=1.445	Lung: RR = 1.41 Laryngeal cancer: OR=1.5
Change (p.a.)	1.3%	-0.5%	0.4%	0.4%

4.2.2 The results

Summary of the occupationally exposed population surviving to 2015

The total number of workers in the EU-28 exposed to silica between 1966 and 2005 and surviving until 2015 is summarised below.

Table 4-14: Occupationally exposed population surviving to 2015 (silica)		
Scenario	**No. of workers exposed 1966-2005 & surviving to 2015 (million)**	**% of current & at risk population**
Low	6.6	2.1
High	20.2	6.3
Midpoint	14.7	4.6
Central	13.3	4.1

The break-down of these figures by Member State is provided below. The minimum and maximum values across all scenarios are presented for each Member State.

Table 4-15: Occupationally exposed population surviving to 2015 by Member State (silica, 1966-2005)				
Member State	**Number of workers exposed over the period and surviving to 2015**		**% of current & at risk population**	
	Min	**Max**	**Min**	**Max**
Austria	111,328	341,069	2.1%	6.3%
Belgium	146,145	447,737	2.1%	6.3%
Bulgaria	93,491	286,424	2.1%	6.3%
Croatia	54,848	168,037	2.1%	6.3%
Cyprus	10,995	33,685	2.1%	6.3%
Czech Republic	136,796	419,097	2.1%	6.3%
Denmark	73,468	225,081	2.1%	6.3%
Estonia	17,047	52,227	2.1%	6.3%
Finland	71,028	217,606	2.1%	6.3%
France	862,129	2,641,265	2.1%	6.3%
Germany	1,054,018	3,229,145	2.1%	6.3%
Greece	140,947	431,813	2.1%	6.3%
Hungary	127,934	391,946	2.1%	6.3%
Ireland	60,088	184,089	2.1%	6.3%
Italy	789,183	2,417,781	2.1%	6.3%
Latvia	25,781	78,985	2.1%	6.3%
Lithuania	37,921	116,176	2.1%	6.3%
Luxembourg	7,308	22,388	2.1%	6.3%
Malta	5,573	17,075	2.1%	6.3%
Netherlands	219,387	672,125	2.1%	6.3%
Poland	493,348	1,511,445	2.1%	6.3%
Portugal	134,675	412,596	2.1%	6.3%
Romania	257,939	790,236	2.1%	6.3%
Slovakia	70,374	215,602	2.1%	6.3%
Slovenia	26,778	82,038	2.1%	6.3%
Spain	602,958	1,847,253	2.1%	6.3%
Sweden	126,530	387,643	2.1%	6.3%
UK	842,139	2,580,021	2.1%	6.3%
Total	***6,600,157***	***20,220,584***	***2.1%***	***6.3%***

AFs per Member State

Table 4-16: Overall attributable fractions across all industries by Member State (silica)						
Cancer site/ scenario	Lung			Laryngeal cancer		
	C-Low	C-Core	C-High	C-Low	C-Core	C-High
Austria	0.7%	1.7%	2.7%	0.8%	2.0%	3.6%
Belgium	0.7%	1.7%	2.7%	0.8%	2.0%	3.6%
Bulgaria	0.7%	1.7%	2.7%	0.8%	2.0%	3.6%
Croatia	0.7%	1.7%	2.7%	0.8%	2.0%	3.6%
Cyprus	0.7%	1.7%	2.7%	0.8%	2.0%	3.6%
Czech Republic	0.7%	1.7%	2.7%	0.8%	2.0%	3.6%
Denmark	0.7%	1.7%	2.7%	0.8%	2.0%	3.6%
Estonia	0.7%	1.7%	2.7%	0.8%	2.0%	3.6%
Finland	0.7%	1.7%	2.7%	0.8%	2.0%	3.6%
France	0.7%	1.7%	2.7%	0.8%	2.0%	3.6%
Germany	0.7%	1.7%	2.7%	0.8%	2.0%	3.6%
Greece	0.7%	1.7%	2.7%	0.8%	2.0%	3.6%
Hungary	0.7%	1.7%	2.7%	0.8%	2.0%	3.6%
Ireland	0.7%	1.7%	2.7%	0.8%	2.0%	3.6%
Italy	0.7%	1.7%	2.7%	0.8%	2.0%	3.6%
Latvia	0.7%	1.7%	2.7%	0.8%	2.0%	3.6%
Lithuania	0.7%	1.7%	2.7%	0.8%	2.0%	3.6%
Luxembourg	0.7%	1.7%	2.7%	0.8%	2.0%	3.6%
Malta	0.7%	1.7%	2.7%	0.8%	2.0%	3.6%
Netherlands	0.7%	1.7%	2.7%	0.8%	2.0%	3.6%
Poland	0.7%	1.7%	2.7%	0.8%	2.0%	3.6%
Portugal	0.7%	1.7%	2.7%	0.8%	2.0%	3.6%
Romania	0.7%	1.7%	2.7%	0.8%	2.0%	3.6%
Slovakia	0.7%	1.7%	2.7%	0.8%	2.0%	3.6%
Slovenia	0.7%	1.7%	2.7%	0.8%	2.0%	3.6%
Spain	0.7%	1.7%	2.7%	0.8%	2.0%	3.6%
Sweden	0.7%	1.7%	2.7%	0.8%	2.0%	3.6%
UK	0.7%	1.7%	2.7%	0.8%	2.0%	3.6%
EU-28	***0.7%***	***1.7%***	***2.7%***	***0.8%***	***2.0%***	***3.6%***

4.3 Asbestos

4.3.1 Summary of methodology/assumptions

Summary of the relevant cancer endpoints and exposure period(s)

IARC (2016)[72] lists the following cancer sites as relevant to asbestos (either with sufficient or limited evidence of carcinogenicity in humans):

- Pharynx
- Stomach
- Colon and rectum
- Larynx
- Lung

[72] IARC (2016): List of classifications by cancer sites with sufficient or limited evidence in humans, available at https://monographs.iarc.fr/ENG/Classification/Table4.pdf

- Mesothelium (pleura and peritoneum)
- Ovary

The AFs for all (7 of 7) cancer sites indicated as relevant in IARC (2016) are estimated in this study.

The typical latency is modelled to be between 10 and 50 years. The relevant exposure period is thus defined as 1965-2005 for all cancer sites.[73]

Exposed population

The estimates of the numbers of exposed workers from CAREX and national databases (France, Finland, Poland, Romania, and the UK) are summarised below. Please note that only several examples of entries from the CAREX database are reproduced in the table below.

Table 4-17: Published data – workforce exposed to asbestos

Study	Country	Year/period	No. of exposed workers	% of exposed workforce	Notes
Carex	EU15	1990-1993 (mean)	1,216,318		
	France		138,111		
	Finland		7,400		
	Belgium		10,465		
	Sweden		12,389		
	UK		95,111		
SUMER	France	1994	92,000 (91,000 men and 1,000 women)	0.8% (1.3% men, no data for women)	
		2003	106,600 (104,400 men and 2,200 women)	0.6% (1% men and <0.1% women)	
		2010	81,400 (75,700 men and 5,700 women)	0.4% (0.6% men and 0.1% women)	
FinJem	Finland	2006	4,000		Asbestos removal from old buildings
ASA	Finland	2005	1,867 (1,805 men and 62 women)		
		2014	1,302 (1,234 men and 68 women)		
Central Register	Poland	2013	1,421		
Ministerului Sănătăţii şi Familiei	Romania	2006	7,255		
Rushton	UK	Ever exposed workers, published in 2004-2005	432,638 (350,302 men; 82,336 women)		Based on Carex

[73] For ovarian cancer, the source is Slack et al (2012): Female cancers: breast, cervix and ovary, available at http://www.nature.com/bjc/journal/v107/n1s/full/bjc2012115a.html

Extrapolations of the data in the table above over the EU-28 are summarised below.

Table 4-18: Occupationally exposed population in the EU-28 (asbestos)	
Estimate and method of extrapolation	**Exposed population in the EU-28**
A: France 2010 exposed workers extrapolated on the basis of population	620,000
B: CAREX early to mid-1990s	1.7 million
C: France 1994 share (0.8%) applied to EU workforce	1.76 million
D: France 2010 share (0.4%) applied to EU workforce	880,000
E: Finland 2005 data extrapolated on the basis of population	170,000
F: Poland 2013 data extrapolated on the basis of population	19,000
G: Romania 2006 data extrapolated on the basis of population	190,000
H: Rushton et al data extrapolated on the basis of population, converted into an annual estimate	680,000

Estimates E and G in the table above have been used for the LOW scenario while estimates B and C are used for the CENTRAL scenario. Estimate F is not used since it is assumed that it is an outlier.

In addition to the annual estimates above, some sources have estimated the total number of people with a history of occupational exposure to asbestos. The estimates for France and Germany are summarised below.

Table 4-19: Total population ever occupationally exposed to asbestos		
Source	**National estimate**	**Ever-exposed population in the EU28**
Santé Publique France (2016) >0.1f/ml	Ever-exposed before 1997, alive in 2007 (France): 16.4% men 0.81% women 8.6% overall	43 million
BauA (2014) – Central Registration and Medical Care Agency (GVS) compulsory for >10.000 fibres/m3, voluntary below this threshold	Exposed between 1972-2013 and alive in 2013 and receiving medical examinations under GVS (Germany): 565,000	3.5 million
Neuman et al 2013	Between 1.5 to 2.5 million workers since 1945	Adjusting for natural mortality, current ever-exposed: 4.5 million to 7.5 million
Sources: BauA (2013): National Asbestos Profile for Germany, available at https://www.baua.de/DE/Angebote/Publikationen/Berichte/Gd80.pdf? blob=publicationFile&v=8 Neuman et al (2013): Malignant Pleural Mesothelioma Incidence, Etiology, Diagnosis, Treatment, and Occupational Health, available at https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3659962/ Santé Publique France (2016): Estimation de parts de cancers attribuables à certaines expositions professionnelles en France, available at http://invs.santepubliquefrance.fr/Publications-et-outils/Rapports-et-syntheses/Travail-et-sante/2016/Estimation-de-parts-de-cancers-attribuables-a-certaines-expositions-professionnelles-en-France		

The estimates in BauA(2014) and Neuman et al (2013) broadly correspond to the ever-exposed workforce surviving to 2015 estimated in this study under the CENTRAL scenario – see the results

section below. However, the French estimate is significantly higher and it is therefore taken as the basis for the HIGH scenario.

Rate of change

Comparing the number of workers exposed in France in 1994 and 2010 suggests an annual rate of decline of around 0.8% (although there appears to be an increase between 1994 and 2003). A similar comparison for Finland (2005 ASA report vs 2014 ASA report) suggests a decline in number of works exposed to asbestos (3.5% p.a.).[74] Looking at a similar period in the SUMER data (2003 and 2010 SUMER) suggests an annual decrease of 3.7%.

A gradual decline is consistent with the data presented in the tables in the preceding section as well as what can reasonably expected to constitute a past trend. The default rate of decline for asbestos for the CENTRAL scenario is taken to be the average of the two trends 3.5%/3.7% p.a. and 0.8% p.a., i.e. 2.2% per annum.

In addition, the models estimating the exposed populations under the LOW and CENTRAL scenario take into account asbestos restrictions/bans in individual EU Member states, since such measures are expected to have significantly reduced (although not eliminated) exposure. It has been assumed that following a ban, the annual reduction in the exposed workforce doubled. It is recognised that this is a simplification and that, most likely, a sharper drop ensued immediately following the ban with the reductions subsequently tailing off. However, it is also highly likely that some construction companies, for example, implemented the necessary changes before the effective date of the ban, in preparation for the new legal regime. As a result, the rates of decline used are seen as a reasonable approximation of the long-term trends.

The timings of the general ban and other restrictions in individual Member States are summarised below.

Table 4-20: Limitations and general ban of asbestos

Country	Date
Austria	1990
Belgium	1998
Bulgaria	2005
Croatia	1993 (*Crocidolite and amosite); 2006 (General)*
Cyprus	2005
Czech Republic	1998 (Import); 2005 (General)
Denmark	1980 and 1986 (Asbestos cement)
Estonia	2000
Finland	1992
France	1996
Germany	1990 (Building construction); 1993 (General)
Greece	2005
Hungary	1988 (Amphiboles); 2003 (Asbestos Cement); 2005 (General)
Ireland	2000 (Chrysotile)
Italy	1992
Latvia	2001
Lithuania	2005

[74] Finnish ASA has data on the numbers of workers exposed but these have increased over time, probably as a result of improved notification rather than an increase in the number of workers. See http://annhyg.oxfordjournals.org/content/51/5/463.full.pdf

Table 4-20: Limitations and general ban of asbestos	
Country	**Date**
Luxembourg	2002 (Chrysotile, crocidolite and amosite)
Malta	2005
The Netherlands	1991
Poland	1997
Portugal	2005
Romania	2005
Slovakia	2005
Slovenia	1996 (Asbestos cement)
Spain	2002 (Chrysotile, crocidolite and amosite)
Sweden	1975 (Construction material); 1986 (General)
UK	1986 (Import); 1999 (Chrysotile)
Source: Kazan-Allen (2016)[75]	

It is recognised that there are inconsistencies in the data underpinning the assessment (e.g. an increase in the population exposed to asbestos in France between 1994 and 2003, i.e. following the 1996 ban).

Relative risk

The published risk ratios are summarised below. These have been used to estimate the risk from asbestos exposure for all cancer sites with the exception of mesothelium and lung cancer (see the next section for the methodology for the calculation of mesothelioma and lung cancer incidence linked to asbestos exposure).

Pharynx

The relative risk estimates identified through literature review are summarised below.

Table 4-21: Literature review of relative risk* (pharynx – asbestos)		
Study & summary of data/methodology	**Cancer site**	**Relative risk**
IOM (2006).* Meta-analysis of case-control studies- discussed in IARC monograph	Pharynx	RR 1.5 (95% CI: 1.1-1.7) for "any" exposure compared to no exposure
Langevin et al (2013). Case-control study in Boston of 674 cases and 587 controls	Pharynx	OR 1.41 (95% CI 1.01 to 1.97) in men
Offermans et al (2014). Prospective cohort study in Netherlands using a general population job-exposure matrix (DOMJEM) and a Finnish job exposure matrix (FINJEM)	Pharynx	HR 2.20, 95% confidence interval (95% CI) 1.08-4.49 for "ever" exposure compared to "never exposed using the FINJEM matrix
Purdue et al (2006). Cohort of Swedish construction workers	Pharynx	RR 1.9 (95% CI 1.2-3.1)
Notes: *Meta-analysis on studies till 2006, so other studies in table are post 2006 Sources:		

[75] Kazan-Allen (2016): Chronology of National Asbestos Bans, available at: http://ibasecretariat.org/asbestos_ban_list.php

Table 4-21: Literature review of relative risk* (pharynx – asbestos)		
Study & summary of data/methodology	**Cancer site**	**Relative risk**
IOM (2006): Asbestos: Selected Cancers. Institute of Medicine of the National Academy of Science. Available at http://books.nap.edu/catalog/11665.html Langevin et al (2013): Occupational; asbestos exposure is associated with pharyngeal squamous cell carcinoma in men from the greater Boston area. Occup Environ Med., 70 (12), pp 858-863 Offermans et al (2014): Occupational asbestos exposure and the risk of oral cavity and pharyngeal cancer in the prospective Netherlands Cohort Study. Scan J Environ Health, 40(4), pp 420-427. Purdue et al (2006): Occupational exposures and head and neck cancers among Swedish construction workers. Scand J Environ Health, 32(4), pp 270-275		

Stomach

The relative risk estimates identified through literature review are summarised below.

Table 4-22: Literature review of relative risk (stomach – asbestos)		
Study & summary of data/methodology	**Cancer site**	**Relative risk**
Fortunato and Rushton (2015). Meta-analysis of 40 mortality cohort studies	Stomach	SMR 1.15 (95% CI: 1.03-1.27)
IOM (2006). Meta-analysis of 42 cohort studies	Stomach	RR 1.17 (95% CI: 1.04-1.28) for any versus no exposure; RR 1.31 (95% CI: 0.96-1.76) for high versus no exposure; RR 1.33 (95% CI: 0.98-1.79) for higher bound
IOM (2006). Meta-analysis of 5 case-control studies	Stomach	RR 1.11 (95% CI: 0.76-1.64) OR 1.42 (95% CI: 0.92-2.20) for when extreme exposure is only considered
Peng et al (2015). Meta-analysis of 32 studies	Stomach	SMR 1.19 (95% CI: 1.06-1.34)
Reep et al (2015). Population based occupational study in Germany	Stomach	HR 4.59 (95% CI: 1.53-13.76)
Rushton et al (2011). Burden of occupational cancer study	Stomach	Males: RR 1.66 (95% CI: 1.49, 1.86) for high exposure, RR 1.21 (95% CI: 1.06, 1.38) for low exposure; Females: RR 1 for high and low exposure
Sources: Fortunato L and Rushton L (2015): Stomach cancer and occupational exposure to asbestos: Br J Cancer, 112(11), pp 1805-1815 IOM (2006): Asbestos: Selected Cancers. Institute of Medicine of the National Academy of Science. Available at http://books.nap.edu/catalog/11665.html Peng WJ et al (2015): Stomach cancer mortality among workers exposed to asbestos: a meta-analysis. J Cancer Res Clin Oncol., 141(7), pp 1141-1149. Reep K et al (2015): Occupational exposure to asbestos is associated with increased mortality in men recruited for a population-based study in Germany. Int J Occup Environ Health, 28(5), pp 849-862 Rushton L et al (2010): The burden of Occupational Cancer in Great Britain. HSE Books. Available at: http://www.hse.gov.uk/research/rrpdf/rr800.pdf		

Colon and rectum

The relative risk estimates identified through literature review are summarised below.

Table 4-23: Literature review of relative risk* (colorectal - asbestos)		
Study & summary of data/methodology	**Cancer site**	**Relative risk**
Barry et al (2000). Cohort of 5000 asbestos insulation board producers in London. Reported in IARC	Colon	SMR 1.83 (95% CI: 1.20-2.66)
Ferrante et al (2007). Cohort of family members employed in an asbestos cement factory in Italy. Reported in IARC	Rectal	SMR 2.00 (95% CI: 0.96-3.69)
IOM (2006).* Meta-analysis of cohort studies- discussed in IARC monograph	Colorectum	RR 1.15 (95% CI: 1.01-1.31); high exposure RR 1.24 (95% CI: 0.91-1.69); upper bound RR: 1038 (95% CI: 1.14-1.67)
Paris et al (2016). Retired volunteers previously exposed to asbestos (part of the French ARDCo screening program)	Colon Rectal	Cumulative exposure (HR = 1.10; 95% CI: 1.01, 1.21); ≥20-40 years since first exposure (HR = 4.53; 95% CI: 7.86, 11.04 vs. 0-20 years TSFE); ≥60 years Time Since First Exposure TSFE (HR = 0.26; 95% CI: 0.10, 0.69) TSFE 20-29 years (HR = 1.05; 95% CI: 1.20, 19.30)- noted small number of cases for this.
Note: *Meta-analysis on studies till 2006, so other studies in table are post 2006 Sources: IARC (2012): Asbestos IARC Monograph 100C-11. Available at http://monographs.iarc.fr/ENG/Monographs/vol100C/mono100C-11.pdf IOM (2006): Asbestos: Selected Cancers. Institute of Medicine of the National Academy of Science. Available at http://books.nap.edu/catalog/11665.html Paris C et al (2016): Occupational Asbestos Exposure and Incidence of Colon and Rectal Cancers in French Men: The Asbestos-Related Diseases Cohort (ARDCo-Nut). Environ Health Perspect., DOI:10.1289/EHP153		

Larynx and ovary

The relative risk estimates identified through literature review are summarised below.

Table 4-24: Literature review of relative risk (Lung, larynx and ovary – asbestos)		
Study & summary of data/methodology	**Cancer site**	**Relative risk**
Fortunato and Rushton (2012) A meta-analysis of occupational cohort studies (in Rushton et al 2012)	Larynx	RR=1.37 (95% CI: 1.17, 1.6)
Camargo et al (2011) Meta-analysis of 18 cohort studies of women occupationally exposed to asbestos.	Ovary	Overall pooled SMR estimate for ovarian cancer was 1.77 (95% CI 1.37–2.28)
Reid et al (2009) Crocidolite asbestos 2,552 women were residents of the town and 416 worked for the asbestos company (Australian Blue Asbestos). Standardized incidence ratios compared the Wittenoom women with the Western	Ovary	Women workers SIR= 0.65 (95% CI 0.02-3.64) All women (residents and workers) SIR = 1.27 (95% CI 0.52-2.02)

Table 4-24: Literature review of relative risk (Lung, larynx and ovary – asbestos)		
Study & summary of data/methodology	**Cancer site**	**Relative risk**
Australian population		
Magnani (2008): Italy asbestos cement workers. 777 women in cohort of 3,434 (Crocidolite and chrysotile)	Ovary	SMR = 2.27
Pira et al (2005) Italy – asbestos – textile factory workers 1077 (mixed fibres including crocidolite)	Ovary	SMR = 2.61
Browne and Gee (2000) All identified studies of asbestos workers providing data on laryngeal disease were reviewed, together with studies of laryngeal cancers giving epidemiological or experimental evidence of associated exposures.	Larynx	No indication that asbestos exposure increases the RR of laryngeal cancer.
Berry et al (2000) London – insulation board manufacturing plant 700 (crocidolite and chrysotile)	Ovary	Ovary RR = 2.5 (95% CI 1.2-4.8)
Goodman et al (1999): Meta-analysis based on 69 asbestos-exposed occupational cohorts IOM (2006): Meta-analysis of 15 cohort studies	Larynx	Goodman et al: Meta-analysis based on 69 asbestos-exposed occupational cohorts Meta-SMR = 133 (114–155) IOM: Meta-analysis of 15 cohort studies Any exposure overall relative risk: 1.4 (95% CI 1.19–1.64) High exposure overall relative risk: 2.02 (95% CI 1.64–2.47)

Note: Many studies question link between asbestos and lung cancer.

Sources:

Berry et al (2000): Mortality from all cancers of asbestos factory workers in east London 1933–80. Occup Environ Med2000;57:782–785, available at http://oem.bmj.com/content/57/11/782

Browne and Gee (2000): Asbestos exposure and laryngeal cancer. Ann Occup Hyg. 2000 Jun; 44(4):239-50

Camargo et al (2011): Occupational Exposure to Asbestos and Ovarian Cancer: A Meta-analysis. Environ Health Perspect. 2011 Sep; 119(9): 1211–1217, available at https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3230399/

Fortunato and Rushton (2012):Stomach cancer and asbestos: a meta-analysis of occupational studies. Epidemiology

Goodman et al (1999): Cancer in asbestos-exposed occupational cohorts: a meta-analysis. Cancer Causes Control 1999; 10:453–465, abstract available at https://www.ncbi.nlm.nih.gov/pubmed/10530617

IOM, Effects. IoMUCoASH. Asbestos: Selected Cancers; 2006 available at https://www.ncbi.nlm.nih.gov/pubmed/20669440

Magnani et al (2008): Cancer risk after cessation of asbestos exposure: a cohort study of Italian asbestos cement workers. Occup Environ Med. 2008 Mar;65(3):164-70, available at http://oem.bmj.com/content/65/3/164.long

Pira et al (2005): Cancer mortality in a cohort of asbestos textile workers. British Journal of Cancer 2005;92:580–586

Table 4-24: Literature review of relative risk (Lung, larynx and ovary – asbestos)		
Study & summary of data/methodology	**Cancer site**	**Relative risk**
http://www.nature.com/bjc/journal/v92/n3/full/6602240a.html Reid et al (2009): Gynecologic and breast cancers in women after exposure to blue asbestos at Wittenoom. Cancer Epidemiol Biomarkers Prev. 2009 Jan;18(1):140-7, available at http://cebp.aacrjournals.org/content/18/1/140.long Rushton L et al (2012): The burden of Occupational Cancer in Great Britain. HSE Books.		

The highest and lowest identified relative risk is summarised below.

Table 4-25: Summary of relative risk – exposure to asbestos		
Cancer site	**Lowest**	**Highest**
Pharynx	OR=1.41	HR=2.2
Stomach	RR=1.11	HR=4.59
Colon and rectum	RR=1.15	SMR=2.00
Larynx	1	RR=2.02
Lung	Lung cancer incidence estimated from mesothelioma incidence	
Mesothelium (pleura and peritoneum)	Cancer incidence calculated differently, i.e. drawing on mesothelioma statistics and assuming AF of 95% (see below)	
Ovary	SIR=1	RR=2.61

Calculation of mesothelioma linked to occupational exposure to asbestos

Since the vast majority of mesothelioma cases occur as a result of asbestos exposure, the use of the same approach applied to the other carcinogens considered in this study is not seen as appropriate. Instead, the AF for asbestos in published literature is applied to the data on mesothelioma incidence in individual Member States.

The combined AF for men and women (combined 95%, men 97%, women 83%) given in Rushton et al (2012) has been applied to mesothelioma incidence in EU Member States. These AFs relate to occupational and para-occupational[76] exposure.

Cancer incidence statistics collected for the purposes of this project do not provide data on mesothelioma incidence specifically. Mesothelioma incidence across the EU has been estimated from the UK data because the UK appears to have the most comprehensive source of mesothelioma statistics. The UK data suggest that there are currently around 40 cases of mesothelioma per year per million inhabitants whilst other sources[77] and countries suggest a similar or lower order of magnitude. A review of mesothelioma incidence data carried out by Bianchi & Bianchi (2014)[78] suggests that the highest incidence rates are reported from some countries in Europe (United Kingdom, The Netherlands, Malta, Belgium) whilst lower incidence/mortality rates are reported for

[76] Defined in Rushton et al 2012 as, for example, "exposure from living near an asbestos factory or handling clothes contaminated due to occupational exposure."

[77] For example, see http://www.google.co.uk/url?sa=t&rct=j&q=&esrc=s&source=web&cd=9&cad=rja&uact=8&sqi=2&ved=0ahUKEwjYzYvv6p7SAhULBcAKHZ7uD3wQFghSMAg&url=http%3A%2F%2Fec.europa.eu%2Fsocial%2FBlobServlet%3FdocId%3D11280%26langId%3Den&usg=AFQjCNGeTbkYFSLDPsFMLj2Pt0zXRiDj3Q&bvm=bv.147448319,d.d24

[78] Bianchi & Bianchi (2014): Global mesothelioma epidemic: Trend and features, Indian J Occup Environ Med 2014;18:82-8, available at http://www.ijoem.com/text.asp?2014/18/2/82/146897

Central Europe. This has also been confirmed in Pelclova et al (2007)[79] who have reported a mesothelioma incidence rate in the Czech Republic of around 5 cases per million and estimated the proportion of occupational mesotheliomas at 10%. It is, however, not clear to that extent the lower per capita incidence of mesothelioma reflects past exposure patterns or a lack of reliable data collection. The UK data have been extrapolated to the other EU Member States using per capita incidence rates provided in Bianchi & Bianchi (2014). Where not data on national incidence was available, the average of all available national rates was applied.

The estimated mesothelioma incidence is given below.

Table 4-26: Estimated mesothelioma incidence

Member State	Number of incidences
Austria	104
Belgium	272
Bulgaria	145
Croatia	94
Cyprus	14
Czech Republic	212
Denmark	120
Estonia	26
Finland	99
France	1,339
Germany	1,372
Greece	219
Hungary	199
Ireland	46
Italy	1,226
Latvia	40
Lithuania	59
Luxembourg	11
Malta	11
Netherlands	582
Poland	275
Portugal	209
Romania	401
Slovakia	109
Slovenia	42
Spain	937
Sweden	129
UK	2,663
EU-28	***10,955***

Calculation of lung cancer incidence

Mesothelioma incidence has been used to estimate the number of lung cancer cases linked to asbestos exposure. When mesothelioma is used as a proxy for lung cancer caused by asbestos exposure, available evidence suggests that between 2 and 10 lung cancer cases arise for each case of

[79] Pelclova et al (2007): Asbestos exposure, legislation and diseases in the Czech Republic, available at http://apps.szu.cz/svi/cejph/archiv/2007-3-02-full.pdf

mesothelioma, with the central estimate being between 6 and 7, see Takala (2017).[80] These values have been used to estimate lung cancer incidence linked to occupational exposure to asbestos (2 for the LOW scenario, 10 for HIGH, 6.5 for CENTRAL, and 6 for MID-POINT).

Summary of the scenarios

The assumptions underpinning the different estimates are summarised below.

Table 4-27: Summary of the scenarios (asbestos)

Aspect/scenario	Low	High	Midpoint	Central
Exposed population (EU-28) – point/period	180,000 (2005)	43 million (over 1966-2005)	43 million (over 1966-2005)	1.76 million (1994)
Relevant cancer sites	Pharynx, stomach, colon and rectum, larynx, lung, mesothelium (pleura and peritoneum), ovary (7 of 7 cancer sites in IARC 2016)	Pharynx, stomach, colon and rectum, larynx, lung, mesothelium (pleura and peritoneum), ovary (7 of 7 cancer sites in IARC 2016)	Pharynx, stomach, colon and rectum, larynx, lung, mesothelium (pleura and peritoneum), ovary (7 of 7 cancer sites in IARC 2016)	Pharynx, stomach, colon and rectum, larynx, lung, mesothelium (pleura and peritoneum), ovary (7 of 7 cancer sites in IARC 2016)
Relative risk	Pharynx: OR=1.41 Stomach: RR=1.11 Colon and rectum: RR=1.15 Larynx: 1 Ovary: SIR=1 Lung: Meso*2	Pharynx: HR=2.2 Stomach: HR=4.59 Colon and rectum: SMR=2.00 Larynx: RR=2.02 Ovary: RR=2.61 Lung: Meso*10	Pharynx: 1.8 Stomach: 2.85 Colon and rectum: 1.58 Larynx: 1.51 Ovary: 1.8 Lung: Meso*6	Pharynx: HR=2.2 Stomach: RR/SMR=1.16 Colon and rectum: RR=1.15 Larynx: RR=1.37 Ovary: SMR=1.77 Lung: Meso*2
Change (p.a.)	-0.8%	-3.7%	-2.2%	-2.2%

4.3.2 The results

Summary of the occupationally exposed population surviving to 2015

The total number of workers in the EU-28 exposed to asbestos between 1966 and 2005 2005 and surviving until 2015 is estimated to have been between 0.6 million and 43 million.

Table 4-28: Occupationally exposed population surviving to 2015 (asbestos)

Scenario	No. of workers exposed 1966-2005 & surviving to 2015 (million)	% of current & at risk population
Low	0.6	0.2%
High	43	13.4%
Midpoint	22	6.9%
Central	5.6	1.7%

The break-down of these figures by Member State is provided below. The minimum and maximum values across all scenarios are presented for each Member State.

[80] Takala (2017): Cancer at work is preventable, available at https://roadmaponcarcinogens.eu/content/uploads/2017/04/Takala-Helsinki-Occupational-cancer-6.3.2017-English.pdf

Table 4-29: Occupationally exposed population by Member State 1966-2005 (asbestos)				
Member State	Number of workers exposed over the period and surviving to 2015		% of current & at risk population	
	Min	Max	Min	Max
Austria	10,732	725,300	0.2%	13.4%
Belgium	13,375	952,133	0.2%	13.4%
Bulgaria	8,182	609,094	0.2%	13.4%
Croatia	4,800	357,338	0.2%	13.4%
Cyprus	962	71,632	0.2%	13.4%
Czech Republic	12,519	891,228	0.2%	13.4%
Denmark	7,283	478,646	0.2%	13.4%
Estonia	1,538	111,064	0.2%	13.4%
Finland	6,764	462,749	0.2%	13.4%
France	79,995	5,616,771	0.2%	13.4%
Germany	99,745	6,866,925	0.2%	13.4%
Greece	12,336	918,269	0.2%	13.4%
Hungary	11,197	833,492	0.2%	13.4%
Ireland	5,421	391,473	0.2%	13.4%
Italy	75,154	5,141,522	0.2%	13.4%
Latvia	2,309	167,965	0.2%	13.4%
Lithuania	3,319	247,053	0.2%	13.4%
Luxembourg	650	47,610	0.2%	13.4%
Malta	488	36,310	0.2%	13.4%
Netherlands	21,021	1,429,305	0.2%	13.4%
Poland	45,465	3,214,158	0.2%	13.4%
Portugal	11,787	877,405	0.2%	13.4%
Romania	22,575	1,680,473	0.2%	13.4%
Slovakia	6,159	458,487	0.2%	13.4%
Slovenia	2,485	174,459	0.2%	13.4%
Spain	53,995	3,928,268	0.2%	13.4%
Sweden	12,543	824,340	0.2%	13.4%
UK	76,523	5,486,532	0.2%	13.4%
Total	***609,319***	***43,000,000***	***0.2%***	***13.4%***

AFs per Member State

Table 4-30: Overall attributable fractions across all industries by Member State (asbestos)												
Cancer site/ scenario	Pharynx			Stomach			Colon & rectum			Larynx		
	C-Low	C-Core	C-High	C-Low	C-Core	C-High	C-Low	C-Core	C-High	C-Low	C-Core	C-High
Austria	0.1%	1.0%	2.8%	0.0%	0.1%	0.2%	0.01%	0.1%	0.3%	0.1%	0.3%	0.5%
Belgium	0.0%	0.5%	1.5%	0.0%	0.1%	0.1%	0.00%	0.1%	0.1%	0.1%	0.2%	0.3%
Bulgaria	0.2%	3.5%	9.5%	0.1%	0.5%	0.8%	0.03%	0.4%	0.9%	0.5%	1.1%	1.8%
Croatia	0.2%	3.4%	9.2%	0.1%	0.5%	0.8%	0.03%	0.4%	0.9%	0.5%	1.1%	1.7%
Cyprus	0.1%	0.8%	2.4%	0.0%	0.1%	0.2%	0.01%	0.1%	0.2%	0.1%	0.3%	0.4%
Czech Republic	0.2%	3.4%	9.3%	0.1%	0.5%	0.8%	0.03%	0.4%	0.9%	0.5%	1.1%	1.7%
Denmark	0.1%	1.0%	2.8%	0.0%	0.1%	0.2%	0.01%	0.1%	0.3%	0.1%	0.3%	0.5%
Estonia	0.1%	0.9%	2.5%	0.0%	0.1%	0.2%	0.01%	0.1%	0.2%	0.1%	0.3%	0.4%
Finland	0.1%	0.8%	2.2%	0.0%	0.1%	0.2%	0.01%	0.1%	0.2%	0.1%	0.2%	0.4%
France	0.1%	1.2%	3.4%	0.0%	0.2%	0.3%	0.01%	0.2%	0.3%	0.2%	0.4%	0.6%
Germany	0.1%	1.1%	3.2%	0.0%	0.2%	0.3%	0.01%	0.1%	0.3%	0.2%	0.3%	0.6%
Greece	0.1%	0.8%	2.3%	0.0%	0.1%	0.2%	0.01%	0.1%	0.2%	0.1%	0.2%	0.4%

Table 4-30: Overall attributable fractions across all industries by Member State (asbestos)												
Cancer site/ scenario	Pharynx			Stomach			Colon & rectum			Larynx		
	C-Low	C-Core	C-High	C-Low	C-Core	C-High	C-Low	C-Core	C-High	C-Low	C-Core	C-High
Hungary	0.2%	3.3%	8.9%	0.1%	0.4%	0.8%	0.03%	0.4%	0.9%	0.5%	1.0%	1.7%
Ireland	0.0%	0.7%	2.0%	0.0%	0.1%	0.2%	0.01%	0.1%	0.2%	0.1%	0.2%	0.4%
Italy	0.4%	6.0%	15.7%	0.2%	0.8%	1.4%	0.05%	0.8%	1.6%	0.9%	1.9%	3.1%
Latvia	0.1%	0.9%	2.7%	0.0%	0.1%	0.2%	0.01%	0.1%	0.2%	0.1%	0.3%	0.5%
Lithuania	0.1%	1.7%	4.7%	0.0%	0.2%	0.4%	0.01%	0.2%	0.4%	0.2%	0.5%	0.8%
Luxembourg	0.1%	1.0%	2.8%	0.0%	0.1%	0.2%	0.01%	0.1%	0.3%	0.1%	0.3%	0.5%
Malta	0.4%	6.3%	16.3%	0.2%	0.9%	1.5%	0.06%	0.8%	1.7%	0.9%	2.0%	3.2%
Netherlands	0.0%	0.5%	1.4%	0.0%	0.1%	0.1%	0.00%	0.1%	0.1%	0.1%	0.2%	0.2%
Poland	0.2%	3.4%	9.4%	0.1%	0.5%	0.8%	0.03%	0.4%	0.9%	0.5%	1.1%	1.7%
Portugal	0.1%	0.9%	2.5%	0.0%	0.1%	0.2%	0.01%	0.1%	0.2%	0.1%	0.3%	0.4%
Romania	0.2%	3.4%	9.3%	0.1%	0.5%	0.8%	0.03%	0.4%	0.9%	0.5%	1.1%	1.7%
Slovakia	0.2%	3.3%	9.0%	0.1%	0.5%	0.8%	0.03%	0.4%	0.9%	0.5%	1.0%	1.7%
Slovenia	0.2%	3.4%	9.4%	0.1%	0.5%	0.8%	0.03%	0.4%	0.9%	0.5%	1.1%	1.7%
Spain	0.0%	0.7%	2.0%	0.0%	0.1%	0.2%	0.01%	0.1%	0.2%	0.1%	0.2%	0.4%
Sweden	0.1%	0.9%	2.6%	0.0%	0.1%	0.2%	0.01%	0.1%	0.2%	0.1%	0.3%	0.5%
UK	0.1%	0.8%	2.4%	0.0%	0.1%	0.2%	0.01%	0.1%	0.2%	0.1%	0.3%	0.4%
EU-28	***0.1%***	***2.1%***	***5.8%***	***0.1%***	***0.3%***	***0.5%***	***0.02%***	***0.3%***	***0.5%***	***0.3%***	***0.6%***	***1.0%***

Table 4-31: Overall attributable fractions across all industries by Member State (asbestos)						
Cancer site/ scenario	Lung			Ovary (women only)		
	C-Low	C-Core	C-High	C-Low	C-Core	C-High
Austria	0.1%	0.6%	1.2%	0.0%	0.1%	0.1%
Belgium	0.1%	0.3%	0.7%	0.0%	0.0%	0.0%
Bulgaria	0.4%	2.0%	4.2%	0.1%	0.2%	0.3%
Croatia	0.4%	1.9%	4.1%	0.1%	0.2%	0.3%
Cyprus	0.1%	0.5%	1.0%	0.0%	0.0%	0.1%
Czech Republic	0.4%	1.9%	4.1%	0.1%	0.2%	0.3%
Denmark	0.1%	0.6%	1.2%	0.0%	0.1%	0.1%
Estonia	0.1%	0.5%	1.1%	0.0%	0.0%	0.1%
Finland	0.1%	0.4%	0.9%	0.0%	0.0%	0.1%
France	0.2%	0.7%	1.4%	0.0%	0.1%	0.1%
Germany	0.1%	0.6%	1.4%	0.0%	0.1%	0.1%
Greece	0.1%	0.5%	1.0%	0.0%	0.0%	0.1%
Hungary	0.4%	1.9%	3.9%	0.1%	0.2%	0.3%
Ireland	0.1%	0.4%	0.8%	0.0%	0.0%	0.1%
Italy	0.8%	3.5%	7.2%	0.2%	0.3%	0.6%
Latvia	0.1%	0.5%	1.2%	0.0%	0.1%	0.1%
Lithuania	0.2%	0.9%	2.0%	0.0%	0.1%	0.1%
Luxembourg	0.1%	0.6%	1.2%	0.0%	0.1%	0.1%
Malta	0.8%	3.7%	7.5%	0.2%	0.4%	0.6%
Netherlands	0.1%	0.3%	0.6%	0.0%	0.0%	0.0%
Poland	0.4%	2.0%	4.2%	0.1%	0.2%	0.3%
Portugal	0.1%	0.5%	1.1%	0.0%	0.0%	0.1%
Romania	0.4%	2.0%	4.1%	0.1%	0.2%	0.3%
Slovakia	0.4%	1.9%	4.0%	0.1%	0.2%	0.3%
Slovenia	0.4%	2.0%	4.1%	0.1%	0.2%	0.3%
Spain	0.1%	0.4%	0.9%	0.0%	0.0%	0.1%

Table 4-31: Overall attributable fractions across all industries by Member State (asbestos)						
Cancer site/ scenario	Lung			Ovary (women only)		
	C-Low	C-Core	C-High	C-Low	C-Core	C-High
Sweden	0.1%	0.5%	1.1%	0.0%	0.0%	0.1%
UK	0.1%	0.5%	1.0%	0.0%	0.0%	0.1%
EU-28	***0.3%***	***1.2%***	***2.5%***	***0.1%***	***0.1%***	***0.2%***

4.4 Formaldehyde

4.4.1 Methodology/assumptions

Summary of the relevant cancer endpoints and exposure period(s)

The relevant cancer sites include **nasopharyngeal (NFC) and sinonasal cancer (NFC and SNC respectively) and leukaemia** (Binazzi et al 2015[81]; Hansen & Lassen, 2011; IARC, 2016[82]; Rushton et al 2012). All (100%) cancer sites for which formaldehyde was identified in IARC (2016) as a carcinogenic for humans with sufficient or limited evidence are therefore considered in this study.

Two studies, Siew et al (2012)[83] and Bosetti et al (2008) have also considered lung cancer. Bosetti et al (2008) also suggest that there may be a link between formaldehyde and brain cancer.

In line with Hutchings (2007) and Nadler & Zurbenko (2014), it is assumed that the typical latency is 0-20 years for leukaemia and 10-50 years for NFC, SNC and lung cancer. The relevant exposure period is thus defined as 1996-2015 for leukaemia and 1966-2005 for NFC, SNC and lung cancer. Latency for brain cancer is assumed to be the same as for the central nervous system, i.e. 10-50 years.

Exposed population

The starting point for estimating the occupationally exposed population is the CAREX database, with further estimates being available from SUMER (France in 2003 and 2010), FinJem (Finland, reproduced in Santonen, 2013[84]), Regex (Czech Republic in 2009-16), and Siew et al (2012). These estimates are summarised below.

[81] Binazzi et al (2015): Occupational exposure and sinonasal cancer: a systematic review and meta-analysis, available at http://www.ncbi.nlm.nih.gov/pmc/articles/PMC4339645/

[82] IARC (2016): List of Classifications by cancer sites with sufficient or limited evidence in humans, Volumes 1 to 117, 24 October 2016 update, available at https://monographs.iarc.fr/ENG/Classification/Table4.pdf

[83] Siew et al (2012): Occupational exposure to wood dust and formaldehyde and risk of nasal, nasopharyngeal, and lung cancer among Finnish men, In: Cancer Management and Research August 2012, available at https://www.researchgate.net/profile/Pentti_Kyyroenen/publication/230699498_Occupational_exposure_to_wood_dust_and_formaldehyde_and_risk_of_nasal_nasopharyngeal_and_lung_cancer_among_Finnish_men/links/00b7d5229fa1e27a67000000.pdf

[84] Santonen (2013): Well-being through work, available at http://ec.europa.eu/social/BlobServlet?docId=11305&langId=en

Table 4-32: Published data – workforce exposed to formaldehyde					
Study	**Country**	**Year/period**	**No. of exposed workers**	**% of exposed workforce**	**Notes**
Carex	EU15	1990-1993 (mean)	971,402		
	France	1990-1993 (mean)	307,025		
	Finland	1990-1993 (mean)	10,530		
	Czech Republic	1997	43,669		
	UK	1990-1993 (mean)	93,807		
SUMER	France	2003	153,600 (66,800 men and 86,800 women)	0.9% (0.7% men and 1.2% women)	
		2010	139,400 (66,100 men and 73,300 women)	0.6% (0.6% men and 0.7% women)	
FinJem	Finland	2006	10,700		Woodworking & furniture industry, foundries
Siew et al (2012)	Global	Not specified		1%	
Regex	Czech Republic	2009-2016	173		
Rushton	UK	2004-2005	793,896 (528,665 men; 265,231 women)		Based on Carex

According to Eurostat, the total number of people in employment or self-employment in the EU-28 was 220 million in 2015. Applying the estimates of the proportion of the exposed workforce in the table above suggests an occupationally exposed population between 1.3 million and 2.2 million. It is assumed that this is relevant to the period before the Siew et al (2012) study was published.

The lowest estimate is therefore 990,000 which relies on extrapolation to the EU-28 of the FinJem data (the Regex data for the Czech Republic are considered to be an outlier). The highest estimate can be derived on the basis of applying the 1% estimate in Siew et al (2012) to the total EU workforce which yields an estimate of 2.2 million (which is assumed to relate to 2012). All other estimates and extrapolations (CAREX, SUMER) fall between these two values. The central estimate is based on CAREX data for 1993/1997.

Rate of change

Comparing the number of workers exposed in France in 2003 and 2010 (SUMER) suggests an annual rate of decline of around 3%; this is fully accounted for by a decline in the number of exposed women. A similar comparison for Finland (1993 CAREX vs 2006 FinJem) suggests no decline in the number of workers exposed to formaldehyde.[85] There is also no evidence of a similar decline in any other Member State.

[85] Finnish ASA has data on the numbers of workers exposed but these have increased over time, probably as a result of improved notification rather than an increase in the number of workers. See http://annhyg.oxfordjournals.org/content/51/5/463.full.pdf

For this reason, two scenarios for the annual rate of change have been modelled:

- no decline in the number of workers exposed to formaldehyde;
- an annual decline of 3% throughout the EU.

A generic staff turnover factor of 10% per annum has been used.

Relative risk

The relative risk estimates identified through literature review are summarised below.

Table 4-33: Literature review of relative risk

Study & summary of data/methodology	Cancer site	Relative risk
Mannetje et al (1999)[86] (also cited in Rushton & Hutchings, 2007)[87] pooled data from eight European studies (four from Italy, and one each from the Netherlands, France, Germany and Sweden)	SNC	OR=1.66 (95% CI 1.27-2.17) for men and 0.83 (0.41-1.69) for women
Hansen & Lassen (2011)[88]	SNC	OR=2.8 (95% CI 1.8-4.3)
Coggon et al (2003) (cited in Rushton & Hutchings, 2007)[89] Cohort of 14,014 British male chemical workers exposed to formaldehyde (1941-2000)	Not specified	SMR=0.87 (95% CI 0.11-3.14)
Luce et al (2012) (cited in Rushton & Hutchings, 2007) Pooled analysis of 12 case-control studies	Not specified	Non-significant elevated risk
Rushton & Hutchings (2007) and Rushton & Hutchings (2007a)[90] Literature review	Leukaemia SNC	Leukaemia: RR=1.4 (average of the different occupations) SNC: OR=1.33 (average of male 1.66 and female 1)
Slack et al (2012)[91], original source: Hauptmann et al (2004)	NFC	NFC: SMR=2.1**
Siew et al (2012)[92]	Nasal,	Lung cancer RR=1.18 (95% CI, 1.12–1.25)*

[86] Mannetje et al (1999): Sinonasal cancer, occupation, and tobacco smoking in European women and men, Am J Ind Med. 1999 Jul;36(1):101-7, available at https://www.researchgate.net/publication/12936573_Sinonasal_cancer_occupation_and_tobacco_smoking_in_European_women_and_men

[87] Rushton & Hutchings (2007): Technical Annex 2: Sinonasal cancer, available at http://www.hse.gov.uk/research/rrpdf/rr595ann2.pdf

[88] Hansen & Lassen (2011): Occupation and cancer risk by use of Danish registers, available at http://journals.sagepub.com/doi/pdf/10.1177/1403494811399166

[89] Rushton & Hutchings (2007): Technical Annex 2: Sinonasal cancer, available at http://www.hse.gov.uk/research/rrpdf/rr595ann2.pdf

[90] Rushton & Hutchings (2007): The burden of occupational cancer, available at http://www.hse.gov.uk/research/rrpdf/rr595main.pdf

[91] Slack et al (2012): Nasopharynx and sinonasal cancers, available at https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3384014/

[92] Siew et al (2012): Occupational exposure to wood dust and formaldehyde and risk of nasal, nasopharyngeal, and lung cancer among Finnish men, In: Cancer Management and Research August 2012, available at https://www.researchgate.net/profile/Pentti_Kyyroenen/publication/230699498_Occupational_exposure_

Table 4-33: Literature review of relative risk		
Study & summary of data/methodology	**Cancer site**	**Relative risk**
Cohort of Finnish men born 1906-1945 and exposed in in 1970, followed up 1971-1995	nasopharyngeal, and lung cancer	NFC: no indication of increased risk
Bosetti et al (2008) Pooled results of cohort studies	Oral and pharyngeal, brain, NFC, SNC, lung	NFC RR=1.33 (0.49 when excluding six cases at one US plant) Leukaemia RR=0.9 (industry workers), 1.39 (professionals) Lung cancer RR=1.06 (industry workers), 0.63 (professionals) Oral and pharyngeal RR=1.09 (industry workers), 0.96 (professionals) Brain RR=0.92 (industry workers), 1.56 (professionals) All lymphatic and hematopeietic cancers cancer RR=0.85 (industry workers), 1.31 (professionals)

Notes:
*Siew et al (2012) conclude that this may be a result of residual confounding from smoking. In addition, they note that *"Finnish workers were exposed at relatively low formaldehyde levels; out of 27 occupations, only two were detected with average exposure at 1 ppm: (1) floor layers and (2) varnishers, lacquerers in the wood industry."*
** also cited in IARC (2016)
Sources:
Bosetti et al (2008): Formaldehyde and cancer risk: a quantitative review of cohort studies through 2006, In: Ann Oncol. 2008 Jan;19(1):29-43, available at https://academic.oup.com/annonc/article-lookup/doi/10.1093/annonc/mdm202
Hansen & Lassen (2011): Occupation and cancer risk by use of Danish registers, available at http://journals.sagepub.com/doi/pdf/10.1177/1403494811399166
Mannetje et al (1999): Sinonasal cancer, occupation, and tobacco smoking in European women and men, Am J Ind Med. 1999 Jul;36(1):101-7, available at https://www.researchgate.net/publication/12936573_Sinonasal_cancer_occupation_and_tobacco_smoking_in_European_women_and_men
Rushton & Hutchings (2007): Technical Annex 2: Sinonasal cancer, available at http://www.hse.gov.uk/research/rrpdf/rr595ann2.pdf
Siew et al (2012): Occupational exposure to wood dust and formaldehyde and risk of nasal, nasopharyngeal, and lung cancer among Finnish men, In: Cancer Management and Research August 2012, available at https://www.researchgate.net/profile/Pentti_Kyyroenen/publication/230699498_Occupational_exposure_to_wood_dust_and_formaldehyde_and_risk_of_nasal_nasopharyngeal_and_lung_cancer_among_Finnish_men/links/00b7d5229fa1e27a67000000.pdf

to_wood_dust_and_formaldehyde_and_risk_of_nasal_nasopharyngeal_and_lung_cancer_among_Finnish_men/links/00b7d5229fa1e27a67000000.pdf

Table 4-34: Summary of the relative risk		
Cancer site	**Lowest**	**Highest**
Leukaemia	RR=1	RR=1.4
NFC	RR=1	RR=2.1
SNC	OR=1	OR=2.8
Lung	RR=1	RR=1.18
Brain	RR=1	RR=1.56

Formaldehyde NFC RR in a meta-analysis (Collins et al 1997 cited in Bosetti et al 2008): 1.3 but this meta-analysis concluded that the available studies did not support a causal relationship between formaldehyde and nasopharyngeal cancer risk.

Summary of the scenarios (formaldehyde)

The assumptions underpinning the different estimates are summarised below. Please note that the estimates of the exposed population are point estimates for a specific year and do not represent the lowest and highest annual estimates over the whole assessment period since these also depend on the annual rate of change. Please note that relative risk below 1 has been rounded to 1. The central estimates of the relative risks are close to the high estimates to account for the potential for high exposure in the past.

Table 4-35: Summary of the scenarios (formaldehyde)				
Aspect/scenario	**Low**	**High**	**Midpoint**	**Central**
Exposed population (EU-28) - point	990,000 (2006)	2.2 million (2012)	1.6 million (assumed 2009)	1.4 million (1993/1997)
Relevant cancer sites	Leukaemia, NFC, SNC	Leukaemia, NFC, SNC, Lung, Brain	Leukaemia, NFC, SNC, Lung, Brain	Leukaemia, NFC, SNC, Lung, Brain
Relative risks	Leukaemia: RR=1 NFC: RR=1 SNC: OR=1 Lung: RR=1 Brain: RR=1	Leukaemia: RR=1.4 NFC: SMR=2.1 SNC: OR=2.8 Lung: RR=1.18 Brain: RR=1.56	Leukaemia: RR=1.2 NFC: RR=1.55 SNC: OR=1.9 Lung: RR=1.09 Brain: RR=1.28	Leukaemia: RR=1.4 NFC: SMR=2.1 SNC: OR=2.8 Lung: RR=1.18 Brain: RR=1.56
Rate of change (per annum)	0%	-3%	-1.5%	0%

Please note that the different rates of change have been assigned to the different scenarios on the basis of which one produces the highest or lowest number work workers exposed over the whole period. This is because the total exposed population over the whole assessment period is driven more by the estimated annual rate of change than the starting estimate for a single year.

4.4.2 The results

Summary of the occupationally exposed population surviving to 2015

The total number of workers in the EU-28 exposed to formaldehyde between 1966 and 2005 2005 and surviving until 2015 is estimated to have been between 3.5 and 13 million, and between 1996 and 2015, 2.8-8.5 million.

Table 4-36: Occupationally exposed population surviving to 2015 (formaldehyde)				
Scenario	No. of workers exposed 1966-2005 & surviving to 2015 (million)	% of current & at risk population	No. of workers exposed 1996-2015 & surviving to 2015 (million)	% of current & at risk population
Low	3.5	1.1%	2.8	0.8%
High	13	4.1%	8.2	2.3%
Midpoint	6.2	1.9%	4.9	1.4%
Central	5	1.6%	4.1	1.1%

The break-down of these figures by Member State is provided below. The minimum and maximum values across all scenarios are presented for each Member State.

Table 4-37: Occupationally exposed population surviving to 2015 by Member State (formaldehyde)								
Period	1966-2005				1996-2015			
Parameter	Number of workers exposed over the period and surviving to 2015		% of current & at risk population		Number of workers exposed over the period and surviving to 2015		% of current & at risk population	
Min/max	Min	Max	Min	Max	Min	Max	Min	Max
Austria	58,923	219,846	1.1%	4.1%	48,027	139,143	0.8%	2.3%
Belgium	57,872	288,601	0.8%	4.1%	47,171	182,659	0.6%	2.3%
Bulgaria	49,482	184,623	1.1%	4.1%	40,332	116,850	0.8%	2.3%
Croatia	29,030	108,313	1.1%	4.1%	23,662	68,552	0.8%	2.3%
Cyprus	2,895	21,712	0.5%	4.1%	2,359	13,742	0.4%	2.3%
Czech Republic	72,402	270,141	1.1%	4.1%	59,014	170,975	0.8%	2.3%
Denmark	38,885	319,275	1.1%	9.0%	31,694	260,236	0.8%	6.4%
Estonia	9,023	33,665	1.1%	4.1%	7,354	26,003	0.8%	2.7%
Finland	37,156	140,264	1.1%	4.1%	30,285	88,775	0.8%	2.3%
France	456,300	1,702,501	1.1%	4.1%	371,924	1,077,533	0.8%	2.3%
Germany	452,026	2,081,436	0.9%	4.1%	368,440	1,317,366	0.6%	2.3%
Greece	36,182	278,337	0.5%	4.1%	29,491	176,163	0.4%	2.3%
Hungary	67,712	252,640	1.1%	4.1%	55,191	159,899	0.8%	2.3%
Ireland	11,831	118,660	0.4%	4.1%	9,643	75,101	0.3%	2.3%
Italy	417,692	1,558,448	1.1%	4.1%	340,455	986,361	0.8%	2.3%
Latvia	13,645	50,912	1.1%	4.1%	11,122	32,223	0.8%	2.3%
Lithuania	20,070	74,884	1.1%	4.1%	16,359	47,395	0.8%	2.3%
Luxembourg	2,279	14,431	0.6%	4.1%	1,858	9,134	0.5%	2.3%
Malta	2,950	11,006	1.1%	4.1%	2,404	6,966	0.8%	2.3%
Netherlands	55,850	433,237	0.5%	4.1%	45,523	274,201	0.4%	2.3%
Poland	261,115	974,244	1.1%	4.1%	212,831	616,611	0.8%	2.3%
Portugal	71,279	265,951	1.1%	4.1%	58,099	168,323	0.8%	2.3%
Romania	136,520	509,369	1.1%	4.1%	111,275	322,386	0.8%	2.3%
Slovakia	37,247	138,972	1.1%	4.1%	30,360	87,957	0.8%	2.3%
Slovenia	14,173	52,880	1.1%	4.1%	11,552	33,468	0.8%	2.3%
Spain	251,195	1,190,699	0.9%	4.1%	204,745	753,607	0.6%	2.3%
Sweden	38,377	249,866	0.6%	4.1%	31,280	158,143	0.4%	2.3%
UK	331,003	1,663,025	0.8%	4.1%	269,797	1,052,548	0.6%	2.3%
Total	***3,493,273***	***13,033,744***	***1.1%***	***4.1%***	***2,847,320***	***8,249,213***	***0.8%***	***2.3%***

AFs per Member State

Table 4-38: Overall attributable fractions across all industries by Member State (formaldehyde)															
Cancer site/ scenario	Leukaemia			NFC			SNC			Lung			Brain		
	C-Low	C-Core	C-High	C-Low	C-Core	C-High	C-Low	C-Core	C-High	C-Low	C-Core	C-High	C-Low	C-Core	C-High
Austria	0.3%	0.3%	0.3%	0.1%	1.2%	3.5%	0.9%	2.0%	3.6%	0.1%	0.2%	0.2%	0.6%	0.6%	0.6%
Belgium	0.2%	0.2%	0.2%	0.0%	0.9%	2.6%	0.6%	1.4%	2.6%	0.1%	0.1%	0.2%	0.5%	0.5%	0.5%
Bulgaria	0.7%	0.7%	0.7%	0.1%	2.5%	7.1%	1.9%	4.1%	7.3%	0.3%	0.4%	0.5%	1.3%	1.3%	1.3%
Croatia	0.7%	0.7%	0.7%	0.1%	2.5%	6.9%	1.8%	4.0%	7.1%	0.3%	0.4%	0.5%	1.3%	1.3%	1.3%
Cyprus	0.2%	0.2%	0.2%	0.0%	0.6%	1.7%	0.4%	1.0%	1.8%	0.1%	0.1%	0.1%	0.3%	0.3%	0.3%
Czech Republic	0.7%	0.7%	0.7%	0.1%	2.5%	6.9%	1.8%	4.0%	7.1%	0.3%	0.4%	0.5%	1.3%	1.3%	1.3%
Denmark	2.5%	2.5%	2.5%	0.4%	9.0%	22.3 %	6.7%	13.9 %	22.8 %	1.1%	1.6%	1.8%	4.8%	4.8%	4.8%
Estonia	1.1%	1.1%	1.1%	0.2%	4.1%	11.0 %	3.0%	6.5%	11.3 %	0.5%	0.7%	0.8%	2.1%	2.1%	2.1%
Finland	0.3%	0.3%	0.3%	0.1%	1.2%	3.3%	0.9%	1.9%	3.4%	0.1%	0.2%	0.2%	0.6%	0.6%	0.6%
France	0.7%	0.7%	0.7%	0.1%	2.8%	7.7%	2.0%	4.5%	7.9%	0.3%	0.5%	0.5%	1.4%	1.4%	1.4%
Germany	0.3%	0.3%	0.3%	0.0%	1.0%	2.8%	0.7%	1.6%	2.8%	0.1%	0.2%	0.2%	0.5%	0.5%	0.5%
Greece	0.2%	0.2%	0.2%	0.0%	0.6%	1.7%	0.4%	0.9%	1.7%	0.1%	0.1%	0.1%	0.3%	0.3%	0.3%
Hungary	0.6%	0.6%	0.6%	0.1%	2.4%	6.7%	1.8%	3.9%	6.9%	0.3%	0.4%	0.4%	1.2%	1.2%	1.2%
Ireland	0.1%	0.1%	0.1%	0.0%	0.4%	1.3%	0.3%	0.7%	1.3%	0.0%	0.1%	0.1%	0.2%	0.2%	0.2%
Italy	0.5%	0.5%	0.5%	0.1%	1.7%	4.9%	1.3%	2.8%	5.1%	0.2%	0.3%	0.3%	0.9%	0.9%	0.9%
Latvia	0.5%	0.5%	0.5%	0.1%	1.9%	5.3%	1.4%	3.0%	5.4%	0.2%	0.3%	0.3%	1.0%	1.0%	1.0%
Lithuania	0.6%	0.6%	0.6%	0.1%	2.1%	5.9%	1.5%	3.4%	6.1%	0.2%	0.4%	0.4%	1.1%	1.1%	1.1%
Lux.	0.2%	0.2%	0.2%	0.0%	0.7%	2.0%	0.5%	1.1%	2.1%	0.1%	0.1%	0.1%	0.4%	0.4%	0.4%
Malta	0.5%	0.5%	0.5%	0.1%	1.7%	4.9%	1.3%	2.8%	5.0%	0.2%	0.3%	0.3%	0.9%	0.9%	0.9%
Netherlands	0.1%	0.1%	0.1%	0.0%	0.6%	1.7%	0.4%	0.9%	1.7%	0.1%	0.1%	0.1%	0.3%	0.3%	0.3%
Poland	0.7%	0.7%	0.7%	0.1%	2.6%	7.1%	1.9%	4.1%	7.3%	0.3%	0.4%	0.5%	1.3%	1.3%	1.3%
Portugal	0.5%	0.5%	0.5%	0.1%	2.1%	5.8%	1.5%	3.4%	6.0%	0.2%	0.3%	0.4%	1.1%	1.1%	1.1%
Romania	0.7%	0.7%	0.7%	0.1%	2.5%	7.0%	1.8%	4.0%	7.2%	0.3%	0.4%	0.5%	1.3%	1.3%	1.3%
Slovakia	0.6%	0.6%	0.6%	0.1%	2.4%	6.8%	1.8%	3.9%	6.9%	0.3%	0.4%	0.4%	1.2%	1.2%	1.2%
Slovenia	0.7%	0.7%	0.7%	0.1%	2.5%	7.1%	1.9%	4.1%	7.3%	0.3%	0.4%	0.5%	1.3%	1.3%	1.3%
Spain	0.2%	0.2%	0.2%	0.0%	0.9%	2.7%	0.7%	1.5%	2.8%	0.1%	0.2%	0.2%	0.5%	0.5%	0.5%
Sweden	0.2%	0.2%	0.2%	0.0%	0.7%	2.0%	0.5%	1.1%	2.0%	0.1%	0.1%	0.1%	0.3%	0.3%	0.3%
UK	0.2%	0.2%	0.2%	0.0%	0.9%	2.5%	0.6%	1.4%	2.6%	0.1%	0.1%	0.2%	0.5%	0.5%	0.5%
EU-28	***0.4 %***	***0.4 %***	***0.4 %***	***0.1 %***	***1.7 %***	***4.8%***	***1.2 %***	***2.7%***	***4.9%***	***0.2 %***	***0.3 %***	***0.3 %***	***0.9 %***	***0.9 %***	***0.9 %***

4.5 Benzene

4.5.1 Methodology/assumptions

Summary of the relevant cancer endpoints and exposure period(s)

The relevant cancer endpoints are **leukaemia,** non-Hodgkin's lymphoma[93] and multiple myeloma (IARC, 2016[94]; Rushton et al 2012[95]; WHO, 2010).

[93] IARC (2016) lists benzene under the category 'leukaemia and/or lymphoma'.

[94] IARC (2016): List of classifications by cancer sites with sufficient or limited evidence in humans, available at https://monographs.iarc.fr/ENG/Classification/Table4.pdf

Due to the absence of relative risk estimates for non-Hodgkin's lymphoma and multiple myeloma, only cancer incidence associated with one of the three identified cancer sites has been quantified in this study. However, please note that this is the only cancer site listed in IARC (2016) and, as such, 100% of the cancer sites listed in IARC have been quantified in this study.

In line with Hutchings (2007) and Triebig (2010[96]), it is assumed that the typical latency is between 0-20 years. The relevant exposure period is thus defined as 1996-2015.

Exposed population

The starting point for estimating the occupationally exposed population is the CAREX database, with further estimates being available for the Czech Republic, Finland, France, Poland, Romania, and the UK (although the data for the UK are based on CAREX). These estimates are summarised below.

Table 4-39: Published data – workforce exposed to benzene

Study	Country	Year/period	No. of exposed workers	% of exposed workforce	Notes
Carex	EU15	1990-1993 (mean)	1,367,753		
	France	1990-1993 (mean)	69,575		
	Finland	1990-1993 (mean)	14,010		
	Czech Republic	1997	67,211		
SUMER	France	2003	47,400 (43,400 men and 4,000 women)	0.3% (0.4% men and <0.1% women)	
		2010	36,900 (28,800 men and 8,100 women)	0.2% (0.2% men and 0.1% women)	
FinJem	Finland	2006	5,000		Coking plants, oil refineries, handling of gasoline
ASA	Finland	2005	1,503 (1,374 men and 129 women)		
		2014	2,043 (1,935 men and 108 women)		
Regex	Czech Republic	2009-2016	266		
Central Register	Poland	2013	10,595		
Ministerului Sănătăţii şi Familiei	Romania	2006	8,050		

[95] Rushton et al (2012): Occupational cancer in the UK – overview report, available at http://www.hse.gov.uk/research/rrpdf/rr931.pdf

[96] Triebig G (2010): Implications of latency period between benzene exposure and development of leukaemia – a synopsis of literature, Chemico-biological interactions, 84(1-2), 26-29, available at: http://www.sciencedirect.com/science/article/pii/S0009279709005596

Of all the data sources, the highest estimates are provided by CAREX, with the national estimates showing a lower order of magnitude. Extrapolations to the EU-28 are summarised below. No extrapolations have been carried out on the basis of the Regex data for the Czech Republic; due to the low number of exposed workers, it is assumed to be an outlier.

Table 4-40: Occupationally exposed population in the EU-28 (benzene)	
Estimate and method of extrapolation	**Exposed population in the EU-28**
A: France 2010 exposed workers extrapolated on the basis of population	280,000
B: CAREX early to mid-1990s	1.6 million
C: France 2010 share (0.2%) applied to EU workforce	420,000
D: France 2003 share (0.3%) applied to EU workforce	630,000
E: Finland 2005 data extrapolated on the basis of population	140,000
F: Poland 2013 data extrapolated on the basis of population	140,000
G: Romania 2006 data extrapolated on the basis of population	200,000

Estimates E and F in the table above forms the basis for the LOW scenario while estimate B is used for the HIGH scenario. The CENTRAL scenario is based on the average of the remaining estimates (A, C, D, G: 380,000).

Rate of change

Comparing the number of workers exposed in France in 2003 and 2010 (SUMER) suggests an annual rate of decline of around 3.5%. A similar comparison for Finland (2005 ASA report vs 2014 ASA report) suggests a slight increase in number of works exposed to benzene (3.5% p.a.).[97] .

For this reason, the following scenarios are modelled:

- no change;
- an annual increase of 3.5%; and
- an annual decrease of 3.5%.

Although the generic staff turnover factor of 10% per annum has been applied, this is seen as broadly consistent with sector-specific turnover rates that have been identified as relevant to benzene:

- A, B (agriculture, hunting and forestry; fishing): 9% male and 10% female
- C-E (mining and quarrying; manufacturing; electricity, gas and water): 9% male and 14% female
- F (construction): 13% male and 16% female
- G-Q (grouped 'service industries'): 11% male and 15% female

Relative risk

The relative risk estimates identified through literature review are summarised below.

[97] Finnish ASA has data on the numbers of workers exposed but these have increased over time, probably as a result of improved notification rather than an increase in the number of workers. See http://annhyg.oxfordjournals.org/content/51/5/463.full.pdf

Table 4-41: Literature review of relative risk for benzene		
Study & summary of data/methodology	**Cancer site**	**Relative risk**
Bloemen (2004). Mortality cohort study of 2266 chemical workers	Leukaemia	SMR 1.14 (95% CI: 0.59, 1.19)
Collins JJ et al (2003). Cohort at the Solutia plant, Illinois	Leukaemia	SMR 2.7 (95% CI: 0.8, 6.4) for exposure over 100 ppm for 40 days
Collins JJ et al (2015). Updated mortality study of workers with benzene exposure	Leukaemia	SMR 1.21 (95% CI: 0.74-1.97)
Constantini et al (2003). Follow up of shoe factory workers	Leukaemia	SMR for men 1.4 (95% CI: 02, 5.0) for low exposure, 7.0 (95% CI: 1.9,8.0) for highest exposed group
Guénel P (2003). Cohort case-control study of gas and electric utility workers	Leukaemia	OR 3.6 (95% CI: 1.1, 11.7) for > 16.8 ppm years
Khalade et al (2010)	Leukaemia	Summary effect size: 1.40 (CI 1.23-1.57); Random-effects model summary effect size: 1.72 (CI 1.37-2.17); Effect estimates from nine studies based on cumulative exposures: 1.64 (CI 1.13-2.39) for low, 1.90 (CI 1.26-2.89) for medium and 2.62 (CI 1.57-4.39) for high exposure
Khalade et al (2010) et al. Literature review and meta-analysis. Summary effect estimate from nine studies	Leukaemia	1.64 (95% CI: 1.13, 2.39) for low exposure and 2.62 (95% CI: 1.57, 4.39) for high exposure
Richardson DB (2008). Cohort of 1,845 rubber hydrochloride workers	Leukaemia	RR 1.19 (95% CI: 1.04, 1.17) for mortality 10 years after exposure
Rushton and Romaniuk (1997). Case-control study of petroleum workers in the UK	All Leukaemia	Cumulative continuous exposure OR 1.004 (95% CI: 0.99, 1.02)
Rushton et al (2012). Following studies have been used : Collins et al (2003)- Higher exposure Lewis et al (2000)- Higher exposure Bloeman (2003)- Low exposure	Leukaemia	2.17 (95% CI:0.9, 5.2) 1.32 (95% CI: 0.49, 2.88) 1.11 (95% CI: 0.3, 2.83)

Table 4-41: Literature review of relative risk for benzene		
Study & summary of data/methodology	**Cancer site**	**Relative risk**
Swaen GMH et al (2005)	Leukaemia	Coating workers: RR 3.6 (cohort from 1936-1987) Chemical workers: RR 1.2 (cohort from 1946-1976) UK petroleum distribution: OR 1.00 (inconclusive results) Monsanto cohort: RR 1.3 (cohort from 1940-1998; peaks appear to be better predictor of myeloid leukaemia risk that cumulative exposure) Dow cohort: RR 1.9 (cohort from 1938-1982; not statistically significant) Caprolactam cohort: RR 0.85 (cohort from 1952-1969)
Yin et al (1996). Cohort study in China	Leukaemia	RR 2.3 (95% CI: 1.1, 5.0)
Yin et al (1997). Cohort study in China	Leukaemia	RR 2.3

Sources:
Bloemen LJ et al (2004): Lymphohaematopoietic cancer risk among chemical workers exposed to benzene. Occup Environ Me, 61, pp 270-274.
Collins JJ et al (2003): Lymphohaematopoietic cancer mortality among workers with benzene exposure. Occup Environ Med, 60, pp 676-679.
Collins JJ et al (2015): Lymphatic and Hematopoietic Cancers Among Benzene-Exposed Workers. JOEM, 54(2), pp 159-163.
Constantini et al (2003): Exposure to benzene and risk of leukaemia among shoe factory workers. Scand J Work Environ Health, 29(1), pp 51-59.
Guénel P et al (2003): Leukaemia in relation to occupational exposures to benzene and other agents: a case-control study nested in a cohort of gas and electric utility workers. Am J Ind Med, 42(2), pp 87-97.
Khalade A et al (2010): Exposure to benzene at work and the risk of leukaemia: a systematic review and meta-analysis, Environmental Health, 2010, 9(31), available at : https://ehjournal.biomedcentral.com/articles/10.1186/1476-069X-9-31
Khalade A et al (2010): Exposure to benzene at work and the risk of leukaemia: a systematic review and meta-analysis. Environmental Health, 9:31.
Richardson DB (2008): Temporal Variation in the Association between Benzene and Leukaemia Association. Environmental Health Perspectives, 116, pp 370-374.
Rushton L and Romaniuk H (1997): A case-control study to investigate the risk of leukaemia associated with exposure to benzene in petroleum marketing and distribution workers in the United Kingdom. Occupational and Environmental Medicine, 54, pp 152-166.
Rushton L et al (2012): The burden of occupational cancer in Great Britain. Available at http://www.hse.gov.uk/research/rrpdf/rr931.pdf
Swaen GMH et al (2005): Leukaemia risk in caprolactam workers exposed to Benzene, Ann Epidemiol, 15, 21-28, available at: http://www.tsac.nl/publicaties/Swaen_Scheffers_Leukaemia_Risk_in_Caprolactam_Workers_Exposed_to_Benzene_Ann_Epid_jan2005.pdf
Yin SN et al (1996): A cohort study of cancer among benzene-exposed workers in China: overall results. Am J Ind Med, 29, pp 227-235.
Yin SN et al (1997): An Expanded Cohort Study of Cancer Among Benzene-exposed Workers in China. Environmental Health Perspectives, 104(6), 1339-1341.

The highest and lowest relative risks are summarised below.

Table 4-42: Summary of relative risk - benzene		
Cancer site	**Lowest**	**Highest**
Leukaemia	OR=1.004	OR=3.6

Summary of the scenarios

The assumptions underpinning the different estimates are summarised below. Please note that the estimates of the exposed population are point estimates for a specific year and do not represent the lowest and highest annual estimates over the whole assessment period since these also depend on the annual rate of change.

Table 4-43: Summary of the scenarios (benzene)				
Aspect/scenario	**Low**	**High**	**Midpoint**	**Central**
Exposed population (EU-28) - point	140,000 (2006)	1.6 million (early to mid-1990s)	900,000 (assumed in 2005)	380,000 (2003-2010)
Relevant cancer sites	Leukaemia (1 of 3 identified in literature, 1 of 1 in IARC 2016)	Leukaemia (1 of 3 identified in literature, 1 of 1 in IARC 2016)	Leukaemia (1 of 3 identified in literature, 1 of 1 in IARC 2016)	Leukaemia (1 of 3 identified in literature, 1 of 1 in IARC 2016)
Relative risk	Leukaemia: OR=1.004	Leukaemia: OR=3.6	Leukaemia: OR=2.3	Leukaemia: *=2.13
Change (p.a.)	-3.5%	+3.5%	0%	0%

4.5.2 The results

Summary of the occupationally exposed population surviving to 2015

The total number of workers in the EU-28 exposed to benzene compounds between 1996 and 2015 2005 and surviving until 2015 has been estimated to be between 0.4 and 8.1 million.

Table 4-44: Occupationally exposed population surviving to 2015 (benzene)		
Scenario	**No. of workers exposed 1996-2015 & surviving to 2015 (million)**	**% of current & at risk population**
Low	0.4	0.1%
High	8.1	2.2%
Midpoint	2.6	0.7%
Central	1.1	0.3%

The break-down of these figures by Member State is provided below. The minimum and maximum values across all scenarios are presented for each Member State.

Table 4-45: Occupationally exposed population surviving to 2015 by Member State (benzene, 1996-2015)				
Member State	**Number of workers exposed over the period and surviving to 2015**		**% of current & at risk population**	
	Min	**Max**	**Min**	**Max**
Austria	7,473	245,204	0.1%	4.0%
Belgium	9,810	103,321	0.1%	1.3%
Bulgaria	6,275	36,666	0.1%	0.7%
Croatia	3,682	21,511	0.1%	0.7%

Table 4-45: Occupationally exposed population surviving to 2015 by Member State (benzene, 1996-2015)				
Member State	Number of workers exposed over the period and surviving to 2015		% of current & at risk population	
	Min	Max	Min	Max
Cyprus	738	13,984	0.1%	2.3%
Czech Republic	9,182	53,649	0.1%	0.7%
Denmark	4,931	248,330	0.1%	6.1%
Estonia	1,144	30,524	0.1%	3.2%
Finland	4,768	70,419	0.1%	1.8%
France	57,868	699,412	0.1%	1.5%
Germany	70,748	2,379,943	0.1%	4.1%
Greece	9,461	174,800	0.1%	2.2%
Hungary	8,587	50,174	0.1%	0.7%
Ireland	4,033	53,349	0.1%	1.6%
Italy	52,972	976,745	0.1%	2.2%
Latvia	1,730	36,061	0.1%	2.5%
Lithuania	2,545	125,672	0.1%	6.0%
Luxembourg	491	2,866	0.1%	0.7%
Malta	374	6,837	0.1%	2.2%
Netherlands	14,726	214,790	0.1%	1.8%
Poland	33,115	193,483	0.1%	0.7%
Portugal	9,040	214,915	0.1%	2.9%
Romania	17,313	101,159	0.1%	0.7%
Slovakia	4,724	27,600	0.1%	0.7%
Slovenia	1,797	10,502	0.1%	0.7%
Spain	40,472	452,027	0.1%	1.4%
Sweden	8,493	171,267	0.1%	2.4%
UK	56,526	1,496,421	0.1%	3.2%
Total	***443,017***	***8,138,778***	***0.1%***	***2.2%***

AFs per Member State

Table 4-46: Overall attributable fractions across all industries by Member State (benzene)			
Cancer site/ scenario	Leukaemia		
	C-Low	C-Core	C-High
Austria	0.1%	0.3%	0.7%
Belgium	0.1%	0.3%	0.7%
Bulgaria	0.1%	0.3%	0.7%
Croatia	0.1%	0.3%	0.7%
Cyprus	0.1%	0.3%	0.7%
Czech Republic	0.1%	0.3%	0.7%
Denmark	0.1%	0.3%	0.7%
Estonia	0.1%	0.3%	0.7%
Finland	0.1%	0.3%	0.7%
France	0.1%	0.3%	0.7%
Germany	0.1%	0.3%	0.7%
Greece	0.1%	0.3%	0.7%
Hungary	0.1%	0.3%	0.7%
Ireland	0.1%	0.3%	0.7%
Italy	0.1%	0.3%	0.7%
Latvia	0.1%	0.3%	0.7%
Lithuania	0.1%	0.3%	0.7%
Luxembourg	0.1%	0.3%	0.7%

Table 4-46: Overall attributable fractions across all industries by Member State (benzene)			
Cancer site/ scenario	Leukaemia		
	C-Low	C-Core	C-High
Malta	0.1%	0.3%	0.7%
Netherlands	0.1%	0.3%	0.7%
Poland	0.1%	0.3%	0.7%
Portugal	0.1%	0.3%	0.7%
Romania	0.1%	0.3%	0.7%
Slovakia	0.1%	0.3%	0.7%
Slovenia	0.1%	0.3%	0.7%
Spain	0.1%	0.3%	0.7%
Sweden	0.1%	0.3%	0.7%
UK	0.1%	0.3%	0.7%
EU-28	***0.1%***	***0.3%***	***0.7%***

4.6 Mineral oils

4.6.1 Methodology/assumptions

Summary of the relevant cancer endpoints and exposure period(s)

The relevant cancer endpoints are bladder, lung and non-melanoma skin cancer (NMSC) (IARC, 2016[98]; Rushton et al 2012[99]).

Only one cancer site (skin cancer, other malignant neoplasms) was identified in IARC (2016) as relevant to mineral oils (untreated or mildly treated). As a result, more cancer sites are covered in this report than those that were identified as relevant in IARC (2016).

The typical latency for all the relevant cancer endpoints is modelled to be between 10 and 50 years. The relevant exposure period is thus defined as 1966-2005.

Exposed population

The key source of data for mineral oils is SUMER which provides estimates for 1994, 2003 and 2010, suggesting an exposed (predominantly male) workforce in France between 0.5 and 0.7 million. This allows the exposed population in France to be estimated as well as the change in the exposed population over time.

No exposure data are available for other Member States, with the exception of the estimate in Rushton et al (2012). The UK data relate to "workers ever exposed" but when converted into an annual estimate suggests an exposed workforce of around 1.3 million, i.e. one that is significantly greater than the SUMER estimate for France. According to Rushton et al (2012), the key sectors where most exposure occurs include metal working and personal and household services.

The key uncertainty with regard to the data presented below is that it is unclear how some of the sources have defined 'mineral oils'. This is significant since different mineral oils have different carcinogenic potential.

[98] IARC (2016): List of classifications by cancer sites with sufficient or limited evidence in humans, available at https://monographs.iarc.fr/ENG/Classification/Table4.pdf

[99] Rushton et al (2012): Occupational cancer in the UK – overview report, available at http://www.hse.gov.uk/research/rrpdf/rr931.pdf

Table 4-47: Published data – workforce exposed to mineral oils					
Study	**Country**	**Year/period**	**No. of exposed workers**	**% of exposed workforce**	**Notes**
SUMER	France	1994	523,000 (490,000 men and 32,000 women)	4.4% (6.9% men and 0.7% women)	
		2003	669,100 (639,700 men and 29,400 women)	3.8% (6.4% men and 0.4% women)	
		2010	537,500 (525,000 men and 12,500 women)	2.5% (4.4% men and 0.1% women)	
Rushton	UK	Published in 2004-2005 Data for a 50 year period	6,386,783 (4,426,581 Men; 466,252 Women)		

The results of the extrapolation of the French and British data, using a range of different extrapolation techniques, is summarised below.

Table 4-48: Occupationally exposed population in the EU-28 (mineral oils)	
Estimate and method of extrapolation	**Exposed population in the EU-28**
A: France 1994 share (4.4%) applied to current EU workforce	9.7 million
B: France 2003 share (3.8%) applied to current EU workforce	8.4 million
C: France 2010 share (2.5%) applied to current EU workforce	5.5 million
D: France 2010 exposed workers extrapolated on the basis of population	4 million
E: UK exposed workers per year (historical average), extrapolated on the basis of population	10.2 million
F: UK exposed workers, extrapolated on the basis of population	50 million

Estimate D in the table above (4 million in the early 1990s) forms the basis for the LOW scenario while estimates A and E are used for the HIGH scenario (10 million in 1994). The CENTRAL scenario is based on the extrapolations of the SUMER data (A,B,C in the table above).

Rate of change

In terms of the proportion of workforce exposed to mineral oils, there has been a decreasing trend from 1994. However, in terms of the absolute number, the trend in the SUMER data is less clear-cut. For this reason, the following scenarios are modelled:

- no change; and
- an annual decrease of 3.5% (reflecting the decreasing share of the workforce that is exposed).

A generic staff turnover factor of 10% per annum has been used.

Relative risk

The relative risk estimates identified through literature review are summarised below.

Table 4-49: Literature review of relative risk for mineral oils		
Study & summary of data/methodology	**Cancer site**	**Relative risk**
Colt et al (2014). Case-control study in the New England Bladder Cancer Study	Bladder	OR=1.7 (95% CI: 1.1–2.8) for metalworking fluids
Colt et al 2011 (in IIAC, 2015) in Northern New England	Bladder	OR=2.2 (95% CI of 1.4-3.4) for precision metalworkers OR=1.6 (95% CI 1.01-2.6) for metalworking/plastic workings machine operators OR=1.7 (95% CI 1.1-2.5) for men reporting use of metalworking fluids
Dryson et al 2008 (in IIAC, 2015)	Bladder	No association between work as a sheet metal worker and bladder cancer in New Zealand (OR=0.39, CI 0.15-1.00)
Friesen et al (2009). Cohort of 46,399 hourly workers at three automobile plants in Michigan	Bladder	2.1 (95% CI: 1.2-3.6) for straight metalworking fluids for >8.98 mg/m^3 years with a 20 year lag. 1.0 (95% CI: 0.6-1.9) for soluble metalworking fluids for >17.91 mg/m^3 years with a 20 year lag.
Hours et al 1994 (in IIAC, 2015)	Bladder	OR=2.6 (95% CI of 1.1-1.4) for bladder cancer cases exposed to cutting fluids after adjustment for socio-professional status and tobacco smoking.
Ugnat et al (2004). Population based case-control study in Canada	Bladder	OR=1.64 (95% CI: 1.06-2.55) for mineral, cutting or lubricating oil
Zhao et al (2005). Retrospective cohort study of workers of an aerospace company.	Bladder	RR=1.99 (95% CI: 1.03-3.85)
Acquavella et al (1993).	Lung	For metal component workers in USA RR=1.8 (95% CI 1.2-2.6)
Eisen et al (1992)	Lung	Lung cancer for male automotive works in USA exposed to straight oils RR=1.0 (0.9-1.2); ever exposed to soluble oils RR 1.1 (95% CI 1.0-1.2)
Friesen et al (2012). Cohort of female autoworkers in Michigan	Lung	SMR=2.08 (95% CI: 1.71, 2.52) for exposure to metalworking fluids
Rønneberg et al (1988). Men exposed to mineral oils in Norwegian cable manufacturing company	Lung	Lung cancer: <1 year work: RR=2.3 (95% CI 1.0-4.5) Lung cancer: 1+ year work: RR=1.9 (95% CI 1.1-3.3)
IOM (2011). From Mitropoulos and Norman (2005)	NMSC	OR=1.21 (95% CI: 0.48-3.06)
Rushton & Hutchings (2007)	NMSC	1.20 (higher) and 1.0 (lower+background).
Sources: Colt JS et al (2014): A Case-Control Study of Occupational Exposure to Metalworking Fluids and Bladder Cancer Risk Among Men. Occup Environ Med, 71(10), pp 667-674. IIAC (industrial injuries advisory council) (2015); Information note: Bladder cancer and mineral oils, available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/429918/bladder-cancer-and-mineral-oils-iiac-inf-note.pdf. Friesen MC et al (2009): Quantitative exposure to metalworking fluids and bladder cancer incidence in a cohort of autoworkers. Am J Epidemiol, 169(12), pp 147-1478. Friesen MC (2012): Metalworking fluid exposure and cancer risk in a retrospective cohort of female autoworkers. Cancer Causes Control, 23(7), pp 1075-1082. IOM (2011): Health, socio-economic and environmental aspects of possible amendments to the EU Directive on the protection of workers from the risks related to exposure of carcinogens and mutagens at work. Mineral		

Table 4-49: Literature review of relative risk for mineral oils		
Study & summary of data/methodology	**Cancer site**	**Relative risk**
Oils as Used Engine Oils. Rushton L et al (2012): The burden of occupational cancer in Great Britain. Available at http://www.hse.gov.uk/research/rrpdf/rr931.pdf Ugnat AM et al (2004): Occupational exposure to chemical and petrochemical industries and bladder cancer risk in four western Canadian provinces		

The lowest and highest relative risks identified through literature are summarised below.

Table 4-50: Summary of relative risk – mineral oils		
Cancer site	**Lowest**	**Highest**
Bladder	OR=1	OR=2.6
Lung	RR=1	RR=2.3
NMSC	RR=1	OR=1.21

Summary of the scenarios

The assumptions underpinning the different estimates are summarised below. Please note that the estimates of the exposed population are point estimates for a specific year and do not represent the lowest and highest annual estimates over the whole assessment period since these also depend on the annual rate of change.

Table 4-51: Summary of the scenarios (Mineral oils)				
Aspect/scenario	**Low**	**High**	**Midpoint**	**Central**
Exposed population (EU-28) - point	4 million (early 1990s[100])	10 million (1994)	7 million (assumed 1994)	1994: 9.7 million 2003: 8.4 million 2010: 5.5 million
Relevant cancer sites	Bladder, lung, NMSC (2 more than IARC 2016)	Bladder, lung, NMSC (2 more than IARC 2016)	Bladder, lung, NMSC (2 more than IARC 2016)	Bladder, lung, NMSC (2 more than IARC 2016)
Relative risk	Bladder: OR=1 Lung: RR=1 NMSC: OR=1	Bladder: OR=2.6 Lung: RR=2.3 NMSC: OR=1.21	Bladder: OR=1.8 Lung: RR=1.7 NMSC: OR=1.1	Bladder: OR=1.7 Lung: RR=1.9 NMSC: OR=1.21
Change (p.a.)	0%	+2.8%	+1.4%	-3.5%

4.6.2 The results

Summary of the occupationally exposed population surviving to 2015

The total number of workers in the EU-28 exposed to mineral oils between 1966 and 2005 and surviving to 2015 has been estimated to be between 14 and 37 million.

Table 4-52: Occupationally exposed population surviving to 2015 (Mineral oils)		
Scenario	**No. of workers exposed 1966-2005 & surviving to 2015 (million)**	**% of current & at risk population**
Low	14.1	4.4%
High	36.6	11.4%

[100] For the purposes of this assessment, the reference year is 1994.

Table 4-52: Occupationally exposed population surviving to 2015 (Mineral oils)		
Scenario	**No. of workers exposed 1966-2005 & surviving to 2015 (million)**	**% of current & at risk population**
Midpoint	24.9	7.8%
Central	35.5	11.1%

The break-down of these figures by Member State is provided below. The minimum and maximum values across all scenarios are presented for each Member State.

Table 4-53: Occupationally exposed population surviving to 2015 by Member State (Mineral oils, 1966-2005)				
Member State	**Number of workers exposed over the period and surviving to 2015**		**% of current & at risk population**	
	Min	**Max**	**Min**	**Max**
Austria	238,071	616,794	4.4%	11.4%
Belgium	312,526	809,692	4.4%	11.4%
Bulgaria	199,928	517,973	4.4%	11.4%
Croatia	117,292	303,879	4.4%	11.4%
Cyprus	23,512	60,916	4.4%	11.4%
Czech Republic	292,535	757,899	4.4%	11.4%
Denmark	157,110	407,040	4.4%	11.4%
Estonia	36,455	94,449	4.4%	11.4%
Finland	151,892	393,522	4.4%	11.4%
France	1,843,638	4,776,494	4.4%	11.4%
Germany	2,253,986	5,839,624	4.4%	11.4%
Greece	301,411	780,895	4.4%	11.4%
Hungary	273,584	708,800	4.4%	11.4%
Ireland	128,496	332,908	4.4%	11.4%
Italy	1,687,643	4,372,343	4.4%	11.4%
Latvia	55,133	142,837	4.4%	11.4%
Lithuania	81,092	210,093	4.4%	11.4%
Luxembourg	15,627	40,487	4.4%	11.4%
Malta	11,918	30,878	4.4%	11.4%
Netherlands	469,152	1,215,479	4.4%	11.4%
Poland	1,055,009	2,733,315	4.4%	11.4%
Portugal	287,998	746,144	4.4%	11.4%
Romania	551,595	1,429,072	4.4%	11.4%
Slovakia	150,493	389,897	4.4%	11.4%
Slovenia	57,264	148,359	4.4%	11.4%
Spain	1,289,407	3,340,594	4.4%	11.4%
Sweden	270,580	701,017	4.4%	11.4%
UK	1,800,888	4,665,739	4.4%	11.4%
Total	***14,114,233***	***36,567,139***	***4.4%***	***11.4%***

AFs per Member State

Table 4-54: Overall attributable fractions across all industries by Member State (Mineral oils)									
Cancer site/ scenario	**Bladder**			**Lung**			**NMSC**		
	C-Low	**C-Core**	**C-High**	**C-Low**	**C-Core**	**C-High**	**C-Low**	**C-Core**	**C-High**
Austria	1.1%	7.2%	14.3%	1.1%	9.1%	20.3%	0%	2.3%	18.6%
Belgium	1.1%	7.2%	14.3%	1.1%	9.1%	20.3%	0%	2.3%	18.6%
Bulgaria	1.1%	7.2%	14.3%	1.1%	9.1%	20.3%	0%	2.3%	18.6%

Table 4-54: Overall attributable fractions across all industries by Member State (Mineral oils)									
Cancer site/ scenario	Bladder			Lung			NMSC		
	C-Low	C-Core	C-High	C-Low	C-Core	C-High	C-Low	C-Core	C-High
Croatia	1.1%	7.2%	14.3%	1.1%	9.1%	20.3%	0%	2.3%	18.6%
Cyprus	1.1%	7.2%	14.3%	1.1%	9.1%	20.3%	0%	2.3%	18.6%
Czech Republic	1.1%	7.2%	14.3%	1.1%	9.1%	20.3%	0%	2.3%	18.6%
Denmark	1.1%	7.2%	14.3%	1.1%	9.1%	20.3%	0%	2.3%	18.6%
Estonia	1.1%	7.2%	14.3%	1.1%	9.1%	20.3%	0%	2.3%	18.6%
Finland	1.1%	7.2%	14.3%	1.1%	9.1%	20.3%	0%	2.3%	18.6%
France	1.1%	7.2%	14.3%	1.1%	9.1%	20.3%	0%	2.3%	18.6%
Germany	1.1%	7.2%	14.3%	1.1%	9.1%	20.3%	0%	2.3%	18.6%
Greece	1.1%	7.2%	14.3%	1.1%	9.1%	20.3%	0%	2.3%	18.6%
Hungary	1.1%	7.2%	14.3%	1.1%	9.1%	20.3%	0%	2.3%	18.6%
Ireland	1.1%	7.2%	14.3%	1.1%	9.1%	20.3%	0%	2.3%	18.6%
Italy	1.1%	7.2%	14.3%	1.1%	9.1%	20.3%	0%	2.3%	18.6%
Latvia	1.1%	7.2%	14.3%	1.1%	9.1%	20.3%	0%	2.3%	18.6%
Lithuania	1.1%	7.2%	14.3%	1.1%	9.1%	20.3%	0%	2.3%	18.6%
Luxembourg	1.1%	7.2%	14.3%	1.1%	9.1%	20.3%	0%	2.3%	18.6%
Malta	1.1%	7.2%	14.3%	1.1%	9.1%	20.3%	0%	2.3%	18.6%
Netherlands	1.1%	7.2%	14.3%	1.1%	9.1%	20.3%	0%	2.3%	18.6%
Poland	1.1%	7.2%	14.3%	1.1%	9.1%	20.3%	0%	2.3%	18.6%
Portugal	1.1%	7.2%	14.3%	1.1%	9.1%	20.3%	0%	2.3%	18.6%
Romania	1.1%	7.2%	14.3%	1.1%	9.1%	20.3%	0%	2.3%	18.6%
Slovakia	1.1%	7.2%	14.3%	1.1%	9.1%	20.3%	0%	2.3%	18.6%
Slovenia	1.1%	7.2%	14.3%	1.1%	9.1%	20.3%	0%	2.3%	18.6%
Spain	1.1%	7.2%	14.3%	1.1%	9.1%	20.3%	0%	2.3%	18.6%
Sweden	1.1%	7.2%	14.3%	1.1%	9.1%	20.3%	0%	2.3%	18.6%
UK	1.1%	7.2%	14.3%	1.1%	9.1%	20.3%	0%	2.3%	18.6%
EU-28	***1.1%***	***7.2%***	***14.3%***	***1.1%***	***9.1%***	***20.3%***	***0%***	***2.3%***	***18.6%***

4.7 Cd and Cd compounds

4.7.1 Methodology/assumptions

Summary of the relevant cancer endpoints and exposure period(s)

The relevant cancer endpoints are **lung, kidney and prostate** cancer (IARC, 2016[101]; Rushton et al 2012[102], Boffetta et al 2011[103]).

Due to a lack of relative risk estimates for prostate cancer, only cancer incidence associated with two of the three cancer sites identified in IARC (2016) as relevant to cadmium and cadmium compounds has been quantified in this study.

[101] IARC (2016): List of classifications by cancer sites with sufficient or limited evidence in humans, available at https://monographs.iarc.fr/ENG/Classification/Table4.pdf

[102] Rushton et al (2012): Occupational cancer in the UK – overview report, available at http://www.hse.gov.uk/research/rrpdf/rr931.pdf

[103] Boffetta P et al (2011): Occupational exposure to arsenic, cadmium, chromium, lead and nickel, and renal cell carcinoma: a case-control study from Central and Eastern Europe, available at http://www.ncbi.nlm.nih.gov/pubmed/21217163

The typical latency for lung and kidney cancer endpoints is modelled to be between 10 and 50 years. The relevant exposure period is thus defined as 1966-2005.

Exposed population

The starting point for estimating the occupationally exposed population is the CAREX database, with further estimates being available for the Czech Republic, Finland, France, and the UK (although the data for the UK are based on CAREX). These estimates are summarised below.

Table 4-55: Published data – workforce exposed to Cd and Cd compounds

Study	Country	Year/period	No. of exposed workers	% of exposed workforce	Notes
Carex	EU15	1990-1993 (mean)	207,350		
	France	1990-1993 (mean)	22,034		
	Finland	1990-1993 (mean)	1,040		
	Czech Republic	1997	10,382		
SUMER	France	2003	27,700 (21,200 men)	0.2% (0.2% men)	
		2010	39,700 (37,200 men and 2,500 women)	0.2% (0.3% men and 0.1% women)	
ASA	Finland	2005	964 (747 men and 217 women)		
		2014	1,550 (1,375 men and 175 women)		
Regex	Czech Republic	2009-2016	49		Cadmium only
Rushton	UK	Published in 2004-2005	189,825 ever exposed (130,986 men; 58,639 women)		Based on Carex

Extrapolations to the EU-28 are summarised below. No extrapolations have been carried out on the basis of the Regex data for the Czech Republic; it is assumed that this is an outlier.

Table 4-56: Occupationally exposed population in the EU-28 (Cd and Cd compounds)

Estimate and method of extrapolation	Exposed population in the EU-28
A: France 2010 exposed workers extrapolated on the basis of population	300,000
B: CAREX early to mid-1990s	330,000
C: France 2010 share (0.2%) applied to current EU workforce	440,000
D: Rushton ever exposed workers extrapolated on the basis of population	300,000
E: Finland 2014 exposed workers extrapolated on the basis of population	140,000
F: Finland 2005 data extrapolated on the basis of population	90,000

Estimate F in the table above forms the basis for the LOW scenario while estimate C is used for the HIGH scenario. The CENTRAL scenario is based on the extrapolations of estimates A, B and D.

Rate of change

Comparing the number of workers exposed in France in 2003 and 2010 (SUMER) suggests an annual increase of around 2.5%. However, the other estimates in the table above suggest either no change over time or a slight decrease (estimated at around 0.6%).

For this reason, the following scenarios are modelled:

- no change;
- an annual increase of 2.5%; and
- an annual decrease of 0.6%.

A generic staff turnover factor of 10% per annum has been used.

Relative risk

The relative risk estimates identified through literature review are summarised below.

Table 4-57: Literature review of relative risk for Cd and Cd compounds

Study & summary of data/methodology	Cancer site	Relative risk
Beveridge R et al (2010). Two population occupational case-control studies in Montreal	Lung	OR=1.54 (95% CI: 0.9-2.7)
Rushton et al (2012). From Verougstraete et al 2003	Lung	1.19 (95% CI 1.09 - 1.29)
t'Mannetje A et al (2003). Population based case-control study in Europe	Lung	OR=1.19 (95% CI: 0.77, 1.82)
Boffetta et al 2011	Renal cell carcinoma	OR=1.4 (95% CI 0.69 - 2.85)
Mandel et al (1995). International multi-centre case-control study	Renal cell cancer	RR=2.0 (95% CI, 1.0-3.9)
Pesch et al (2000) Population-based study of 935 cases and 4290 controls for occupational exposure	Renal cell carcinoma	High exposure: OR=1.4 (95% CI : 1.1-1.8) in men, OR=2.5, (95% CI : 1.2-5.3) in women

Sources:
Beveridge R et al (2010): Lung cancer risk associated with occupational exposure to nickel, chromium (VI), and cadmium in two population-based case-control studies in Montreal. American Journal of Industrial Medicine, 53(5), 476-485.
Boffetta P et al (2011): Occupational exposure to arsenic, cadmium, chromium, lead and nickel, and renal cell carcinoma: a case-control study from Central and Eastern Europe, available at http://www.ncbi.nlm.nih.gov/pubmed/21217163
Mandel JS et al (1995): International renal-cell cancer study. IV. Occupation. Int J Cancer, 61(5), 601-605.
Pesch P et al (2000): Occupational risk factors for renal cell carcinoma: agent-specific results from a case-control study in Germany. International Journal of Epidemiology, 29, 1014-1024.
Rushton L et al (2012): The burden of occupational cancer in Great Britain. Available at http://www.hse.gov.uk/research/rrpdf/rr931.pdf
t'Mannetje A et al (2003): Occupational exposure to metal compounds and lung cancer. Results from a multi-center case-control study in Central/Eastern Europe and UK. Epidemiology, 22(12), 1669-1680.

The lowest and highest relative risks identified through literature are summarised below.

Table 4-58: Summary of relative risk - cadmium		
Cancer site	**Lowest**	**Highest**
Lung	OR=1.19	OR=1.54
Renal cell	1.77	OR=2.5

Summary of the scenarios

The assumptions underpinning the different estimates are summarised below. Please note that the estimates of the exposed population are point estimates for a specific year and do not represent the lowest and highest annual estimates over the whole assessment period since these also depend on the annual rate of change.

Table 4-59: Summary of the scenarios (Cd and Cd compounds)				
Aspect/scenario	**Low**	**High**	**Midpoint**	**Central**
Exposed population (EU-28) - point	90,000 (2005)	440,000 (2010)	270,000 (2007)	310,000 (1990s)
Relevant cancer sites	Lung, kidney (2 of 3 cancer sites in IARC 2016)	Lung, kidney (2 of 3 cancer sites in IARC 2016)	Lung, kidney (2 of 3 cancer sites in IARC 2016)	Lung, kidney (2 of 3 cancer sites in IARC 2016)
Relative risk	Lung: OR=1.19 Kidney: 1.77	Lung: OR=1.54 Kidney: OR=2.5	Lung: OR=1.37 Kidney: 2.14	Lung: OR/*=1.19 Kidney: OR=1.4
Change (p.a.)	+2.5%	-0.6%	+1.2%	0%

4.7.2 The results

Summary of the occupationally exposed population surviving to 2015

The total number of workers in the EU-28 exposed to Cd and Cd compounds between 1966 and 2005 and surviving to 2015 has been estimated to be between 0.2 and 1.4 million.

Table 4-60: Occupationally exposed population surviving to 2015 (Cd and Cd compounds)		
Scenario	**No. of workers exposed 1966-2005 & surviving to 2015 (million)**	**% of current & at risk population**
Low	0.2	0.1%
High	1.4	0.4%
Midpoint	0.8	0.3%
Central	1.1	0.4%

The break-down of these figures by Member State is provided below. The minimum and maximum values across all scenarios are presented for each Member State.

Table 4-61: Occupationally exposed population surviving to 2015 by Member State (Cd and Cd compounds, 1966-2005)				
Member State	**Number of workers exposed over the period and surviving to 2015**		**% of current & at risk population**	
	Min	**Max**	**Min**	**Max**
Austria	4,183	23,712	0.1%	0.4%
Belgium	5,492	31,128	0.1%	0.4%
Bulgaria	3,513	25,643	0.1%	0.6%
Croatia	2,061	14,653	0.1%	0.6%
Cyprus	413	2,342	0.1%	0.4%
Czech Republic	5,140	36,633	0.1%	0.6%

Table 4-61: Occupationally exposed population surviving to 2015 by Member State (Cd and Cd compounds, 1966-2005)				
Member State	Number of workers exposed over the period and surviving to 2015		% of current & at risk population	
	Min	Max	Min	Max
Denmark	2,761	39,735	0.1%	1.1%
Estonia	641	3,631	0.1%	0.4%
Finland	2,669	15,128	0.1%	0.4%
France	32,395	183,626	0.1%	0.4%
Germany	39,606	234,035	0.1%	0.5%
Greece	5,296	30,020	0.1%	0.4%
Hungary	4,807	32,970	0.1%	0.5%
Ireland	2,258	12,798	0.1%	0.4%
Italy	29,654	168,089	0.1%	0.4%
Latvia	969	5,491	0.1%	0.4%
Lithuania	1,425	8,077	0.1%	0.4%
Luxembourg	275	1,556	0.1%	0.4%
Malta	209	1,187	0.1%	0.4%
Netherlands	8,244	46,728	0.1%	0.4%
Poland	18,538	135,544	0.1%	0.6%
Portugal	5,061	28,685	0.1%	0.4%
Romania	9,692	69,604	0.1%	0.6%
Slovakia	2,644	18,317	0.1%	0.5%
Slovenia	1,006	7,327	0.1%	0.6%
Spain	22,657	128,425	0.1%	0.4%
Sweden	4,754	26,950	0.1%	0.4%
UK	31,644	179,368	0.1%	0.4%
Total	***248,007***	***1,405,777***	***0.1%***	***0.4%***

AFs per Member State

Table 4-62: Overall attributable fractions across all industries by Member State (Cd and Cd compounds)						
Cancer site/ scenario	Lung			Kidney		
	C-Low	C-Core	C-High	C-Low	C-Core	C-High
Austria	0%	0.2%	0.1%	0%	0.5%	0.6%
Belgium	0%	0.1%	0.1%	0%	0.4%	0.5%
Bulgaria	0%	0.3%	0.2%	0%	0.8%	1.0%
Croatia	0%	0.3%	0.2%	0%	0.8%	1.0%
Cyprus	0%	0.1%	0.0%	0%	0.2%	0.3%
Czech Republic	0%	0.3%	0.2%	0%	0.8%	1.0%
Denmark	0%	0.6%	0.3%	0%	1.6%	2.0%
Estonia	0%	0.2%	0.1%	0%	0.4%	0.5%
Finland	0%	0.1%	0.0%	0%	0.2%	0.2%
France	0%	0.1%	0.1%	0%	0.3%	0.3%
Germany	0%	0.2%	0.1%	0%	0.7%	0.8%
Greece	0%	0.1%	0.0%	0%	0.2%	0.3%
Hungary	0%	0.3%	0.2%	0%	0.8%	1.0%
Ireland	0%	0.1%	0.0%	0%	0.2%	0.3%
Italy	0%	0.2%	0.1%	0%	0.5%	0.6%
Latvia	0%	0.1%	0.1%	0%	0.4%	0.5%
Lithuania	0%	0.2%	0.1%	0%	0.5%	0.7%
Luxembourg	0%	0.2%	0.1%	0%	0.5%	0.6%

Table 4-62: Overall attributable fractions across all industries by Member State (Cd and Cd compounds)						
Cancer site/ scenario	Lung			Kidney		
	C-Low	C-Core	C-High	C-Low	C-Core	C-High
Malta	0%	0.2%	0.1%	0%	0.5%	0.6%
Netherlands	0%	0.2%	0.1%	0%	0.5%	0.6%
Poland	0%	0.3%	0.2%	0%	0.8%	1.0%
Portugal	0%	0.1%	0.1%	0%	0.3%	0.4%
Romania	0%	0.3%	0.2%	0%	0.8%	1.0%
Slovakia	0%	0.3%	0.2%	0%	0.8%	1.0%
Slovenia	0%	0.3%	0.2%	0%	0.8%	1.0%
Spain	0%	0.1%	0.1%	0%	0.3%	0.4%
Sweden	0%	0.1%	0.1%	0%	0.4%	0.5%
UK	0%	0.2%	0.1%	0%	0.5%	0.6%
EU-28	***0%***	***0.2%***	***0.1%***	***0%***	***0.5%***	***0.6%***

4.8 Wood dust

4.8.1 Methodology/assumptions

Summary of the relevant cancer endpoints and exposure period(s)

The relevant cancer endpoints are nasopharyngeal cancer (NFC) and sinonasal cancer (SNC) (IARC, 2016[104]; Rushton et al 2012[105]).

As a result, cancer incidence associated with 100% (2 of 2) cancer sites identified in IARC (2016) as relevant to wood dust has been quantified in this study.

The typical latency is modelled to be between 10 and 50 years. The relevant exposure period is thus defined as 1966-2005.

Exposed population

The starting point for estimating the occupationally exposed population is the CAREX database, with further estimates being available for the Czech Republic, Finland, France, Lithuania, and the UK (although the data for the UK are based on CAREX). These estimates are summarised below.

Table 4-63: Published data – workforce exposed to wood dust					
Study	Country	Year/period	No. of exposed workers	% of exposed workforce	Notes
Carex	EU15	1990-1993 (mean)	2,513,013		
	France	1990-1993 (mean)	177,949		
	Finland	1990-1993 (mean)	64,800		
	Czech Republic	1997	183,677		
	Lithuania	1997	47,263		

[104] IARC (2016): List of classifications by cancer sites with sufficient or limited evidence in humans, available at https://monographs.iarc.fr/ENG/Classification/Table4.pdf

[105] Rushton et al (2012): Occupational cancer in the UK – overview report, available at http://www.hse.gov.uk/research/rrpdf/rr931.pdf

Table 4-63: Published data – workforce exposed to wood dust					
Study	**Country**	**Year/period**	**No. of exposed workers**	**% of exposed workforce**	**Notes**
	UK	1990-1993 (mean)	433,834		
SUMER	France	2003	379,900 (357,500 men and 22,400 women)	2.2% (3.6% men and 0.3% women)	
		2010	369,600 (351,500 men and 18,100 women)	1.7% (3% men and 0.2% women)	
FinJem	Finland	2006	65,000		Woodworking & furniture industry, construction work
ASA	Finland	2005	957 (811 men and 146 women)		Oak and beech dust
		2014	661 (601 men and 60 women)		
Siew et al (2012)	Global	Not specified	62 million	2%	
Regex	Czech Republic	2009-2016	1,214		
Smailtye (2012)	Lithuania	1947-1996	1,518 (1,080 men and 438 women)		
Rushton	UK	Published 2004-2005, refers to ever exposed workers	2,149,042 (1,744,690 men; 404,352 women)		Based on Carex

Extrapolations to the EU-28 are summarised below. The Finish ASA data have not been considered because they only relate to oak and beech dust. The data from Lithuania have also not been considered because they relate to a time period that is not relevant to this study. The Czech Regex data are seen as an outlier and they have therefore not been considered.

Table 4-64: Occupationally exposed population in the EU-28 (wood dust)	
Estimate and method of extrapolation	**Exposed population in the EU-28**
A: France 2010 exposed workers extrapolated on the basis of population	2.8 million
B: CAREX early to mid-1990s	4.4 million
C: France 2003 share (2.2%) applied to EU workforce	4.6 million
D: Rushton ever exposed workers extrapolated on the basis of population	17 million (corresponds to annual workforce of 3.4 million)
E: Finland 2006 exposed workers extrapolated on the basis of population	6 million

Estimate A in the table above forms the basis for the LOW scenario while estimate E is used for the HIGH scenario. The CENTRAL scenario is based on the extrapolations of estimates B, C and D (4.1 million).

Rate of change

Comparing the number of workers exposed in France in 2003 and 2010 (SUMER) suggests an annual decline of around 0.4%.

The following scenarios are modelled:

- no change; and
- an annual decrease of 0.4%.

A generic staff turnover factor of 10% per annum has been used.

Relative risk

The relative risk estimates identified through literature review are summarised below.

Table 4-65: Literature review of relative risk for wood dust

Study & summary of data/methodology	Cancer site	Relative risk
Hildesheim A et al (2001). Case-control study in Taiwan of 375 cases	Nasopharyngeal (NFC)	RR of 1.7 (95% CI = 1.0-3.0)
Rushton et al (2012). From Demers et al (1995)	NFC	SMR=2.40 (95% CI 1.10, 4.50)
Rushton et al (2012). From Demers et al (1995)	SNC	SMR=3.1 (95% CI 1.6, 5.6)
Alonso-Sardón et al (2005). Meta-analysis that included four case control studies	SNC	OR 10.28 (95% CI: 5.92, 17.85)- authors note large degree of heterogeneity was found
Binazzi et al (2015). Meta-analysis of 28 studies	SNC	RR_{pooled}: 5.91 (95% CI: 4.31-8.11) for case control studies RR_{pooled}: 1.61 (95% CI: 1.10-2.37) for cohort studies
t'Mannetje et al (1999). Analysis of case-control studies in Europe	SNC	Men: OR 2.36, 95% CI 1.75–3.2 Women: OR 1.17, 95% CI 0.31–4.47
Roush et al (1980). Case-control study in the United States	SNC	OR 4.0 (95% CI: 1.5, 10.8)
Stellman et al (1998)	SNC	OR 1.4 (95% CI: 0.4-1.8) for wood occupation

Sources:
Alonso-Sardón M et al (2015): Association between Occupational Exposure to Wood Dust and Cancer: A Systematic review and meta-analysis. PLoS ONE, 10(7), e0133024.
Binazzi A et al (2015): Occupational exposure and sinonasal cancer: a systematic review and meta-analysis. BMC Cancer, 15:49.
d'Errico et al (2009): A case-control study on occupational risk factors for sino-nasal cancer, available at http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2693673
Hildesheim A et al (2001): Occupational exposure to wood, formaldehyde, and solvents and risk of nasopharyngeal carcinomas. Cancer Epidemiology, Biomarkers & Prevention. 10, 1145-1153.
IARC (2012):
Roush GC et al (1980): Sinonasal cancer and occupation: a case-control study. American Journal of Epidemiology, 111(2), 183-193.
Rushton L et al (2012): The burden of occupational cancer in Great Britain. Available at http://www.hse.gov.uk/research/rrpdf/rr931.pdf

Table 4-65: Literature review of relative risk for wood dust		
Study & summary of data/methodology	**Cancer site**	**Relative risk**
t'Mannetje A et al (1999): Sinonasal cancer, occupation, and tobacco smoking in European women and men. American Journal of Industrial Medicine, 36(1), 101-107.		

The highest and lowest identified relative risk is summarised below. Please note that the high estimate for SNC draws on Binazzi et al (2015) rather than Alonso-Sardón et al (2005). This is to avoid the influence of a study by d'Errico et al (2009[106]) which derived an unusually high sinonasal adenocarcinoma OR for occupational exposure to wood dust (58.6). Since this study is considered an outlier, the relative risk considered here is based on Binazzi et al (2015).

Table 4-66: Summary of relative risk – exposure to wood dust		
Cancer site	**Lowest**	**Highest**
NFC	RR= 1.7	2.4
SNC	OR=1.4	RR=5.91

Summary of the scenarios

The assumptions underpinning the different estimates are summarised below. Please note that the estimates of the exposed population are point estimates for a specific year and do not represent the lowest and highest annual estimates over the whole assessment period since these also depend on the annual rate of change.

Table 4-67: Summary of the scenarios (wood dust)				
Aspect/scenario	**Low**	**High**	**Midpoint**	**Central**
Exposed population (EU-28) - point	2.8 million (2010)	6 million (2006)	4.4 million (assumed 2008)	4.1 million (assumed 2000)
Relevant cancer sites	NFC, SNC (2 of 2 cancer sites in IARC 2016)	NFC, SNC (2 of 2 cancer sites in IARC 2016)	NFC, SNC (2 of 2 cancer sites in IARC 2016)	NFC, SNC (2 of 2 cancer sites in IARC 2016))
Relative risk	NFC: RR= 1.7 SNC: OR=1.4	NFC: 2.4 SNC: RR=5.91	NFC: 1.74 SNC: 3.93	NFC: SMR=2.4 SNC: RR=1.61
Change (p.a.)	0%	-0.4%	-0.2%	0%

4.8.2 The results

Summary of the occupationally exposed population surviving to 2015

The total number of workers in the EU-28 exposed to wood dust between 1966 and 2005 and surviving to 2015 has been estimated to be between 9.8 and 18.1 million.

Table 4-68: Occupationally exposed population surviving to 2015 (wood dust)		
Scenario	**No. of workers exposed 1966-2005 & surviving to 2015 (million)**	**% of current & at risk population**
Low	9.8	3.1%
High	18.1	5.6%
Midpoint	12.8	4.0%

[106] d'Errico et al (2009): A case-control study on occupational risk factors for sino-nasal cancer, available at http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2693673

Table 4-68: Occupationally exposed population surviving to 2015 (wood dust)		
Scenario	No. of workers exposed 1966-2005 & surviving to 2015 (million)	% of current & at risk population
Central	14.5	4.5%

The break-down of these figures by Member State is provided below. The minimum and maximum values across all scenarios are presented for each Member State.

Table 4-69: Occupationally exposed population surviving to 2015 by Member State (wood dust, 1966-2005)				
Member State	Number of workers exposed over the period and surviving to 2015		% of current & at risk population	
	Min	Max	Min	Max
Austria	166,650	304,561	3.1%	5.6%
Belgium	218,768	399,810	3.1%	5.6%
Bulgaria	139,950	255,765	3.1%	5.6%
Croatia	82,104	150,050	3.1%	5.6%
Cyprus	16,459	30,079	3.1%	5.6%
Czech Republic	204,775	374,236	3.1%	5.6%
Denmark	109,977	200,988	3.1%	5.6%
Estonia	25,519	46,637	3.1%	5.6%
Finland	106,324	194,313	3.1%	5.6%
France	1,290,546	2,358,538	3.1%	5.6%
Germany	1,577,790	2,883,491	3.1%	5.6%
Greece	210,988	385,590	3.1%	5.6%
Hungary	191,509	349,992	3.1%	5.6%
Ireland	89,947	164,383	3.1%	5.6%
Italy	1,181,350	2,158,977	3.1%	5.6%
Latvia	38,593	70,530	3.1%	5.6%
Lithuania	56,765	103,740	3.1%	5.6%
Luxembourg	10,939	19,992	3.1%	5.6%
Malta	8,343	15,247	3.1%	5.6%
Netherlands	328,406	600,179	3.1%	5.6%
Poland	738,506	1,349,657	3.1%	5.6%
Portugal	201,598	368,431	3.1%	5.6%
Romania	386,117	705,647	3.1%	5.6%
Slovakia	105,345	192,523	3.1%	5.6%
Slovenia	40,085	73,257	3.1%	5.6%
Spain	902,585	1,649,519	3.1%	5.6%
Sweden	189,406	346,149	3.1%	5.6%
UK	1,260,622	2,303,850	3.1%	5.6%
Total	***9,879,963***	***18,056,131***	***3.1%***	***5.6%***

AFs per Member State

Table 4-70: Overall attributable fractions across all industries by Member State (wood dust)						
Cancer site/ scenario	NFC			SNC		
	C-Low	C-Core	C-High	C-Low	C-Core	C-High
Austria	0.4%	5.9%	13.6%	0.4%	2.7%	5.8%
Belgium	0.4%	5.9%	13.6%	0.4%	2.7%	5.8%
Bulgaria	0.4%	5.9%	13.6%	0.4%	2.7%	5.8%
Croatia	0.4%	5.9%	13.6%	0.4%	2.7%	5.8%
Cyprus	0.4%	5.9%	13.6%	0.4%	2.7%	5.8%

Table 4-70: Overall attributable fractions across all industries by Member State (wood dust)						
Cancer site/ scenario	NFC			SNC		
	C-Low	C-Core	C-High	C-Low	C-Core	C-High
Czech Republic	0.4%	5.9%	13.6%	0.4%	2.7%	5.8%
Denmark	0.4%	5.9%	13.6%	0.4%	2.7%	5.8%
Estonia	0.4%	5.9%	13.6%	0.4%	2.7%	5.8%
Finland	0.4%	5.9%	13.6%	0.4%	2.7%	5.8%
France	0.4%	5.9%	13.6%	0.4%	2.7%	5.8%
Germany	0.4%	5.9%	13.6%	0.4%	2.7%	5.8%
Greece	0.4%	5.9%	13.6%	0.4%	2.7%	5.8%
Hungary	0.4%	5.9%	13.6%	0.4%	2.7%	5.8%
Ireland	0.4%	5.9%	13.6%	0.4%	2.7%	5.8%
Italy	0.4%	5.9%	13.6%	0.4%	2.7%	5.8%
Latvia	0.4%	5.9%	13.6%	0.4%	2.7%	5.8%
Lithuania	0.4%	5.9%	13.6%	0.4%	2.7%	5.8%
Luxembourg	0.4%	5.9%	13.6%	0.4%	2.7%	5.8%
Malta	0.4%	5.9%	13.6%	0.4%	2.7%	5.8%
Netherlands	0.4%	5.9%	13.6%	0.4%	2.7%	5.8%
Poland	0.4%	5.9%	13.6%	0.4%	2.7%	5.8%
Portugal	0.4%	5.9%	13.6%	0.4%	2.7%	5.8%
Romania	0.4%	5.9%	13.6%	0.4%	2.7%	5.8%
Slovakia	0.4%	5.9%	13.6%	0.4%	2.7%	5.8%
Slovenia	0.4%	5.9%	13.6%	0.4%	2.7%	5.8%
Spain	0.4%	5.9%	13.6%	0.4%	2.7%	5.8%
Sweden	0.4%	5.9%	13.6%	0.4%	2.7%	5.8%
UK	0.4%	5.9%	13.6%	0.4%	2.7%	5.8%
EU-28	***0.4%***	***5.9%***	***13.6%***	***0.4%***	***2.7%***	***5.8%***

4.9 Arsenic

4.9.1 Methodology/assumptions

Summary of the relevant cancer endpoints and exposure period(s)

The relevant cancer sites include (IARC, 2016[107]; Rushton et al, 2012[108], Mannetje et al, 2011; and d'Errico et al, 2009):

- lung, skin (malignant neoplasms other than melanoma), urinary bladder (all with sufficient evidence in humans according to IARC 2016)
- kidney, liver and bile duct, prostate, (all with limited evidence in humans according to IARC 2016).

Please note that the classification in IARC (2016) relates to arsenic and inorganic arsenic compounds.

Due to the absence of relative risk estimates for occupational exposure, occupational cancer incidence could not be quantified for most of the cancer sites listed above. Therefore, this report

[107] IARC (2016): List of classifications by cancer sites with sufficient or limited evidence in humans, available at https://monographs.iarc.fr/ENG/Classification/Table4.pdf

[108] Rushton et al (2012): Occupational cancer in the UK – overview report, available at http://www.hse.gov.uk/research/rrpdf/rr931.pdf

has only quantified lung cancer incidence associated with occupational exposure to arsenic. As a result, only one of the six cancer sites (i.e. 17%) for which arsenic or inorganic arsenic compounds were identified in IARC (2016) as a carcinogenic for humans with sufficient or limited evidence are therefore considered in this study.

Although this may be a significant omission, it should also be noted that some of these cancer sites (in terms of occupational exposure to arsenic) have become less relevant over time. As noted in Rushton et al (2012), for arsenic to cause to NMSC it must be ingested or come into direct contact with the skin, e.g. in word preservation or in the use of pesticides and sheep dips. However, it is also noted that the use of arsenic in pesticides and sheep dips has ceased.

The typical latency for lung cancer is modelled to be between 10 and 50 years. The relevant exposure period is thus defined as 1966-2005.

Exposed population

The starting point for estimating the occupationally exposed population is the CAREX database, with further estimates being available from the Finish ASA for 2005 and 2014, and the Romanian Ministry of Health for 2006. No estimates are available for France from the SUMER database. These estimates are summarised below.

Table 4-71: Published data – workforce exposed to arsenic

Study	Country	Year/period	No. of exposed workers	% of exposed workforce	Notes
Carex	EU15	1990-1993 (mean)	147,569		Arsenic and arsenic compounds
	Finland	1990-1993 (mean)	4,600		
	UK	1990-1993 (mean)	25,020		
ASA	Finland	2005	1,241 (1,070 men and 171 women)		Arsenic and its inorganic compounds
		2014	2,472 (2,210 men and 262 women)		
Ministerului Sănătăţii şi Familiei	Romania	2006	411		Arsenic and its compounds
Rushton et al	UK	Ever exposed (estimated in 2004/5 for a period of 10-50 years)	Ever exposed: 136,849 (92,144 men; 44,705 women)	0.34% (proportion of population ever exposed)	Estimated based on Carex

Applying a generic staff turnover of 10% per annum to the estimates of the population ever exposed in Rushton et al (2012)[109] suggests an occupationally exposed population between 25,000 and 45,000 per annum (assuming no change over time). It can therefore be concluded that the different sources (with the exception of the data published for Romania) are of a similar order of magnitude,

[109] Rushton et al (2012): The burden of occupational cancer in Great Britain – Overview report, available at http://www.hse.gov.uk/research/rrpdf/rr931.pdf

although the Carex data suggest a somewhat higher exposure in Finland in 1990-93 than the estimates published in 2005 and 2014. The Carex data have therefore been taken as the basis for all the scenarios modelled for arsenic.

The data published for Romania are considered to be an outlier and they are not used for modelling at the EU level.

Rate of change

Comparing the number of workers exposed in Finland in 2005 and 2014 (ASA) suggests an annual rate of increase of around 6%, this increase is evident in both men and women. It is, however, not clear to what extent this increase is a result of improved notification and to what extent it reflect a real increase in the number of workers exposed to arsenic.[110] On the contrary, comparing the Carex data for Finland with the ASA data suggests a decline in the exposed population of 4% per annum between 1990 and 2014.

For this reason, three scenarios for the annual rate of change have been modelled:

- no decline in the number of workers exposed to formaldehyde;
- an annual decline of 4% throughout the EU; and
- an annual increase in the number of workers exposed of around 6%.

A generic staff turnover factor of 10% per annum has been used.

Relative risk

The relative risk estimates identified through literature review are summarised below.

[110] See http://annhyg.oxfordjournals.org/content/51/5/463.full.pdf

Table 4-72: Literature review of relative risk for arsenic		
Study & summary of data/methodology	**Cancer site**	**Relative risk**
Rushton et al (2012) from Lee-Feldstein (1986)	Lung	2.05 (95% CI 1.43, 2.85), 1.74
Mannetje et al (2011)	Lung	1.65 (95% CI:1.05-2.58)
d'Errico et al (2009)	Lung	OR=4.4
t'Mannetje A et al (2003)	Lung	OR=1.65 (95% CI: 1.05-2.58)
Chen et al (2002). Case-control study of tin miners in China	Lung	OR=2.1 (95% CI: 1.1, 3.9) for low exposure group, OR=3.6 (95% CI: 1.85,7.3)
Lubin et al (2000). Cohort study of workers at a Montana copper smelter. From IARC review	Lung	RR=3.68 (95% CI: 2.1-6.4) for heaviest exposed group; RR: 0..95 (0.6-1.4) for lowest exposed group; SMR=1.6
Ades and Kazantis (1998). Zinc-lead-cadmium smelter in UK. From IARC review.	Lung	SMR=1.2
Wall (1980). Copper smelter in Sweden. From IARC review.	Lung	SMR=2.9
Binks et al (2005). Tin smelter in UK. From IARC review.	Lung	SMR=1.5
IARC . Literature review	Lung	Around 2-3 in cohort studies
Sources: Chen W and Chen J (2002): Nested case-control study of lung cancer in four Chinese tin mines. Occup Environ Med, 59, 113-188. d'Errico A et al (2009): A case-control study on occupational risk factors for sino-nasal cancer, available at http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2693673/ IARC (2012): Monograph 100C- Arsenic and Arsenic Compounds. Available at http://monographs.iarc.fr/ENG/Monographs/vol100C/mono100C-6.pdf Lubin JH et al (2000): Respiratory cancer in a cohort of copper smelter workers: results from more than 50 years of follow-up. Am J Epidemiol, 151: 554–565. Rushton L et al (2012): The burden of occupational cancer in Great Britain. Available at http://www.hse.gov.uk/research/rrpdf/rr931.pdf Mannetje A et al (2003): Occupational exposure to metal compounds and lung cancer. Results from a multi-center case-control study in Central/Eastern Europe and UK. Epidemiology, 22(12), 1669-1680 Mannetje et al (2011): Occupational exposure to metal compounds and lung cancer. Results from a multi-center case-control study in Central/Eastern Europe and UK. http://www.ncbi.nlm.nih.gov/pubmed/21960145		

The highest and lowest risk estimates are summarised below.

Table 4-73: Summary of relative risk – exposure to arsenic		
Cancer site	**Lowest**	**Highest**
Lung	SMR=1.2	OR=4.4

Summary of the scenarios

The assumptions underpinning the different estimates are summarised below. Please note that the estimates of the exposed population are point estimates for a specific year and do not represent the lowest and highest annual estimates over the whole assessment period since these also depend on the annual rate of change.

Table 4-74: Summary of the scenarios (arsenic)				
Aspect/scenario	**Low**	**High**	**Midpoint**	**Central**
Exposed population (EU-28) - point	250,000 in 1990-93 or 1997	250,000 in 1990-93 or 1997	250,000 in 1990-93 or 1997	250,000 in 1990-93 or 1997
Relevant cancer sites	Lung (1 of 6)	Lung (1 of 6)	Lung (1 of 6)	Lung (1 of 6)
Relative risks	SMR=1.2	OR=4.4	2.8	OR=1.65
Rate of change (per annum)	+6%	-4%	+2%	0%

4.9.2 The results

Summary of the occupationally exposed population surviving to 2015

The total number of workers in the EU-28 exposed to arsenic between 1966 and 2005 and surviving until 2015 is estimated to have been between 0.88 million and 0.9 9million.

Table 4-75: Occupationally exposed population surviving to 2015 (arsenic)		
Scenario	**No. of workers exposed 1966-2005 & surviving to 2015 (million)**	**% of current & at risk population**
Low	0.88	0.3%
High	0.99	0.3%
Midpoint	0.89	0.3%
Central	0.88	0.3%

The break-down of these figures by Member State is provided below. The minimum and maximum values across all scenarios are presented for each Member State.

Table 4-76: Occupationally exposed population surviving to 2015 by Member State (arsenic, 1966-2005)				
Member State	**Number of workers exposed over the period and surviving to 2015**		**% of current & at risk population**	
	Min	**Max**	**Min**	**Max**
Austria	12,967	16,301	0.2%	0.3%
Belgium	14,886	18,715	0.2%	0.3%
Bulgaria	23,962	30,494	0.5%	0.7%
Croatia	13,693	17,425	0.5%	0.7%
Cyprus	491	609	0.1%	0.1%
Czech Republic	34,232	43,563	0.5%	0.7%
Denmark	5,738	7,213	0.2%	0.2%
Estonia	5,044	6,419	0.6%	0.8%
Finland	15,880	19,964	0.5%	0.6%
France	89,482	112,495	0.2%	0.3%
Germany	136,718	171,881	0.3%	0.3%
Greece	6,000	7,543	0.1%	0.1%
Hungary	30,809	39,207	0.5%	0.6%
Ireland	2,562	3,220	0.1%	0.1%
Italy	63,252	79,519	0.2%	0.2%
Latvia	5,913	7,525	0.5%	0.6%
Lithuania	6,779	8,627	0.4%	0.5%
Luxembourg	1,005	1,263	0.3%	0.4%
Malta	453	561	0.2%	0.2%
Netherlands	15,863	19,943	0.1%	0.2%

Table 4-76: Occupationally exposed population surviving to 2015 by Member State (arsenic, 1966-2005)				
Member State	Number of workers exposed over the period and surviving to 2015		% of current & at risk population	
	Min	Max	Min	Max
Poland	126,657	161,182	0.5%	0.7%
Portugal	15,362	19,313	0.2%	0.3%
Romania	65,040	82,769	0.5%	0.7%
Slovakia	17,116	21,781	0.5%	0.6%
Slovenia	6,846	8,713	0.5%	0.7%
Spain	40,553	50,983	0.1%	0.2%
Sweden	14,330	18,016	0.2%	0.3%
UK	86,375	108,589	0.2%	0.3%
Total	***883,978***	***999,094***	***0.3%***	***0.3%***

AFs per Member State

Table 4-77: Overall attributable fractions across all industries by Member State (arsenic and lung cancer)			
Scenario	C-Low	C-Core	C-High
Austria	0.01%	0.2%	0.4%
Belgium	0.01%	0.1%	0.3%
Bulgaria	0.03%	0.4%	0.9%
Croatia	0.03%	0.3%	0.8%
Cyprus	0.00%	0.1%	0.1%
Czech Republic	0.03%	0.3%	0.8%
Denmark	0.01%	0.1%	0.3%
Estonia	0.03%	0.4%	1.0%
Finland	0.02%	0.3%	0.7%
France	0.01%	0.1%	0.3%
Germany	0.01%	0.2%	0.4%
Greece	0.00%	0.1%	0.1%
Hungary	0.03%	0.3%	0.8%
Ireland	0.00%	0.1%	0.1%
Italy	0.01%	0.1%	0.3%
Latvia	0.02%	0.3%	0.8%
Lithuania	0.02%	0.2%	0.6%
Luxembourg	0.01%	0.2%	0.5%
Malta	0.01%	0.1%	0.3%
Netherlands	0.01%	0.1%	0.2%
Poland	0.03%	0.4%	0.9%
Portugal	0.01%	0.2%	0.4%
Romania	0.03%	0.4%	0.8%
Slovakia	0.03%	0.3%	0.8%
Slovenia	0.03%	0.4%	0.9%
Spain	0.01%	0.1%	0.2%
Sweden	0.01%	0.2%	0.4%
UK	0.01%	0.1%	0.3%
EU-28	***0.01%***	***0.2%***	***0.4%***

4.10 Vinyl chloride

4.10.1Methodology/assumptions

Summary of the relevant cancer endpoints and exposure period(s)

Information in Bofetta P et al (2003)[111]; Carreon et al (2014)[112]; Gennaro V et al (2008)[113]; IOM (2011)[114]; Ward E et al (2001)[115]; IARC, 2016[116]; Rushton et al 2012[117] suggests that the main endpoint is liver cancer. In addition, Budroni et al (2010)[118] have identified an increased risk of non-Hodgkin lymphoma (NHL), and haemolymphatic cancers[119] more generally, among workers employed in the manufacture and polymerisation of VCM in Sardinia, Italy.

The two cancer endpoints considered in this study thus are liver cancer and NHL, which both have a latency period of 10-50 years (1966-2005). This means that one more cancer site has been considered in this study than identified as carcinogenic for humans with sufficient or limited evidence in IARC (2016).

Exposed population

The starting point for estimating the occupationally exposed population is the CAREX database, with further estimates being available from national registers and studies for the Czech Republic, Finland, Poland, Romania and the UK (although the UK data are based on CAREX). These estimates are summarised below.

[111] Bofetta P et al (2003): Meta-analysis of studies of occupational exposure to vinyl chloride in relation to cancer mortality. Scand J Environ Health, 29(3), 220-229.

[112] Carreon et al (2014): Coronary Artery Disease and Cancer Mortality in a Cohort of Workers Exposed to Vinyl Chloride, Carbon Disulfide, Rotating Shift Work, and *o*-Toluidine. Am J Ind Med, 57(4), 398-411.

[113] Gennaro V et al (2008): Reanalysis of updated mortality among vinyl and polyvinyl chloride workers: Confirmation of historical evidence and new findings. BMC Public Health, 8, 21.

[114] IOM (2011): Health, socio-economic and environmental aspects of possible amendments to the EU Directive on the protection of workers from the risks related to exposure of carcinogens and mutagens at work. Vinyl chloride monomer.

[115] Ward E et al (2001): Update of the Follow-Up of Mortality and Cancer Incidence among European Workers Employed in the Vinyl Chloride Industry. Epidemiology, 12(6), 710-**718.**

[116] IARC (2016): List of classifications by cancer sites with sufficient or limited evidence in humans, available at https://monographs.iarc.fr/ENG/Classification/Table4.pdf

[117] Rushton et al (2012): Occupational cancer in the UK – overview report, available at http://www.hse.gov.uk/research/rrpdf/rr931.pdf

[118] Budroni et al (2010): Cancer incidence among petrochemical workers in the Porto Torres industrial area 1990-2006, available at http://www.ncbi.nlm.nih.gov/pubmed/20812660 and https://www.researchgate.net/publication/46123152_Cancer_incidence_among_petrochemical_workers_in_the_Porto_Torres_industrial_area_1990-2006

[119] The two general groups for tumours of the haemolymphatic system are lymphoid (lymphoma and leukaemia) and myeloid leukaemias. Source: https://www.researchgate.net/publication/310455731_Tumors_of_the_Hemolymphatic_System

Table 4-78: Published data – workforce exposed to vinyl chloride				
Study	**Country**	**Year/period**	**No. of exposed workers**	**% of exposed workforce**
Carex	EU15	1990-1993 (mean)	39,638	
	Finland	1990-1993 (mean)	180	
	Czech Republic	1997	779	
ASA	Finland	2005	90 (72 men and 18 women)	
		2014	41 (33 men and 8 women)	
Regex	Czech Republic	2009-2016	175	
Central Register	Poland	2013	1,527	
Ministerului Sănătăţii şi Familiei	Romania	2006	770	
Rushton	UK	Published in 2004-2005; ever exposed workers	23,908	

Extrapolations to the EU-28 are summarised below.

Table 4-79: Occupationally exposed population in the EU-28 (vinyl chloride)	
Estimate and method of extrapolation	**Exposed population in the EU-28**
A: CAREX early 1990s	50,000-60,000
B: ASA 2005 exposed workers extrapolated on the basis of population	9,000
C: ASA 2014 exposed workers extrapolated on the basis of population	4,000
D: Romania 2006 extrapolated on the basis of population	20,000
E: UK ever-exposed workers extrapolated on the basis of population	37,000

The average of estimates B and C in the table above (6,500) has been taken as the basis for the LOW scenario while CAREX data (estimate A) are used for the HIGH scenario. The CENTRAL scenario is based on the extrapolation of the Romanian data for 2006 (estimate D).

The relative risk for NHL in Budroni et al (2010) specifically relates to workers involved in the manufacture and polymerisation of VCM and not to all workers potentially exposed to VCM. However, the sources considered in this section provide no specific estimate of the workforce involved in VCM production and polymerisation. However, the breakdown by sector in the CAREX database[120] suggests that about two-thirds of workers exposed to VCM work in the broader chemicals sector. In the absence of more specific information, it has been assumed that the risk of NHL is relevant to two-thirds of the total workforce exposed to VCM.

Rate of change

Comparing the number of workers exposed in Finland in 2005 and 2014 (ASA) suggests an annual decrease of around 10%. The following scenarios are modelled:

- no change; and
- an annual decrease of 10%.

[120] See http://partner.ttl.fi/en/chemical_safety/carex/Documents/5_exposures_by_agent_and_industry.pdf

A generic staff turnover factor of 10% per annum has been used.

Relative risk

The relative risk estimates identified through literature review are summarised below.

Table 4-80: Literature review of relative risk for vinyl chloride

Study & summary of data/methodology	Cancer site	Relative risk
Bofetta P et al (2003). Meta-analysis of six studies	Liver	SMR: 1.35 (95% CI 1.04-1.77)
Carreon et al (2014). Mortality study of 1,874 workers	Hepatobiliary (biliary passages, liver, and gallbladder)	SMR 3.80 (95% CI:1.89-6.80)
Gennaro V et al (2008). Updated cancer mortality study for VC-PVC plant in Italy	Liver	RR: 9.57 (95% CI: 3.71-24.68) for autoclave workers
IOM (2011) from European cohort in Kielhorn et al (2000).	Liver	2.86 (95% CI, 1.83, 4.25
Rushton L et al (2012) from Simonato et al (1991).	Liver	High exposure: 2.86 (95% CI, 1.83, 4.25); Low exposure: 1.89 (95% CI, 0.32, 3.96); Average: 2.38
Ward E et al (2001). Update of the European Multicentric Cohort Study of Workers in the Vinyl Chloride Industry	Liver	SMR: 2.40 (95% CI: 1.80-3.14)
Budroni et al (2010), petrochemical workers in Sardinia	non-Hodgkin lymphoma (NHL)	NHL sir=4.06; 95% CI 1.64-10.0

Sources:
Bofetta P et al (2003): Meta-analysis of studies of occupational exposure to vinyl chloride in relation to cancer mortality. Scand J Environ Health, 29(3), 220-229.
Budroni et al (2010): Cancer incidence among petrochemical workers in the Porto Torres industrial area 1990-2006, available at http://www.ncbi.nlm.nih.gov/pubmed/20812660 and https://www.researchgate.net/publication/46123152_Cancer_incidence_among_petrochemical_workers_in_the_Porto_Torres_industrial_area_1990-2006
Carreon et al (2014): Coronary Artery Disease and Cancer Mortality in a Cohort of Workers Exposed to Vinyl Chloride, Carbon Disulfide, Rotating Shift Work, and *o*-Toluidine. Am J Ind Med, 57(4), 398-411.
Gennaro V et al (2008): Reanalysis of updated mortality among vinyl and polyvinyl chloride workers: Confirmation of historical evidence and new findings. BMC Public Health, 8, 21.
IOM (2011): Health, socio-economic and environmental aspects of possible amendments to the EU Directive on the protection of workers from the risks related to exposure of carcinogens and mutagens at work. Vinyl chloride monomer.
Rushton L et al (2012): The burden of occupational cancer in Great Britain. Available at http://www.hse.gov.uk/research/rrpdf/rr931.pdf
Ward E et al (2001): Update of the Follow-Up of Mortality and Cancer Incidence among European Workers Employed in the Vinyl Chloride Industry. Epidemiology, 12(6), 710-718.

The lowest and highest relative risks identified through literature are summarised in the following table.

Table 4-81: Summary of relative risk – exposure to vinyl chloride		
Cancer site	**Lowest**	**Highest**
Liver	RR=1.89	RR=9.57
NHL	SIR=4.06	SIR=4.06

Summary of the scenarios

The assumptions underpinning the different estimates are summarised below. Please note that the estimates of the exposed population are point estimates for a specific year and do not represent the lowest and highest annual estimates over the whole assessment period since these also depend on the annual rate of change.

Table 4-82: Summary of the scenarios (vinyl chloride)				
Aspect/scenario	**Low**	**High**	**Midpoint**	**Central**
Exposed population (EU-28) - point	6,500 (2010) (NHL 4,300)	50,000-60,000 in early 1990s (NHL 30,000-40,000)	27,000 (assumed in 2002) (NHL 18,000)	20,000 (assumed in 2006)
Relevant cancer sites	Liver NHL (1 more than in IARC 2016	Liver NHL (1 more than in IARC 2016)	Liver NHL (1 more than in IARC 2016)	Liver NHL (1 more than in IARC 2016)
Relative risk	Liver: RR=1.89 NHL: SIR=4.06	Liver: RR=9.57 NHL: SIR=4.06	Liver: RR=5.73 NHL: SIR=4.06	Liver: SMR=2.40 NHL: SIR=4.06
Change (p.a.)	0%	-10%	-5%	-5%

4.10.2The results

Summary of the occupationally exposed population surviving to 2015

The total number of workers in the EU-28 exposed to vinyl chloride between 1966 and 2005 and surviving until 2015 is summarised below.

Table 4-83: Occupationally exposed population surviving to 2015 (vinyl chloride)		
Scenario	**No. of workers exposed 1966-2005 & surviving to 2015 (million)**	**% of current & at risk population**
Low	0.02	0.01%
High	0.32	0.1%
Midpoint	0.17	0.1%
Central	0.16	0.1%

The break-down of these figures by Member State is provided below. The minimum and maximum values across all scenarios are presented for each Member State.

Table 4-84: Occupationally exposed population surviving to 2015 by Member State (vinyl chloride, 1966-2005)				
Member State	**Number of workers exposed over the period and surviving to 2015**		**% of current & at risk population**	
	Min	**Max**	**Min**	**Max**
Austria	387	3,104	0.01%	0.06%
Belgium	508	6,734	0.01%	0.09%
Bulgaria	325	6,209	0.01%	0.14%

Table 4-84: Occupationally exposed population surviving to 2015 by Member State (vinyl chloride, 1966-2005)				
Member State	Number of workers exposed over the period and surviving to 2015		% of current & at risk population	
	Min	Max	Min	Max
Croatia	191	3,548	0.01%	0.13%
Cyprus	38	286	0.01%	0.05%
Czech Republic	475	8,869	0.01%	0.13%
Denmark	255	37,415	0.01%	1.05%
Estonia	59	1,218	0.01%	0.15%
Finland	247	1,847	0.01%	0.05%
France	2,996	46,922	0.01%	0.11%
Germany	3,663	57,096	0.01%	0.11%
Greece	490	3,665	0.01%	0.05%
Hungary	445	7,982	0.01%	0.13%
Ireland	209	1,562	0.01%	0.05%
Italy	2,742	31,372	0.01%	0.08%
Latvia	90	1,218	0.01%	0.10%
Lithuania	132	1,947	0.01%	0.11%
Luxembourg	25	425	0.01%	0.12%
Malta	19	289	0.01%	0.11%
Netherlands	762	7,046	0.01%	0.07%
Poland	1,714	32,817	0.01%	0.14%
Portugal	468	3,502	0.01%	0.05%
Romania	896	16,852	0.01%	0.13%
Slovakia	245	4,435	0.01%	0.13%
Slovenia	93	1,774	0.01%	0.14%
Spain	2,095	15,678	0.01%	0.05%
Sweden	440	3,290	0.01%	0.05%
UK	2,926	25,370	0.01%	0.06%
Total	***22,935***	***324,292***	***0.01%***	***0.10%***

AFs per Member State

Table 4-85: Overall attributable fractions by Member State (vinyl chloride monomer)						
Cancer site/ scenario	Liver			NHL		
	C-Low	C-Core	C-High	C-Low	C-Core	C-High
Austria	0.04%	0.1%	0.1%	0.02%	0.1%	0.3%
Belgium	0.04%	0.1%	0.1%	0.02%	0.1%	0.3%
Bulgaria	0.04%	0.1%	0.1%	0.02%	0.1%	0.3%
Croatia	0.04%	0.1%	0.1%	0.02%	0.1%	0.3%
Cyprus	0.04%	0.1%	0.1%	0.02%	0.1%	0.3%
Czech Republic	0.04%	0.1%	0.1%	0.02%	0.1%	0.3%
Denmark	0.04%	0.1%	0.1%	0.02%	0.1%	0.3%
Estonia	0.04%	0.1%	0.1%	0.02%	0.1%	0.3%
Finland	0.04%	0.1%	0.1%	0.02%	0.1%	0.3%
France	0.04%	0.1%	0.1%	0.02%	0.1%	0.3%
Germany	0.04%	0.1%	0.1%	0.02%	0.1%	0.3%
Greece	0.04%	0.1%	0.1%	0.02%	0.1%	0.3%
Hungary	0.04%	0.1%	0.1%	0.02%	0.1%	0.3%
Ireland	0.04%	0.1%	0.1%	0.02%	0.1%	0.3%
Italy	0.04%	0.1%	0.1%	0.02%	0.1%	0.3%
Latvia	0.04%	0.1%	0.1%	0.02%	0.1%	0.3%

Table 4-85: Overall attributable fractions by Member State (vinyl chloride monomer)						
Cancer site/ scenario	Liver			NHL		
	C-Low	C-Core	C-High	C-Low	C-Core	C-High
Lithuania	0.04%	0.1%	0.1%	0.02%	0.1%	0.3%
Luxembourg	0.04%	0.1%	0.1%	0.02%	0.1%	0.3%
Malta	0.04%	0.1%	0.1%	0.02%	0.1%	0.3%
Netherlands	0.04%	0.1%	0.1%	0.02%	0.1%	0.3%
Poland	0.04%	0.1%	0.1%	0.02%	0.1%	0.3%
Portugal	0.04%	0.1%	0.1%	0.02%	0.1%	0.3%
Romania	0.04%	0.1%	0.1%	0.02%	0.1%	0.3%
Slovakia	0.04%	0.1%	0.1%	0.02%	0.1%	0.3%
Slovenia	0.04%	0.1%	0.1%	0.02%	0.1%	0.3%
Spain	0.04%	0.1%	0.1%	0.02%	0.1%	0.3%
Sweden	0.04%	0.1%	0.1%	0.02%	0.1%	0.3%
UK	0.04%	0.1%	0.1%	0.02%	0.1%	0.3%
EU-28	***0.04%***	***0.1%***	***0.1%***	***0.02%***	***0.1%***	***0.3%***

4.11 Ethylene oxide

4.11.1Methodology/assumptions

Summary of the relevant cancer endpoints and exposure period(s)

The relevant cancer endpoints and latency periods are (Hagmar L et al, 1996[121]; Coggon et al, 2004[122]; Kiran et al, 2012[123]; Shore et al, 1993[124]; IARC, 2016[125] and Rushton et al, 2012[126]):

- Lymphoma, latency 0-20 years, relevant period 1996-2015;
- Leukaemia, latency 0-20 years, relevant period 1996-2015; and
- Breast, latency 10-50 years, relevant period 1966-2005.

IOM (2012) has also identified cancer of the stomach, pancreas and brain as relevant.

Due to a lack of reliable relative risk estimates for cancers of the breast, stomach, and pancreas, only cancer incidence associated with two of the three cancer sites identified in IARC (2016) as relevant to ethylene oxide has been quantified in this study.

Although studies into the relationship between ethylene oxide and breast cancer are available (e.g. Steenland et al 2003[127] and Mikotzy et al 2009)[128], these do not provide relative risk estimates that

[121] Hagmar L et al (1996): Cancer incidence in Swedish sterilant workers exposed to ethylene oxide. Occupational and Environmental Medicine, 52, 154-156.

[122] Coggon D et al (2004): Mortality of workers exposed to ethylene oxide: extended follow-up of a British cohort. Occup Environ Med, 61, 358-362.

[123] Kiran S (2010): Occupational exposure to ethylene oxide and risk of lymphoma http://www.ncbi.nlm.nih.gov/pubmed/20811284.

[124] Shore RE et al (1993): Ethylene oxide: an assessment of the epidemiological evidence on carcinogenicity. Br J Ind Med, 50, 971-997.

[125] IARC (2016): List of classifications by cancer sites with sufficient or limited evidence in humans, available at https://monographs.iarc.fr/ENG/Classification/Table4.pdf

[126] Rushton et al (2012): Occupational cancer in the UK – overview report, available at http://www.hse.gov.uk/research/rrpdf/rr931.pdf

are useful for this study; Steenland et al 2003 concluded that (for a cohort of female sterilisation workers) the breast cancer SIR was below 1. As a result, quantification of breast cancer resulting from occupational exposure to ethylene oxide is not attempted in this study.

Exposed population

The starting point for estimating the occupationally exposed population is the CAREX database, with further estimates being available from national studies and registers for the Czech Republic, Finland and the UK. These estimates are summarised below.

Table 4-86: Published data – workforce exposed to ethylene oxide

Study	Country	Year/period	No. of exposed workers
Carex	EU15	1990-1993 (mean)	46,918
	Finland	1990-1993 (mean)	260
	Czech Republic	1997	385
	UK	1990-1993 (mean)	3,064
ASA	Finland	2005	133 (4 men and 129 women)
		2014	27 (16 men and 11 women)
Regex	Czech Republic	2009-2016	36
Rushton et al	UK	Published in 2004-2005; ever exposed workers	9,739 (5,310 men; 4,429 women)

Extrapolations to the EU-28 are summarised below.

Table 4-87: Occupationally exposed population in the EU-28 (ethylene oxide)

Estimate and method of extrapolation	Exposed population in the EU-28
A: CAREX early to mid-1990s	50,000
B: ASA 2005 extrapolated on the basis of population	13,000
C: ASA 2014 extrapolated on the basis of population	2,500
D: Rushton et al ever exposed workers extrapolated on the basis of population	15,000

Estimate C in the table above (2,500 in 2014) forms the basis for the LOW scenario while estimate A is used for both the CENTRAL and HIGH scenarios (50,000 in the early to mid-1990s). The key uncertainty with regard to the use of data based on CAREX (estimate A) is that there are large differences between Member States that provided specific data to CAREX and those where data were estimated on basis of average values. This is significant since some large Member States (such as Germany) appear to have rather limited numbers of exposed workers in the CAREX database. As a result, estimate A may still be an underestimate.

Rate of change

Comparing the number of workers exposed in Finland in 2005 and 2014 (ASA) suggests an annual rate of decline of 15.5%. However, when extrapolated over the relevant reference period, this

[127] See https://www.ncbi.nlm.nih.gov/pubmed/12948284
[128] See https://www.ncbi.nlm.nih.gov/pubmed/21776215

estimate suggests a rapid decline that is unlikely to have occurred in all Member States over the whole period. For this reason, only a 0% change over time is modelled.

A generic staff turnover factor of 10% per annum has been used.

Relative risk

The relative risk estimates identified through literature review are summarised below.

Table 4-88: Literature review of relative risk for ethylene oxide		
Study & summary of data/methodology	**Cancer site**	**Relative risk**
Hagmar L et al (1996). Cohort of 2170 workers	Leukaemia	SIR 2.44 (95% CI: 0.30,8.81)
IOM (2011) and Rushton et al (2012) from Coggon et al (2004)	Leukaemia	1.08 for medical and research institute workers; 2.29 for manufacturing (highest exposure)
Kiran et al (2012). Case control study in six European countries	Lymphoma	OR 1.3 (95% CI 0.7-2.1)
Shore et al (1993). Meta-analysis	Leukaemia	SMR 1.06 (95% CI: 0.73, 1.48)
Sources: Coggon D et al (2004): Mortality of workers exposed to ethylene oxide: extended follow-up of a British cohort. Occup Environ Med, 61, 358-362. Hagmar L et al (1996): Cancer incidence in Swedish sterilant workers exposed to ethylene oxide. Occupational and Environmental Medicine, 52, 154-156. Kiran S (2010): Occupational exposure to ethylene oxide and risk of lymphoma http://www.ncbi.nlm.nih.gov/pubmed/20811284. Rushton L et al (2012): The burden of occupational cancer in Great Britain. Available at http://www.hse.gov.uk/research/rrpdf/rr931.pdf Shore RE et al (1993): Ethylene oxide: an assessment of the epidemiological evidence on carcinogenicity. Br J Ind Med, 50, 971-997.		

The lowest and highest relative risks identified through literature are summarised below.

Table 4-89: Summary of relative risk – exposure to ethylene oxide		
Cancer site	**Lowest**	**Highest**
Lymphoma	OR=1.3	OR:=1.3
Leukaemia	1.08	2.29

Summary of the scenarios

The assumptions underpinning the different estimates are summarised below. Please note that in this instance the assumptions used for the high and central scenarios are identical.

Table 4-90: Summary of the scenarios (ethylene oxide)				
Aspect/scenario	**Low**	**High**	**Midpoint**	**Central**
Exposed population (EU-28) - point	2,500 (2014)	50,000 (early to mid-1990s)	26,250 (assumed in 2004)	50,000 (early to mid-1990s)
Relevant cancer sites	Lymphoma Leukaemia (2 of 3 in IARC 2016)	Lymphoma Leukaemia (2 of 3 in IARC 2016)	Lymphoma Leukaemia (2 of 3 in IARC 2016)	Lymphoma Leukaemia (2 of 3 in IARC 2016)
Relative risk	Lymphoma: OR=1.3 Leukaemia: 1.08	Lymphoma: OR=1.3 Leukaemia: SMR=2.29	Lymphoma: OR=1.3 Leukaemia: 1.685	Lymphoma: OR=1.3 Leukaemia: SMR=2.29
Change (p.a.)	0%	0%	-7.75%	0%

4.11.2The results

Summary of the occupationally exposed population surviving to 2015

The total number of workers in the EU-28 exposed to ethylene oxide between 1996 and 2015 and surviving until 2015 is summarised below.

Table 4-91: Occupationally exposed population surviving to 2015 (ethylene oxide)		
Scenario	**Number of workers exposed 1996-2005 and surviving to 2015 (million)**	**% of current & at risk population**
Low	0.007	0.002%
High & Central	0.15	0.04%
Midpoint	0.08	0.02%

The break-down of these figures by Member State is provided below. The minimum and maximum values across all scenarios are presented for each Member State.

Table 4-92: Occupationally exposed population surviving to 2015 by Member State (ethylene oxide, 1996-2015)				
Member State	**Number of workers exposed over the period and surviving to 2015**		**% of current & at risk population**	
	Min	**Max**	**Min**	**Max**
Austria	121	1,274	0.002%	0.021%
Belgium	159	1,672	0.002%	0.021%
Bulgaria	102	1,069	0.002%	0.021%
Croatia	60	627	0.002%	0.021%
Cyprus	12	126	0.002%	0.021%
Czech Republic	149	1,565	0.002%	0.021%
Denmark	80	54,202	0.002%	1.330%
Estonia	19	195	0.002%	0.021%
Finland	77	813	0.002%	0.021%
France	939	38,311	0.002%	0.080%
Germany	1,148	12,057	0.002%	0.021%
Greece	154	1,612	0.002%	0.021%
Hungary	139	1,463	0.002%	0.021%
Ireland	65	687	0.002%	0.021%
Italy	860	10,277	0.002%	0.023%
Latvia	28	295	0.002%	0.021%
Lithuania	41	509	0.002%	0.024%

Table 4-92: Occupationally exposed population surviving to 2015 by Member State (ethylene oxide, 1996-2015)				
Member State	Number of workers exposed over the period and surviving to 2015		% of current & at risk population	
	Min	Max	Min	Max
Luxembourg	8	84	0.002%	0.021%
Malta	6	72	0.002%	0.023%
Netherlands	239	2,517	0.002%	0.021%
Poland	537	5,644	0.002%	0.021%
Portugal	147	1,541	0.002%	0.021%
Romania	281	2,951	0.002%	0.021%
Slovakia	77	805	0.002%	0.021%
Slovenia	29	306	0.002%	0.021%
Spain	657	6,897	0.002%	0.021%
Sweden	138	2,013	0.002%	0.029%
UK	917	9,633	0.002%	0.021%
Total	***7,191***	***147,044***	***0.002%***	***0.040%***

AFs per Member State

Table 4-93: Overall attributable fractions across all industries by Member State (ethylene oxide)						
Cancer site/ scenario	Lymphoma			Leukaemia		
	C-Low	C-Core	C-High	C-Low	C-Core	C-High
Austria	0%	0.00%	0.02%	0%	0.02%	0.08%
Belgium	0%	0.00%	0.02%	0%	0.02%	0.07%
Bulgaria	0%	0.00%	0.02%	0%	0.02%	0.07%
Croatia	0%	0.00%	0.02%	0%	0.02%	0.07%
Cyprus	0%	0.00%	0.01%	0%	0.01%	0.04%
Czech Republic	0%	0.00%	0.02%	0%	0.02%	0.07%
Denmark	0%	0.40%	1.44%	0%	1.69%	6.26%
Estonia	0%	0.01%	0.02%	0%	0.02%	0.09%
Finland	0%	0.01%	0.02%	0%	0.02%	0.10%
France	0%	0.02%	0.09%	0%	0.10%	0.40%
Germany	0%	0.01%	0.02%	0%	0.03%	0.10%
Greece	0%	0.00%	0.01%	0%	0.01%	0.04%
Hungary	0%	0.00%	0.02%	0%	0.02%	0.07%
Ireland	0%	0.00%	0.01%	0%	0.01%	0.05%
Italy	0%	0.01%	0.03%	0%	0.03%	0.12%
Latvia	0%	0.01%	0.02%	0%	0.02%	0.09%
Lithuania	0%	0.01%	0.03%	0%	0.03%	0.12%
Luxembourg	0%	0.00%	0.01%	0%	0.01%	0.05%
Malta	0%	0.01%	0.03%	0%	0.03%	0.12%
Netherlands	0%	0.01%	0.02%	0%	0.03%	0.10%
Poland	0%	0.00%	0.02%	0%	0.02%	0.08%
Portugal	0%	0.00%	0.01%	0%	0.01%	0.05%
Romania	0%	0.00%	0.02%	0%	0.02%	0.07%
Slovakia	0%	0.00%	0.02%	0%	0.02%	0.07%
Slovenia	0%	0.00%	0.02%	0%	0.02%	0.07%
Spain	0%	0.00%	0.01%	0%	0.01%	0.05%
Sweden	0%	0.01%	0.03%	0%	0.04%	0.14%
UK	0%	0.01%	0.02%	0%	0.02%	0.09%
EU-28	***0%***	***0.01%***	***0.04%***	***0%***	***0.05%***	***0.20%***

4.12 PAHs

4.12.1Methodology/assumptions

Summary of the relevant cancer endpoints and exposure period(s)

The relevant cancer endpoints and latency periods are (Sim et al (2009)[129]; Boffetta et al (1997)[130]; Armstrong et al (2004)[131]; Partanen and Boffetta (1994)[132] Carta et al (2004)[133]; Rushton et al 2012[134]):

- Bladder, 10-50 years, 1966-2005;
- Lung, 10-50 years, 1966-2005;
- Non-melanoma skin cancer (NMSC), 10-50 years, 1966-2005;
- Stomach, 10-50 years, 1966-2005;
- Kidney, 10-50 years , 1966-2005;
- Mesothelioma, 10-50 years , 1966-2005;
- Pancreas, 10-50 years , 1966-2005; and
- Lymphoma and leukaemia, 0-20 years, 1996-2015.

Exposed population

The starting point for estimating the occupationally exposed population is the CAREX database, with further estimates being available for France from SUMER (1994), for Finland from the ASA register (2005 and 2014) and Antilla (2015), for the Czech Republic from the Regex register and for the UK from Rushton et al (2012), although the data in Ruston et al are based on CAREX. These estimates are summarised below.

[129] Sim et al (2009): Mortality and cancer incidence in workers in two Australian prebake aluminium smelters. Occup Environ Med. 2009 Jul;66(7):464-70, available at https://www.researchgate.net/publication/24011508_Mortality_and_cancer_incidence_in_workers_in_two_Australian_prebake_aluminium_smelters

[130] Boffetta P, Jourenkova N, Gustavsson P. Cancer risk from occupational and environmental exposure to polycyclic aromatic hydrocarbons. Cancer Causes Control. 1997;8:444–472.

[131] Armstrong et al (2004): Lung Cancer Risk after Exposure to Polycyclic Aromatic Hydrocarbons: A Review and Meta-Analysis. Environ Health Perspect. 2004 Jun; 112(9): 970–978, available at https://www.researchgate.net/publication/8508549_Lung_Cancer_Risk_after_Exposure_to_Polycyclic_Aromatic_Hydrocarbons_A_Review_and_Meta-Analysis

[132] Partanen and Boffetta (1994): Cancer risk in asphalt workers and roofers: review and meta-analysis of epidemiologic studies. Am J Ind Med. 1994 Dec;26(6):721-40, abstract available at https://www.ncbi.nlm.nih.gov/pubmed/7892824

[133] Carta, P, Aru, G, Cadeddu, C et al (2004), Mortality for Pancreatic Cancer among Aluminium Smelter Workers in Sardinia, Italy, G Ital Med Lav Ergon 2 : 83-9.

[134] Rushton et al (2012): Occupational cancer in the UK – overview report, available at http://www.hse.gov.uk/research/rrpdf/rr931.pdf

Table 4-94: Published data – workforce exposed to PAHs					
Study	**Country**	**Year/period**	**No. of exposed workers**	**% of exposed workforce**	**Notes**
Carex	EU15	1990-1993 (mean)	959,332		
	France	1990-1993 (mean)	117,202		
	Finland	1990-1993 (mean)	6,190		
	Czech Republic	1997	34,522		
	UK	1990-1993 (mean)	106,285		
SUMER	France	1994	73,000 (63,000 men and 10,000 women)	0.6% (0.9% men)	
ASA	Finland	2005	55 (41 men and 14 women)		
		2014	84 (68 men and 16 women)		
Regex	Czech Republic	2009-2016	68		
Rushton	UK	Published in 2004-2005; ever exposed workers	522,591 (316,728 men; 178,832 women)		Based on Carex

Extrapolations to the EU-28 are summarised below.

Table 4-95: Occupationally exposed population in the EU-28 (PAHs)	
Estimate and method of extrapolation	**Exposed population in the EU-28**
A: CAREX early to mid-1990s	1.3 million
B: France 1994 exposed workers extrapolated on the basis of population	600,000
C: France 1994 share (0.6%) applied to current EU workforce	1.1 million
D: ASA 2005 exposed workers extrapolated on the basis of population	5,000
E: ASA 2014 exposed workers extrapolated on the basis of population	8,000
H: Rushton ever exposed workers extrapolated on the basis of population	800,000

Estimates D and E in the table above have been used for the LOW scenario while estimates A and C are used for the HIGH scenario. The CENTRAL scenario is based on the extrapolation of the Rushton et al and SUMER data (estimates B and F).

Rate of change

Comparing the number of workers exposed in Finland in 2005 and 2014 (ASA) suggests an annual increase of around 4.8%. The following scenarios are modelled:

- no change; and
- an annual increase of 4.8%.

A generic staff turnover factor of 10% per annum has been used.

Relative risk

The relative risk estimates identified through literature review are summarised below.

Table 4-96: Literature review of relative risk

Study & summary of data/methodology	Cancer site	Relative risk
Armstrong and Gibbs (2009) Mortality, occupational exposure and smoking histories were ascertained for a cohort of 16,431 persons (15,703 men and 728 women) who had worked in one of four aluminium smelters in Quebec from 1950 to 1999	Lung cancer	RR=1.35 (95% CI 1.22-1.51)
Sim et al (2009), Australia 4396 male workers employed for > 90 days between 1983 and 2002 at 2 prebake aluminium smelters, starting to operate in 1962 and 1986. Subjects were identified from company records and health survey records. The cohort was followed in national mortality and cancer registries up to 2002	Lung, bladder, stomach, kidney and mesothelioma	Lung SIR=1.23 (0.90-1.72), bladder SIR= 1.26 (95% CI 0.73-2.16), stomach SIR=1.95 (95% CI 1.16-3.29), kidney SIR=1.99 (95% CI 1.12-3.35), mesothelioma SIR=2.41 (95% CI 1.00-5.78)
Björ et al (2008) A historical cohort comprised of 2264 male non-office workers employed from 1942 on and tracked up to the year 2000 was examined	Lung, CNS and oesophagus cancer	An elevated risk of cancer was found for the lungs, central nervous system, and oesophagus. The highest lung cancer risk was observed for the workers employed for ≥10 years in the factory when they were compared with the reference group from northern Sweden, standardised incidence ratio 1.99 (95% CI 1.21–3.07)
Boffetta et al (1997)	Bladder	1.44 (95% CI: 1.20, 1.74)
Gibbs and Sevigny (2007), Canada Study groups combined from Gibbs et al. (2007) and Gibbs & Sevigny (2007a), and a small plant (D) using the prebake process, adding 568 men and 42 women. Cancer incidence from 1980 to [not stated] was obtained from Quebec cancer registry, which was also used to calculate expected numbers.	Lung and bladder cancer	Lung SMR=1.20 (95% CI 1.10-1.31), bladder SMR=1.81 (95% CI 1.59-2.07)
Bosetti et al (2006) Reviews the results from cohort studies conducted on workers exposed to PAHs in these industries, with a focus on cancers	Lung, respiratory tract, bladder and kidney cancer	Lung Pooled RR average across industries: 1.12 Bladder Pooled RR average across industries: 1.49 Kidney Pooled RR average across

Table 4-96: Literature review of relative risk		
Study & summary of data/methodology	**Cancer site**	**Relative risk**
of the respiratory and urinary tract		industries: 1.23
Spinelli et al (2006), Friesen et al (2007), Canada A cohort study of 6423 male workers in British Columbia, Canada	Lung and bladder cancer	Lung SIR=1.10 (95% CI 0.93-1.30), bladder SIR=1.80 (95% CI 1.45-2.21). Adjustment for smoking gave lower numbers but still significant trends for both bladder and lung cancer
Armstrong et al (2004) A review and meta-analysis of published reports of occupational epidemiologic studies, 39 cohorts included	Lung cancer	Average estimated unit relative risk was 1.20 (95% CI 1.11-1.29)
Carta et al (2004), Italy 1152 men employed for > 1 year between 1972 and 1980 in a pre-bake aluminium smelter and followed up to 2001	Lung, bladder, pancreas lymphomas and leukaemias	Lung SMR= 0.70 (95% CI 0.39–1.26), bladder SMR=0.79 (95% CI 0.26–2.44), pancreas SMR=2.41 (95% CI 1.11–5.23) and lymphomas and leukaemias SMR=2.03 (95% CI 1.03–4.00)
Moulin et al (2000), France 2133 men employed > 1 year in 1950–94 followed for mortality 1968–94. The plant used both Söderberg and prebake processes, but only pre-bake process since 1982	Lung and bladder cancer	Lung SMR=0.63 (95% CI 0.38–0.98), bladder SMR=1.77 (0.71–3.64)
Romundstad et al (2000), Norway 11,103 men employed > 3 years between 1953 and 1996 in 6 aluminium plants in Norway followed up 1953–96	Lung and bladder	Lung SIR= 1.0 (95% CI 0.9–1.2), Bladder SIR= 1.3 (95% CI 1.1–1.5)
Partanen and Boffetta (1994) A meta-analysis of 20 studies of asphalt workers and roofers	Non melanoma skin cancer	For NMSC, a combined overall RR of 1.74 (95% CI 1.07–2.65)
Mur et al (1987), France 6455 workers who worked > 1 year in one of 11 plants between 1950 and 1976 followed up for mortality to 1976; follow-up 95% complete, cause of deaths known for 71.3%	Lung and bladder cancer	Lung SMR=1.14 (95% CI 0.85–1.48), bladder SMR=2.09 (95% CI 0.96–3.68)
Sources: Armstrong et al (2004): Lung Cancer Risk after Exposure to Polycyclic Aromatic Hydrocarbons: A Review and Meta-Analysis. Environ Health Perspect. 2004 Jun; 112(9): 970–978, available at https://www.researchgate.net/publication/8508549_Lung_Cancer_Risk_after_Exposure_to_Polycyclic_Aromatic_Hydrocarbons_A_Review_and_Meta-Analysis Armstrong and Gibbs (2009): Exposure–response relationship between lung cancer and polycyclic aromatic hydrocarbons (PAHs). Occup Environ Med 2009;66:740-746, available at https://www.researchgate.net/publication/26310683_Exposure-response_relationship_between_lung_cancer_and_polycyclic_aromatic_hydrocarbons_PAHs Björ et al (2008): Long-term follow-up study of mortality and the incidence of cancer in a cohort of workers at a primary aluminium smelter in Sweden. Scand J Work Environ Health 2008;34(6):463-470, abstract available at http://www.sjweh.fi/show_abstract.php?abstract_id=1293 Boffetta P, Jourenkova N, Gustavsson P. Cancer risk from occupational and environmental exposure to		

Table 4-96: Literature review of relative risk		
Study & summary of data/methodology	**Cancer site**	**Relative risk**
polycyclic aromatic hydrocarbons. Cancer Causes Control. 1997;8:444–472. Boffetta et al (2003): Cancer mortality among European asphalt workers: an international epidemiological study. II. Exposure to bitumen fume and other agents. Am J Ind Med. 2003 Jan;43(1):28-39, available at https://www.researchgate.net/publication/10980937_Cancer_mortality_among_European_asphalt_workers_An_international_epidemiological_study_II_Exposure_to_bitumen_fume_and_other_agents Bosetti et al (2006): Occupational exposures to polycyclic aromatic hydrocarbons, and respiratory and urinary tract cancers: a quantitative review to 2005. Ann Oncol 2006; 18(3):431-446, available at https://academic.oup.com/annonc/article/18/3/431/499235/Occupational-exposures-to-polycyclic-aromatic Friesen et al (2007): Comparison of two indices of exposure to polycyclic aromatic hydrocarbons in a retrospective aluminium smelter cohort. Occup Environ Med 2007;64:273-278, available at http://oem.bmj.com/content/64/4/273.abstract Gibbs and Sevigny (2007): Mortality and cancer experience of Quebec aluminium reduction plant workers. Part 3: monitoring the mortality of workers first employed after January 1, 1950. J Occup Environ Med. 2007 Nov;49(11):1269-87, abstract available at https://www.researchgate.net/publication/5852801_Mortality_and_Cancer_Experience_of_Quebec_Aluminum_Reduction_Plant_Workers_Part_3_Monitoring_the_Mortality_of_Workers_First_Employed_After_January_1_1950 Moulin et al (2000): A mortality study among workers in a French aluminium reduction plant. International Archives of Occupational and Environmental Health. 2000 Jun;73(5)5:323–330, abstract available at http://link.springer.com/article/10.1007/s004200000124 Mur et al (1987): Mortality of aluminium reduction plant workers in France. Int J Epidemiol. 1987 Jun;16(2):257-64, abstract available at https://www.ncbi.nlm.nih.gov/pubmed/3610453# Partanen and Boffetta (1994): Cancer risk in asphalt workers and roofers: review and meta-analysis of epidemiologic studies. Am J Ind Med. 1994 Dec;26(6):721-40, abstract available at https://www.ncbi.nlm.nih.gov/pubmed/7892824 Romundstad et al (2000): Lung and bladder cancer among workers in a Norwegian aluminium reduction plant. Occup Environ Med 2000;57:495-499, available at https://www.researchgate.net/publication/12463137_Lung_and_bladder_cancer_among_workers_in_a_Norwegian_aluminium_reduction_plant Sim et al (2009): Mortality and cancer incidence in workers in two Australian prebake aluminium smelters. Occup Environ Med. 2009 Jul;66(7):464-70, available at https://www.researchgate.net/publication/24011508_Mortality_and_cancer_incidence_in_workers_in_two_Australian_prebake_aluminium_smelters Spinelli et al (2006): Cancer risk in aluminium reduction plant workers (Canada). Cancer Causes Control. 2006 Sep;17(7):939-48, abstract available at http://link.springer.com/article/10.1007%2Fs10552-006-0031-9		

The lowest and highest relative risks identified through literature are summarised below.

Table 4-97: Summary of relative risk – exposure to PAHs		
Cancer site	**Lowest**	**Highest**
Bladder	SMR: 1	SMR: 2.09
Lung	SMR: 1	SIR: 1.99
NMSC	RR: 1.74	RR: 1.74
Stomach	SIR: 1.95	SIR: 1.95
Kidney	SIR: 1.99	SIR: 1.99
Mesothelioma	SIR: 2.41	SIR: 2.41
Pancreas	SMR: 2.41	SMR: 2.41
Lymphoma and leukaemia	SMR: 2.03	SMR: 2.03

Summary of the scenarios

The assumptions underpinning the different estimates are summarised below.

Table 4-98: Summary of the scenarios (PAHs)				
Aspect/scenario	**Low**	**High**	**Midpoint**	**Central**
Exposed population (EU-28) - point	5,000 (2005) 8,000 (2014)	1.2 million (assumed in 1994)	600,000 (assumed in 1996)	700,000 (assumed in 1994)
Relevant cancer sites	Bladder, Lung, NMSC, Stomach, Kidney, Mesothelioma, Pancreas, Lymphoma and Leukaemia	Bladder, Lung, NMSC, Stomach, Kidney, Mesothelioma, Pancreas, Lymphoma and Leukaemia	Bladder, Lung, NMSC, Stomach, Kidney, Mesothelioma, Pancreas, Lymphoma and Leukaemia	Bladder, Lung, NMSC, Stomach, Kidney, Mesothelioma, Pancreas, Lymphoma and Leukaemia
Relative risk	Bladder: SMR=1 Lung: SMR=1 NMSC: RR=1.74 Stomach: SIR=1.95 Kidney: SIR=1.99 Mesothelioma: SIR=2.41 Pancreas: SMR= 2.41 Lymphoma and Leukaemia: SMR=2.03	Bladder: SMR=2.09 Lung: SIR=1.99 NMSC: RR=1.74 Stomach: SIR=1.95 Kidney: SIR=1.99 Mesothelioma: SIR=2.41 Pancreas: SMR= 2.41 Lymphoma and Leukaemia: SMR=2.03	Bladder: SMR=1.55 Lung: SIR=1.5 NMSC: RR=1.74 Stomach: SIR=1.95 Kidney: SIR=1.99 Mesothelioma: SIR=2.41 Pancreas: SMR= 2.41 Lymphoma and Leukaemia: SMR=2.03	Bladder: RR=1.49 Lung: RR=1.12 NMSC: RR=1.74 Stomach: SIR=1.95 Kidney: RR=1.23 Mesothelioma: SIR=2.41 Pancreas: SMR= 2.41 Lymphoma and Leukaemia: SMR=2.03
Change (p.a.)	4.8%	0%	2.4%	4.8%

4.12.2The results

Summary of the occupationally exposed population surviving to 2015

The total number of workers in the EU-28 exposed to PAHs between 1966 and 2005 and 1996 and 2015 (and surviving until 2015) is summarised below.

Table 4-99: Occupationally exposed population surviving to 2015 (PAHs)				
Scenario	**No. of workers exposed 1966-2005 & surviving to 2015 (million)**	**% of current & at risk population**	**No. of workers exposed 1996-2015 & surviving to 2015 (million)**	**% of current & at risk population**
Low	0.012	0.004%	0.018	0.005%

Table 4-99: Occupationally exposed population surviving to 2015 (PAHs)				
Scenario	No. of workers exposed 1966-2005 & surviving to 2015 (million)	% of current & at risk population	No. of workers exposed 1996-2015 & surviving to 2015 (million)	% of current & at risk population
High	4.23	1.32%	4.16	1.14%
Midpoint	2.07	0.65%	2.35	0.64%
Central	2.74	0.85%	4.16	1.14%

The break-down of these figures by Member State is provided below. The minimum and maximum values across all scenarios are presented for each Member State.

Table 4-100: Occupationally exposed population surviving to 2015 by Member State (PAHs, 1966-2005)				
Member State	Number of workers exposed over the period and surviving to 2015		% of current & at risk population	
	Min	Max	Min	Max
Austria	195	71,420	0.004%	1.32%
Belgium	255	93,756	0.004%	1.32%
Bulgaria	163	59,977	0.004%	1.32%
Croatia	96	35,187	0.004%	1.32%
Cyprus	19	7,054	0.004%	1.32%
Czech Republic	239	87,759	0.004%	1.32%
Denmark	128	47,132	0.004%	1.32%
Estonia	30	10,936	0.004%	1.32%
Finland	124	45,567	0.004%	1.32%
France	1,507	553,081	0.004%	1.32%
Germany	1,842	676,183	0.004%	1.32%
Greece	246	90,422	0.004%	1.32%
Hungary	224	82,073	0.004%	1.32%
Ireland	105	38,548	0.004%	1.32%
Italy	1,379	506,283	0.004%	1.32%
Latvia	45	16,539	0.004%	1.32%
Lithuania	66	24,327	0.004%	1.32%
Luxembourg	13	4,688	0.004%	1.32%
Malta	10	3,575	0.004%	1.32%
Netherlands	383	140,743	0.004%	1.32%
Poland	862	316,496	0.004%	1.32%
Portugal	235	86,398	0.004%	1.32%
Romania	451	165,475	0.004%	1.32%
Slovakia	123	45,147	0.004%	1.32%
Slovenia	47	17,179	0.004%	1.32%
Spain	1,054	386,815	0.004%	1.32%
Sweden	221	81,172	0.004%	1.32%
UK	1,472	540,256	0.004%	1.32%
Total	***11,534***	***4,234,188***	***0.004%***	***1.32%***

Table 4-101: Occupationally exposed population surviving to 2015 by Member State (PAHs, 1996-2015)				
Member State	Number of workers exposed over the period and surviving to 2015		% of current & at risk population	
	Min	Max	Min	Max
Austria	306	70,103	0.005%	1.14%

Table 4-101: Occupationally exposed population surviving to 2015 by Member State (PAHs, 1996-2015)				
Member State	Number of workers exposed over the period and surviving to 2015		% of current & at risk population	
	Min	Max	Min	Max
Belgium	401	92,028	0.005%	1.14%
Bulgaria	257	58,872	0.005%	1.14%
Croatia	151	34,538	0.005%	1.14%
Cyprus	30	6,924	0.005%	1.14%
Czech Republic	375	86,141	0.005%	1.14%
Denmark	202	46,263	0.005%	1.14%
Estonia	47	10,735	0.005%	1.14%
Finland	195	44,727	0.005%	1.14%
France	2,366	542,886	0.005%	1.14%
Germany	2,893	663,719	0.005%	1.14%
Greece	387	88,755	0.005%	1.14%
Hungary	351	80,561	0.005%	1.14%
Ireland	165	37,838	0.005%	1.14%
Italy	2,166	496,951	0.005%	1.14%
Latvia	71	16,235	0.005%	1.14%
Lithuania	104	23,879	0.005%	1.14%
Luxembourg	20	4,602	0.005%	1.14%
Malta	15	3,510	0.005%	1.14%
Netherlands	602	138,149	0.005%	1.14%
Poland	1,354	310,663	0.005%	1.14%
Portugal	370	84,805	0.005%	1.14%
Romania	708	162,425	0.005%	1.14%
Slovakia	193	44,315	0.005%	1.14%
Slovenia	73	16,862	0.005%	1.14%
Spain	1,655	379,685	0.005%	1.14%
Sweden	347	79,676	0.005%	1.14%
UK	2,311	530,298	0.005%	1.14%
Total	***18,116***	***4,156,141***	***0.005%***	***1.14%***

AFs per Member State

Table 4-102: Overall attributable fractions across all industries by Member State (PAHs)												
Cancer site/ scenario	Bladder			Lung			NMSC			Stomach		
	C-Low	C-Core	C-High	C-Low	C-Core	C-High	C-Low	C-Core	C-High	C-Low	C-Core	C-High
Austria	0.4%	0.4%	0.4%	0.1%	0.1%	0.1%	0.1%	0.6%	1.4%	0.1%	0.8%	1.9%
Belgium	0.4%	0.4%	0.4%	0.1%	0.1%	0.1%	0.1%	0.6%	1.4%	0.1%	0.8%	1.9%
Bulgaria	0.4%	0.4%	0.4%	0.1%	0.1%	0.1%	0.1%	0.6%	1.4%	0.1%	0.8%	1.9%
Croatia	0.4%	0.4%	0.4%	0.1%	0.1%	0.1%	0.1%	0.6%	1.4%	0.1%	0.8%	1.9%
Cyprus	0.4%	0.4%	0.4%	0.1%	0.1%	0.1%	0.1%	0.6%	1.4%	0.1%	0.8%	1.9%
Czech Republic	0.4%	0.4%	0.4%	0.1%	0.1%	0.1%	0.1%	0.6%	1.4%	0.1%	0.8%	1.9%
Denmark	0.4%	0.4%	0.4%	0.1%	0.1%	0.1%	0.1%	0.6%	1.4%	0.1%	0.8%	1.9%
Estonia	0.4%	0.4%	0.4%	0.1%	0.1%	0.1%	0.1%	0.6%	1.4%	0.1%	0.8%	1.9%
Finland	0.4%	0.4%	0.4%	0.1%	0.1%	0.1%	0.1%	0.6%	1.4%	0.1%	0.8%	1.9%
France	0.4%	0.4%	0.4%	0.1%	0.1%	0.1%	0.1%	0.6%	1.4%	0.1%	0.8%	1.9%
Germany	0.4%	0.4%	0.4%	0.1%	0.1%	0.1%	0.1%	0.6%	1.4%	0.1%	0.8%	1.9%
Greece	0.4%	0.4%	0.4%	0.1%	0.1%	0.1%	0.1%	0.6%	1.4%	0.1%	0.8%	1.9%
Hungary	0.4%	0.4%	0.4%	0.1%	0.1%	0.1%	0.1%	0.6%	1.4%	0.1%	0.8%	1.9%

Table 4-102: Overall attributable fractions across all industries by Member State (PAHs)												
Cancer site/ scenario	Bladder			Lung			NMSC			Stomach		
	C-Low	C-Core	C-High	C-Low	C-Core	C-High	C-Low	C-Core	C-High	C-Low	C-Core	C-High
Ireland	0.4%	0.4%	0.4%	0.1%	0.1%	0.1%	0.1%	0.6%	1.4%	0.1%	0.8%	1.9%
Italy	0.4%	0.4%	0.4%	0.1%	0.1%	0.1%	0.1%	0.6%	1.4%	0.1%	0.8%	1.9%
Latvia	0.4%	0.4%	0.4%	0.1%	0.1%	0.1%	0.1%	0.6%	1.4%	0.1%	0.8%	1.9%
Lithuania	0.4%	0.4%	0.4%	0.1%	0.1%	0.1%	0.1%	0.6%	1.4%	0.1%	0.8%	1.9%
Luxembourg	0.4%	0.4%	0.4%	0.1%	0.1%	0.1%	0.1%	0.6%	1.4%	0.1%	0.8%	1.9%
Malta	0.4%	0.4%	0.4%	0.1%	0.1%	0.1%	0.1%	0.6%	1.4%	0.1%	0.8%	1.9%
Netherlands	0.4%	0.4%	0.4%	0.1%	0.1%	0.1%	0.1%	0.6%	1.4%	0.1%	0.8%	1.9%
Poland	0.4%	0.4%	0.4%	0.1%	0.1%	0.1%	0.1%	0.6%	1.4%	0.1%	0.8%	1.9%
Portugal	0.4%	0.4%	0.4%	0.1%	0.1%	0.1%	0.1%	0.6%	1.4%	0.1%	0.8%	1.9%
Romania	0.4%	0.4%	0.4%	0.1%	0.1%	0.1%	0.1%	0.6%	1.4%	0.1%	0.8%	1.9%
Slovakia	0.4%	0.4%	0.4%	0.1%	0.1%	0.1%	0.1%	0.6%	1.4%	0.1%	0.8%	1.9%
Slovenia	0.4%	0.4%	0.4%	0.1%	0.1%	0.1%	0.1%	0.6%	1.4%	0.1%	0.8%	1.9%
Spain	0.4%	0.4%	0.4%	0.1%	0.1%	0.1%	0.1%	0.6%	1.4%	0.1%	0.8%	1.9%
Sweden	0.4%	0.4%	0.4%	0.1%	0.1%	0.1%	0.1%	0.6%	1.4%	0.1%	0.8%	1.9%
UK	0.4%	0.4%	0.4%	0.1%	0.1%	0.1%	0.1%	0.6%	1.4%	0.1%	0.8%	1.9%
EU-28	***0.4%***	***0.4%***	***0.4%***	***0.1%***	***0.1%***	***0.1%***	***0.1%***	***0.6%***	***1.4%***	***0.1%***	***0.8%***	***1.9%***

Table 4-103: Overall attributable fractions across all industries by Member State (PAHs) continued												
Cancer site/ scenario	Kidney			Mesothelioma			Pancreas			Lymphoma and leukaemia		
	C-Low	C-Core	C-High	C-Low	C-Core	C-High	C-Low	C-Core	C-High	C-Low	C-Core	C-High
Austria	0.2%	0.2%	0.2%	0%	1.2%	3.9%	0.1%	1.2%	3.5%	0.03%	1.2%	3.3%
Belgium	0.2%	0.2%	0.2%	0%	1.2%	3.9%	0.1%	1.2%	3.5%	0.03%	1.2%	3.3%
Bulgaria	0.2%	0.2%	0.2%	0%	1.2%	3.9%	0.1%	1.2%	3.5%	0.03%	1.2%	3.3%
Croatia	0.2%	0.2%	0.2%	0%	1.2%	3.9%	0.1%	1.2%	3.5%	0.03%	1.2%	3.3%
Cyprus	0.2%	0.2%	0.2%	0%	1.2%	3.9%	0.1%	1.2%	3.5%	0.03%	1.2%	3.3%
Czech Republic	0.2%	0.2%	0.2%	0%	1.2%	3.9%	0.1%	1.2%	3.5%	0.03%	1.2%	3.3%
Denmark	0.2%	0.2%	0.2%	0%	1.2%	3.9%	0.1%	1.2%	3.5%	0.03%	1.2%	3.3%
Estonia	0.2%	0.2%	0.2%	0%	1.2%	3.9%	0.1%	1.2%	3.5%	0.03%	1.2%	3.3%
Finland	0.2%	0.2%	0.2%	0%	1.2%	3.9%	0.1%	1.2%	3.5%	0.03%	1.2%	3.3%
France	0.2%	0.2%	0.2%	0%	1.2%	3.9%	0.1%	1.2%	3.5%	0.03%	1.2%	3.3%
Germany	0.2%	0.2%	0.2%	0%	1.2%	3.9%	0.1%	1.2%	3.5%	0.03%	1.2%	3.3%
Greece	0.2%	0.2%	0.2%	0%	1.2%	3.9%	0.1%	1.2%	3.5%	0.03%	1.2%	3.3%
Hungary	0.2%	0.2%	0.2%	0%	1.2%	3.9%	0.1%	1.2%	3.5%	0.03%	1.2%	3.3%
Ireland	0.2%	0.2%	0.2%	0%	1.2%	3.9%	0.1%	1.2%	3.5%	0.03%	1.2%	3.3%
Italy	0.2%	0.2%	0.2%	0%	1.2%	3.9%	0.1%	1.2%	3.5%	0.03%	1.2%	3.3%
Latvia	0.2%	0.2%	0.2%	0%	1.2%	3.9%	0.1%	1.2%	3.5%	0.03%	1.2%	3.3%
Lithuania	0.2%	0.2%	0.2%	0%	1.2%	3.9%	0.1%	1.2%	3.5%	0.03%	1.2%	3.3%
Luxembourg	0.2%	0.2%	0.2%	0%	1.2%	3.9%	0.1%	1.2%	3.5%	0.03%	1.2%	3.3%
Malta	0.2%	0.2%	0.2%	0%	1.2%	3.9%	0.1%	1.2%	3.5%	0.03%	1.2%	3.3%
Netherlands	0.2%	0.2%	0.2%	0%	1.2%	3.9%	0.1%	1.2%	3.5%	0.03%	1.2%	3.3%
Poland	0.2%	0.2%	0.2%	0%	1.2%	3.9%	0.1%	1.2%	3.5%	0.03%	1.2%	3.3%
Portugal	0.2%	0.2%	0.2%	0%	1.2%	3.9%	0.1%	1.2%	3.5%	0.03%	1.2%	3.3%
Romania	0.2%	0.2%	0.2%	0%	1.2%	3.9%	0.1%	1.2%	3.5%	0.03%	1.2%	3.3%
Slovakia	0.2%	0.2%	0.2%	0%	1.2%	3.9%	0.1%	1.2%	3.5%	0.03%	1.2%	3.3%
Slovenia	0.2%	0.2%	0.2%	0%	1.2%	3.9%	0.1%	1.2%	3.5%	0.03%	1.2%	3.3%

Table 4-103: Overall attributable fractions across all industries by Member State (PAHs) continued												
Cancer site/ scenario	Kidney			Mesothelioma			Pancreas			Lymphoma and leukaemia		
	C-Low	C-Core	C-High	C-Low	C-Core	C-High	C-Low	C-Core	C-High	C-Low	C-Core	C-High
Spain	0.2%	0.2%	0.2%	0%	1.2%	3.9%	0.1%	1.2%	3.5%	0.03%	1.2%	3.3%
Sweden	0.2%	0.2%	0.2%	0%	1.2%	3.9%	0.1%	1.2%	3.5%	0.03%	1.2%	3.3%
UK	0.2%	0.2%	0.2%	0%	1.2%	3.9%	0.1%	1.2%	3.5%	0.03%	1.2%	3.3%
EU-28	***0.2%***	***0.2%***	***0.2%***	***0%***	***1.2%***	***3.9%***	***0.1%***	***1.2%***	***3.5%***	***0.03%***	***1.2%***	***3.3%***

4.13 Occupation as a welder

4.13.1Methodology/assumptions

Summary of the relevant cancer endpoints and exposure period(s)

The relevant cancer endpoints and latency periods are (IARC, 2016[135]; t-Mannetje A et al (2012)[136]; Rushton et al 2012[137]):

- Lung, latency 10-50 years, 1966-2005 and
- Melanoma of the eye, latency 10-50 years, 1966-2005.

The relevant health endpoints are lung cancer and melanoma of the eye due to ultra violet radiation (Rushton et al 2012[138]). The quantification carried out in this report thus relates to 'occupation as a welder' rather than only to 'welding fumes'.

All (100%) cancer sites for which the 'occupation as a welder' was identified in IARC (2016) as a carcinogenic for humans with sufficient or limited evidence are considered in this study.

Exposed population

The starting point for estimating the occupationally exposed population is SUMER (1994, 2003 and 2010), with further estimates being available for Finland from FinJem database (2006) and the ASA register (2005 and 2014) and for the UK from Rushton et al (2012). These are summarised below.

Table 4-104: Published data – workforce exposed to welding fumes (occupation as a welder)					
Study	Country	Year/period	No. of exposed workers	% of exposed workforce	Notes
SUMER	France	1994	360,000 (342,000 men and 18,000	3% (4.8% men and 0.4% women)	

[135] IARC (2016): List of classifications by cancer sites with sufficient or limited evidence in humans, available at https://monographs.iarc.fr/ENG/Classification/Table4.pdf

[136] **'t-Mannetje A et al (2012): Welding and lung cancer in Central and Eastern Europe and the United Kingdom. Am J Epidemol, 175(7), 706-714.**

[137] Rushton et al (2012): Occupational cancer in the UK – overview report, available at http://www.hse.gov.uk/research/rrpdf/rr931.pdf

[138] Rushton et al (2012): Occupational cancer in the UK – overview report, available at http://www.hse.gov.uk/research/rrpdf/rr931.pdf

Table 4-104: Published data – workforce exposed to welding fumes (occupation as a welder)					
Study	**Country**	**Year/period**	**No. of exposed workers**	**% of exposed workforce**	**Notes**
			women)		
		2003	594,800 (567,100 men and 27,700 women)	3.4% (0.7% men and 1.2% women)	
		2010	597,600 (573,900 men and 23,800 women)	2.8% (5.7% men and 0.4% women)	
FinJem	Finland	2006	47,000		Metal and machinery industry
ASA	Finland	2005	4,306 (4,243 men and 63 women)		
		2014	4,660 (4,550 men and 110 women)		
Rushton	UK	Published in 2004-2005; ever exposed workers	626,978 (545,544 men; 81,434 women)		

Extrapolations to the EU-28 are summarised below.

Table 4-105: Occupationally exposed population in the EU-28 (occupation as a welder)	
Estimate and method of extrapolation	**Exposed population in the EU-28**
A: France 1994 exposed workers extrapolated on the basis of population	2.9 million
B: France 1994 share (3%) applied to current EU workforce	5.5 million
C: France 2003 exposed workers extrapolated on the basis of population	4.7 million
D: France 2003 share (3.4%) applied to current EU workforce	6.9 million
E: France 2010 exposed workers extrapolated on the basis of population	4.6 million
F: France 2010 share (2.8%) applied to current EU workforce	5.9 million
G: FinJem 2006 exposed workers extrapolated on the basis of population	4.7 million
H: ASA 2005 exposed workers extrapolated on the basis of population	430,000
I: ASA 2014 exposed workers extrapolated on the basis of population	430,000
J: Rushton et al ever exposed workers (averaged per annum) extrapolated on the basis of population	1 million

Estimates H and I in the table above form the basis for the LOW scenario while the average of estimates B, D, F has been used for the HIGH scenario. The CENTRAL scenario is based on the extrapolation of the SUMER and FinJem data (estimates A, C, E and G).

Rate of change

Comparing the number of workers exposed in France in 1994, 2003 and 2010 (SUMER) suggests an annual increase of around 3.2%. Similarly comparing the number of workers exposed in Finland in 2005 and 2014 suggests an annual increase of around 0.9%. The following scenarios are modelled:

- no change; and
- an annual increase of 0.9%
- an annual increase of 3.2%.

A generic staff turnover factor of 10% per annum has been used.

Relative risk

The relative risk estimates identified through literature review are summarised below.

Table 4-106: Literature review of relative risk for occupation as a welder		
Study & summary of data/methodology	**Cancer site**	**Relative risk**
't-Mannetje A et al (2012). Case control study in Europe carried out between 1998 and 2001.	Lung	OR 1.36 (95% CI: 1.00-1.86)
Rushton L et al (2012). Literature review from Ambroise et al (2006)	Lung	RR 1.26 (95% CI: 1.20, 1.32)
Rushton L et al (2012). Literature review from Shah et al (2005)	Melanoma of the eye	RR 2.05 (95% CI: 1.20, 3.51)
Sources: IARC: IARC Monographs- 100F. Available at http://monographs.iarc.fr/ENG/Monographs/vol100F/mono100F-27.pdf Rushton L et al (2012): The burden of occupational cancer in Great Britain. Available at http://www.hse.gov.uk/research/rrpdf/rr931.pdf 't-Mannetje A et al (2012): Welding and lung cancer in Central and Eastern Europe and the United Kingdom. Am J Epidemol, 175(7), 706-714.		

The lowest and highest relative risks identified through literature are summarised below.

Table 4-107: Summary of relative risk – occupation as a welder		
Cancer site	**Lowest**	**Highest**
Lung	RR: 1.1	OR: 1.36
Melanoma of the eye	RR: 2.05	RR: 2.05

Summary of the scenarios

The assumptions underpinning the different estimates are summarised below.

Table 4-108: Summary of the scenarios (occupation as a welder)				
Aspect/scenario	**Low**	**High**	**Midpoint**	**Central**
Exposed population (EU-28) - point	430,000 (2005 and 2014)	6.1 million (assumed in 2002)	3.36 million (assumed in 2003)	4.2 million (assumed in 2003)
Relevant cancer sites	Lung Ocular melanoma (100% of IARC	Lung Ocular melanoma (100% of IARC	Lung Ocular melanoma (100% of IARC	Lung Ocular melanoma (100% of IARC

Table 4-108: Summary of the scenarios (occupation as a welder)				
Aspect/scenario	**Low**	**High**	**Midpoint**	**Central**
	2016)	2016)	2016)	2016)
Relative risk	Lung: RR=1.1 Melanoma of the eye: RR=2.05	Lung: OR=1.36 Melanoma of the eye: RR=2.05	Lung: 1.23 Melanoma of the eye: RR=2.05	Lung: OR=1.36 Melanoma of the eye: RR=2.05
Change (p.a.)	3.2%	0%	1.6%	0.9%

4.13.2The results

Summary of the occupationally exposed population surviving to 2015

The total number of workers occupationally exposed to welding fumes in the EU-28 exposed between 1966 and 2005 and surviving until 2015 is summarised below.

Table 4-109: Occupationally exposed population surviving to 2015 (occupation as a welder)		
Scenario	**No. of workers exposed 1966-2005 & surviving to 2015 (million)**	**% of current & at risk population**
Low	1.1	0.4%
High	21.5	6.7%
Midpoint	10.4	3.2%
Central	13.7	4.3%

The break-down of these figures by Member State is provided below. The minimum and maximum values across all scenarios are presented for each Member State.

Table 4-110: Occupationally exposed population surviving to 2015 by Member State (occupation as a welder, 1966-2005)				
Member State	**Number of workers exposed over the period and surviving to 2015**		**% of current & at risk population**	
	Min	**Max**	**Min**	**Max**
Austria	18,846	363,051	0.35%	6.72%
Belgium	24,740	476,593	0.35%	6.72%
Bulgaria	15,826	304,884	0.35%	6.72%
Croatia	9,285	178,866	0.35%	6.72%
Cyprus	1,861	35,856	0.35%	6.72%
Czech Republic	23,157	446,107	0.35%	6.72%
Denmark	12,437	239,588	0.35%	6.72%
Estonia	2,886	55,594	0.35%	6.72%
Finland	12,024	231,631	0.35%	6.72%
France	145,943	2,811,493	0.35%	6.72%
Germany	178,426	3,437,262	0.35%	6.72%
Greece	23,860	459,643	0.35%	6.72%
Hungary	21,657	417,207	0.35%	6.72%
Ireland	10,172	195,953	0.35%	6.72%
Italy	133,594	2,573,606	0.35%	6.72%
Latvia	4,364	84,076	0.35%	6.72%
Lithuania	6,419	123,663	0.35%	6.72%
Luxembourg	1,237	23,831	0.35%	6.72%
Malta	943	18,175	0.35%	6.72%
Netherlands	37,138	715,443	0.35%	6.72%
Poland	83,515	1,608,857	0.35%	6.72%

Table 4-110: Occupationally exposed population surviving to 2015 by Member State (occupation as a welder, 1966-2005)				
Member State	Number of workers exposed over the period and surviving to 2015		% of current & at risk population	
	Min	Max	Min	Max
Portugal	22,798	439,188	0.35%	6.72%
Romania	43,664	841,166	0.35%	6.72%
Slovakia	11,913	229,497	0.35%	6.72%
Slovenia	4,533	87,326	0.35%	6.72%
Spain	102,070	1,966,307	0.35%	6.72%
Sweden	21,419	412,626	0.35%	6.72%
UK	142,559	2,746,302	0.35%	6.72%
Total	***1,117,287***	***21,523,789***	***0.35%***	***6.72%***

AFs per Member State

Table 4-111: Overall attributable fractions by Member State (occupation as a welder)						
Cancer site/ scenario	Lung			Melanoma of the eye		
	C-Low	C-Core	C-High	C-Low	C-Core	C-High
Austria	0%	1.5%	3.5%	0.8%	4.3%	9.7%
Belgium	0%	1.5%	3.5%	0.8%	4.3%	9.7%
Bulgaria	0%	1.5%	3.5%	0.8%	4.3%	9.7%
Croatia	0%	1.5%	3.5%	0.8%	4.3%	9.7%
Cyprus	0%	1.5%	3.5%	0.8%	4.3%	9.7%
Czech Republic	0%	1.5%	3.5%	0.8%	4.3%	9.7%
Denmark	0%	1.5%	3.5%	0.8%	4.3%	9.7%
Estonia	0%	1.5%	3.5%	0.8%	4.3%	9.7%
Finland	0%	1.5%	3.5%	0.8%	4.3%	9.7%
France	0%	1.5%	3.5%	0.8%	4.3%	9.7%
Germany	0%	1.5%	3.5%	0.8%	4.3%	9.7%
Greece	0%	1.5%	3.5%	0.8%	4.3%	9.7%
Hungary	0%	1.5%	3.5%	0.8%	4.3%	9.7%
Ireland	0%	1.5%	3.5%	0.8%	4.3%	9.7%
Italy	0%	1.5%	3.5%	0.8%	4.3%	9.7%
Latvia	0%	1.5%	3.5%	0.8%	4.3%	9.7%
Lithuania	0%	1.5%	3.5%	0.8%	4.3%	9.7%
Luxembourg	0%	1.5%	3.5%	0.8%	4.3%	9.7%
Malta	0%	1.5%	3.5%	0.8%	4.3%	9.7%
Netherlands	0%	1.5%	3.5%	0.8%	4.3%	9.7%
Poland	0%	1.5%	3.5%	0.8%	4.3%	9.7%
Portugal	0%	1.5%	3.5%	0.8%	4.3%	9.7%
Romania	0%	1.5%	3.5%	0.8%	4.3%	9.7%
Slovakia	0%	1.5%	3.5%	0.8%	4.3%	9.7%
Slovenia	0%	1.5%	3.5%	0.8%	4.3%	9.7%
Spain	0%	1.5%	3.5%	0.8%	4.3%	9.7%
Sweden	0%	1.5%	3.5%	0.8%	4.3%	9.7%
UK	0%	1.5%	3.5%	0.8%	4.3%	9.7%
EU-28	***0%***	***1.5%***	***3.5%***	***0.8%***	***4.3%***	***9.7%***

4.14 Solar radiation

4.14.1Methodology/assumptions

Summary of the relevant cancer endpoints and exposure period(s)

The relevant health endpoint are non-melanoma skin cancer (NMSC), skin melanoma, and cancers of the lip and the eye (IARC, 2016[139]; Rushton et al 2012[140]).

Due to a lack of relative risk estimates, only cancer incidence associated with NMSC, i.e. one of the four cancer sites identified in IARC (2016) as relevant to solar radiation has been quantified in this study.

The typical latency for lung cancer is modelled to be between 10 and 50 years. The relevant exposure period is thus defined as 1966-2005.

Exposed population

The starting point for estimating the occupationally exposed population is the CAREX database, with a further estimate being available for the UK (although the data for the UK are based on CAREX). These estimates are summarised below.

Table 4-112: Published data – workforce exposed to solar radiation

Study	Country	Year/period	No. of exposed workers	% of exposed workforce	Notes
Carex	EU15	1990-1993 (mean)	8,874,907		
	UK	1990-1993 (mean)	1,267,982		
Rushton	UK	2004-2005	5,516,973 (3,735,036 men; 1,781,937 women)		Based on Carex

Extrapolations to the EU-28 are summarised below.

Table 4-113: Occupationally exposed population in the EU-28 (solar radiation)

Estimate and method of extrapolation	Exposed population in the EU-28
A: CAREX early to mid-1990s	14 million
B: Rushton (single year) extrapolated on the basis of population	8.8 million

Estimate B in the table above forms the basis for the LOW scenario while estimate A is used for the HIGH scenario. The CENTRAL scenario is also based on estimate A.

[139] IARC (2016): List of classifications by cancer sites with sufficient or limited evidence in humans, available at https://monographs.iarc.fr/ENG/Classification/Table4.pdf

[140] Rushton et al (2012): Occupational cancer in the UK – overview report, available at http://www.hse.gov.uk/research/rrpdf/rr931.pdf

Rate of change

The decline in the number of people employed in agriculture is taken as a proxy for the long-term trend in the number of people occupationally exposed to solar radiation. Data from the University of Gothenburg for employment in agriculture in the EU suggest an annual rate of decline of around 2%; this rate has been applied throughout the EU.

Two rates of change are thus used as a basis for modelling:

- an annual decline of 2%; and
- no change.

A generic staff turnover factor of 10% per annum has been used.

Relative risk

The relative risk estimates identified through literature review are summarised below.

Table 4-114: Literature review of relative risk for solar radiation

Study & summary of data/methodology	Cancer site	Relative risk
Fartasch M et al (2012). Meta-analysis of the literature	NMSC	OR=1.77 (95% CI: 1.40, 2.22) for work outdoors
Rushton L et al (2012), based on Freedman et al (2002)	NMSC	Average RR 1.15 Mixed outdoor and indoor work: 1.01 (95% CI: 0.93,1.09); Outdoor work 1.30 (95% CI: 1.14, 1.47); Farming 1.15 (95% CI: 1.00, 1.32)

Sources:
Fartasch M et al (2012): The Relationship Between Occupational Sun Exposure and Non-Melanoma Skin Cancer. Dtsch Arztebl, 109(43), 715-720.
Rushton L et al (2012): The burden of occupational cancer in Great Britain. Available at http://www.hse.gov.uk/research/rrpdf/rr931.pdf

The lowest and highest relative risks identified through literature are summarised below. In terms of the lowest estimated, mixed outdoor and indoor work has not been taken into account since the risk of exposure to solar radiation is sought.

Table 4-115: Summary of relative risk – exposure to solar radiation

Cancer site	Lowest	Highest
NMSC	RR=1.15	OR=1.77

Summary of the scenarios

The assumptions underpinning the different estimates are summarised below. Please note that the estimates of the exposed population are point estimates for a specific year and do not represent the lowest and highest annual estimates over the whole assessment period since these also depend on the annual rate of change.

Please note that for solar radiation the high and central scenarios are identical.

Table 4-116: Summary of the scenarios (solar radiation)				
Aspect/scenario	**Low**	**High**	**Midpoint**	**Central**
Exposed population (EU-28) - point	8.8 million (assumed 2004)	14 million (early to mid-1990s)	11.4 million (assumed 2000)	14 million (early to mid-1990s)
Relevant cancer sites	NMSC (1 of 4 cancer sites in IARC 2016)	NMSC (1 of 4 cancer sites in IARC 2016)	NMSC (1 of 4 cancer sites in IARC 2016)	NMSC (1 of 4 cancer sites in IARC 2016)
Relative risk	RR=1.15	OR=1.77	1.46	OR=1.77
Change (p.a.)	0%	-2%	-1%	-2%

4.14.2The results

Summary of the occupationally exposed population surviving to 2015

The total number of workers in the EU-28 exposed to solar radiation between 1966 and 2005 and surviving to 2015 has been estimated to be between 31.1 and 40.9 million.

Table 4-117: Occupationally exposed population surviving to 2015 (solar radiation)		
Scenario	**No. of workers exposed 1966-2005 & surviving to 2015 (million)**	**% of current & at risk population**
Low	31.1	9.7%
High & central	40.9	12.8%
Midpoint	36	11.3%

The break-down of these figures by Member State is provided below. The minimum and maximum values across all scenarios are presented for each Member State.

Table 4-118: Occupationally exposed population surviving to 2015 by Member State (solar radiation, 1966-2005)				
Member State	**Number of workers exposed over the period and surviving to 2015**		**% of current & at risk population**	
	Min	**Max**	**Min**	Max
Austria	523,756	724,671	9.7%	13.4%
Belgium	617,209	798,017	8.7%	11.3%
Bulgaria	439,841	880,825	9.7%	19.4%
Croatia	258,042	503,329	9.7%	18.9%
Cyprus	51,727	114,921	9.7%	21.5%
Czech Republic	643,577	1,258,322	9.7%	19.0%
Denmark	345,641	552,330	9.7%	15.5%
Estonia	80,202	210,886	9.7%	25.5%
Finland	334,162	561,643	9.7%	16.3%
France	4,056,003	4,707,622	9.7%	11.3%
Germany	4,958,769	7,261,808	9.7%	14.2%
Greece	663,104	1,396,328	9.7%	20.4%
Hungary	601,884	1,132,490	9.7%	18.2%
Ireland	282,692	328,108	9.7%	11.3%
Italy	1,713,293	4,309,298	4.5%	11.3%
Latvia	121,292	411,883	9.7%	32.9%
Lithuania	178,403	723,609	9.7%	39.3%
Luxembourg	34,380	41,656	9.7%	11.7%
Malta	12,338	30,433	4.6%	11.3%
Netherlands	887,739	1,197,953	8.3%	11.3%
Poland	2,321,019	4,655,792	9.7%	19.4%

Table 4-118: Occupationally exposed population surviving to 2015 by Member State (solar radiation, 1966-2005)				
Member State	Number of workers exposed over the period and surviving to 2015		% of current & at risk population	
	Min	Max	Min	Max
Portugal	633,595	1,114,573	9.7%	17.1%
Romania	1,213,509	2,390,812	9.7%	19.1%
Slovakia	331,084	629,161	9.7%	18.4%
Slovenia	125,981	251,664	9.7%	19.4%
Spain	2,836,695	3,305,238	9.7%	11.3%
Sweden	595,275	719,492	9.7%	11.7%
UK	3,865,525	4,598,464	9.5%	11.3%
Total	***31,051,314***	***40,908,635***	***9.7%***	***12.8%***

AFs per Member State

Table 4-119: Overall attributable fractions across all industries by Member State (solar radiation)			
Cancer site & scenario	NMSC		
	C-Low	C-Core	C-High
Austria	5.1%	9.4%	14.1%
Belgium	3.4%	6.3%	9.6%
Bulgaria	7.2%	13.0%	19.1%
Croatia	7.0%	12.7%	18.7%
Cyprus	7.9%	14.2%	20.8%
Czech Republic	7.0%	12.7%	18.8%
Denmark	5.8%	10.7%	15.9%
Estonia	9.3%	16.4%	23.7%
Finland	6.1%	11.1%	16.6%
France	4.3%	7.9%	11.9%
Germany	5.4%	9.9%	14.8%
Greece	7.5%	13.6%	19.9%
Hungary	6.8%	12.3%	18.2%
Ireland	4.3%	8.0%	12.0%
Italy	1.8%	3.3%	5.2%
Latvia	11.6%	20.2%	28.7%
Lithuania	13.6%	23.2%	32.4%
Luxembourg	4.5%	8.3%	12.5%
Malta	1.8%	3.4%	5.3%
Netherlands	3.2%	6.0%	9.2%
Poland	7.2%	13.0%	19.2%
Portugal	6.4%	11.6%	17.2%
Romania	7.1%	12.8%	18.9%
Slovakia	6.9%	12.4%	18.3%
Slovenia	7.2%	13.0%	19.1%
Spain	4.3%	8.0%	12.1%
Sweden	4.5%	8.3%	12.5%
UK	3.6%	6.8%	10.3%
EU-28	***4.9%***	***9.0%***	***13.5%***

4.15 Environmental tobacco smoke (ETS)

4.15.1Methodology/assumptions

Summary of the relevant cancer endpoints and exposure period(s)

The relevant health endpoints are cancers if the larynx, lung, and pharynx (IARC, 2016[141]; Rushton et al 2012[142]). In terms of the entries in IARC (2016), only entries titled 'tobacco smoke, second-hand' are considered. This is seen as more appropriate for occupational exposure than 'tobacco smoking'.

Due to a lack of relative risk estimates for laryngeal and pharyngeal, only cancer incidence associated with lung cancer, i.e. one of the three cancer sites identified in IARC (2016) as relevant to environmental tobacco smoke has been quantified in this study.

The typical latency for lung cancer is modelled to be between 10 and 50 years. The relevant exposure period is thus defined as 1966-2005.

Exposed population

The starting point for estimating the occupationally exposed population is the CAREX database, with further estimates being available for the Finland and the UK (although the data for the UK are based on CAREX). These estimates are summarised below.

Table 4-120: Published data – workforce exposed to ETS

Study	Country	Year/period	No. of exposed workers	% of exposed workforce	Notes
Carex	EU15	1990-1993 (mean)	7,322,551		
	Finland	1990-1993 (mean)	109,787		
	UK	1990-1993 (mean)	1,314,624		
ASA	Finland	2005	11,587 (3,824 men and 7,763 women)		
		2014	119 (36 men and 83 women)		
Rushton	UK	Published: 2004-2005 Refers to ever exposed workers	2,282,428 (758,415 men; 1,524,013 women)		Based on Carex

[141] IARC (2016): List of classifications by cancer sites with sufficient or limited evidence in humans, available at https://monographs.iarc.fr/ENG/Classification/Table4.pdf

[142] Rushton et al (2012): Occupational cancer in the UK – overview report, available at http://www.hse.gov.uk/research/rrpdf/rr931.pdf

Extrapolations to the EU-28 are summarised below.

Table 4-121: Occupationally exposed population in the EU-28 (ETS)	
Estimate and method of extrapolation	**Exposed population in the EU-28**
A: CAREX early to mid-1990s	10.2 million
B: Rushton (single year) extrapolated on the basis of population	3.7 million
C: Finland 2005 data extrapolated on the basis of population	1.1 million

Estimate C in the table above forms the basis for the LOW scenario while estimate A is used for the HIGH scenario. The CENTRAL scenario is also based on estimate A.

Rate of change

The key assumptions underpinning the modelling for ETS:

- for Member States that have banned smoking in the workplace, the example of Finland is used where the number of occupationally exposed workers in Finland in 1990 and 2008 in Kaupinnen et al (2013) suggests an annual rate of decline of around 22%;
- for Member States that have not introduced a smoking ban, an annual 3% decline is assumed;
- for Member States that have introduced a partial smoking ban, the average of the above two values (12.5%) is used.

A generic staff turnover factor of 10% per annum has been used.

Relative risk

The relative risk estimates identified through literature review are summarised below.

Table 4-122: Literature review of relative risk for ETS		
Study & summary of data/methodology	**Cancer site**	**Relative risk**
Rushton L et al (2012), based on Zhong et al (2000)	Lung	1.29 (95% CI: 0.93, 1.78) for males
Rushton L et al (2012), based on Zhong et al (2000)	Lung	1.15 (95% CI: 1.04, 1.28) for females
Stayner L et al (2007). Meta-analysis from 22 studies worldwide	Lung	RR=1.24 (95% CI: 1.18, 1.29) RR=2.01 (95% CI: 1.33, 2.60) for highly exposed
Sources: Rushton L et al (2012): The burden of occupational cancer in Great Britain. Available at http://www.hse.gov.uk/research/rrpdf/rr931.pdf Stayner L et al (2007): Lung Cancer Risk and Workplace Exposure to Environmental Tobacco Smoke. Am J Public Health, 97(3), 545-551		

The lowest and highest relative risks identified through literature are summarised below.

Table 4-123: Summary of relative risk – exposure to ETS		
Cancer site	**Lowest**	**Highest**
Lung	RR=1.15	RR=2.01

Summary of the scenarios

The assumptions underpinning the different estimates are summarised below. Please note that the estimates of the exposed population are point estimates for a specific year and do not represent the lowest and highest annual estimates over the whole assessment period since these also depend on the annual rate of change.

Please note that for ETS the high and central scenarios are identical.

Table 4-124: Summary of the scenarios (ETS)				
Aspect/scenario	**Low**	**High**	**Midpoint**	**Central**
Exposed population (EU-28) - point	1.1 million in 2005	10.2 million (early to mid-1990s)	5.7million (assumed 2000)	10.2 million (early to mid-1990s)
Relevant cancer sites	Lung (1 of 3 cancer sites in IARC 2016)	Lung (1 of 3 cancer sites in IARC 2016))	Lung (1 of 3 cancer sites in IARC 2016)	Lung (1 of 3 cancer sites in IARC 2016)
Relative risk	RR=1.15	RR=2.01	RR=1.63	RR=1.24
Change (p.a.)	Pre-smoking ban: -3% Post-smoking ban: -22% Partial smoking ban: -12.5%	Pre-smoking ban: -3% Post-smoking ban: -22% Partial smoking ban: -12.5%	Pre-smoking ban: -3% Post-smoking ban: -22% Partial smoking ban: -12.5%	Pre-smoking ban: -3% Post-smoking ban: -22% Partial smoking ban: -12.5%

4.15.2The results

Summary of the occupationally exposed population surviving to 2015

The total number of workers in the EU-28 exposed to ETS between 1966 and 2005 and surviving to 2015 has been estimated to be between 11.7 and 74 million.

Table 4-125: Occupationally exposed population surviving to 2015 (ETS)		
Scenario	**No. of workers exposed 1966-2005 & surviving to 2015 (million)**	**% of current & at risk population**
Low	11.8	2.3%
High & central	74.0	14.5%
Midpoint	51.1	10%

The break-down of these figures by Member State is provided below. The minimum and maximum values across all scenarios are presented for each Member State.

Table 4-126: Occupationally exposed population surviving to 2015 by Member State (ETS, 1966-2005)				
Member State	**Number of workers exposed over the period and surviving to 2015**		**% of current & at risk population**	
	Min	**Max**	**Min**	**Max**
Austria	192,786	1,220,448	2.2%	14.2%

Table 4-126: Occupationally exposed population surviving to 2015 by Member State (ETS, 1966-2005)				
Member State	Number of workers exposed over the period and surviving to 2015		% of current & at risk population	
	Min	Max	Min	Max
Belgium	253,079	1,321,462	2.2%	11.7%
Bulgaria	161,899	1,546,030	2.2%	21.5%
Croatia	94,981	883,445	2.2%	20.9%
Cyprus	19,040	99,957	2.2%	11.8%
Czech Republic	236,890	2,208,614	2.2%	21.0%
Denmark	127,225	722,040	2.2%	12.8%
Estonia	29,521	251,268	2.2%	19.1%
Finland	123,000	764,143	2.2%	14.0%
France	1,492,950	8,091,017	2.2%	12.2%
Germany	1,825,244	13,762,149	2.2%	16.9%
Greece	244,078	1,194,229	2.2%	11.0%
Hungary	221,544	1,987,752	2.2%	20.2%
Ireland	104,054	464,175	2.2%	10.0%
Italy	1,366,628	6,107,840	2.2%	10.0%
Latvia	44,646	337,769	2.2%	17.0%
Lithuania	65,667	647,914	2.2%	22.2%
Luxembourg	12,655	78,296	2.2%	13.9%
Malta	9,651	43,134	2.2%	10.0%
Netherlands	414,616	2,438,258	2.5%	14.4%
Poland	854,330	8,171,871	2.2%	21.5%
Portugal	233,216	1,475,026	2.2%	14.2%
Romania	446,673	4,196,366	2.2%	21.1%
Slovakia	121,867	1,104,307	2.2%	20.4%
Slovenia	46,371	441,723	2.2%	21.4%
Spain	1,044,142	4,666,563	2.2%	10.0%
Sweden	501,051	1,395,888	5.1%	14.3%
UK	1,458,332	9,150,085	2.2%	14.1%
Total	***11,746,138***	***73,954,145***	***2.3%***	***14.5%***

AFs per Member State

Table 4-127: Overall attributable fractions across all industries by Member State (ETS)			
Cancer site & scenario	Lung		
	C-Low	C-Core	C-High
Austria	1.9%	2.5%	2.9%
Belgium	1.5%	2.0%	2.4%
Bulgaria	2.8%	3.7%	4.4%
Croatia	2.7%	3.6%	4.3%
Cyprus	1.5%	2.0%	2.5%
Czech Republic	2.7%	3.6%	4.3%
Denmark	1.7%	2.2%	2.7%
Estonia	2.5%	3.3%	3.9%
Finland	1.8%	2.4%	2.9%
France	1.6%	2.1%	2.5%
Germany	2.2%	2.9%	3.5%
Greece	1.4%	1.9%	2.3%
Hungary	2.6%	3.4%	4.1%
Ireland	1.1%	1.5%	1.8%
Italy	1.2%	1.5%	1.8%

Table 4-127: Overall attributable fractions across all industries by Member State (ETS)			
Cancer site & scenario	Lung		
	C-Low	C-Core	C-High
Latvia	2.2%	2.9%	3.5%
Lithuania	2.9%	3.8%	4.5%
Luxembourg	1.8%	2.4%	2.9%
Malta	1.2%	1.6%	1.9%
Netherlands	1.9%	2.5%	3.0%
Poland	2.8%	3.7%	4.4%
Portugal	1.8%	2.4%	2.9%
Romania	2.7%	3.6%	4.3%
Slovakia	2.6%	3.5%	4.2%
Slovenia	2.8%	3.6%	4.4%
Spain	1.3%	1.7%	2.1%
Sweden	1.9%	2.5%	3.0%
UK	1.8%	2.4%	2.9%
EU-28	***1.9%***	***2.5%***	***3.0%***

4.16 Epichlorohydrine

4.16.1Methodology/assumptions

Summary of the relevant cancer endpoints and exposure period(s)

Limited epidemiological evidence is available for the risk from occupational exposure to epichlorohydrine, although there is some evidence linking epichlorohydrine to Central Nervous System (CNS) tumours and lung cancer (IOM, 2011[143]; and Brown et al 2012[144], drawing on Barbone et al, 1994).

Brown et al (2012) note that due to the very small number of exposed to high concentrations of ECH, no attributable fraction (AF) was calculated in the Burden of Occupational Cancer in the UK study.

The typical latency for lung cancer is modelled to be between 10 and 50 years. The relevant exposure period is thus defined as 1966-2005.

Exposed population

The starting point for estimating the occupationally exposed population is the CAREX database, with further estimates being available from the Finish ASA for 2005 and 2014. These estimates are summarised below.

[143] IOM (2011): Health, socio-economic and environmental aspects of possible amendments to the EU Directive on the protection of workers from the risks related to exposure of carcinogens and mutagens at work. Epichlorohydrine.

[144] Brown et al 2012: Occupational cancer in Britain - Remaining cancer sites: brain, bone, soft tissue sarcoma and thyroid, available at http://www.nature.com/bjc/journal/v107/n1s/full/bjc2012124a.html and http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3384011/

Table 4-128: Published data – workforce exposed to epichlorohydrine					
Study	**Country**	**Year/period**	**No. of exposed workers**	**% of exposed workforce**	**Notes**
Carex	EU15	1990-1993 (mean)	47,581		
	Finland	1990-1993 (mean)	330		
ASA	Finland	2005	256 (185 men and 71 women)		
		2014	187 (144 men and 43 women)		

Both estimates are of a similar order of magnitude, although the Finnish data show a marked decline over time. The Carex data have therefore been taken as the basis for all the scenarios modelled for epichlorohydrine.

Rate of change

Comparing the number of workers exposed in Finland in 2005 and 2014 (ASA) suggests an annual rate of decline of around 3.5%, which is more marked in men than women. Comparing the Carex data for Finland with the ASA data suggests a decline in the exposed population of 2% per annum between 1990 and 2014.

For this reason, two scenarios for the annual rate of change have been modelled:

- an annual decline of 3.5% throughout the EU; and
- an annual decline of 2% throughout the EU.

A generic staff turnover factor of 10% per annum has been used.

Relative risk

A literature search was performed in PubMed for occupational cancer for epichlorohydrine and DistillerSR used to identify relevant studies for the relative risk.

The relative risk estimates identified through literature review are summarised below. No other evidence has been identified but Tsai et al (1996)[145] note that their research does not support a link between occupational exposure to ECH and cancer.

[145] Tsai et al (1996): Mortality study of employees with potential exposure to epichlorohydrin: a 10 year update, available at http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1128471/

Table 4-129: Literature review of relative risk of epichlorohydrine		
Study & summary of data/methodology	**Cancer site**	**Relative risk**
Barbone et al (1994). Small scale study	CNS	OR=4.2 (95% CI: 0.7–26.0)
IOM (2011) from Barbone et al, 1994)	Lung	OR=1.7 (95% CI:0.7-2.6)
Sources: IOM (2011): Health, socio-economic and environmental aspects of possible amendments to the EU Directive on the protection of workers from the risks related to exposure of carcinogens and mutagens at work. Epichlorohydrin. Rushton L et al (2012): The burden of occupational cancer in Great Britain. Available at http://www.hse.gov.uk/research/rrpdf/rr931.pdf		

The highest and lowest risk estimates are summarised below. Based on Tsai et al (1996), it is assumed that the low boundary of relative risk is 1.

Table 4-130: Summary of relative risk – exposure to ECH		
Cancer site	Lowest	Highest
CNS	1	OR=4.2
Lung	1	OR=1.7

Summary of the scenarios

The assumptions underpinning the different estimates are summarised below. Please note that the estimates of the exposed population are point estimates for a specific year and do not represent the lowest and highest annual estimates over the whole assessment period since these also depend on the annual rate of change.

Table 4-131: Summary of the scenarios (ECH)				
Aspect/scenario	**Low**	**High**	**Midpoint**	**Central**
Exposed population (EU-28) - point	54,000 in 1990-93 or 1997	54,000 in 1990-93 or 1997	54,000 in 1990-93 or 1997	54,000 in 1990-93 or 1997
Relevant cancer sites	CNS, Lung (2 of 2)	CNS, Lung (2 of 2)	CNS, Lung (2 of 2)	CNS, Lung (2 of 2)
Relative risks	CNS OR=1 Lung OR=1	CNS OR=4.2 Lung OR=1.7	CNS OR=2.6 Lung OR=1.4	CNS OR=4.2 Lung OR=1.7
Rate of change (per annum)	-2%	-3.5%	-2.75%	-2%

4.16.2The results

Summary of the occupationally exposed population surviving to 2015

The total number of workers in the EU-28 exposed to epichlorohydrine between 1966 and 2005 and surviving until 2015 is estimated to have been between 0.16 million and 0.17 million.

Table 4-132: Occupationally exposed population surviving to 2015 (epichlorhydrine)		
Scenario	**No. of workers exposed 1966-2005 & surviving to 2015 (million)**	**% of current & at risk population**
Low	0.16	0.1%

Table 4-132: Occupationally exposed population surviving to 2015 (epichlorhydrine)		
Scenario	No. of workers exposed 1966-2005 & surviving to 2015 (million)	% of current & at risk population
High	0.17	0.1%
Midpoint	0.17	0.1%
Central	0.16	0.1%

The break-down of these figures by Member State is provided below. The minimum and maximum values across all scenarios are presented for each Member State.

Table 4-133: Occupationally exposed population surviving to 2015 by Member State (ECH, 1966-2005)				
Member State	Number of workers exposed over the period and surviving to 2015		% of current & at risk population	
	Min	Max	Min	Max
Austria	1,035	1,116	0.0%	0.0%
Belgium	1,331	1,435	0.0%	0.0%
Bulgaria	1,198	1,425	0.0%	0.0%
Croatia	685	814	0.0%	0.0%
Cyprus	50	56	0.0%	0.0%
Czech Republic	1,711	2,036	0.0%	0.0%
Denmark	65,203	71,400	1.8%	2.0%
Estonia	227	271	0.0%	0.0%
Finland	987	1,064	0.0%	0.0%
France	33,473	36,084	0.1%	0.1%
Germany	14,685	15,830	0.0%	0.0%
Greece	598	645	0.0%	0.0%
Hungary	1,540	1,832	0.0%	0.0%
Ireland	311	335	0.0%	0.0%
Italy	4,681	5,047	0.0%	0.0%
Latvia	275	327	0.0%	0.0%
Lithuania	475	566	0.0%	0.0%
Luxembourg	75	81	0.0%	0.0%
Malta	34	39	0.0%	0.0%
Netherlands	3,189	3,437	0.0%	0.0%
Poland	6,332	7,534	0.0%	0.0%
Portugal	876	945	0.0%	0.0%
Romania	3,251	3,869	0.0%	0.0%
Slovakia	856	1,018	0.0%	0.0%
Slovenia	342	407	0.0%	0.0%
Spain	2,833	3,054	0.0%	0.0%
Sweden	1,481	1,596	0.0%	0.0%
UK	8,693	9,371	0.0%	0.0%
Total	***160,203***	***166,710***	***0.1%***	***0.1%***

AFs per Member State

Table 4-134: Overall attributable fractions across all industries by Member State (ECH)						
Cancer site/ scenario	CNS			Lung		
	C-Low	C-Core	C-High	C-Low	C-Core	C-High
Austria	0%	0.1%	0.5%	0%	0.01%	0.03%
Belgium	0%	0.1%	0.5%	0%	0.01%	0.03%
Bulgaria	0%	0.1%	0.7%	0%	0.02%	0.04%

Table 4-134: Overall attributable fractions across all industries by Member State (ECH)						
Cancer site/ scenario	CNS			Lung		
	C-Low	C-Core	C-High	C-Low	C-Core	C-High
Croatia	0%	0.1%	0.6%	0%	0.02%	0.04%
Cyprus	0%	0.0%	0.2%	0%	0.01%	0.02%
Czech Republic	0%	0.1%	0.6%	0%	0.02%	0.04%
Denmark	0%	5.8%	32.6%	0%	1.34%	3.00%
Estonia	0%	0.1%	0.7%	0%	0.02%	0.04%
Finland	0%	0.1%	0.7%	0%	0.02%	0.05%
France	0%	0.3%	2.0%	0%	0.06%	0.13%
Germany	0%	0.1%	0.7%	0%	0.02%	0.05%
Greece	0%	0.0%	0.2%	0%	0.01%	0.01%
Hungary	0%	0.1%	0.6%	0%	0.02%	0.04%
Ireland	0%	0.0%	0.3%	0%	0.01%	0.02%
Italy	0%	0.0%	0.3%	0%	0.01%	0.02%
Latvia	0%	0.1%	0.5%	0%	0.02%	0.04%
Lithuania	0%	0.1%	0.6%	0%	0.02%	0.04%
Luxembourg	0%	0.1%	0.5%	0%	0.01%	0.03%
Malta	0%	0.0%	0.3%	0%	0.01%	0.02%
Netherlands	0%	0.1%	0.7%	0%	0.02%	0.05%
Poland	0%	0.1%	0.7%	0%	0.02%	0.04%
Portugal	0%	0.0%	0.3%	0%	0.01%	0.02%
Romania	0%	0.1%	0.6%	0%	0.02%	0.04%
Slovakia	0%	0.1%	0.6%	0%	0.02%	0.04%
Slovenia	0%	0.1%	0.7%	0%	0.02%	0.04%
Spain	0%	0.0%	0.2%	0%	0.01%	0.02%
Sweden	0%	0.1%	0.6%	0%	0.02%	0.04%
UK	0%	0.1%	0.5%	0%	0.01%	0.03%
EU-28	***0%***	***0.2%***	***1.2%***	***0%***	***0.03%***	***0.08%***

4.17 Tetrachloroethylene

4.17.1Methodology/assumptions

Summary of the relevant cancer endpoints and exposure period(s)

The relevant cancer endpoints and latency periods are (IARC, 2016[146]; Lynge E et al (2006)[147], Rushton et al 2012[148]):

- Cervix (women only), latency 0-20 years, 1996-2015;
- Non-Hodgkin lymphoma (NHL), 10-50 years, 1966-2005;
- Oesophagus, 10-50 years, 1966-2005;

[146] IARC (2016): List of classifications by cancer sites with sufficient or limited evidence in humans, available at https://monographs.iarc.fr/ENG/Classification/Table4.pdf

[147] Lynge E et al (2006): Cancer in Persons Working in Dry Cleaning in the Nordic Countries. Environmental Health Perspectives, 114(2), 213-219.

[148] Rushton et al (2012): Occupational cancer in the UK – overview report, available at http://www.hse.gov.uk/research/rrpdf/rr931.pdf

- Pancreas, 10-50 years, 1966-2005; and
- Bladder, 10-50 years , 1966-2005.

Only one cancer site (bladder) was identified in IARC (2016) as relevant to tetrachloroethylene. As a result, more cancer sites are covered in this report than those that were identified as relevant in IARC (2016).

Exposed population

The starting point for estimating the occupationally exposed population is the CAREX database, with further estimates being available for France from SUMER (2003 and 2010) and for the UK from Rushton et al (2012), although the data in Ruston are based on CAREX. These estimates are summarised below.

Table 4-135: Published data – workforce exposed to tetrachloroethylene

Study	Country	Year/period	No. of exposed workers	% of exposed workforce	Notes
Carex	EU15	1990-1993 (mean)	801,908		
	UK	1990-1993 (mean)	119,475		
SUMER		2003	47,400 (27,800 men, 19,600 women)	0.3% (0.3% men, 0.3% women)	
	France	2010	30,300 (20,700 men, 9,600 women)	0.1% (0.2% men, 0.1% women)	
Rushton	UK	Published in 2004-2005, refers to ever exposed workers	189,605 women and 249,421 men		Based on Carex

Extrapolations to the EU-28 are summarised below.

Table 4-136: Occupationally exposed population in the EU-28 (tetrachloroethylene)

Estimate and method of extrapolation	Exposed population in the EU-28
A: France 2010 exposed workers extrapolated on the basis of population	230,000
B: CAREX early to mid-1990s	1.1 million
C: France 2010 share (0.1%) applied to current EU workforce	220,000
D: Rushton ever exposed workers extrapolated on the basis of population	690,000

Estimate C in the table above (220,000 in 2010) forms the basis for the LOW scenario while estimate B is used for the HIGH scenario (1.1 million in the early to mid-1990s). The CENTRAL scenario is based on the extrapolation of the Rushton data (estimate D).

Rate of change

Comparing the number of workers exposed in France in 2003 and 2010 (SUMER) suggests an annual rate of decline of around 6%. The following scenarios are modelled:

- no change; and
- an annual decrease of 6%.

A generic staff turnover factor of 10% per annum has been used.

Relative risk

The relative risk estimates identified through literature review are summarised below.

Table 4-137: Literature review of relative risk

Study & summary of data/methodology	Cancer site	Relative risk
Lynge E et al (2006). Case-control studies in cohorts of laundry and dry cleaning workers in Denmark, Norway, Sweden and Finland	Bladder Pancreas Cervix	RR 1.44 (95% CI: 1.07, 1.93) RR 1.27 (95% CI: 0.7-2.0) RR 1.2 (95% CI: 0.6-2.2)
Rushton et al (2012). From Ruder et al (2001)	Cervical	1.95 (95% CI: 1.00, 3.40)
Rushton et al (2012). From Ruder et al (2001)	Oesophagus	SMR=2.47 (95% CI: 1.35, 4.14)
Rushton et al (2012). From Ruder et al (2001)	NHL	SMR=1.39 (95% CI: 0.56, 2.86)
Weiderpass E and Labrèche F (2012). Literature review	Cervical	Dry cleaners: SMR 1.89-1.98 Metal cleaners: SMR: 1.4-1.8 Textile Industry: RR 1.09-1.34 Manufacturing: SIR 1.19-1.59

Sources:
IOM (2011): Health, socio-economic and environmental aspects of possible amendments to the EU Directive on the protection of workers from the risks related to exposure of carcinogens and mutagens at work. Epichlorohydrin.
Lynge E (1994): Danish Cancer Registry as a resource for occupational research. J Occup Med, 36(11), 1169-1173.
Lynge E et al (2006): Cancer in Persons Working in Dry Cleaning in the Nordic Countries. Environmental Health Perspectives, 114(2), 213-219.
Rushton L et al (2012): The burden of occupational cancer in Great Britain. Available at http://www.hse.gov.uk/research/rrpdf/rr931.pdf
Weiderpass E and Labrèche F (2012): Malignant tumours of the Female Reproductive System. Saf Health Work, 3, 166-180.

The lowest and highest relative risks identified through literature are summarised below.

Table 4-138: Summary of relative risk – exposure to tetrachloroethylene		
Cancer site	**Lowest**	**Highest**
Bladder	RR=1.44	RR=1.44
Cervical	RR=1.09	1.95
NHL	1.29	1.29
Oesophagus	2.47	2.47
Pancreas	RR=1.27	RR=1.27

Summary of the scenarios

The assumptions underpinning the different estimates are summarised below. Please note that the estimates of the exposed population are point estimates for a specific year and do not represent the lowest and highest annual estimates over the whole assessment period since these also depend on the annual rate of change.

Table 4-139: Summary of the scenarios (tetrachloroethylene)				
Aspect/scenario	**Low**	**High**	**Midpoint**	**Central**
Exposed population (EU-28) - point	220,000 (2010)	1.1 million (assumed in 1994)	660,000 (assumed in 2002)	690,000 (assumed in 1994)
Relevant cancer sites	Bladder, cervix, NHL, oesophagus, pancreas (4 more than IARC 2016)	Bladder, cervix, NHL, oesophagus, pancreas (4 more than IARC 2016)	Bladder, cervix, NHL, oesophagus, pancreas (4 more than IARC 2016)	Bladder, cervix, NHL, oesophagus, pancreas (4 more than IARC 2016)
Relative risk	Bladder: RR=1.44 Cervical: RR=1.09 NHL: RR=1.29 Oesophagus: SMR=2.47 Pancreas: RR=1.27	Bladder: RR=1.44 Cervical: RR=1.95 NHL: RR=1.29 Oesophagus: SMR=2.47 Pancreas: RR=1.27	Bladder: RR=1.44 Cervical: RR=1.52 NHL: RR=1.29 Oesophagus: SMR=2.47 Pancreas: RR=1.27	Bladder: RR=1.44 Cervical: RR=1.2 NHL: SMR=1.39 Oesophagus: SMR=2.47 Pancreas: RR=1.27
Change (p.a.)	0%	-6%	-3%	-6%

4.17.2The results

Summary of the occupationally exposed population surviving to 2015

The total number of workers in the EU-28 exposed to tetrachloroethylene between 1966 and 2005 and surviving until 2015 is summarised below.

Table 4-140: Occupationally exposed population surviving to 2015 (tetrachloroethylene)		
Scenario	**No. of workers exposed 1966-2005 & surviving to 2015 (million)**	**% of current & at risk population**
Low	0.8	0.1%
High	4.9	0.6%
Midpoint	2.9	0.4%
Central	3.3	0.4%

The break-down of these figures by Member State is provided below. The minimum and maximum values across all scenarios are presented for each Member State.

Table 4-141: Occupationally exposed population surviving to 2015 by Member State (tetrachloroethylene, 1966-2005)				
Member State	Number of workers exposed over the period and surviving to 2015		% of current & at risk population	
	Min	Max	Min	Max
Austria	13,094	74,639	0.1%	0.5%
Belgium	17,189	73,253	0.1%	0.4%
Bulgaria	10,996	119,828	0.1%	1.0%
Croatia	6,451	68,473	0.1%	1.0%
Cyprus	1,293	5,511	0.1%	0.4%
Czech Republic	16,089	171,183	0.1%	1.0%
Denmark	8,641	43,526	0.1%	0.5%
Estonia	2,005	19,392	0.1%	0.9%
Finland	8,354	35,602	0.1%	0.4%
France	101,398	543,739	0.1%	0.5%
Germany	123,967	800,916	0.1%	0.6%
Greece	16,577	70,648	0.1%	0.4%
Hungary	15,047	154,065	0.1%	1.0%
Ireland	7,067	30,118	0.1%	0.4%
Italy	92,819	707,906	0.1%	0.7%
Latvia	3,032	26,586	0.1%	0.8%
Lithuania	4,460	60,017	0.1%	1.3%
Luxembourg	859	3,675	0.1%	0.4%
Malta	655	5,807	0.1%	0.9%
Netherlands	25,803	109,965	0.1%	0.4%
Poland	58,024	633,378	0.1%	1.0%
Portugal	15,840	80,565	0.1%	0.5%
Romania	30,337	325,248	0.1%	1.0%
Slovakia	8,277	85,592	0.1%	1.0%
Slovenia	3,149	34,237	0.1%	1.0%
Spain	70,916	302,226	0.1%	0.4%
Sweden	14,882	63,422	0.1%	0.4%
UK	99,047	461,016	0.1%	0.4%
Total	***776,268***	***4,876,725***	***0.1%***	***0.6%***

The total number of female workers in the EU-28 exposed to tetrachloroethylene between 1996 and 2015 is summarised below.

Table 4-142: Occupationally exposed population surviving to 2015 (women only) by Member State (tetrachloroethylene)		
Scenario	Number of female workers exposed 1996-2015 (million)	Exposed workers as % of current female population
Low	0.2	0.1%
High	0.7	0.4%
Midpoint	0.66	0.35%
Central	0.4	0.2%

The break-down of these figures by Member State is provided below. The minimum and maximum values across all scenarios are presented for each Member State.

Table 4-143: Occupationally exposed population surviving to 2015 (women only) by Member State (tetrachloroethylene, 1996-2015)				
Member State	Number of female workers exposed		Exposed workers as % of overall female population	
	Min	Max	Min	Max
Austria	3,842	11,503	0.1%	0.4%
Belgium	5,044	14,649	0.1%	0.4%
Bulgaria	3,227	15,946	0.1%	0.6%
Croatia	1,893	9,112	0.1%	0.6%
Cyprus	379	1,102	0.1%	0.4%
Czech Republic	4,721	22,780	0.1%	0.6%
Denmark	2,536	7,364	0.1%	0.4%
Estonia	588	2,581	0.1%	0.5%
Finland	1,499	7,120	0.1%	0.4%
France	29,755	86,420	0.1%	0.4%
Germany	36,378	123,431	0.1%	0.4%
Greece	4,865	14,128	0.1%	0.4%
Hungary	4,416	20,502	0.1%	0.6%
Ireland	2,074	6,023	0.1%	0.4%
Italy	27,238	109,097	0.1%	0.5%
Latvia	890	3,538	0.1%	0.5%
Lithuania	1,309	7,987	0.1%	0.7%
Luxembourg	252	733	0.1%	0.4%
Malta	192	764	0.1%	0.5%
Netherlands	7,572	21,991	0.1%	0.4%
Poland	17,027	84,286	0.1%	0.6%
Portugal	4,648	13,500	0.1%	0.4%
Romania	8,902	43,282	0.1%	0.6%
Slovakia	2,429	11,390	0.1%	0.6%
Slovenia	924	4,556	0.1%	0.6%
Spain	20,810	60,440	0.1%	0.4%
Sweden	4,367	12,683	0.1%	0.4%
UK	29,065	84,416	0.1%	0.4%
Total	***227,797***	***715,459***	***0.1%***	***0.4%***

AFs per Member State

Table 4-144: Overall attributable fractions across all industries by Member State (tetrachloroethylene)															
Cancer site/ scenario	Bladder			NHL			Oesophagus			Pancreas			Cervix		
	C-Low	C-Core	C-High	C-Low	C-Core	C-High	C-Low	C-Core	C-High	C-Low	C-Core	C-High	C-Low	C-Core	C-High
Austria	0.03%	0.2%	0.4%	0%	0.2%	0.8%	0.1%	0.6%	1.3%	0%	0.1%	0.4%	0%	0.05%	0.3%
Belgium	0.03%	0.2%	0.4%	0%	0.2%	0.8%	0.1%	0.6%	1.3%	0%	0.1%	0.4%	0%	0.05%	0.3%
Bulgaria	0.03%	0.2%	0.4%	0%	0.2%	0.8%	0.1%	0.6%	1.3%	0%	0.1%	0.4%	0%	0.05%	0.3%
Croatia	0.03%	0.2%	0.4%	0%	0.2%	0.8%	0.1%	0.6%	1.3%	0%	0.1%	0.4%	0%	0.05%	0.3%
Cyprus	0.03%	0.2%	0.4%	0%	0.2%	0.8%	0.1%	0.6%	1.3%	0%	0.1%	0.4%	0%	0.05%	0.3%
Czech Republic	0.03%	0.2%	0.4%	0%	0.2%	0.8%	0.1%	0.6%	1.3%	0%	0.1%	0.4%	0%	0.05%	0.3%
Denmark	0.03%	0.2%	0.4%	0%	0.2%	0.8%	0.1%	0.6%	1.3%	0%	0.1%	0.4%	0%	0.05%	0.3%
Estonia	0.03%	0.2%	0.4%	0%	0.2%	0.8%	0.1%	0.6%	1.3%	0%	0.1%	0.4%	0%	0.05%	0.3%
Finland	0.03%	0.2%	0.4%	0%	0.2%	0.8%	0.1%	0.6%	1.3%	0%	0.1%	0.4%	0%	0.05%	0.3%
France	0.03%	0.2%	0.4%	0%	0.2%	0.8%	0.1%	0.6%	1.3%	0%	0.1%	0.4%	0%	0.05%	0.3%
Germany	0.03%	0.2%	0.4%	0%	0.2%	0.8%	0.1%	0.6%	1.3%	0%	0.1%	0.4%	0%	0.05%	0.3%
Greece	0.03%	0.2%	0.4%	0%	0.2%	0.8%	0.1%	0.6%	1.3%	0%	0.1%	0.4%	0%	0.05%	0.3%
Hungary	0.03%	0.2%	0.4%	0%	0.2%	0.8%	0.1%	0.6%	1.3%	0%	0.1%	0.4%	0%	0.05%	0.3%

Table 4-144: Overall attributable fractions across all industries by Member State (tetrachloroethylene)															
Cancer site/ scenario	Bladder			NHL			Oesophagus			Pancreas			Cervix		
	C-Low	C-Core	C-High	C-Low	C-Core	C-High	C-Low	C-Core	C-High	C-Low	C-Core	C-High	C-Low	C-Core	C-High
Ireland	0.03%	0.2%	0.4%	0%	0.2%	0.8%	0.1%	0.6%	1.3%	0%	0.1%	0.4%	0%	0.05%	0.3%
Italy	0.03%	0.2%	0.4%	0%	0.2%	0.8%	0.1%	0.6%	1.3%	0%	0.1%	0.4%	0%	0.05%	0.3%
Latvia	0.03%	0.2%	0.4%	0%	0.2%	0.8%	0.1%	0.6%	1.3%	0%	0.1%	0.4%	0%	0.05%	0.3%
Lithuania	0.03%	0.2%	0.4%	0%	0.2%	0.8%	0.1%	0.6%	1.3%	0%	0.1%	0.4%	0%	0.05%	0.3%
Luxembourg	0.03%	0.2%	0.4%	0%	0.2%	0.8%	0.1%	0.6%	1.3%	0%	0.1%	0.4%	0%	0.05%	0.3%
Malta	0.03%	0.2%	0.4%	0%	0.2%	0.8%	0.1%	0.6%	1.3%	0%	0.1%	0.4%	0%	0.05%	0.3%
Netherlands	0.03%	0.2%	0.4%	0%	0.2%	0.8%	0.1%	0.6%	1.3%	0%	0.1%	0.4%	0%	0.05%	0.3%
Poland	0.03%	0.2%	0.4%	0%	0.2%	0.8%	0.1%	0.6%	1.3%	0%	0.1%	0.4%	0%	0.05%	0.3%
Portugal	0.03%	0.2%	0.4%	0%	0.2%	0.8%	0.1%	0.6%	1.3%	0%	0.1%	0.4%	0%	0.05%	0.3%
Romania	0.03%	0.2%	0.4%	0%	0.2%	0.8%	0.1%	0.6%	1.3%	0%	0.1%	0.4%	0%	0.05%	0.3%
Slovakia	0.03%	0.2%	0.4%	0%	0.2%	0.8%	0.1%	0.6%	1.3%	0%	0.1%	0.4%	0%	0.05%	0.3%
Slovenia	0.03%	0.2%	0.4%	0%	0.2%	0.8%	0.1%	0.6%	1.3%	0%	0.1%	0.4%	0%	0.05%	0.3%
Spain	0.03%	0.2%	0.4%	0%	0.2%	0.8%	0.1%	0.6%	1.3%	0%	0.1%	0.4%	0%	0.05%	0.3%
Sweden	0.03%	0.2%	0.4%	0%	0.2%	0.8%	0.1%	0.6%	1.3%	0%	0.1%	0.4%	0%	0.05%	0.3%
UK	0.03%	0.2%	0.4%	0%	0.2%	0.8%	0.1%	0.6%	1.3%	0%	0.1%	0.4%	0%	0.05%	0.3%
EU-28	***0.03%***	***0.2%***	***0.4%***	***0%***	***0.2%***	***0.8%***	***0.1%***	***0.6%***	***1.3%***	***0%***	***0.1%***	***0.4%***	***0%***	***0.05%***	***0.3%***

4.18 Shift work

4.18.1Methodology/assumptions

Summary of the relevant cancer endpoints and exposure period(s)

The relevant health endpoint is breast cancer (IARC, 2016[149]; Hansen & Stevens 2012[150]; Menegaux et al 2013[151]; Rushton et al 2012[152]).

The only cancer site identified in IARC (2016) as relevant to shift work has been quantified in this study.

The typical latency for lung cancer is modelled to be between 10 and 50 years. The relevant exposure period is thus defined as 1966-2005.

Exposed population

Several sources for data on the number of workers subject to shift work (i.e. working at night) have been identified. It should be noted that workforce data considered in this report focus on the

[149] IARC (2016): List of classifications by cancer sites with sufficient or limited evidence in humans, available at https://monographs.iarc.fr/ENG/Classification/Table4.pdf

[150] Hansen J & Stevens RG (2012): Case-control study of shift-work and breast cancer risk in Danish nurses: impact of shift systems, Eur J Cancer, 48(11), 1722-9, available at: http://www.ncbi.nlm.nih.gov/pubmed/?term=Case-control+study+of+shift-work+and+breast+cancer+risk+in+Danish+nurses%3A+impact+of+shift+systems

[151] Menegaux F et al (2013): Night work and breast cancer: a population-based case-control study in France (the CECILE study), International Journal of Cancer, 132(4), 924-931, available at: http://onlinelibrary.wiley.com/doi/10.1002/ijc.27669/abstract

[152] Rushton et al (2012): Occupational cancer in the UK – overview report, available at http://www.hse.gov.uk/research/rrpdf/rr931.pdf

female workforce engaged in shift work, due to the fact that breast cancer is the only cancer endpoint which predominantly affects women[153].

Table 4-145: Published data – workforce exposed to shift work					
Study	**Country**	**Year/period**	**No. of exposed workers**	**% of exposed workforce**	**Notes**
Akerstedt et al (2015)	Sweden		3,404 women		
Hansen and Stevens (2012)	Denmark	2002-2005	91,140 female members of the Danish Nurses Association which corresponds to 95% of nurses in Denmark		Sector – Healthcare 2/3 of cohort have worked nights
Rushton et al (2012)	UK	Published 2004-2005, refers to ever exposed workers	1,953,645 women		

In addition, the exposed population can be estimated from the Labour Force Survey (Eurostat) data for percentage of people employed in shift work (total plus breakdown into males and females), percentage of people sometimes involved in night work (to account for night working shifts) and the total employed population[154]. Data are available for all 28 Member States over a varying period:

- 1995 to 2015: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Spain, Sweden, UK
- 1996 to 2015: Slovenia
- 1997 to 2015: Estonia, Hungary
- 1999 to 2015: Cyprus
- 2000 to 2015: Lithuania
- 2001 to 2015: Malta, Poland, Slovakia
- 2002 to 2015: Croatia, Czech Republic, Latvia, Portugal, Romania
- 2004 to 2015: Bulgaria

Data are extrapolated back to 1966 based on trends between the years for which data are available.

Extrapolations to the EU-28 are summarised below. No extrapolation has been carried out from the Swedish estimate since this is seen as an outlier.

Table 4-146: Occupationally exposed population in the EU-28 (shift work)	
Estimate and method of extrapolation	**Exposed population in the EU-28 (females only)**
A: Eurostat Labour Force Survey (LFS)	9 million (annual average estimated over 1966-2005) 5.6 million in 2007 (night work only)

[153] Less than 1% of breast cancer cases develop in men. Source: http://www.nationalbreastcancer.org/male-breast-cancer

[154] Data from Eurostat for Employees working shifts as a percentage of the total of employees, by sex and age (%) [lfsa_ewpshi], Employed persons working at nights as a percentage of the total employment, by sex, age and professional status (%) [lfsa_ewpnig] (frequency = sometimes) and Employment and activity by sex and age - annual data [lfsi_emp_a]

Table 4-146: Occupationally exposed population in the EU-28 (shift work)	
Estimate and method of extrapolation	**Exposed population in the EU-28 (females only)**
B: Rushton (converted to annual estimate) extrapolated on the basis of population	3 million
C: Office of National Statistics ONS (UK estimate for 2014, extrapolated on the basis Eurostat LFS data for female workers)[155]	12.6 million (2014)[156]

Estimate B in the table above forms the basis for the LOW scenario while estimate A is used for the HIGH scenario. The CENTRAL scenario is also based on estimate A. Please also note that the 9 million annual estimate over the whole reference period (estimate A) corresponds to the average of recent annual estimates from Eurostat LFS (5.6 million in night-work) and the ONS estimate which considers a range of types of shift-work which may involve irregular sleeping patterns (12.6 million).

Rate of change

Two rates of change are thus used as a basis for modelling:

- rates of decline estimated for individual Member States on the basis of the Labour Force data, these range between -5% p.a.to +6 p.a.; and
- no change.

A generic staff turnover factor of 10% per annum has been used.

Relative risk

The relative risk estimates identified through literature review are summarised below.

Table 4-147: Literature review of relative risk		
Study & summary of data/methodology	**Cancer site**	**Relative risk**
Davis et al (2001). Case control study of women with breast cancer	Breast	1.6 (95% CI: 1.0-2.5) for women who had worked "graveyard shifts"*
Hansen C et al (2012): Nested case-control study in Denmark	Breast	OR of 1.4 (95% CI: 0.9-2.1 for women ever compared and never night shifts.
Hansen J (2001). Population case-control study in Denmark	Breast	RR of 1.5 (95% CI: 1.2-1.7) for > 6 years of shift work
Kamdar BB et al (2013). Meta-analysis of 15 pooled studies	Breast	Night-shift work exposure: 1.21 (95% CI 1.00-1.47); Short-term night-shift workers (<8 years): 1.13 (95% CI 0.97-1.32); long-term night-shift workers (>8 years): 1.04 (95% CI 0.92-1.18)
Lie et al (2006). Nested case-control study of nurses in Norway	Breast	RR of 2.21 (95% CI: 1.10-4.45) for > 30 years of night work. IARC note

[155] See https://www.ons.gov.uk/ons/about-ons/business-transparency/freedom-of-information/what-can-i-request/published-ad-hoc-data/labour/march-2015/people-aged-over-16-in-employment-who-do-shift-work-.xls

[156] Excluding 'Other types of shift-work', some of which are also likely to entail circadian disruption.

Table 4-147: Literature review of relative risk		
Study & summary of data/methodology	**Cancer site**	**Relative risk**
		there are limitations for this study in exposure misclassification and potential confounders.
O' Leary et al (2006). Case-control study in the United States	Breast	OR of 1.04 (95% CI: 0.79-1.38) for any evening or overnight shift work; OR of 0.55 (95% CI: 0.32-0.94)
Megdal et al 2005 (systematic review and meta-analysis) (also cited in Rushton & Hutchings 2007)	Breast	Rr=1.51 (95% CI 1.36-1.68)
Schernhammer ES et al (2006). Nurses Health Cohort Study I in the United States	Breast	1–14 years of shift work: 1.08 (95% CI: 0.99–1.18) 15–29 years of shift work: 1.08 (95% CI: 0.90–1.30); ≥ 30 years of shift work: 1.36 (95% CI: 1.04–1.78)
Schernhammer ES et al (2006). Nurses Health Cohort Study II in the United States	Breast	Women reporting more than 20 years of rotating night shift work compared with those who did not report rotating night shift work: RR 1.79 (95% CI 1.06-3.01).
Schwartzbaum et al (2007). Retrospective cohort study of 1, 148,661 female workers in Sweden	Breast	Shift-work in 1970: 0.94 (95% CI 0.74-1.18) Shift-work in 1960 and 1970: 0.97 (0.64-1.40)
Tynes et al (1996). Nested case-control study of radio and telegraph workers in Norway	Breast	Increase in woman ≥ 50 years of age, 0-3.1 years of shift work RR of 3.2 (95% CI: 0.6-17.3), 3.1-20.7 years RR of 4.3 (95% CI: 0.7-20.6). IARC discuss this study and note the lack of control for breast cancer confounders.
Wang F (2013). Literature review and meta-analysis	Breast	RR of 1.19 (95% CI: 1.05-1.35)

Notes:
* Graveyard shifts are defined as beginning before work after 19:00 and leaving work before 09:00

Sources:
Davis S et al (2001): Night shift work, light at night, and risk of breast cancer. J Natl Cancer Inst, 93, 1557–1562.
Hansen C and Lassen CF (2012): Nested case-control study of night shift work and breast cancer risk among women in the Danish military. Occup Environ Med, 69(8), 551-556.
Hansen J (2001): Increased breast cancer risk among women who work predominantly at night. Epidemiology, 12,74–77.
Kamdar BB et al (2011): Night-shift work and risk of breast cancer: a systematic review and meta-analysis, Breast Cancer Res Treat, 138(1), 291-301.
Lie JA et al (2006): Breast cancer and night work among Norwegian nurses. Cancer Causes Control , 17:39–44;
Megdal SP et al (2005): Night work and breast cancer risk: a systematic review and meta-analysis, Eur J Cancer, 41(13), 2023-2032, available at https://www.ncbi.nlm.nih.gov/pubmed/16084719
O'Leary ES et al (2006): Shift work, light at night, and breast cancer on Long Island, New York. Am J Epidemiol, 164, 358–366.
Schernhammer ES et al (2001): Rotating Night Shifts and Risk of Breast Cancer in Women Participating in the

Table 4-147: Literature review of relative risk		
Study & summary of data/methodology	**Cancer site**	**Relative risk**
Nurses' Health Study. J Natl Cancer Inst, 93(20), 1563-1568. Schernhammer ES et al (2006): Night work and risk of breast cancer, Epidemiology, 17(1), 108-111, available at: http://www.ncbi.nlm.nih.gov/pubmed/16357603 Schwartzbaum J et al (2007): Cohort study of cancer risk among male and female shift workers. Scand J Work Environ Health, 33:336–343. Tynes T et al (1996): Incidence of breast cancer in Norwegian female radio and telegraph operators. Cancer Causes Control, 7, 197–204. Wang F et al (2013): A meta-analysis on dose-response relationship between night shift work and the risk of breast cancer. Ann Oncol, 24(11), 2724-2732.		

The lowest and highest relative risks identified through literature are summarised below.

Table 4-148: Summary of relative risk – shift work		
Cancer site	**Lowest**	**Highest**
Breast	RR=1	RR=4.3

Summary of the scenarios

The assumptions underpinning the different estimates are summarised below. Please note that the estimates of the exposed population are point estimates for a specific year and do not represent the lowest and highest annual estimates over the whole assessment period since these also depend on the annual rate of change.

Table 4-149: Summary of the scenarios (shift work)				
Aspect/scenario	**Low**	**High**	**Midpoint**	**Central**
Exposed population (EU-28) – point, females only	3 million (assumed 2004)	9 million (annual average over 1966-2005)	6 million (assumed 2004)	9 million (annual average over 1966-2005)
Relevant cancer sites	Breast (1 of 1 in IARC 2016)	Breast (1 of 1 in IARC 2016)	Breast (1 of 1 in IARC 2016)	Breast (1 of 1 in IARC 2016)
Relative risk	RR=1	RR=4.3	RR=2.62	RR=1.51
Change (p.a.)	0%	-5% p.a.to +6 p.a., depending on the Member State	0%	-5% p.a.to +6 p.a., depending on the Member State

4.18.2The results

Summary of the occupationally exposed population surviving to 2015

The total number of female workers in the EU-28 engaged in night-time shift work between 1966 and 2005 and surviving to 2015 has been estimated to be between 10.6 million and 32.1 million.

Table 4-150: Occupationally exposed population surviving to 2015 (shift work, women only)		
Scenario	**Number of female workers exposed 1966-2005 (million)**	**Exposed female workers as % of current female population**
Low	10.6	6.6%
High & Central	32.1	20.0%
Midpoint	21.2	13.2%

The break-down of these figures by Member State is provided below. The minimum and maximum values across all scenarios are presented for each Member State.

Table 4-151: Occupationally exposed population surviving to 2015 (women only) by Member State (shift work, 1966-2005)				
Member State	Number of workers exposed over the period and surviving to 2015 (women only)		Exposed female workers as % of overall female population	
	Min	Max	Min	Max
Austria	178,550	563,855	6.6%	20.9%
Belgium	234,390	468,780	6.6%	13.2%
Bulgaria	149,943	585,286	6.6%	25.8%
Croatia	87,967	223,030	6.6%	16.8%
Cyprus	17,634	35,268	6.6%	13.2%
Czech Republic	219,397	967,091	6.6%	29.1%
Denmark	117,830	478,118	6.6%	26.8%
Estonia	27,341	123,736	6.6%	29.9%
Finland	113,917	668,109	6.6%	38.8%
France	1,382,701	2,912,346	6.6%	13.9%
Germany	1,690,457	4,205,822	6.6%	16.4%
Greece	226,054	452,108	6.6%	13.2%
Hungary	205,184	523,203	6.6%	16.9%
Ireland	96,370	219,683	6.6%	15.1%
Italy	1,265,708	2,531,415	6.6%	13.2%
Latvia	41,349	393,603	6.6%	62.9%
Lithuania	60,818	732,530	6.6%	79.6%
Luxembourg	11,720	23,441	6.6%	13.2%
Malta	8,939	17,877	6.6%	13.2%
Netherlands	351,857	906,335	6.6%	17.0%
Poland	791,241	2,998,503	6.6%	25.0%
Portugal	215,994	3,351,626	6.6%	102.6%
Romania	413,688	1,287,763	6.6%	20.6%
Slovakia	112,867	272,940	6.6%	16.0%
Slovenia	42,947	170,501	6.6%	26.2%
Spain	967,036	1,934,073	6.6%	13.2%
Sweden	202,931	581,607	6.6%	18.9%
UK	1,350,640	6,240,725	6.6%	30.5%
Total	***10,585,470***	***32,072,586***	***6.6%***	***20.0%***

AFs per Member State

Table 4-152: Overall attributable fractions across all industries by Member State (shift work)			
Cancer site& scenario	Breast		
	C-Low	C-Core	C-High
Austria	7.0%	9.6%	12.4%
Belgium	4.4%	6.2%	8.0%
Bulgaria	8.5%	11.6%	14.9%
Croatia	5.7%	7.9%	10.2%
Cyprus	2.6%	3.7%	4.9%
Czech Republic	9.5%	12.9%	16.5%
Denmark	8.8%	12.0%	15.4%
Estonia	9.7%	13.2%	16.9%
Finland	12.2%	16.5%	20.9%

Table 4-152: Overall attributable fractions across all industries by Member State (shift work)			
Cancer site& scenario	Breast		
	C-Low	C-Core	C-High
France	4.8%	6.6%	8.6%
Germany	5.6%	7.7%	10.1%
Greece	4.2%	5.8%	7.6%
Hungary	5.7%	7.9%	10.3%
Ireland	5.1%	7.1%	9.3%
Italy	3.1%	4.4%	5.8%
Latvia	18.5%	24.3%	30.0%
Lithuania	22.3%	28.9%	35.1%
Luxembourg	2.3%	3.3%	4.3%
Malta	2.9%	4.1%	5.4%
Netherlands	5.8%	8.0%	10.4%
Poland	8.3%	11.3%	14.6%
Portugal	27.0%	34.3%	41.1%
Romania	6.9%	9.5%	12.3%
Slovakia	5.4%	7.5%	9.8%
Slovenia	8.6%	11.8%	15.1%
Spain	2.5%	3.5%	4.6%
Sweden	6.4%	8.8%	11.4%
UK	9.9%	13.5%	17.2%
EU-28	***6.7%***	***9.3%***	***12.0%***

4.19 Dioxins

4.19.1Methodology/assumptions

Summary of the relevant cancer endpoints and exposure period(s)

The relevant cancer endpoint is lung cancer (IARC, 2016[157]; Rushton et al 2012[158]). The latency period for lung cancer is 10-50 years and the relevant reference period is thus defined as 1966-2005.

IARC (2016) lists the following cancer sites for 2,3,7,8-tetrachlorodibenzo-para-dioxin (TCDD):

- Lung
- Soft tissue
- Leukaemia and/or lymphoma
- Multiple or unspecified sites - all cancer sites (combined)

However, a lack of relative risk quantifications, only lung cancer incidence (and overall cancer incidence across all cancer sites) could be estimated. As a result, cancer incidence relating to only one of the three specific cancer sites in IARC (2011) could be quantified.

[157] IARC (2016): List of classifications by cancer sites with sufficient or limited evidence in humans, available at https://monographs.iarc.fr/ENG/Classification/Table4.pdf

[158] Rushton et al (2012): Occupational cancer in the UK – overview report, available at http://www.hse.gov.uk/research/rrpdf/rr931.pdf

Exposed population

Estimates are available for Finland from the ASA register (2005 and 2014) for workers exposed to 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) and for the UK from Rushton et al (2012). These are summarised below.

Table 4-153: Published data – workforce exposed to dioxins					
Study	**Country**	**Year/period**	**No. of exposed workers**	**% of exposed workforce**	**Notes**
ASA	Finland	2005	63 (33 men and 30 women)		2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)
		2014	16 (11 men and 5 women)		
Rushton	UK	Published in 2004-2005, Ever exposed workers	2,733,496 (2,084,061 men and 649,435 women)		

Extrapolations to the EU-28 are summarised below.

Table 4-154: Occupationally exposed population in the EU-28 (dioxins)	
Estimate and method of extrapolation	**Exposed population in the EU-28**
A: Finland 2005 exposed workers extrapolated on the basis of population	6,000
B: Finland 2014 exposed workers extrapolated on the basis of population	1,500
C: Rushton ever exposed workers extrapolated on the basis of population	4.2 million

Estimates A and B in the table above form the basis for the LOW scenario while estimate C is used for the HIGH scenario (4.2 million in the early to mid-1990s). The CENTRAL scenario is equal to the midpoint, which is 2.1 million in 2002.

Rate of change

Comparing the number of workers exposed in Finland in 2005 and 2014 (ASA) suggests an annual rate of decline of around 14%. The following scenarios are modelled:

- no change; and
- an annual decrease of 14%.

A generic staff turnover factor of 10% per annum has been used.

Relative risk

The relative risk estimates identified through literature review are summarised below.

Table 4-155: Literature review of relative risk for dioxins		
Study & summary of data/methodology	**Cancer site**	**Relative risk**
IARC. Literature review of industrial cohort studies	Lung	RR around 1.5
Rushton L et al (2012). Literature review	Lung	1.1 (average of RRs for agriculture and farming 1.03, pesticide manufacture 1.22, pulp and paper manufacture 1.04, and other industries 1.12)
Sources: IARC: IARC Monographs- 100F. Available at http://monographs.iarc.fr/ENG/Monographs/vol100F/mono100F-27.pdf Rushton L et al (2012): The burden of occupational cancer in Great Britain. Available at http://www.hse.gov.uk/research/rrpdf/rr931.pdf		

The lowest and highest relative risks identified through literature are summarised below.

Table 4-156: Summary of relative risk – dioxins		
Cancer site	**Lowest**	**Highest**
Lung	RR: 1.1	RR: 1.5

Summary of the scenarios

The assumptions underpinning the different estimates are summarised below. Please note that the estimates of the exposed population are point estimates for a specific year and do not represent the lowest and highest annual estimates over the whole assessment period since these also depend on the annual rate of change.

Table 4-157: Summary of the scenarios (dioxins)				
Aspect/scenario	**Low**	**High**	**Midpoint**	**Central**
Exposed population (EU-28) - point	6,000 (2005) 1,500 (2014)	4.2 million (assumed in 1994)	2.1 million (assumed in 2002)	2.1 million (assumed in 2002)
Relevant cancer sites	Lung (1 of 3 in IARC 2016)	Lung (1 of 3 in IARC 2016)	Lung (1 of 3 in IARC 2016)	Lung (1 of 3 in IARC 2016)
Relative risk	Lung: RR=1.1	Lung: RR=1.5	Lung: RR=1.25	Lung: RR=1.5
Change (p.a.)	-14%	0%	0%	0%

4.19.2The results

Summary of the occupationally exposed population surviving to 2015

The total number of workers in the EU-28 exposed to dioxins between 1966 and 2005 and surviving until 2015 is summarised below.

Table 4-158: Occupationally exposed population surviving to 2015 (dioxins)		
Scenario	**No. of workers exposed 1966-2005 & surviving to 2015 (million)**	**% of current & at risk population**
Low	0.4	0.14%
High	14.8	4.63%
Midpoint	7.4	2.3%
Central	7.4	2.3%

The break-down of these figures by Member State is provided below. The minimum and maximum values across all scenarios are presented for each Member State.

Table 4-159: Occupationally exposed population surviving to 2015 by Member State (dioxins, 1966-2005)				
Member State	Number of workers exposed over the period and surviving to 2015		% of current & at risk population	
	Min	Max	Min	Max
Austria	7,409	249,970	0.14%	4.63%
Belgium	9,726	328,146	0.14%	4.63%
Bulgaria	6,222	209,920	0.14%	4.63%
Croatia	3,650	123,154	0.14%	4.63%
Cyprus	732	24,687	0.14%	4.63%
Czech Republic	9,104	307,156	0.14%	4.63%
Denmark	4,890	164,962	0.14%	4.63%
Estonia	1,135	38,277	0.14%	4.63%
Finland	4,727	159,483	0.14%	4.63%
France	57,377	1,935,782	0.14%	4.63%
Germany	70,148	2,366,639	0.14%	4.63%
Greece	9,380	316,475	0.14%	4.63%
Hungary	8,514	287,257	0.14%	4.63%
Ireland	3,999	134,919	0.14%	4.63%
Italy	52,523	1,771,991	0.14%	4.63%
Latvia	1,716	57,888	0.14%	4.63%
Lithuania	2,524	85,145	0.14%	4.63%
Luxembourg	486	16,408	0.14%	4.63%
Malta	371	12,514	0.14%	4.63%
Netherlands	14,601	492,600	0.14%	4.63%
Poland	32,834	1,107,738	0.14%	4.63%
Portugal	8,963	302,392	0.14%	4.63%
Romania	17,167	579,164	0.14%	4.63%
Slovakia	4,684	158,014	0.14%	4.63%
Slovenia	1,782	60,126	0.14%	4.63%
Spain	40,129	1,353,851	0.14%	4.63%
Sweden	8,421	284,103	0.14%	4.63%
UK	56,047	1,890,896	0.14%	4.63%
Total	***439,261***	***14,819,658***	***0.14%***	***4.63%***

AFs per Member State

Table 4-160: Overall attributable fractions across all industries by Member State (dioxins)			
Cancer site & scenario	Lung		
	C-Low	C-Core	C-High
Austria	1.1%	1.1%	1.1%
Belgium	1.1%	1.1%	1.1%
Bulgaria	1.1%	1.1%	1.1%
Croatia	1.1%	1.1%	1.1%
Cyprus	1.1%	1.1%	1.1%
Czech Republic	1.1%	1.1%	1.1%
Denmark	1.1%	1.1%	1.1%
Estonia	1.1%	1.1%	1.1%
Finland	1.1%	1.1%	1.1%
France	1.1%	1.1%	1.1%

Table 4-160: Overall attributable fractions across all industries by Member State (dioxins)			
Cancer site & scenario	Lung		
	C-Low	C-Core	C-High
Germany	1.1%	1.1%	1.1%
Greece	1.1%	1.1%	1.1%
Hungary	1.1%	1.1%	1.1%
Ireland	1.1%	1.1%	1.1%
Italy	1.1%	1.1%	1.1%
Latvia	1.1%	1.1%	1.1%
Lithuania	1.1%	1.1%	1.1%
Luxembourg	1.1%	1.1%	1.1%
Malta	1.1%	1.1%	1.1%
Netherlands	1.1%	1.1%	1.1%
Poland	1.1%	1.1%	1.1%
Portugal	1.1%	1.1%	1.1%
Romania	1.1%	1.1%	1.1%
Slovakia	1.1%	1.1%	1.1%
Slovenia	1.1%	1.1%	1.1%
Spain	1.1%	1.1%	1.1%
Sweden	1.1%	1.1%	1.1%
UK	1.1%	1.1%	1.1%
EU-28	***1.1%***	***1.1%***	***1.1%***

4.20 Inorganic acid mists

4.20.1 Methodology/assumptions

Summary of the relevant cancer endpoints and exposure period(s)

The relevant cancer endpoints and latency periods are (IARC, 2016[159]; Rushton et al 2012[160]):

- Larynx, 10-50 years, 1966-2005; and
- Lung, 10-50 years, 1966-2005.

All (100%) cancer sites for which inorganic acid mists were identified in IARC (2016) as a carcinogenic are considered in this study.

Exposed population

Estimates of occupationally exposed populations are available only from CAREX and Rushton et al (2012). These estimates are summarised below.

[159] IARC (2016): List of classifications by cancer sites with sufficient or limited evidence in humans, available at https://monographs.iarc.fr/ENG/Classification/Table4.pdf

[160] Rushton et al (2012): Occupational cancer in the UK – overview report, available at http://www.hse.gov.uk/research/rrpdf/rr931.pdf

Table 4-161: Published data – workforce exposed to inorganic acid mists containing sulphuric acid					
Study	**Country**	**Year/period**	**No. of exposed workers**	**% of exposed workforce**	**Notes**
Carex	EU15	1990-1993 (mean)	699,231		
	UK	1990-1993 (mean)	42,333		
Rushton	UK	Published in 2004-2005; ever exposed workers	246,679 total (136,098 men; 96,613 women)		Based on Carex

Extrapolations to the EU-28 are summarised below.

Table 4-162: Occupationally exposed population in the EU-28 (inorganic acid mists)	
Estimate and method of extrapolation	**Exposed population in the EU-28**
A: CAREX early to mid-1990s	840,000
B: Rushton ever exposed workers extrapolated on the basis of population (converted to an annual estimate)	390,000

Estimate B in the table above (390,000) forms the basis for the LOW scenario while estimate B is used for the HIGH scenario (840,000). Due to a lack of other data, the CENTRAL scenario is set to be equal to the midpoint, i.e. 615,000 (assumed in 1994).

Rate of change

The following scenarios are modelled:

- no change; and
- an annual decrease of 3%.

A generic staff turnover factor of 10% per annum has been used.

Relative risk

The relative risk estimates identified through literature review are summarised below.

Table 4-163: Literature review of relative risk for inorganic acid mists		
Study & summary of data/methodology	**Cancer site**	**Relative risk**
Rushton L et al (2012). Literature review from Steenland and Beaumont (1989)	Larynx	RR 4.28 (95% CI: 2.13, 8.58)
	Lung	RR 1.36 (95% CI: 0.97, 1.94)
Source: Rushton L et al (2012): The burden of occupational cancer in Great Britain. Available at http://www.hse.gov.uk/research/rrpdf/rr931.pdf		

The lowest and highest relative risks identified through literature are summarised below.

Table 4-164: Summary of relative risk – exposure to inorganic acid mists		
Cancer site	**Lowest**	**Highest**
Larynx	RR: 4.28	RR: 4.28
Lung	RR: 1.36	RR: 1.36

Summary of the scenarios

The assumptions underpinning the different estimates are summarised below. Please note that the estimates of the exposed population are point estimates for a specific year and do not represent the lowest and highest annual estimates over the whole assessment period since these also depend on the annual rate of change.

Table 4-165: Summary of the scenarios (inorganic acid mists)				
Aspect/scenario	**Low**	**High**	**Midpoint**	**Central**
Exposed population (EU-28) - point	390,000 (2004)	840,000 (early to mid-1990s)	615,000 (assumed in 2000)	615,000 (assumed in 2000)
Relevant cancer sites	Larynx Lung (2 of 2 in IARC 2016)	Larynx Lung (2 of 2 in IARC 2016)	Larynx Lung (2 of 2 in IARC 2016)	Larynx Lung (2 of 2 in IARC 2016)
Relative risk	Larynx: RR=4.28 Lung: RR=1.36	Larynx: RR=4.28 Lung: RR=1.36	Larynx: RR=4.28 Lung: RR=1.36	Larynx: RR=4.28 Lung: RR=1.36
Change (p.a.)	0%	-3%	-1.5%	-1.5%

4.20.2The results

Summary of the occupationally exposed population surviving to 2015

The total number of workers in the EU-28 exposed to inorganic acid mists between 1966 and 2005 and surviving until 2015 is summarised below.

Table 4-166: Occupationally exposed population surviving to 2015 (inorganic acid mists)		
Scenario	**No. of workers exposed 1966-2005 & surviving to 2015 (million)**	**% of current & at risk population**
Low	1.4	0.4%
High	2.5	0.8%
Midpoint & central	2.1	0.6%

The break-down of these figures by Member State is provided below. The minimum and maximum values across all scenarios are presented for each Member State.

Table 4-167: Occupationally exposed population surviving to 2015 by Member State (inorganic acid mists, 1966-2005)				
Member State	Number of workers exposed over the period and surviving to 2015		% of current & at risk population	
	Min	Max	Min	Max
Austria	20,006	34,968	0.37%	0.65%
Belgium	28,499	45,904	0.40%	0.65%
Bulgaria	19,493	34,208	0.43%	0.75%
Croatia	11,436	19,547	0.43%	0.73%
Cyprus	672	3,454	0.13%	0.65%
Czech Republic	28,522	48,868	0.43%	0.74%
Denmark	11,168	23,076	0.31%	0.65%
Estonia	2,741	5,355	0.33%	0.65%
Finland	5,779	22,310	0.17%	0.65%
France	179,751	1,101,398	0.43%	2.63%
Germany	219,759	331,068	0.43%	0.65%
Greece	7,806	44,272	0.11%	0.65%
Hungary	26,674	43,981	0.43%	0.71%
Ireland	4,312	18,874	0.15%	0.65%
Italy	164,542	344,487	0.43%	0.90%
Latvia	3,346	8,098	0.27%	0.65%
Lithuania	4,469	11,911	0.24%	0.65%
Luxembourg	1,524	2,460	0.43%	0.69%
Malta	1,162	2,596	0.43%	0.96%
Netherlands	29,599	68,910	0.28%	0.65%
Poland	102,861	180,812	0.43%	0.76%
Portugal	15,116	42,301	0.23%	0.65%
Romania	53,779	92,849	0.43%	0.74%
Slovakia	14,673	24,434	0.43%	0.72%
Slovenia	5,583	9,774	0.43%	0.75%
Spain	60,112	189,389	0.21%	0.65%
Sweden	23,201	39,743	0.38%	0.65%
UK	124,182	264,516	0.30%	0.65%
Total	*1,376,111*	*2,536,250*	*0.43%*	*0.79%*

AFs per Member State

Table 4-168: Overall attributable fractions across all industries by Member State (inorganic acid mists)						
Cancer site& scenario	Larynx			Lung		
	C-Low	C-Core	C-High	C-Low	C-Core	C-High
Austria	0.7%	2.1%	4.7%	0%	0.2%	0.6%
Belgium	0.7%	2.1%	4.7%	0%	0.2%	0.6%
Bulgaria	0.7%	2.1%	4.7%	0%	0.2%	0.6%
Croatia	0.7%	2.1%	4.7%	0%	0.2%	0.6%
Cyprus	0.7%	2.1%	4.7%	0%	0.2%	0.6%
Czech Republic	0.7%	2.1%	4.7%	0%	0.2%	0.6%
Denmark	0.7%	2.1%	4.7%	0%	0.2%	0.6%
Estonia	0.7%	2.1%	4.7%	0%	0.2%	0.6%
Finland	0.7%	2.1%	4.7%	0%	0.2%	0.6%
France	0.7%	2.1%	4.7%	0%	0.2%	0.6%
Germany	0.7%	2.1%	4.7%	0%	0.2%	0.6%
Greece	0.7%	2.1%	4.7%	0%	0.2%	0.6%
Hungary	0.7%	2.1%	4.7%	0%	0.2%	0.6%
Ireland	0.7%	2.1%	4.7%	0%	0.2%	0.6%

Table 4-168: Overall attributable fractions across all industries by Member State (inorganic acid mists)						
Cancer site& scenario	Larynx			Lung		
	C-Low	C-Core	C-High	C-Low	C-Core	C-High
Italy	0.7%	2.1%	4.7%	0%	0.2%	0.6%
Latvia	0.7%	2.1%	4.7%	0%	0.2%	0.6%
Lithuania	0.7%	2.1%	4.7%	0%	0.2%	0.6%
Luxembourg	0.7%	2.1%	4.7%	0%	0.2%	0.6%
Malta	0.7%	2.1%	4.7%	0%	0.2%	0.6%
Netherlands	0.7%	2.1%	4.7%	0%	0.2%	0.6%
Poland	0.7%	2.1%	4.7%	0%	0.2%	0.6%
Portugal	0.7%	2.1%	4.7%	0%	0.2%	0.6%
Romania	0.7%	2.1%	4.7%	0%	0.2%	0.6%
Slovakia	0.7%	2.1%	4.7%	0%	0.2%	0.6%
Slovenia	0.7%	2.1%	4.7%	0%	0.2%	0.6%
Spain	0.7%	2.1%	4.7%	0%	0.2%	0.6%
Sweden	0.7%	2.1%	4.7%	0%	0.2%	0.6%
UK	0.7%	2.1%	4.7%	0%	0.2%	0.6%
EU-28	***0.7%***	***2.1%***	***4.7%***	***0%***	***0.2%***	***0.6%***

4.21 Rubber manufacturing industry

4.21.1Methodology/assumptions

Summary of the relevant cancer endpoints and exposure period(s)

The relevant cancer endpoints and latency periods are (Alder et al (2006)[161], Carreón et al (2014)[162], De Vocht et al (2009)[163], IARC (2016)[164], Mirabelli D et al (2012)[165], IOM (2011)[166], McLean et al (2009)[167], Corbin et al (2008)[168], Stayner L et al (2007)[169], Boniol et al (2016)[170], Rushton et al 2012[171]):

[161] Alder N et al (2006): Meta-Analysis of Mortality and Cancer Incidence among Workers in the Synthetic Rubber-Producing Industry. American Journal of Epidemiology, 164(5), pp 405-420.

[162] Carreón T et al (2014): Bladder cancer incidence among workers exposed to *o*-toluidine, aniline and nitrobenzene at a rubber chemical manufacturing plant. Occup Environ Med, 71(3), pp175-182.

[163] De Vocht F et al (2009): Cancer mortality and occupational exposure to aromatic amines and inhalable aerosols in rubber tire manufacturing in Poland. Cancer Epidemiology 33, 94–102.

[164] IARC (2016): List of classifications by cancer sites with sufficient or limited evidence in humans, available at https://monographs.iarc.fr/ENG/Classification/Table4.pdf

[165] Mirabelli D et al (2012): Cohort study of workers employment in an Italian tire manufacturing plant, 1962-2004. Cancer Causes and Control, 23(12), 2023-2029.

[166] IOM (2011): Health, socio-economic and environmental aspects of possible amendments to the EU Directive on the protection of workers from the risks related to exposure of carcinogens and mutagens at work. Vinyl chloride monomer. Rubber process dusts and fumes.

[167] McLean D et al (2009): Leukaemia and Occupation: a New Zealand Cancer Registry-based Case-control study. International Journal of Epidemiology, 38, pp 594-606.

[168] Corbin M et al (2008): Lung Cancer and Occupation: a New Zealand Cancer Registry-based Case-control study. American Journal of Industrial Medicine, 54(2), pp 89-101.

[169] Stayner L et al (2007): Lung Cancer Risk and Workplace Exposure to Environmental Tobacco Smoke. Am J Public Health, 97(3), 545-551.

[170] Boniol M et al (2016): Cancer mortality in cohorts of workers in the European rubber manufacturing industry first employed since 1975. Annals of Oncology Advance. Access published February 15, 2016.

[171] Rushton et al (2012): Occupational cancer in the UK – overview report, available at http://www.hse.gov.uk/research/rrpdf/rr931.pdf

- Leukaemia, (except Chronic lymphatic leukaemia), 0-20 years, 1996-2015;
- Lymphoma, 0-20 years, 1996-2015;
- Stomach, 10-50 years, 1966-2005;
- Larynx, 10-50 years, 1966-2005;
- Lung, 10-50 years, 1966-2005; and
- Bladder, 10-50 years, 1966-2005.

Only four cancer sites (stomach, lung, leukaemia and bladder) were identified in IARC (2016) as relevant to rubber manufacturing industry. As a result, more cancer sites are covered in this report than those that were identified as relevant in IARC (2016).

Exposed population

Estimates of the occupationally exposed population are available from CAREX for a number of European countries and national registers and studies for France from SUMER (2003 and 2010), for Finland from ASA register (2005 and 2014), for the Czech Republic from Regex register (2009-2016) and for the UK from Rushton et al (2012). These estimates are summarised below.

Table 4-169: Published data –rubber manufacturing industry

Study	Country	Year/period	No. of exposed workers	% of exposed workforce	Notes
Carex	EU15	1990-1993 (mean)	143,150		Manufacture of rubber products
	France	1990-1993 (mean)	50,795		
	Finland	1990-1993 (mean)	302		
	Czech Republic	1997	6,513		
	UK	1990-1993 (mean)	11,262		
SUMER	France	1994	25,000 (23,000 men)	0.2% (0.3% men)	Vulcanisation fumes
		2003	38,300 (35,000 men)	0.2% (0.3% men)	
		2010	16,200 (15,500 men)	0.1% (0.1% men)	
ASA	Finland	2005	53 (52 men and 1 women)	0.2%	
		2014	80 (78 men and 2 women)	0.4%	
Regex	Czech Republic	2009-2016	167		Exposure to *vulcanisation fumes*
Rushton	UK	2004-2005	146,089 Men; 62,237 women		Based on Carex

Extrapolations to the EU-28 are summarised below. No extrapolations have been carried out on the basis of the Regex data for the Czech Republic and the ASA data for Finland; it is assumed that these are outliers.

Table 4-170: Occupationally exposed population in the EU-28 (rubber manufacturing industry)	
Estimate and method of extrapolation	**Exposed population in the EU-28**
A: France 1994 exposed workers extrapolated on the basis of population	204,000
B: France 1994 share (0.2%) applied to EU workforce	366,000
C: France 2003 exposed workers extrapolated on the basis of population	303,000
D: France 2003 share (0.2%) applied to EU workforce	408,000
E: France 2010 exposed workers extrapolated on the basis of population	125,000
F: France 2010 share (0.1%) applied to EU workforce	212,000
G: CAREX early to mid-1990s	206,000
H: Rushton et al ever exposed workers extrapolated on the basis of population (converted to an annual estimate)	120,000

Estimates E and H in the table above have been used for the LOW scenario (assumed 125,000 in 2010) while estimate D is used for the HIGH scenario (408,000 in 2003). The CENTRAL scenario is based on an average of the extrapolations of the SUMER 1994, 2003, 2010 and CAREX data (estimates A, B, C, F and G).

Rate of change

Comparing the number of workers exposed in France in 1994, 2003 and 2010 (SUMER) suggests an annual decrease of around 2.7%. The other estimates in the table above suggest an increase (estimated at around 4.7%). The following scenarios are modelled:

- no change; and
- an annual increase of 4.7%.
- an annual decrease of 2.7%

A generic staff turnover factor of 10% per annum has been used.

Relative risk

The relative risk estimates identified through literature review are summarised below.

Table 4-171: Literature review of relative risk for the rubber manufacturing industry		
Study & summary of data/methodology	**Cancer site**	**Relative risk**
Alder et al (2006). Literature review and meta-analysis	Bladder	SMR: 1.15 (95% CI: 0.94, 1.39)
Carreón et al (2014). Updated cohort study of 1875 workers	Bladder	SIR: 2.87 (95% CI: 2.02-3.96); SIR: 3.90 (95% CI: 2.57 to 5.68) for moderate to high exposure; SIR: SIR=6.13 (95% CI 2.80-11) for highest quartile with 10 year lag
De Vocht et al (2009). Study of cancer mortality in a Polish tyre rubber manufacturing plant	Bladder	RR of 7.32 (95% CI: 1.05-50.98) for exposure to 0.09-1.64 year mg/m^3 of aromatic amines, RR of 8.27 (95% CI: 1.03-66.27) for exposure to 1.64-8.19 year mg/m^3 of aromatic amines

Table 4-171: Literature review of relative risk for the rubber manufacturing industry		
Study & summary of data/methodology	**Cancer site**	**Relative risk**
IARC (2012) Cohort studies: Szeszenia-Dabrowska et al (1991 and 1999). Cohort study of Polish workers Straughan and Sorahan (2000) and Dost et al (2007)	Bladder	SMR 1.3 (0.7,2.1) for mean and 1.4 (0.4-3.5) for women SMR 1.3 (0.3, 0.8) for men and 0 for women SRR 1.3 (0.7-22) for men and 3.1 (0.4-11.1) for women
Mirabelli D et al (2012). Mortality follow-up of a cohort of 9,501 workers	Bladder	SIR:1.15 (95% CI: 0.90, 1.44)
Rushton et al (2012), from Sorahan et al (1989)	Larynx	SMR: 1.19
Alder et al (2006). Literature review and meta-analysis	Leukaemia	SMR: 1.21 (95% CI: 1.03, 1.43)
IARC (2012) Weiland et al (1996 and 1998) and Straif et al (1998). Cohort study of 11,663 male workers	Leukaemia	Overall SMR: 1.5 (95% CI: 1.0, 2.1)
IOM (2011). Rubber process dust and fumes literature review	Leukaemia	1.03 (95% CI: 0.76,1.41) for tyre manufacture; 1.70 (95% CI: 1.14, 2.54) for all other rubber workers
McLean et al (2009). Review of New Zealand Cancer Registry	Leukaemia	OR for rubber and plastics products machine operators of 3.76 (95% CI: 1.08-13.08). IARC (2012) notes for this study that the strongest findings were for plastics rather compared to the rubber-manufacturing industry
Corbin et al (2008). Review of New Zealand Cancer Registry	Lung	OR for rubber and plastics products machine operators of 4.27 (95% CI: 1.16-15.66)
IARC (2012) Cohort studies: Ietri et al (1997). 925 workers employed in 20 factories Wilcysńska et (2001) and de Vocht et al (2009). Study of 17636 workers in a rubber tyre plant Cross-control studies: Jockel et al (1998). 1004 persons in hospital with 13 worked in rubber/plastics Pohlabeln et al (2000). 12 centre study in 7 European countries	Lung	Overall SMR 2.1 Overall SMR 0.7 (95% CI: 0.6, 0.9) RR 2.3 (95% CI: 1.0, 5.0) for men and 2.6 for women 2.9 (95% CI: 1.0, 8.2) for women ever exposed
IOM (2011). Rubber process dust and fumes literature review	Lung	0.95 (95% CI: 0.78,1.15) for tyre manufacture; 1.05 (95% CI: 0.94, 1.18) for all other rubber workers

Table 4-171: Literature review of relative risk for the rubber manufacturing industry		
Study & summary of data/methodology	**Cancer site**	**Relative risk**
Stayner L et al (2007). Meta-analysis from 22 studies worldwide	Lung	1.24 (95% CI: 1.18, 1.29) 2.01 (95% CI: 1.33, 2.60) for highly exposed
Alder et al (2006). Literature review and meta-analysis	Lymphoma	SMR: 1.02 (95% CI: 0.86, 1.21)
Alder et al (2006). Literature review and meta-analysis	Stomach	SMR: 1.00 (95% CI: 0.90, 1.10)
Boniol et al (2016). Study of the general rubber goods industry	Stomach	SMR 1.83 (95% CI: 1.23-2.72)
IARC (2012) Neves et al (2006). 9188 male workers Mundt et al (1999). 2871 female workers in 5 rubber plants Weiland et al (1996, 1998) and Straif et al (1998, 1999 and 2000). 8933 male workers in Germany employed in five rubber plants Wilczyńska et al (2001) and de Vocht et al (2009). Cohort study of 17,636 workers (male and female) in a rubber tyre plant	Stomach	RR 1.0 (large company), 1.2 (0.8, 1.7) in medium size and RR of 3.5 (2.6, 4.7) in a small company. Overall SMR 1.6 (95% CI: 0.6, 3.2) Overall SMR: 1.2 (95% CI: 0.9, 1.6) Overall (men): SMR 0.9 (95% CI: 0.7-1.2)
Sources: Alder N et al (2006): Meta-Analysis of Mortality and Cancer Incidence among Workers in the Synthetic Rubber-Producing Industry. American Journal of Epidemiology, 164(5), pp 405-420. Boniol M et al (2016): Cancer mortality in cohorts of workers in the European rubber manufacturing industry first employed since 1975. Annals of Oncology Advance. Access published February 15, 2016. Carreón T et al (2014): Bladder cancer incidence among workers exposed to *o*-toluidine, aniline and nitrobenzene at a rubber chemical manufacturing plant. Occup Environ Med, 71(3), pp175-182. Corbin M et al (2008): Lung Cancer and Occupation: a New Zealand Cancer Registry-based Case-control study. American Journal of Industrial Medicine, 54(2), pp 89-101. De Vocht F et al (2009): Cancer mortality and occupational exposure to aromatic amines and inhalable aerosols in rubber tire manufacturing in Poland. Cancer Epidemiology 33, 94–102. IARC (2012): Monograph 100F- 36 Occupational Exposures in the Rubber-Manufacturing Industry. Available at http://monographs.iarc.fr/ENG/Monographs/vol100F/mono100F-36.pdf IOM (2011): Health, socio-economic and environmental aspects of possible amendments to the EU Directive on the protection of workers from the risks related to exposure of carcinogens and mutagens at work. Vinyl chloride monomer. Rubber process dusts and fumes. McLean D et al (2009): Leukaemia and Occupation: a New Zealand Cancer Registry-based Case-control study. International Journal of Epidemiology, 38, pp 594-606. Mirabelli D et al (2012): Cohort study of workers employment in an Italian tire manufacturing plant, 1962-2004. Cancer Causes and Control, 23(12), 2023-2029. Rushton L et al (2012): The burden of occupational cancer in Great Britain. Available at http://www.hse.gov.uk/research/rrpdf/rr931.pdf Stayner L et al (2007): Lung Cancer Risk and Workplace Exposure to Environmental Tobacco Smoke. Am J Public Health, 97(3), 545-551.		

The lowest and highest relative risks identified through literature are summarised below.

Table 4-172: Summary of relative risk – rubber manufacturing		
Cancer site	**Lowest**	**Highest**
Bladder	SMR: 1.15 SIR:1.15	RR of 8.27
Leukaemia	1.03	1.70
Lymphoma	SMR: 1.02	SMR: 1.02
Larynx	SMR: 1.19	SMR: 1.19
Stomach	SMR 0.9	RR of 3.5
Lung -males	RR: 1.29	RR: 2.3
Lung -females	RR: 1.15	RR: 2.9

Summary of the scenarios

The assumptions underpinning the different estimates are summarised below. Please note that the estimates of the exposed population are point estimates for a specific year and do not represent the lowest and highest annual estimates over the whole assessment period since these also depend on the annual rate of change.

Table 4-173: Summary of the scenarios (rubber manufacturing industry)				
Aspect/scenario	**Low**	**High**	**Midpoint**	**Central**
Exposed population (EU-28) - point	125,000 (2010)	408,000 (assumed in 2003)	267,000 (assumed in 2007)	260,000 (assumed in 1999)
Relevant cancer sites	Bladder, Leukaemia, Lymphoma, Larynx, Stomach, Lung (2 more than in IARC 2016)	Bladder, Leukaemia, Lymphoma, Larynx, Stomach, Lung (2 more than in IARC 2016)	Bladder, Leukaemia, Lymphoma, Larynx, Stomach, Lung (2 more than in IARC 2016)	Bladder, Leukaemia, Lymphoma, Larynx, Stomach, Lung (2 more than in IARC 2016)
Relative risk	Bladder: SMR=1.15 Leukaemia: 1.03 Lymphoma: SMR=1.02 Larynx: SMR=1.19 Stomach: SMR=1 Lung-males: RR=1.29 Lung females: RR=1.15	Bladder: RR=8.25 Leukaemia: 1.70 Lymphoma: SMR=1.02 Larynx: SMR=1.19 Stomach: RR=3.5 Lung-males: RR=2.3 Lung females: RR=2.9	Bladder: RR=4.7 Leukaemia: 1.37 Lymphoma: SMR=1.02 Larynx: SMR=1.19 Stomach: RR=2.25 Lung-males: RR=1.8 Lung females: RR=1.9	Bladder: SIR=2.87 Leukaemia: SMR=1.5 Lymphoma: SMR=1.02 Larynx: SMR=1.19 Stomach: SMR=1.83 Lung-males: RR=2.3 Lung females: RR=2.9
Change (p.a.)	4.7%	-2.7%	1%	0%

4.21.2The results

Summary of the occupationally exposed population surviving to 2015

The total number of workers in the EU-28 exposed in rubber manufacturing industry between 1966 and 2005 and 1996-2015 and surviving until 2015 is summarised below.

Table 4-174: Occupationally exposed population surviving to 2015 (rubber manufacturing industry)								
Scenario	No. of workers exposed 1966-2005 & surviving to 2015 (million)	% of current & at risk population	No. of workers exposed 1996-2015 & surviving to 2015 (million)	% of current & at risk population	No. of workers exposed 1966-2005 & surviving to 2015 (million) – WOMEN	% of current & at risk population	No. of workers exposed 1966-2005 & surviving to 2015 (million) – MEN	% of current & at risk population
Low	0.2	0.1%	0.4	0.1%	0.02	0.01%	0.21	0.1%
High	1.8	0.5%	1.2	0.3%	0.2	0.1%	1.6	1%
Midpoint	0.9	0.3%	0.8	0.2%	0.07	0.0%	0.9	0.5%
Central	0.9	0.3%	0.75	0.2%	0.07	0.00%	0.9	0.5%

The break-down of these figures by Member State is provided below. The minimum and maximum values across all scenarios are presented for each Member State.

Table 4-175: Occupationally exposed population surviving to 2015 by Member State (rubber manufacturing industry)								
Member State	Number of workers exposed and surviving to 2015 (1966-2005)		% of current & at risk population		Number of workers exposed and surviving to 2015 (1996-2015)		% of current & at risk population	
	Min	Max	Min	Max	Min	Max	Min	Max
Austria	3,849	29,644	0.1%	0.5%	5,879	19,672	0.10%	0.32%
Belgium	5,053	38,915	0.1%	0.5%	7,718	25,824	0.10%	0.32%
Bulgaria	3,233	24,895	0.1%	0.5%	4,937	16,520	0.10%	0.32%
Croatia	1,897	14,605	0.1%	0.5%	2,897	9,692	0.10%	0.32%
Cyprus	380	2,928	0.1%	0.5%	581	1,943	0.10%	0.32%
Czech Republic	4,730	36,426	0.1%	0.5%	7,224	24,172	0.10%	0.32%
Denmark	2,540	19,563	0.1%	0.5%	3,880	12,982	0.10%	0.32%
Estonia	589	4,539	0.1%	0.5%	900	3,012	0.10%	0.32%
Finland	2,456	18,913	0.1%	0.5%	3,751	12,551	0.10%	0.32%
France	29,811	229,566	0.1%	0.5%	45,529	152,340	0.10%	0.32%
Germany	36,446	280,661	0.1%	0.5%	55,663	186,247	0.10%	0.32%
Greece	4,874	37,531	0.1%	0.5%	7,443	24,906	0.10%	0.32%
Hungary	4,424	34,066	0.1%	0.5%	6,756	22,606	0.10%	0.32%
Ireland	2,078	16,000	0.1%	0.5%	3,173	10,618	0.10%	0.32%
Italy	27,288	210,141	0.1%	0.5%	41,677	139,450	0.10%	0.32%
Latvia	891	6,865	0.1%	0.5%	1,362	4,556	0.10%	0.32%
Lithuania	1,311	10,097	0.1%	0.5%	2,003	6,701	0.10%	0.32%
Luxembourg	253	1,946	0.1%	0.5%	386	1,291	0.10%	0.32%

Table 4-175: Occupationally exposed population surviving to 2015 by Member State (rubber manufacturing industry)								
Member State	Number of workers exposed and surviving to 2015 (1966-2005)		% of current & at risk population		Number of workers exposed and surviving to 2015 (1996-2015)		% of current & at risk population	
	Min	Max	Min	Max	Min	Max	Min	Max
Malta	193	1,484	0.1%	0.5%	294	985	0.10%	0.32%
Netherlands	7,586	58,418	0.1%	0.5%	11,586	38,766	0.10%	0.32%
Poland	17,059	131,367	0.1%	0.5%	26,054	87,175	0.10%	0.32%
Portugal	4,657	35,861	0.1%	0.5%	7,112	23,797	0.10%	0.32%
Romania	8,919	68,683	0.1%	0.5%	13,622	45,578	0.10%	0.32%
Slovakia	2,433	18,739	0.1%	0.5%	3,716	12,435	0.10%	0.32%
Slovenia	926	7,130	0.1%	0.5%	1,414	4,732	0.10%	0.32%
Spain	20,849	160,554	0.1%	0.5%	31,842	106,544	0.10%	0.32%
Sweden	4,375	33,692	0.1%	0.5%	6,682	22,358	0.10%	0.32%
UK	29,119	224,243	0.1%	0.5%	44,473	148,807	0.10%	0.32%
Total	*228,220*	*1,757,472*	*0.1%*	*0.5%*	*348,555*	*1,166,259*	*0.10%*	*0.32%*

Table 4-176: Occupationally exposed population surviving to 2015 by Member State (rubber manufacturing industry)								
Member State	Number of workers exposed and surviving to 2015 (1966-2005) - WOMEN		% of current & at risk population - WOMEN		Number of workers exposed and surviving to 2015 (1966-2005) - MEN		% of current & at risk population - MEN	
	Min	Max	Min	Max	Min	Max	Min	Max
Austria	308	2,372	0.01%	0.09%	3,542	27,273	0.13%	1.03%
Belgium	404	3,113	0.01%	0.09%	4,649	35,802	0.13%	1.03%
Bulgaria	259	1,992	0.01%	0.09%	2,974	22,903	0.13%	1.03%
Croatia	152	1,168	0.01%	0.09%	1,745	13,437	0.13%	1.03%
Cyprus	30	234	0.01%	0.09%	350	2,693	0.13%	1.03%
Czech Republic	378	2,914	0.01%	0.09%	4,352	33,512	0.13%	1.03%
Denmark	203	1,565	0.01%	0.09%	2,337	17,998	0.13%	1.03%
Estonia	47	363	0.01%	0.09%	542	4,176	0.13%	1.03%
Finland	196	1,513	0.01%	0.09%	2,260	17,400	0.13%	1.03%
France	2,385	18,365	0.01%	0.09%	27,426	211,200	0.13%	1.03%
Germany	2,916	22,453	0.01%	0.09%	33,530	258,208	0.13%	1.03%
Greece	390	3,002	0.01%	0.09%	4,484	34,529	0.13%	1.03%
Hungary	354	2,725	0.01%	0.09%	4,070	31,341	0.13%	1.03%
Ireland	166	1,280	0.01%	0.09%	1,912	14,720	0.13%	1.03%
Italy	2,183	16,811	0.01%	0.09%	25,105	193,330	0.13%	1.03%
Latvia	71	549	0.01%	0.09%	820	6,316	0.13%	1.03%
Lithuania	105	808	0.01%	0.09%	1,206	9,290	0.13%	1.03%
Luxembourg	20	156	0.01%	0.09%	232	1,790	0.13%	1.03%
Malta	15	119	0.01%	0.09%	177	1,365	0.13%	1.03%
Netherlands	607	4,673	0.01%	0.09%	6,979	53,744	0.13%	1.03%
Poland	1,365	10,509	0.01%	0.09%	15,694	120,858	0.13%	1.03%
Portugal	373	2,869	0.01%	0.09%	4,284	32,992	0.13%	1.03%
Romania	714	5,495	0.01%	0.09%	8,205	63,189	0.13%	1.03%
Slovakia	195	1,499	0.01%	0.09%	2,239	17,240	0.13%	1.03%
Slovenia	74	570	0.01%	0.09%	852	6,560	0.13%	1.03%

Table 4-176: Occupationally exposed population surviving to 2015 by Member State (rubber manufacturing industry)								
Member State	Number of workers exposed and surviving to 2015 (1966-2005) - WOMEN		% of current & at risk population - WOMEN		Number of workers exposed and surviving to 2015 (1966-2005) - MEN		% of current & at risk population - MEN	
	Min	Max	Min	Max	Min	Max	Min	Max
Spain	1,668	12,844	0.01%	0.09%	19,181	147,710	0.13%	1.03%
Sweden	350	2,695	0.01%	0.09%	4,025	30,997	0.13%	1.03%
UK	2,330	17,939	0.01%	0.09%	26,790	206,303	0.13%	1.03%
Total	***18,258***	***140,598***	***0.01%***	***0.09%***	***209,963***	***1,616,874***	***0.13%***	***1.03%***

AFs per Member State

Table 4-177: Attributable fractions by Member State (rubber manufacturing industry)												
Cancer site/ scenario	Bladder			Leukaemia			Lymphoma			Larynx		
	C-Low	C-Core	C-High	C-Low	C-Core	C-High	C-Low	C-Core	C-High	C-Low	C-Core	C-High
Austria	0.3%	0.5%	0.8%	0%	0.1%	0.2%	0%	0%	0.04%	0%	0.1%	0.2%
Belgium	0.3%	0.5%	0.8%	0%	0.1%	0.2%	0%	0%	0.04%	0%	0.1%	0.2%
Bulgaria	0.3%	0.5%	0.8%	0%	0.1%	0.2%	0%	0%	0.04%	0%	0.1%	0.2%
Croatia	0.3%	0.5%	0.8%	0%	0.1%	0.2%	0%	0%	0.04%	0%	0.1%	0.2%
Cyprus	0.3%	0.5%	0.8%	0%	0.1%	0.2%	0%	0%	0.04%	0%	0.1%	0.2%
Czech Republic	0.3%	0.5%	0.8%	0%	0.1%	0.2%	0%	0%	0.04%	0%	0.1%	0.2%
Denmark	0.3%	0.5%	0.8%	0%	0.1%	0.2%	0%	0%	0.04%	0%	0.1%	0.2%
Estonia	0.3%	0.5%	0.8%	0%	0.1%	0.2%	0%	0%	0.04%	0%	0.1%	0.2%
Finland	0.3%	0.5%	0.8%	0%	0.1%	0.2%	0%	0%	0.04%	0%	0.1%	0.2%
France	0.3%	0.5%	0.8%	0%	0.1%	0.2%	0%	0%	0.04%	0%	0.1%	0.2%
Germany	0.3%	0.5%	0.8%	0%	0.1%	0.2%	0%	0%	0.04%	0%	0.1%	0.2%
Greece	0.3%	0.5%	0.8%	0%	0.1%	0.2%	0%	0%	0.04%	0%	0.1%	0.2%
Hungary	0.3%	0.5%	0.8%	0%	0.1%	0.2%	0%	0%	0.04%	0%	0.1%	0.2%
Ireland	0.3%	0.5%	0.8%	0%	0.1%	0.2%	0%	0%	0.04%	0%	0.1%	0.2%
Italy	0.3%	0.5%	0.8%	0%	0.1%	0.2%	0%	0%	0.04%	0%	0.1%	0.2%
Latvia	0.3%	0.5%	0.8%	0%	0.1%	0.2%	0%	0%	0.04%	0%	0.1%	0.2%
Lithuania	0.3%	0.5%	0.8%	0%	0.1%	0.2%	0%	0%	0.04%	0%	0.1%	0.2%
Luxembourg	0.3%	0.5%	0.8%	0%	0.1%	0.2%	0%	0%	0.04%	0%	0.1%	0.2%
Malta	0.3%	0.5%	0.8%	0%	0.1%	0.2%	0%	0%	0.04%	0%	0.1%	0.2%
Netherlands	0.3%	0.5%	0.8%	0%	0.1%	0.2%	0%	0%	0.04%	0%	0.1%	0.2%
Poland	0.3%	0.5%	0.8%	0%	0.1%	0.2%	0%	0%	0.04%	0%	0.1%	0.2%
Portugal	0.3%	0.5%	0.8%	0%	0.1%	0.2%	0%	0%	0.04%	0%	0.1%	0.2%
Romania	0.3%	0.5%	0.8%	0%	0.1%	0.2%	0%	0%	0.04%	0%	0.1%	0.2%
Slovakia	0.3%	0.5%	0.8%	0%	0.1%	0.2%	0%	0%	0.04%	0%	0.1%	0.2%
Slovenia	0.3%	0.5%	0.8%	0%	0.1%	0.2%	0%	0%	0.04%	0%	0.1%	0.2%
Spain	0.3%	0.5%	0.8%	0%	0.1%	0.2%	0%	0%	0.04%	0%	0.1%	0.2%
Sweden	0.3%	0.5%	0.8%	0%	0.1%	0.2%	0%	0%	0.04%	0%	0.1%	0.2%
UK	0.3%	0.5%	0.8%	0%	0.1%	0.2%	0%	0%	0.04%	0%	0.1%	0.2%
EU-28	***0.3%***	***0.5%***	***0.8%***	***0%***	***0.1%***	***0.2%***	***0%***	***0%***	***0.04%***	***0%***	***0.1%***	***0.2%***

Table 4-178: Attributable fractions by Member State (rubber manufacturing industry) continued									
Cancer site/ scenario	Stomach			Lung - men			Lung - women		
	C-Low	C-Core	C-High	C-Low	C-Core	C-High	C-Low	C-Core	C-High
Austria	0.1%	0.2%	0.5%	0%	0.1%	0.3%	0%	0.7%	2.1%
Belgium	0.1%	0.2%	0.5%	0%	0.1%	0.3%	0%	0.7%	2.1%
Bulgaria	0.1%	0.2%	0.5%	0%	0.1%	0.3%	0%	0.7%	2.1%
Croatia	0.1%	0.2%	0.5%	0%	0.1%	0.3%	0%	0.7%	2.1%
Cyprus	0.1%	0.2%	0.5%	0%	0.1%	0.3%	0%	0.7%	2.1%
Czech Republic	0.1%	0.2%	0.5%	0%	0.1%	0.3%	0%	0.7%	2.1%
Denmark	0.1%	0.2%	0.5%	0%	0.1%	0.3%	0%	0.7%	2.1%
Estonia	0.1%	0.2%	0.5%	0%	0.1%	0.3%	0%	0.7%	2.1%
Finland	0.1%	0.2%	0.5%	0%	0.1%	0.3%	0%	0.7%	2.1%
France	0.1%	0.2%	0.5%	0%	0.1%	0.3%	0%	0.7%	2.1%
Germany	0.1%	0.2%	0.5%	0%	0.1%	0.3%	0%	0.7%	2.1%
Greece	0.1%	0.2%	0.5%	0%	0.1%	0.3%	0%	0.7%	2.1%
Hungary	0.1%	0.2%	0.5%	0%	0.1%	0.3%	0%	0.7%	2.1%
Ireland	0.1%	0.2%	0.5%	0%	0.1%	0.3%	0%	0.7%	2.1%
Italy	0.1%	0.2%	0.5%	0%	0.1%	0.3%	0%	0.7%	2.1%
Latvia	0.1%	0.2%	0.5%	0%	0.1%	0.3%	0%	0.7%	2.1%
Lithuania	0.1%	0.2%	0.5%	0%	0.1%	0.3%	0%	0.7%	2.1%
Luxembourg	0.1%	0.2%	0.5%	0%	0.1%	0.3%	0%	0.7%	2.1%
Malta	0.1%	0.2%	0.5%	0%	0.1%	0.3%	0%	0.7%	2.1%
Netherlands	0.1%	0.2%	0.5%	0%	0.1%	0.3%	0%	0.7%	2.1%
Poland	0.1%	0.2%	0.5%	0%	0.1%	0.3%	0%	0.7%	2.1%
Portugal	0.1%	0.2%	0.5%	0%	0.1%	0.3%	0%	0.7%	2.1%
Romania	0.1%	0.2%	0.5%	0%	0.1%	0.3%	0%	0.7%	2.1%
Slovakia	0.1%	0.2%	0.5%	0%	0.1%	0.3%	0%	0.7%	2.1%
Slovenia	0.1%	0.2%	0.5%	0%	0.1%	0.3%	0%	0.7%	2.1%
Spain	0.1%	0.2%	0.5%	0%	0.1%	0.3%	0%	0.7%	2.1%
Sweden	0.1%	0.2%	0.5%	0%	0.1%	0.3%	0%	0.7%	2.1%
UK	0.1%	0.2%	0.5%	0%	0.1%	0.3%	0%	0.7%	2.1%
EU-28	***0.1%***	***0.2%***	***0.5%***	***0%***	***0.1%***	***0.3%***	***0%***	***0.7%***	***2.1%***

4.22 Ionising radiation

4.22.1Methodology/assumptions

Summary of the relevant cancer endpoints and exposure period(s)

The relevant cancer endpoints and reference periods for which AFs have been calculated in this study are (IARC (2016)[172], Mohner et al (2010)[173], Lie et al (2008)[174], Buja et al (2006)[175], Rajaraman

[172] IARC (2016): List of classifications by cancer sites with sufficient or limited evidence in humans, available at https://monographs.iarc.fr/ENG/Classification/Table4.pdf

[173] Mohner et al (2010): Leukaemia and exposure to ionizing radiation among German uranium miners. 2006 Apr;49(4):238–248, abstract available at http://journals.lww.com/healthphysics/Abstract/2010/09000/Occupational_and_Diagnostic_Exposure_to_Ionizing.6.aspx

[174] Lie et al (2008): Ionizing radiation exposure and cancer risk among Norwegian nurses. Eur J Cancer Prev. 2008 Aug;17(4):369-75, abstract available at https://www.ncbi.nlm.nih.gov/pubmed/18562964

et al (2006)[176], Zielinski et al (2005)[177], Blettner et al (2003)[178], Zeeb et al (2002)[179], Sont et al (2001)[180], Ritz (1999)[181], Wingren et al (1997)[182], Wiggs et al (1994)[183], Wang et al (1990)[184] and Rushton et al 2012[185]):

- Bone, 0-20 years, 1996-2015
- Bladder, 10-50 years, 1966-2005
- Breast, 10-50 years, 1966-2005
- Brain, 10-50 years, 1966-2005
- Malignant melanoma, 10-50 years, 1966-2005
- Leukaemia (except Chronic lymphatic leukaemia), 0-20 years, 1996-2015
- Liver, 10-50 years, 1966-2005
- Lung (men and women), 10-50 years, 1966-2005
- Thyroid, 10-50 years, 1966-2005

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[175] Buja et al (2006): Cancer incidence among female flight attendants: a meta-analysis of published data. J Womens Health (Larchmt). 2006 Jan-Feb;15(1):98-105, abstract available at https://www.ncbi.nlm.nih.gov/pubmed/16417424

[176] Rajaraman et al (2006): Lung cancer risk among US radiologic technologists, 1983–1998. Int. J. Cancer 2006; 119,2481–2486, available at http://onlinelibrary.wiley.com/doi/10.1002/ijc.22148/full

[177] Zielinski et al (2005): Decreases in occupational exposure to ionizing radiation among Canadian dental workers. J Can Dent Assoc. 2005 Jan;71(1):29-33, available at https://www.researchgate.net/publication/8082738_Decreases_in_occupational_exposure_to_ionizing_radiation_among_Canadian_dental_workers

[178] Blettner et al (2003): Mortality from cancer and other causes among male airline cockpit crew in Europe. 2003 Jun;106(6)942-956, available at http://onlinelibrary.wiley.com/doi/10.1002/ijc.11328/pdf

[179] Zeeb et al (2002): Cohort mortality study of German cockpit crew, 1960-1997. Epidemiology. 2002 Nov;13(6):693-9, available at https://www.researchgate.net/publication/11054851_Cohort_Mortality_Study_of_German_Cockpit_Crew_1960-1997

[180] Sont et al (2001): First Analysis of Cancer Incidence and Occupational Radiation Exposure Based on the National Dose Registry of Canada. Am J Epidemiol 2001;153(4):309-318, available at https://academic.oup.com/aje/article/153/4/309/129004/First-Analysis-of-Cancer-Incidence-and#987950

[181] Ritz (1999): Radiation exposure and cancer mortality in uranium processing workers. Epidemiology. 1999 Sep;10(5):531-8, abstract available at https://www.ncbi.nlm.nih.gov/pubmed/10468427

[182] Wingren et al (1997) Diagnostic X-ray exposure and female papillary thyroid cancer: a pooled analysis of two Swedish studies, Eur J Cancer Prev. 1997 Dec;6(6):550-6, abstract available at http://journals.lww.com/eurjcancerprev/Abstract/1997/12000/Diagnostic_X_ray_exposure_and_female_papillary.10.aspx

[183] Wiggs et al (1994): Mortality through 1990 among white male workers at the Los Alamos National Laboratory: considering exposures to plutonium and external ionizing radiation. Health Physics. 1994; 67(6):577-588, abstract available at http://europepmc.org/abstract/med/7960779

[184] Wang et al (1990): Cancer incidence among medical diagnostic X-ray workers in China, 1950 to 1985. International journal of cancer. 1990 May; 45(5):889–895, available at http://onlinelibrary.wiley.com/doi/10.1002/ijc.2910450519/full

[185] Rushton et al (2012): Occupational cancer in the UK – overview report, available at http://www.hse.gov.uk/research/rrpdf/rr931.pdf

Referring specifically to X-radiation and/or gamma-radiation and/or radioiodines[186] (including iodine-131), IARC (2016)[187] has identified the following cancer sites:

- Salivary gland (X-radiation, gamma-radiation, radioiodines including iodine-131);
- Oesophagus (X-radiation, gamma-radiation);
- Stomach (X-radiation, gamma-radiation);
- Colon and rectum (X-radiation, gamma-radiation);
- Liver and bile duct (X-radiation, gamma-radiation);
- Pancreas (X-radiation, gamma-radiation);
- Lung (X-radiation, gamma-radiation);
- Bone (X-radiation, gamma-radiation, radioiodines including iodine-131);
- Skin (other malignant neoplasms) (X-radiation, gamma-radiation);
- Breast (X-radiation, gamma-radiation);
- Ovary (X-radiation, gamma-radiation);
- Prostate (X-radiation, gamma-radiation);
- Kidney (X-radiation, gamma-radiation);
- Urinary bladder (X-radiation, gamma-radiation);
- Brain and central nervous system (X-radiation, gamma-radiation);
- Thyroid (radioiodines including iodine-131, X-radiation, gamma-radiation);
- Leukaemia and/or lymphoma (X-radiation, gamma-radiation, radioiodines including iodine-131);
- Multiple sites (unspecified) (X-radiation, gamma-radiation – exposure in utero)
- Digestive tract (unspecified) (radioiodines including iodine-131);
- Soft tissue (radioiodines including iodine-131);

This study has therefore calculated AFs only for nine of the 20 cancer sites (45%) identified as relevant in IARC (2016).

Exposed population

Estimates of the occupationally exposed population are available from the CAREX database and from national sources from the following sources: for France from Metz Flament et al (2013) and Richardson et al (2015) for Finland from FinJem (2006); for Romania from the Ministerului Sănătăţii şi Familiei database (2006) and for the UK from Rushton et al (2012). These estimates are summarised below.

[186] Also see https://www.ncbi.nlm.nih.gov/pubmed/24502125

[187] IARC (2016): List of classifications by cancer sites with sufficient or limited evidence in humans, available at https://monographs.iarc.fr/ENG/Classification/Table4.pdf

Table 4-179: Published data – workforce exposed to ionising radiation					
Study	**Country**	**Year/period**	**No. of exposed workers**	**% of exposed workforce**	**Notes**
Carex	EU15	1990-1993 (mean)	162,235		
	France	1990-1993 (mean)	22,114		
	Finland	1990-1993 (mean)	4,060		
	UK	1990-1993 (mean)	37,717		
FinJem	Finland	2006	13,300		Nuclear power plants, health care and aviation
Ministerului Sănătăţii şi Familiei	Romania	2006	7,339		
Rushton	UK	Published in 2004-2005, refers to ever exposed workers	291,455 (252,035 men; 39,420 women)		Based on Carex

Extrapolations to the EU-28 are summarised below.

Table 4-180: Occupationally exposed population in the EU-28 (Ionising radiation)	
Estimate and method of extrapolation	**Exposed population in the EU-28**
A: CAREX early to mid-1990s	220,000
B: Finland 2006 exposed workers extrapolated on the basis of population	1.3 million
C: Romania 2006 exposed workers extrapolated on the basis of population	170,000
D: Rushton ever exposed workers extrapolated on the basis of population	460,000

Estimate C in the table above (approx. 170,000 in 2006) forms the basis for the LOW scenario while estimate B is used for the HIGH scenario (1.3 million in 2006). The CENTRAL scenario is based on the extrapolation of Rushton data (estimate D).

In addition, cohort studies have been carried out for France and the UK (Metz Flament et al, 2013[188] and Richardson et al, 2015)[189] with the size of the cohorts in the nuclear industry. The size of the cohorts suggests a past EU exposed population in the region of the low hundreds of thousands.

Rate of change

None of the sources of data provides estimates of the changes in exposed populations over time. The following generic scenarios are therefore modelled:

[188] Metz-Flament et al (2013): Mortality associated with chronic external radiation exposure in the French combined cohort of nuclear workers, available at https://www.ncbi.nlm.nih.gov/pubmed/23716722

[189] Richardson et al (2015): Risk of cancer from occupational exposure to ionising radiation: retrospective cohort study of workers in France, the United Kingdom, and the United States (INWORKS), available at http://www.bmj.com/content/351/bmj.h5359v

- no change;
- an annual decrease of 3%.

A generic staff turnover factor of 10% per annum has been used.

Relative risk

The relative risk estimates identified through literature review are summarised below.

Table 4-181: Literature review of relative risk for ionising radiation

Study & summary of data/methodology	Cancer site	Relative risk
Mohner et al (2010) Case-control study of former uranium miners in East Germany with 377 cases and 980 controls	Leukaemia	Ignoring diagnostic exposure, for the highest dose category (absorbed dose lagged by 20 y) OR = 2.64 (90% CI 1.60-4.35)
Hammer et al (2009) Systematic review of the epidemiological literature on health of aircrew members since 1990, focusing on cancer. 65 relevant publications were reviewed	Multiple sites	Ionising radiation is considered to contribute little if at all to the elevated risks for cancers among aircrew
Lie et al (2008) A cohort of 43 316 nurses who graduated between 1914 and 1984, and were registered by the Norwegian Board of Health's registry of nurses, was followed up from 1953 through 2002 by linkage to the Norwegian Cancer Registry	Breast, thyroid, ovary, leukaemia, malignant melanoma or other skin cancer	No firm evidence that nurses potentially exposed to ionizing radiation had increased risk of radiation-related cancer was found
Band et al (2006) A cohort of 2,740 Air Canada pilots who contributed 62,449 person-years of observation.	A range of cancers studied	Significantly decreased cancer incidence was observed for all cancers SIR=0.71 (90% CI 0.61-0.82), lung cancer SIR=0.28 (90% CI 0.16-0.46), and bladder cancer (SIR = 0.36, 90% CI 0.12-0.82)
Buja et al (2006) 7 published studies reporting standardized incidence ratio (SIR) for cancer among female flight attendants were obtained from online databases and analysed.	Melanoma and breast cancer	Meta-analysis showed a significant excess of melanoma meta-SIR= 2.15 (95% posterior interval [PI] 1.56-2.88) and breast carcinoma meta-SIR=1.40 (PI 1.19-1.65) and a slight but not significant excess of cancer incidence across types meta-SIR=1.11 (PI 0.98-1.25)
Jartti et al (2006) A cohort of 1312 physicians was identified from the Finnish occupational radiation exposure registry. Radiation exposure data were obtained from 1970 to 2001 on the basis of individual dosimeters.	41 cancers studied, specific cancers not identified in study	According to the results from a nationwide cohort, occupational exposure to medical radiation is not a strong risk factor for cancer among physicians
Rajaraman et al (2006) Lung cancer risk among 71,894 US radiologic technologists who were certified during 1926–1982	Lung cancer	Limited evidence that chronic low-to-moderate dose occupational exposure increased lung cancer risk in the US Radiologic Technologist cohort
Zielinski et al (2005) The National Dose Registry (NDR) of Canada was used to assess occupational dose of ionizing radiation received by dental workers. The NDR cohort includes 42,175 people classified as dental workers.	29 types of cancer including bone, leukaemia, liver, lung and thyroid	Dental workers receive very low doses of ionizing radiation, and these doses do not appear to be associated with any increase in cancer incidence

Table 4-181: Literature review of relative risk for ionising radiation		
Study & summary of data/methodology	**Cancer site**	**Relative risk**
Blettner et al (2003) Cockpit crew cohorts were identified and followed-up in Denmark, Finland, Germany, Great Britain, Greece, Iceland, Italy, Norway and Sweden including 28,000 persons	Malignant melanoma and lung cancer	Increased malignant melanoma SMR=1.78 (95% CI 1.15-2.67) and a reduced mortality from lung cancer SMR=0.53 (95% CI 0.44-0.62)
Zeeb et al (2002) All pilots and other cockpit personnel of two German airlines were traced through registries and other sources for the period 1960-1997	Brain and other types of cancer	Most cancer and cardiovascular SMRs were reduced. A slight increase was seen for brain cancer SMR = 1.68 (CI = 0.66-3.62)
Sont et al (2001) A cohort study to investigate the relation between cancer incidence and occupational exposure to ionizing radiation, Canadian National Dose Registry cohort, 1969–1988	Liver, lung, bone, stomach, colon, rectum, bladder, thyroid and other sites	SIRs for males and females combined, bone SIR=0.7 (90% CI 0.44-1.06), leukaemia SIR=0.72 (90% CI 0.60-0.85), liver SIR=1.00 (90% CI 0.70-1.39), lung SIR=0.66 (90% CI 0.61-0.72), thyroid SIR=1.39 (90% CI 1.20-1.61)
Ritz (1999) A study of 4,014 uranium-processing workers	Lung cancer	Lung cancer RR=2.77 (95% CI 1.29-5.95)
Rushton L et al (2012)	Bone Leukaemia (except chronic lymphatic leukaemia) Liver Lung Thyroid	RR=1.03 RR=1.03 RR=1.01 Males RR=1.005 Females RR=1.021 RR=1.09
Wingren et al (1997) A pooled analysis of two Swedish case-controlled studies	Thyroid cancer	For all occupational exposure to X-rays OR=2.1 (95% CI 1.0-4.4)
Wiggs et al (1994) A cohort mortality study was conducted of 15,727 white men employed by the Los Alamos National Laboratory, a nuclear research and development facility	Lung cancer	No cause of death was significantly elevated among plutonium-exposed workers when compared with their unexposed co-workers; however, a rate ratio for lung cancer of 1.78 (95% CI = 0.79-3.99) was observed.
Wang et al (1990) A second follow-up of 27,011 diagnostic X-ray workers in China	Leukaemia, liver, thyroid and bone cancer	Significantly elevated risks were seen for leukaemia (RR = 2.4, n = 34 cases), liver (RR = 1.8, n = 65), thyroid (RR = 1.7, n = 8), and bone (RR = 7.6, n = 4)
Leuraud et al (2015)	Leukaemia	ERR of mortality per Gy of 2.96 (90% CI: 1.17 to 5.21)

Sources:
Band et al (1996): Cohort study of Air Canada pilots: mortality, cancer incidence, and leukaemia risk. Am J Epidemiol. 1996 Jan 15;143(2):137-43, available at www.aje.oxfordjournals.org/content/143/2/137.full.pdf
Buja et al (2006): Cancer incidence among female flight attendants: a meta-analysis of published data. J Womens Health (Larchmt). 2006 Jan-Feb;15(1):98-105, abstract available at https://www.ncbi.nlm.nih.gov/pubmed/16417424
Blettner et al (2003): Mortality from cancer and other causes among male airline cockpit crew in Europe. 2003 Jun;106(6)942-956, available at http://onlinelibrary.wiley.com/doi/10.1002/ijc.11328/pdf
Hammer et al (2009): Epidemiological studies of cancer in aircrew. Radiat Prot Dosimetry 2009;136 (4):232-239, abstract available at http://rpd.oxfordjournals.org/content/136/4/232.abstract

Table 4-181: Literature review of relative risk for ionising radiation		
Study & summary of data/methodology	**Cancer site**	**Relative risk**
Jartti et al (2006): Cancer incidence among physicians occupationally exposed to ionizing radiation in Finland. Scand J Work Environ Health 2006;32(5):368-373, available at, http://www.sjweh.fi/show_abstract.php?abstract_id=1032 Lie et al (2008): Ionizing radiation exposure and cancer risk among Norwegian nurses. Eur J Cancer Prev. 2008 Aug;17(4):369-75, abstract available at https://www.ncbi.nlm.nih.gov/pubmed/18562964 Leuraud et al (2015): Ionising radiation and risk of death from leukaemia and lymphoma in radiation-monitored workers (INWORKS): an international cohort study, available at http://thelancet.com/journals/lanhae/article/PIIS2352-3026(15)00094-0/abstract Mohner et al (2010): Leukaemia and exposure to ionizing radiation among German uranium miners. 2006 Apr;49(4):238–248, abstract available at http://journals.lww.com/healthphysics/Abstract/2010/09000/Occupational_and_Diagnostic_Exposure_to_Ionizing.6.aspx Rajaraman et al (2006): Lung cancer risk among US radiologic technologists, 1983–1998. Int. J. Cancer 2006; 119,2481–2486, available at http://onlinelibrary.wiley.com/doi/10.1002/ijc.22148/full Ritz (1999): Radiation exposure and cancer mortality in uranium processing workers. Epidemiology. 1999 Sep;10(5):531-8, abstract available at https://www.ncbi.nlm.nih.gov/pubmed/10468427 Sont et al (2001): First Analysis of Cancer Incidence and Occupational Radiation Exposure Based on the National Dose Registry of Canada. Am J Epidemiol 2001;153(4):309-318, available at https://academic.oup.com/aje/article/153/4/309/129004/First-Analysis-of-Cancer-Incidence-and#987950 Wang et al (1990): Cancer incidence among medical diagnostic X-ray workers in China, 1950 to 1985. International journal of cancer. 1990 May; 45(5):889–895, available at http://onlinelibrary.wiley.com/doi/10.1002/ijc.2910450519/full Wiggs et al (1994): Mortality through 1990 among white male workers at the Los Alamos National Laboratory: considering exposures to plutonium and external ionizing radiation. Health Physics. 1994; 67(6):577-588, abstract available at http://europepmc.org/abstract/med/7960779 Wingren et al (1997) Diagnostic X-ray exposure and female papillary thyroid cancer: a pooled analysis of two Swedish studies, Eur J Cancer Prev. 1997 Dec;6(6):550-6, abstract available at http://journals.lww.com/eurjcancerprev/Abstract/1997/12000/Diagnostic_X_ray_exposure_and_female_papillary.10.aspx Zeeb et al (2002): Cohort mortality study of German cockpit crew, 1960-1997. Epidemiology. 2002 Nov;13(6):693-9, available at https://www.researchgate.net/publication/11054851_Cohort_Mortality_Study_of_German_Cockpit_Crew_1960-1997 Zielinski et al (2005): Decreases in occupational exposure to ionizing radiation among Canadian dental workers. J Can Dent Assoc. 2005 Jan;71(1):29-33, available at https://www.researchgate.net/publication/8082738_Decreases_in_occupational_exposure_to_ionizing_radiation_among_Canadian_dental_workers		

The lowest and highest relative risks identified through literature are summarised below.

Table 4-182: Summary of relative risk – exposure to ionising radiation		
Cancer site	**Lowest**	**Highest**
Bone	RR: 1.03	RR: 7.6
Bladder	SIR: 1	SIR: 1
Breast	SIR: 1.40	SIR: 1.40
Brain	SIR: 1.68	SIR: 1.68
Malignant melanoma	SMR: 1.78	SMR: 1.78
Leukaemia	SIR: 1	RR: 2.4
Liver	SIR: 1	RR: 1.8
Lung	SIR: 1	RR: 1.78
Thyroid	SIR: 1.39	OR: 2.1

Summary of the scenarios

The assumptions underpinning the different estimates are summarised below. Please note that the estimates of the exposed population are point estimates for a specific year and do not represent the lowest and highest annual estimates over the whole assessment period since these also depend on the annual rate of change.

The Excess Relative Risk (ERR) in Leuraud et al (2015) for leukaemia excluding chronic lyphocyclic leukaemia (ERR of mortality per Gy of 2.96, 90% CI: 1.17 to 5.21), together with estimates of exposure doses in the nuclear and medical fields[190], have been used to estimate the relative risk of mortality for leukaemia: *=1.11 (90%CI: 1.04-1.18), i.e. average of *nuclear=1.05 (90% CI: 1.02-1.08) and *medical= 1.16 (90% CI: 1.06-1.28).

Table 4-183: Summary of the scenarios (ionising radiation)				
Aspect/scenario	**Low**	**High**	**Midpoint**	**Central**
Exposed population (EU-28) - point	170,000 (2006)	1.3 million (2006)	720,000 (assumed in 2006)	460,000 (assumed in 1994)
Relevant cancer sites	Bone Bladder Breast Brain Malignant melanoma Leukaemia Liver Lung Thyroid (9 of 20 in IARC 2016)	Bone Bladder Breast Brain Malignant melanoma Leukaemia Liver Lung Thyroid (9 of 20 in IARC 2016)	Bone Bladder Breast Brain Malignant melanoma Leukaemia Liver Lung Thyroid (9 of 20 in IARC 2016)	Bone Bladder Breast Brain Malignant Melanoma Leukaemia Liver Lung Thyroid (9 of 20 in IARC 2016)
Relative risk	Bone: RR=1.03 Bladder: SIR=1 Breast: SIR=1.4 Brain: SIR=1.68 Malignant melanoma:	Bone: RR=7.6 Bladder: SIR=1 Breast: SIR=1.4 Brain: SIR=1.68 Malignant melanoma:	Bone: RR=4.3 Bladder: SIR=1 Breast: SIR=1.4 Brain: SIR=1.68 Malignant melanoma:	Bone: RR=1.03 Bladder: SIR=1 Breast: SIR=1.4 Brain: SIR=1.68 Malignant melanoma:

[190] The mean cumulative exposure in the nuclear industry is said to be 16 mGy. In the medical field, the average yearly dose was 0.5 mGy in 1982 and 3 mGy in 2006.

Table 4-183: Summary of the scenarios (ionising radiation)				
Aspect/scenario	Low	High	Midpoint	Central
	SMR=1.78 Leukaemia: SIR=1 Liver: SIR =1 Lung: SIR=1 Thyroid: SIR=1.39	SMR=1.78 Leukaemia: RR=2.4 Liver: RR=1.8 Lung: RR=2.77 Thyroid: OR=2.1	SMR=1.78 Leukaemia: RR=1.7 Liver: RR=1.4 Lung: RR=1.88 Thyroid: OR=1.75	SIR=2.15 Leukaemia: *=1.11 Liver: RR=1.01 Lung - Men: RR=1.05 Lung - Women: RR=1.021 Thyroid: RR=1.09
Change (p.a.)	0%	-3%	-1.5%	-3%

4.22.2The results

Summary of the exposed population

The total number of workers in the EU-28 exposed to ionising radiation between 1966 and 2005 and 1996-2005 and surviving until 2015 is summarised below.

Table 4-184: Occupationally exposed population surviving to 2015 (ionising radiation)								
Scenario	No. of workers exposed 1966-2005 & surviving to 2015 (million)	% of current & at risk population	No. of workers exposed 1996-2015 & surviving to 2015 (million)	% of current & at risk population	No. of workers exposed 1966-2005 & surviving to 2015 (million) – WOMEN	% of current & at risk female population	No. of workers exposed 1966-2005 & surviving to 2015 (million) – MEN	% of current & at risk male population
Low	0.6	0.2%	0.5	0.1%	0.1	0.05%	0.5	0.3%
High	6.3	2.0%	4.0	1.1%	0.9	0.5%	5.4	3.4%
Midpoint	2.7	0.8%	2.1	0.6%	0.4	0.2%	2.3	1.5%
Central	1.6	0.5%	1.0	0.3%	0.2	0.1%	1.4	0.9%

The break-down of these figures by Member State is provided below. The minimum and maximum values across all scenarios are presented for each Member State.

Table 4-185: Occupationally exposed population surviving to 2015 by Member State (ionising radiation)								
Member State	Number of workers exposed and surviving to 2015 (1966-2005)		% of current & at risk population		Number of workers exposed and surviving to 2015 (1996-2015)		% of current & at risk population	
	Min	Max	Min	Max	Min	Max	Min	Max
Austria	10,118	105,447	0.19%	1.95%	8,247	66,682	0.13%	1.08%
Belgium	13,282	138,425	0.19%	1.95%	10,827	87,537	0.13%	1.08%
Bulgaria	8,497	88,553	0.19%	1.95%	6,926	55,999	0.13%	1.08%
Croatia	4,985	51,951	0.19%	1.95%	4,063	32,853	0.13%	1.08%
Cyprus	999	10,414	0.19%	1.95%	815	6,586	0.13%	1.08%
Czech Republic	12,432	129,570	0.19%	1.95%	10,134	81,937	0.13%	1.08%
Denmark	6,677	69,587	0.19%	1.95%	5,443	44,005	0.13%	1.08%

Table 4-185: Occupationally exposed population surviving to 2015 by Member State (ionising radiation)								
Member State	Number of workers exposed and surviving to 2015 (1966-2005)		% of current & at risk population		Number of workers exposed and surviving to 2015 (1996-2015)		% of current & at risk population	
	Min	Max	Min	Max	Min	Max	Min	Max
Estonia	1,549	16,147	0.19%	1.95%	1,263	10,211	0.13%	1.08%
Finland	6,455	67,276	0.19%	1.95%	5,262	42,544	0.13%	1.08%
France	78,353	816,590	0.19%	1.95%	63,869	516,391	0.13%	1.08%
Germany	95,793	998,342	0.19%	1.95%	78,085	631,328	0.13%	1.08%
Greece	12,810	133,502	0.19%	1.95%	10,442	84,423	0.13%	1.08%
Hungary	11,627	121,176	0.19%	1.95%	9,478	76,629	0.13%	1.08%
Ireland	5,461	56,914	0.19%	1.95%	4,451	35,991	0.13%	1.08%
Italy	71,723	747,496	0.19%	1.95%	58,465	472,698	0.13%	1.08%
Latvia	2,343	24,420	0.19%	1.95%	1,910	15,442	0.13%	1.08%
Lithuania	3,446	35,918	0.19%	1.95%	2,809	22,713	0.13%	1.08%
Luxembourg	664	6,922	0.19%	1.95%	541	4,377	0.13%	1.08%
Malta	507	5,279	0.19%	1.95%	413	3,338	0.13%	1.08%
Netherlands	19,939	207,798	0.19%	1.95%	16,253	131,407	0.13%	1.08%
Poland	44,837	467,288	0.19%	1.95%	36,549	295,501	0.13%	1.08%
Portugal	12,240	127,561	0.19%	1.95%	9,977	80,666	0.13%	1.08%
Romania	23,442	244,314	0.19%	1.95%	19,109	154,498	0.13%	1.08%
Slovakia	6,396	66,657	0.19%	1.95%	5,214	42,152	0.13%	1.08%
Slovenia	2,434	25,364	0.19%	1.95%	1,984	16,039	0.13%	1.08%
Spain	54,799	571,108	0.19%	1.95%	44,669	361,155	0.13%	1.08%
Sweden	11,499	119,846	0.19%	1.95%	9,374	75,788	0.13%	1.08%
UK	76,536	797,655	0.19%	1.95%	62,388	504,418	0.13%	1.08%
Total	***599,843***	***6,251,519***	***0.19%***	***1.95%***	***488,957***	***3,953,310***	***0.13%***	***1.08%***

Table 4-186: Occupationally exposed population surviving to 2015 by Member State (ionising radiation)								
Member State	Number of workers exposed 1966-2005 and surviving to 2015 - WOMEN		% of current & at risk population 1966-2005 - WOMEN		Number of workers exposed 1966-2005 and surviving to 2015- MEN		% of current & at risk population 1966-2005 - MEN	
	Min	Max	Min	Max	Min	Max	Min	Max
Austria	1,416	14,763	0.05%	0.53%	8,701	90,684	0.33%	3.44%
Belgium	1,859	19,380	0.05%	0.53%	11,423	119,046	0.33%	3.44%
Bulgaria	1,190	12,397	0.05%	0.53%	7,307	76,155	0.33%	3.44%
Croatia	698	7,273	0.05%	0.53%	4,287	44,678	0.33%	3.44%
Cyprus	140	1,458	0.05%	0.53%	859	8,956	0.33%	3.44%
Czech Republic	1,741	18,140	0.05%	0.53%	10,692	111,431	0.33%	3.44%
Denmark	935	9,742	0.05%	0.53%	5,742	59,845	0.33%	3.44%
Estonia	217	2,261	0.05%	0.53%	1,332	13,886	0.33%	3.44%
Finland	904	9,419	0.05%	0.53%	5,552	57,858	0.33%	3.44%
France	10,969	114,323	0.05%	0.53%	67,384	702,267	0.33%	3.44%
Germany	13,411	139,768	0.05%	0.53%	82,382	858,574	0.33%	3.44%
Greece	1,793	18,690	0.05%	0.53%	11,016	114,812	0.33%	3.44%
Hungary	1,628	16,965	0.05%	0.53%	9,999	104,212	0.33%	3.44%
Ireland	765	7,968	0.05%	0.53%	4,696	48,946	0.33%	3.44%
Italy	10,041	104,649	0.05%	0.53%	61,682	642,846	0.33%	3.44%
Latvia	328	3,419	0.05%	0.53%	2,015	21,001	0.33%	3.44%

Table 4-186: Occupationally exposed population surviving to 2015 by Member State (ionising radiation)								
Member State	Number of workers exposed 1966-2005 and surviving to 2015 - WOMEN		% of current & at risk population 1966-2005 - WOMEN		Number of workers exposed 1966-2005 and surviving to 2015- MEN		% of current & at risk population 1966-2005 - MEN	
	Min	Max	Min	Max	Min	Max	Min	Max
Lithuania	482	5,028	0.05%	0.53%	2,964	30,889	0.33%	3.44%
Luxembourg	93	969	0.05%	0.53%	571	5,953	0.33%	3.44%
Malta	71	739	0.05%	0.53%	436	4,540	0.33%	3.44%
Netherlands	2,791	29,092	0.05%	0.53%	17,147	178,707	0.33%	3.44%
Poland	6,277	65,420	0.05%	0.53%	38,560	401,867	0.33%	3.44%
Portugal	1,714	17,859	0.05%	0.53%	10,526	109,702	0.33%	3.44%
Romania	3,282	34,204	0.05%	0.53%	20,160	210,110	0.33%	3.44%
Slovakia	895	9,332	0.05%	0.53%	5,500	57,325	0.33%	3.44%
Slovenia	341	3,551	0.05%	0.53%	2,093	21,813	0.33%	3.44%
Spain	7,672	79,955	0.05%	0.53%	47,127	491,153	0.33%	3.44%
Sweden	1,610	16,778	0.05%	0.53%	9,889	103,068	0.33%	3.44%
UK	10,715	111,672	0.05%	0.53%	65,821	685,983	0.33%	3.44%
Total	***83,978***	***875,213***	***0.05%***	***0.53%***	***515,865***	***5,376,306***	***0.33%***	***3.44%***

AFs per Member State

Table 4-187: Overall attributable fractions across all industries by Member State (ionising radiation)																		
Cancer site/ scenario	Bone			Bladder			Breast			Brain			Malignant melanoma			Leukaemia		
	C-Low	C-Core	C-High	C-Low	C-Core	C-High	C-Low	C-Core	C-High	C-Low	C-Core	C-High	C-Low	C-Core	C-High	C-Low	C-Core	C-High
Austria	0.01%	0.01%	0.01%	0%	0%	0%	0.03%	0.1%	0.1%	0%	0.3%	0.3%	0.3%	0.6%	0.9%	0.01%	0.03%	0.05%
Belgium	0.01%	0.01%	0.01%	0%	0%	0%	0.03%	0.1%	0.1%	0%	0.3%	0.3%	0.3%	0.6%	0.9%	0.01%	0.03%	0.05%
Bulgaria	0.01%	0.01%	0.01%	0%	0%	0%	0.03%	0.1%	0.1%	0%	0.3%	0.3%	0.3%	0.6%	0.9%	0.01%	0.03%	0.05%
Croatia	0.01%	0.01%	0.01%	0%	0%	0%	0.03%	0.1%	0.1%	0%	0.3%	0.3%	0.3%	0.6%	0.9%	0.01%	0.03%	0.05%
Cyprus	0.01%	0.01%	0.01%	0%	0%	0%	0.03%	0.1%	0.1%	0%	0.3%	0.3%	0.3%	0.6%	0.9%	0.01%	0.03%	0.05%
Czech Republic	0.01%	0.01%	0.01%	0%	0%	0%	0.03%	0.1%	0.1%	0%	0.3%	0.3%	0.3%	0.6%	0.9%	0.01%	0.03%	0.05%
Denmark	0.01%	0.01%	0.01%	0%	0%	0%	0.03%	0.1%	0.1%	0%	0.3%	0.3%	0.3%	0.6%	0.9%	0.01%	0.03%	0.05%
Estonia	0.01%	0.01%	0.01%	0%	0%	0%	0.03%	0.1%	0.1%	0%	0.3%	0.3%	0.3%	0.6%	0.9%	0.01%	0.03%	0.05%
Finland	0.01%	0.01%	0.01%	0%	0%	0%	0.03%	0.1%	0.1%	0%	0.3%	0.3%	0.3%	0.6%	0.9%	0.01%	0.03%	0.05%
France	0.01%	0.01%	0.01%	0%	0%	0%	0.03%	0.1%	0.1%	0%	0.3%	0.3%	0.3%	0.6%	0.9%	0.01%	0.03%	0.05%
Germany	0.01%	0.01%	0.01%	0%	0%	0%	0.03%	0.1%	0.1%	0%	0.3%	0.3%	0.3%	0.6%	0.9%	0.01%	0.03%	0.05%
Greece	0.01%	0.01%	0.01%	0%	0%	0%	0.03%	0.1%	0.1%	0%	0.3%	0.3%	0.3%	0.6%	0.9%	0.01%	0.03%	0.05%
Hungary	0.01%	0.01%	0.01%	0%	0%	0%	0.03%	0.1%	0.1%	0%	0.3%	0.3%	0.3%	0.6%	0.9%	0.01%	0.03%	0.05%
Ireland	0.01%	0.01%	0.01%	0%	0%	0%	0.03%	0.1%	0.1%	0%	0.3%	0.3%	0.3%	0.6%	0.9%	0.01%	0.03%	0.05%
Italy	0.01%	0.01%	0.01%	0%	0%	0%	0.03%	0.1%	0.1%	0%	0.3%	0.3%	0.3%	0.6%	0.9%	0.01%	0.03%	0.05%
Latvia	0.01%	0.01%	0.01%	0%	0%	0%	0.03%	0.1%	0.1%	0%	0.3%	0.3%	0.3%	0.6%	0.9%	0.01%	0.03%	0.05%

Table 4-187: Overall attributable fractions across all industries by Member State (ionising radiation)																		
Cancer site/ scenario	Bone			Bladder			Breast			Brain			Malignant melanoma			Leukaemia		
	C-Low	C-Core	C-High	C-Low	C-Core	C-High	C-Low	C-Core	C-High	C-Low	C-Core	C-High	C-Low	C-Core	C-High	C-Low	C-Core	C-High
Lithuania	0.01 %	0.01 %	0.01 %	0%	0%	0%	0.03 %	0.1 %	0.1 %	0%	0.3 %	0.3 %	0.3 %	0.6 %	0.9 %	0.01 %	0.03 %	0.05 %
Luxembourg	0.01 %	0.01 %	0.01 %	0%	0%	0%	0.03 %	0.1 %	0.1 %	0%	0.3 %	0.3 %	0.3 %	0.6 %	0.9 %	0.01 %	0.03 %	0.05 %
Malta	0.01 %	0.01 %	0.01 %	0%	0%	0%	0.03 %	0.1 %	0.1 %	0%	0.3 %	0.3 %	0.3 %	0.6 %	0.9 %	0.01 %	0.03 %	0.05 %
Netherlands	0.01 %	0.01 %	0.01 %	0%	0%	0%	0.03 %	0.1 %	0.1 %	0%	0.3 %	0.3 %	0.3 %	0.6 %	0.9 %	0.01 %	0.03 %	0.05 %
Poland	0.01 %	0.01 %	0.01 %	0%	0%	0%	0.03 %	0.1 %	0.1 %	0%	0.3 %	0.3 %	0.3 %	0.6 %	0.9 %	0.01 %	0.03 %	0.05 %
Portugal	0.01 %	0.01 %	0.01 %	0%	0%	0%	0.03 %	0.1 %	0.1 %	0%	0.3 %	0.3 %	0.3 %	0.6 %	0.9 %	0.01 %	0.03 %	0.05 %
Romania	0.01 %	0.01 %	0.01 %	0%	0%	0%	0.03 %	0.1 %	0.1 %	0%	0.3 %	0.3 %	0.3 %	0.6 %	0.9 %	0.01 %	0.03 %	0.05 %
Slovakia	0.01 %	0.01 %	0.01 %	0%	0%	0%	0.03 %	0.1 %	0.1 %	0%	0.3 %	0.3 %	0.3 %	0.6 %	0.9 %	0.01 %	0.03 %	0.05 %
Slovenia	0.01 %	0.01 %	0.01 %	0%	0%	0%	0.03 %	0.1 %	0.1 %	0%	0.3 %	0.3 %	0.3 %	0.6 %	0.9 %	0.01 %	0.03 %	0.05 %
Spain	0.01 %	0.01 %	0.01 %	0%	0%	0%	0.03 %	0.1 %	0.1 %	0%	0.3 %	0.3 %	0.3 %	0.6 %	0.9 %	0.01 %	0.03 %	0.05 %
Sweden	0.01 %	0.01 %	0.01 %	0%	0%	0%	0.03 %	0.1 %	0.1 %	0%	0.3 %	0.3 %	0.3 %	0.6 %	0.9 %	0.01 %	0.03 %	0.05 %
UK	0.01 %	0.01 %	0.01 %	0%	0%	0%	0.03 %	0.1 %	0.1 %	0%	0.3 %	0.3 %	0.3 %	0.6 %	0.9 %	0.01 %	0.03 %	0.05 %
EU-28	***0.01 %***	***0.01 %***	***0.01 %***	***0%***	***0%***	***0%***	***0.03 %***	***0.1 %***	***0.1 %***	***0%***	***0.3 %***	***0.3 %***	***0.3 %***	***0.6 %***	***0.9 %***	***0.01 %***	***0.03 %***	***0.05 %***

Table 4-188: Overall attributable fractions across all industries by Member State (ionising radiation) cont.												
Cancer site/ scenario	Liver			Lung women			Lung men			Thyroid		
	C-Low	C-Core	C-High	C-Low	C-Core	C-High	C-Low	C-Core	C-High	C-Low	C-Core	C-High
Austria	0%	0%	0%	0%	0%	0%	0.04%	0.04%	0.04%	0.04%	0.04%	0.04%
Belgium	0%	0%	0%	0%	0%	0%	0.04%	0.04%	0.04%	0.04%	0.04%	0.04%
Bulgaria	0%	0%	0%	0%	0%	0%	0.04%	0.04%	0.04%	0.04%	0.04%	0.04%
Croatia	0%	0%	0%	0%	0%	0%	0.04%	0.04%	0.04%	0.04%	0.04%	0.04%
Cyprus	0%	0%	0%	0%	0%	0%	0.04%	0.04%	0.04%	0.04%	0.04%	0.04%
Czech Republic	0%	0%	0%	0%	0%	0%	0.04%	0.04%	0.04%	0.04%	0.04%	0.04%
Denmark	0%	0%	0%	0%	0%	0%	0.04%	0.04%	0.04%	0.04%	0.04%	0.04%
Estonia	0%	0%	0%	0%	0%	0%	0.04%	0.04%	0.04%	0.04%	0.04%	0.04%
Finland	0%	0%	0%	0%	0%	0%	0.04%	0.04%	0.04%	0.04%	0.04%	0.04%
France	0%	0%	0%	0%	0%	0%	0.04%	0.04%	0.04%	0.04%	0.04%	0.04%
Germany	0%	0%	0%	0%	0%	0%	0.04%	0.04%	0.04%	0.04%	0.04%	0.04%
Greece	0%	0%	0%	0%	0%	0%	0.04%	0.04%	0.04%	0.04%	0.04%	0.04%
Hungary	0%	0%	0%	0%	0%	0%	0.04%	0.04%	0.04%	0.04%	0.04%	0.04%
Ireland	0%	0%	0%	0%	0%	0%	0.04%	0.04%	0.04%	0.04%	0.04%	0.04%
Italy	0%	0%	0%	0%	0%	0%	0.04%	0.04%	0.04%	0.04%	0.04%	0.04%
Latvia	0%	0%	0%	0%	0%	0%	0.04%	0.04%	0.04%	0.04%	0.04%	0.04%
Lithuania	0%	0%	0%	0%	0%	0%	0.04%	0.04%	0.04%	0.04%	0.04%	0.04%
Luxembourg	0%	0%	0%	0%	0%	0%	0.04%	0.04%	0.04%	0.04%	0.04%	0.04%
Malta	0%	0%	0%	0%	0%	0%	0.04%	0.04%	0.04%	0.04%	0.04%	0.04%
Netherlands	0%	0%	0%	0%	0%	0%	0.04%	0.04%	0.04%	0.04%	0.04%	0.04%
Poland	0%	0%	0%	0%	0%	0%	0.04%	0.04%	0.04%	0.04%	0.04%	0.04%
Portugal	0%	0%	0%	0%	0%	0%	0.04%	0.04%	0.04%	0.04%	0.04%	0.04%

Table 4-188: Overall attributable fractions across all industries by Member State (ionising radiation) cont.												
Cancer site/ scenario	Liver			Lung women			Lung men			Thyroid		
	C-Low	C-Core	C-High	C-Low	C-Core	C-High	C-Low	C-Core	C-High	C-Low	C-Core	C-High
Romania	0%	0%	0%	0%	0%	0%	0.04%	0.04%	0.04%	0.04%	0.04%	0.04%
Slovakia	0%	0%	0%	0%	0%	0%	0.04%	0.04%	0.04%	0.04%	0.04%	0.04%
Slovenia	0%	0%	0%	0%	0%	0%	0.04%	0.04%	0.04%	0.04%	0.04%	0.04%
Spain	0%	0%	0%	0%	0%	0%	0.04%	0.04%	0.04%	0.04%	0.04%	0.04%
Sweden	0%	0%	0%	0%	0%	0%	0.04%	0.04%	0.04%	0.04%	0.04%	0.04%
UK	0%	0%	0%	0%	0%	0%	0.04%	0.04%	0.04%	0.04%	0.04%	0.04%
EU-28	***0%***	***0%***	***0%***	***0%***	***0%***	***0%***	***0.04%***	***0.04%***	***0.04%***	***0.04%***	***0.04%***	***0.04%***

4.23 Cr(VI) compounds

4.23.1Methodology/assumptions

Summary of the relevant cancer endpoints and exposure period(s)

The relevant health endpoints are cancers of the lung and nasal cavity & paranasal sinus (Beveridge et al (2010)[191], Cole and Rodu (2005).[192]; Gibb (2000)[193]; IARC (2016)[194]; Mannetje A et al (2011)[195]; Rafnsson (1997)[196]; Rushton et al (2012)[197]).

Due to a lack of relative risk estimates for nasal cavity and paranasal sinus cancer, only cancer incidence associated with one of the two cancer sites identified in IARC (2016) as relevant to Cr(VI) compounds (lung cancer) has been quantified in this study.

The typical latency for lung cancer is modelled to be between 10 and 50 years. The relevant exposure period is thus defined as 1966-2005.

Exposed population

An estimate of the exposed population is available from the CAREX database, with further estimates being available for France from SUMER (1994, 2003 and 2010); for Finland from FinJem (2006) and ASA register (2005 and 2014); for the Czech Republic from the Regex register (2009–2016); for Romania from the Ministerului Sănătăţii şi Familiei database (2006) and for the UK from Rushton et al (2012). These estimates are summarised in the following table.

[191] Beveridge R et al (2010): Lung cancer risk associated with occupational exposure to nickel, chromium (VI), and cadmium in two population-based case-control studies in Montreal. American Journal of Industrial Medicine, 53(5), 476-485

[192] Cole P, Rodu B. Epidemiologic studies of chrome and cancer mortality: a series of meta-analyses. Regul Toxicol Pharmacol. 2005;43:225–231

[193] Gibb HJ et al (2000): Lung cancer among workers in chromium chemical production. American Journal of Industrial Medicine, 38, 115-126

[194] IARC (2016): List of classifications by cancer sites with sufficient or limited evidence in humans, available at https://monographs.iarc.fr/ENG/Classification/Table4.pdf

[195] Mannetje A et al (2011): Occupational exposure to metal compounds and lung cancer. Results from a multi-center case-control study in Central/Eastern Europe and UK http://www.ncbi.nlm.nih.gov/pubmed/21960145

[196] Rafnsson V et al (1997): Risk of lung cancer among masons in Iceland. Occupational and Environmental Medicine, 54, 184-188

[197] Rushton L et al (2012): The burden of occupational cancer in Great Britain. Available at http://www.hse.gov.uk/research/rrpdf/rr931.pdf

Table 4-189: Published data – workforce exposed to Cr(VI) compounds					
Study	**Country**	**Year/period**	**No. of exposed workers**	**% of exposed workforce**	**Notes**
Carex	EU15	1990-1993 (mean)	799,000		
	France	1990-1993 (mean)	67,961		
	Finland	1990-1993 (mean)	10,050		
	Czech Republic	1997	37,995		
	UK	1990-1993 (mean)	130,038		
SUMER	France	1994	52,000 (42,000 men and 9,000 women)	0.4% (0.6% men and 0.2% women)	
		2003	108,000 (93,700 men and 14,300 women)	0.6% (0.9% men and 0.2% women)	
		2010	96,100 (84,200 men and 11,900 women)	0.4% (0.7% men and 0.1% women)	
FinJem	Finland	2006	1,000		Excluding exposure to Cr(VI) during welding
ASA	Finland	2005	7,318 (6,762 men and 556 women)		
		2014	6,744 (6,268 men and 476 women)		
Regex	Czech Republic	2009-2016	212		
Ministerului Sănătăţii şi Familiei	Romania	2006	1,622		
Rushton	UK	Published in 2004-2005, refers to ever exposed workers	691,392 (446,917 men; 244,475 women)		Based on Carex

Extrapolations to the EU-28 are summarised below. No extrapolations have been carried out on the basis of the Regex data for the Czech Republic; the FinJem data for Finland and the Ministerului Sănătăţii şi Familiei for Romania ; it is assumed that these are outliers.

Table 4-190: Occupationally exposed population in the EU-28 (Cr (VI) compounds)	
Estimate and method of extrapolation	**Exposed population in the EU-28**
A: France 1994 exposed workers extrapolated on the basis of population	**420,000**
B: France 1994 share (0.4%) applied to EU workforce	**730,000**
C: France 2003 exposed workers extrapolated on the basis of population	**860,000**
D: France 2003 share (0.6%) applied to EU workforce	**1.22 million**
E: France 2010 exposed workers extrapolated on the basis of population	**750,000**
F: France 2010 share (0.4%) applied to EU workforce	**850,000**
G: CAREX early to mid-1990s	**1.17 million**
H: Finland 2005 exposed workers extrapolated on the basis of population	**690,000**
I: Finland 2014 exposed workers extrapolated on the basis of population	**630,000**
J: Rushton et al ever exposed workers extrapolated on the basis of population	**1.08 million**

Estimate A in the table above (420,000 in 1994) forms the basis for the LOW scenario while estimate D is used for the HIGH scenario (1.22 million in 2003). The CENTRAL scenario is based on the average of the extrapolations of the SUMER and ASA data (estimates B, C, E, F, H and I).

Rate of change

Comparing the number of workers exposed in France in 1994, 2003 and 2010 (SUMER) suggests an annual increase of around 2.5%. The other estimates in the table above suggest either no change over time or a slight decrease (estimated at around 0.9%). The following scenarios are modelled:

- no change; and
- an annual increase of 2.5%.
- an annual decrease of 0.9%

A generic staff turnover factor of 10% per annum has been used.

Relative risk

The relative risk estimates identified through literature review are summarised below.

Table 4-191: Literature review of relative risk for chromium (VI)		
Study & summary of data/methodology	**Cancer site**	**Relative risk**
Beveridge et al (2010). Two population case-control studies in Montreal	Lung	OR: 1.28 (95% CI: 0.7-2.2) for < 5 years of exposure; OR: 1.06 (95% CI: 0.7-1.7) for 5-20 years of exposure; OR: 1.11 (95% CI: 0.7-1.6) for >20 years of exposure
Cole and Rodu (2005).	Lung	SMR: 1.41 (95% CI 1.35-1.47)
Gibb (2000). Cohort of 2,357 workers in the United States	Lung	SMR= 1.8 (95% CI: 1.49-2.14) Highest exposure group SMR: 2.28 (95% CI: 1.62-3.14)
IARC (2012). Literature review Luippold et al (2003). Study on 482 chromate workers	Lung Lung	Generally cohort studies RR is above 1 SMR: 2.41 (95% CI: 1.80-3.17) for all workers; SMR: 4.63 (95%CI: 2.83-7.16) for cumulative exposure of 2.7023 mg.yr/m^3

Table 4-191: Literature review of relative risk for chromium (VI)		
Study & summary of data/methodology	**Cancer site**	**Relative risk**
Luippold et al (2005). Two chromate production plants	Lung	RR 0.84 (95% CI: 0.17-2.44)
Mannetje A et al (2011)	Lung	OR: 1.25 (95% CI: 0.95-1.65)
Rafnsson (1997). Retrospective cohort study of masons in Iceland	Lung	SIR: 1.69 in the total cohort SIR: 1.77 with a 30 year lag
Rushton et al (2012). From Cole & Rodu (2005)	Lung	1.18 (CI 95% 1.12, 1.25)
IOM (2011), estimated for low exposure level category	SNC	RR=3.34 (95% CI: 0.4, 10.5)
Rosenan & Stanbury (1996), cited in IOM (2011)	SNC	PMR=5.18 (CI: 2.37, 11.3)
Sources: Beveridge R et al (2010): Lung cancer risk associated with occupational exposure to nickel, chromium (VI), and cadmium in two population-based case-control studies in Montreal. American Journal of Industrial Medicine, 53(5), 476-485. Gibb HJ et al (2000): Lung cancer among workers in chromium chemical production. American Journal of Industrial Medicine, 38, 115-126. IARC (2012): Chromium (VI) compounds. Available at http://monographs.iarc.fr/ENG/Monographs/vol100C/mono100C-9.pdf IOM (2011): Chromium (VI). Available at https://ec.europa.eu/social/BlobServlet?docId=10158&langId=en Mannetje A et al (2011): Occupational exposure to metal compounds and lung cancer. Results from a multi-center case-control study in Central/Eastern Europe and UK http://www.ncbi.nlm.nih.gov/pubmed/21960145 Rafnsson V et al (1997): Risk of lung cancer among masons in Iceland. Occupational and Environmental Medicine, 54, 184-188. Rushton L et al (2012): The burden of occupational cancer in Great Britain. Available at http://www.hse.gov.uk/research/rrpdf/rr931.pdf Shore RE et al (1993): Ethylene oxide: an assessment of the epidemiological evidence on carcinogenicity. Br J Ind Med, 50, 971-997.		

The lowest and highest relative risks identified through literature are summarised below.

Table 4-192: Summary of relative risk – exposure to Chromium (VI)		
Cancer site	**Lowest**	**Highest**
Lung	RR: 1	SMR: 4.63
SNC	RR: 3.34	PMR: 5.18

Summary of the scenarios

The assumptions underpinning the different estimates are summarised below. Please note that the estimates of the exposed population are point estimates for a specific year and do not represent the lowest and highest annual estimates over the whole assessment period since these also depend on the annual rate of change.

Table 4-193: Summary of the scenarios (Cr (VI) compounds))				
Aspect/scenario	**Low**	**High**	**Midpoint**	**Central**
Exposed population (EU-28) - point	420,000 (1994)	1.22 million (assumed in 2003)	820,000 (assumed in 1999)	750,000 (assumed in 2010)
Relevant cancer sites	Lung	Lung	Lung	Lung
Relative risk	Lung: RR=1	Lung: SMR=1.44	Lung: RR=1.22	Lung: OR=1.25

Table 4-193: Summary of the scenarios (Cr (VI) compounds))				
Aspect/scenario	Low	High	Midpoint	Central
	SNC: RR=3.34	SNC: PMR=5.18	SNC: *=4.26	SNC: RR=3.34
Change (p.a.)	+2.5%	-0.9%	+0.8%	0%

4.23.2The results

Summary of the occupationally exposed population surviving to 2015

The total number of workers in the EU-28 exposed to chromium (VI) compounds between 1966 and 2005 and surviving until 2015 is summarised below.

Table 4-194: Occupationally exposed population in EU 28 (Cr (VI) compounds))		
Scenario	No. of workers exposed 1966-2005 & surviving to 2015 (million)	% of current & at risk population
Low	1.5	0.5%
High	5.5	1.7%
Midpoint	2.8	0.9%
Central	2.7	0.8%

The break-down of these figures by Member State is provided below. The minimum and maximum values across all scenarios are presented for each Member State.

Table 4-195: Occupationally exposed population surviving to 2015 by Member State (Cr(VI) compounds, 1966-2005)				
Member State	Number of workers exposed over the period and surviving to 2015		% of current & at risk population	
	Min	Max	Min	Max
Austria	25,716	92,000	0.5%	1.7%
Belgium	33,759	120,773	0.5%	1.7%
Bulgaria	21,596	77,260	0.5%	1.7%
Croatia	12,670	45,326	0.5%	1.7%
Cyprus	2,540	9,086	0.5%	1.7%
Czech Republic	31,599	113,048	0.5%	1.7%
Denmark	16,971	60,714	0.5%	1.7%
Estonia	3,938	14,088	0.5%	1.7%
Finland	16,407	58,697	0.5%	1.7%
France	199,147	712,458	0.5%	1.7%
Germany	243,473	871,033	0.5%	1.7%
Greece	32,558	116,478	0.5%	1.7%
Hungary	29,552	105,724	0.5%	1.7%
Ireland	13,880	49,656	0.5%	1.7%
Italy	182,297	652,175	0.5%	1.7%
Latvia	5,955	21,306	0.5%	1.7%
Lithuania	8,759	31,337	0.5%	1.7%
Luxembourg	1,688	6,039	0.5%	1.7%
Malta	1,287	4,606	0.5%	1.7%
Netherlands	50,677	181,300	0.5%	1.7%
Poland	113,961	407,699	0.5%	1.7%
Portugal	31,109	111,294	0.5%	1.7%
Romania	59,583	213,159	0.5%	1.7%
Slovakia	16,256	58,157	0.5%	1.7%

Table 4-195: Occupationally exposed population surviving to 2015 by Member State (Cr(VI) compounds, 1966-2005)				
Member State	Number of workers exposed over the period and surviving to 2015		% of current & at risk population	
	Min	Max	Min	Max
Slovenia	6,186	22,129	0.5%	1.7%
Spain	139,280	498,280	0.5%	1.7%
Sweden	29,228	104,563	0.5%	1.7%
UK	194,530	695,938	0.5%	1.7%
Total	***1,524,601***	***5,454,323***	***0.5%***	***1.7%***

AFs per Member State

Table 4-196: Overall attributable fractions across all industries by Member State (Cr(VI) compounds)						
Cancer site/ scenario	Lung			SNC		
	C-Low	C-Core	C-High	C-Low	C-Core	C-High
Austria	0%	0.2%	0.5%	0%	1.9%	7.3%
Belgium	0%	0.2%	0.5%	0%	1.9%	7.3%
Bulgaria	0%	0.2%	0.5%	0%	1.9%	7.3%
Croatia	0%	0.2%	0.5%	0%	1.9%	7.3%
Cyprus	0%	0.2%	0.5%	0%	1.9%	7.3%
Czech Republic	0%	0.2%	0.5%	0%	1.9%	7.3%
Denmark	0%	0.2%	0.5%	0%	1.9%	7.3%
Estonia	0%	0.2%	0.5%	0%	1.9%	7.3%
Finland	0%	0.2%	0.5%	0%	1.9%	7.3%
France	0%	0.2%	0.5%	0%	1.9%	7.3%
Germany	0%	0.2%	0.5%	0%	1.9%	7.3%
Greece	0%	0.2%	0.5%	0%	1.9%	7.3%
Hungary	0%	0.2%	0.5%	0%	1.9%	7.3%
Ireland	0%	0.2%	0.5%	0%	1.9%	7.3%
Italy	0%	0.2%	0.5%	0%	1.9%	7.3%
Latvia	0%	0.2%	0.5%	0%	1.9%	7.3%
Lithuania	0%	0.2%	0.5%	0%	1.9%	7.3%
Luxembourg	0%	0.2%	0.5%	0%	1.9%	7.3%
Malta	0%	0.2%	0.5%	0%	1.9%	7.3%
Netherlands	0%	0.2%	0.5%	0%	1.9%	7.3%
Poland	0%	0.2%	0.5%	0%	1.9%	7.3%
Portugal	0%	0.2%	0.5%	0%	1.9%	7.3%
Romania	0%	0.2%	0.5%	0%	1.9%	7.3%
Slovakia	0%	0.2%	0.5%	0%	1.9%	7.3%
Slovenia	0%	0.2%	0.5%	0%	1.9%	7.3%
Spain	0%	0.2%	0.5%	0%	1.9%	7.3%
Sweden	0%	0.2%	0.5%	0%	1.9%	7.3%
UK	0%	0.2%	0.5%	0%	1.9%	7.3%
EU-28	***0%***	***0.2%***	***0.5%***	***0%***	***1.9%***	***7.3%***

4.24 Aromatic amines

4.24.1Methodology/assumptions

Summary of the relevant cancer endpoints and exposure period(s)

The relevant cancer endpoint (Rushton et al 2012[198]) is bladder cancer, which has a latency period of 10-50 years and, as a result, the relevant reference period is 1966-2005. IARC (2016)[199] has also identified *o*-toluidine as relevant to urinary bladder cancer. 100% (1 of 1) cancers identified in IARC (2016) have thus been considered in this study.

Although other cancer sites are relevant to aromatic amines, these are not considered in this report so as to avoid double counting with other carcinogens (rubber industry, cytostatic drugs). The following are listed in IARC (2016) but are considered elsewhere in this report:

- Rubber industry: Oesophagus (limited evidence), stomach (sufficient evidence), larynx (limited evidence), lung (sufficient evidence), prostate (limited evidence), urinary bladder (sufficient evidence);
- Urinary bladder: 4-aminobiphenyl (sufficient evidence), 2-naphylamine (limited evidence), ortho-toluidine (sufficient evidence), 4-chloro-ortho-toluidine (limited evidence), Benzidine (sufficient evidence), auromine production (can involve exposure to 2-naphylamine: sufficient evidence), aluminium production (sufficient evidence)- can involve aromatic amines, is included with PAHs by Rushton, magenta production (sufficient evidence- can involve exposure to ortho-toluidine); and
- Leukaemia and/or lymphoma: mitoxantrone (limited evidence) this would be included in cytostatic drugs.

Exposed population

The starting point for estimating the occupationally exposed population is the SUMER database, with further estimates being available for the UK from Rushton et al (2012). These estimates are summarised below.

Table 4-197: Published data – workforce exposed to aromatic amines

Study	Country	Year/period	No. of exposed workers	% of exposed workforce	Notes
SUMER	France	1994	35,000 (22,000 men and 13,000 women)	0.3% (0.3% men and 0.3% women)	
		2003	70,800 (33,600 men and 37,200 women)	0.4% (0.3% men, 0.5% women	
		2010	62,800 (27,900 men, 35,000 women)	0.3% (0.2% men, 0.4% women)	
Rushton	Great Britain	Ever exposed workers.	195,824		

[198] Rushton et al (2012): Occupational cancer in the UK – overview report, available at http://www.hse.gov.uk/research/rrpdf/rr931.pdf

[199] IARC (2016): List of classifications by cancer sites with sufficient or limited evidence in humans, available at https://monographs.iarc.fr/ENG/Classification/Table4.pdf

Extrapolations to the EU-28 are summarised below.

Table 4-198: Occupationally exposed population in the EU-28 (aromatic amines)	
Estimate and method of extrapolation	**Exposed population in the EU-28**
A: France 1994 exposed workers extrapolated on the basis of population	290,000
B: France 1994 share (0.3%) applied to current EU workforce	550,000
C: France 2003 exposed workers extrapolated on the basis of population	560,000
D: France 2003 share (0.4%) applied to current EU workforce	820,000
E: France 2010 exposed workers extrapolated on the basis of population	500,000
F: France 2010 share (0.3%) applied to current EU workforce	640,000
G: Rushton ever exposed workers extrapolated on the basis of population	310,000

Estimates A and G in the table above form the basis for the LOW scenario while estimate D is used for the HIGH scenario (820,000 in 2003). The CENTRAL scenario is based on the average of the remaining extrapolations of the SUMER data (estimates B, C, E and F).

Rate of change

Comparing the number of workers exposed in France in 1994 and 2010 (SUMER) suggests an average annual increase of around 3.7%. The following scenarios are modelled:

- no change; and
- an annual increase of 3.7%.

A generic staff turnover factor of 10% per annum has been used.

Relative risk

The relative risk estimates identified through literature review are summarised below.

Table 4-199: Literature review of relative risk		
Study & summary of data/methodology	**Cancer site**	**Relative risk**
Harling et al (2010) A meta-analysis of 42 studies to determine summary risk ratios (SRRs) for the risk of bladder cancer among hairdressers	Bladder	The SRR increased with duration of employment from 1.30 (95% CI 1.15 to 1.48) for 'ever registered as hairdresser' to 1.70 (95% CI 1.01 to 2.88) for 'job held ≥10 years'. No difference was found between the risk for smoking-adjusted data (SRR 1.35, 95% CI 1.13 to 1.61) and no adjustment (SRR 1.33, 95% CI 1.18 to 1.50)
Takkouche et al (2009) A meta-analysis of 247 studies reporting relative risk (RR) estimates of hairdresser occupation and cancer of different sites	Lung, larynx, bladder and multiple myeloma	The pooled RR of occupational exposure as a hairdresser was 1.27 (95% CI 1.15–1.41) for lung cancer, 1.52 [95% confidence interval (CI) 1.11–2.08] for larynx cancer, 1.30 (95% CI 1.20–1.42) for bladder cancer and 1.62 (95% CI 1.22–2.14) for multiple myeloma.
Reulen et al (2008) A meta-analysis of 29 studies	Bladder	Bladder cancer SRR=1.23 (95% CI 1.11–1.37)
Czene et al (2003) 38,866 women and 6866 men from Sweden who declared to be employed as "hairdressers, barbers, beautician and others" in	Breast bladder, lung, ovary, NHL, HD, MM and leukaemia	Any census, females: breast RR=1.02 (95% CI 0.95–1.09), bladder RR=1.09 (95% CI 0.81–1.43), lung RR=1.35 (95% CI 1.15–1.58), ovary RR=1.11 (95% CI 0.96–1.28), NHL RR=0.94 (95% CI 0.72–1.20), HD RR=0.58 (95% CI 0.29–1.03), MM

Table 4-199: Literature review of relative risk		
Study & summary of data/methodology	**Cancer site**	**Relative risk**
at least one of the four censuses of 1960, 1970, 1980 and 1990; follow-up from 1960–1998		RR=1.30 (95% CI 0.88–1.84), leukaemia RR=1.01 (95% CI 0.77–1.31)
Gago-Dominguez et al (2001) A population-based case-control study was conducted in Los Angeles, California, which involved 1514 incident cases of bladder cancer and an equal number of age-, sex- and ethnicity-matched controls. Information on personal use of hair dyes was obtained from 897 cases and their matched controls.	Bladder	An elevated bladder cancer risk OR=1.9 (95 % CI 1.1-3.3) was claimed for women who used permanent hair dyes at least once a month, for 1 year or longer. The risk increased to 3.3 (95 % CI 1.3–8.4) for those who used permanent hair dyes at least once a month for 15 and more years.
Mannetje et al (1999) An analysis of 11 studies from six EU countries	Bladder	A pooled estimate of relative risk (RR) among 700 men and 2,425 women of 0.8 (95% CI 0.4 to 1.7)
Sources: Czene et al (2003): Cancer risks in hairdressers: assessment of carcinogenicity of hair dyes and gels. Int J Cancer. 2003 May 20;105(1):108-12, abstract available at https://www.ncbi.nlm.nih.gov/pubmed/12672039 Gago-Dominguez et al (2001): Use of permanent hair dyes and bladder-cancer risk. Int J Cancer. 2001 Feb 15;91(4):575-9, abstract available at https://www.ncbi.nlm.nih.gov/pubmed/11251984 Harling et al (2010): Bladder cancer among hairdressers: a meta-analysis. Occup Environ Med 2010;67:351-358, available at http://oem.bmj.com/content/67/5/351.full Mannetje et al (1999): Occupation and bladder cancer in European women. Cancer Causes Control 1999;10:209–17, abstract available at http://link.springer.com/article/10.1023/A:1008852127139 Reulen et al (2008): A meta-analysis on the association between bladder cancer and occupation. Scandinavian Journal of Urology and Nephrology, 2008; 42(Suppl), available at https://www.researchgate.net/publication/51433999_A_meta-analysis_on_the_association_between_bladder_cancer_and_occupation Takkouche et al (2009): Risk of cancer among hairdressers and related workers: a meta-analysis. International Journal of Epidemiology 2009;1–20, available at http://ije.oxfordjournals.org/content/38/6/1512.full		

The lowest and highest relative risks identified through literature are summarised below.

Table 4-200: Summary of relative risk – exposure to aromatic amines		
Cancer site	**Lowest**	**Highest**
Bladder	RR: 1	OR: 3.3

Summary of the scenarios

The assumptions underpinning the different estimates are summarised below. The estimates of the exposed population are point estimates for a specific year and do not represent the lowest and highest annual estimates over the whole assessment period since these also depend on the annual rate of change.

Table 4-201: Summary of the scenarios (aromatic amines)				
Aspect/scenario	**Low**	**High**	**Midpoint**	**Central**
Exposed population (EU-28) - point	300,000 (1994)	820,000 (assumed in 2003)	560,000 (assumed in 1999)	562,500 (assumed in 2004)
Relevant cancer sites	Bladder (1 of 1 in IARC 2016)	Bladder (1 of 1 in IARC 2016)	Bladder (1 of 1 in IARC 2016)	Bladder (1 of 1 in IARC 2016)
Relative risk	Bladder: RR=1	Bladder: OR=3.3	Bladder: RR=2.15	Bladder: RR/SRR=1.30
Change (p.a.)	0%	3.7%	1.85%	3.7%

4.24.2The results

Summary of the occupationally exposed population surviving to 2015

The total number of workers in the EU-28 exposed to aromatic amines between 1966 and 2005 and surviving until 2015 is summarised below.

Table 4-202: Occupationally exposed population surviving to 2015 (aromatic amines)		
Scenario	**No. of workers exposed 1966-2005 & surviving to 2015 (million)**	**% of current & at risk population**
Low	0.98	0.3%
High	2.89	0.9%
Midpoint	1.83	0.6%
Central	1.46	0.5%

The break-down of these figures by Member State is provided below. The minimum and maximum values across all scenarios are presented for each Member State.

Table 4-203: Occupationally exposed population surviving to 2015 by Member State (aromatic amines, 1966-2005)				
Member State	**Number of workers exposed over the period and surviving to 2015**		**% of current & at risk population**	
	Min	**Max**	**Min**	**Max**
Austria	16,456	48,804	0.30%	0.90%
Belgium	21,603	64,067	0.30%	0.90%
Bulgaria	13,820	40,984	0.30%	0.90%
Croatia	8,108	24,044	0.30%	0.90%
Cyprus	1,625	4,820	0.30%	0.90%
Czech Republic	20,221	59,969	0.30%	0.90%
Denmark	10,860	32,207	0.30%	0.90%
Estonia	2,520	7,473	0.30%	0.90%
Finland	10,499	31,137	0.30%	0.90%
France	127,440	377,938	0.30%	0.90%
Germany	155,805	462,058	0.30%	0.90%
Greece	20,835	61,788	0.30%	0.90%
Hungary	18,911	56,084	0.30%	0.90%
Ireland	8,882	26,341	0.30%	0.90%
Italy	116,657	345,960	0.30%	0.90%
Latvia	3,811	11,302	0.30%	0.90%
Lithuania	5,605	16,624	0.30%	0.90%
Luxembourg	1,080	3,204	0.30%	0.90%
Malta	824	2,443	0.30%	0.90%

Table 4-203: Occupationally exposed population surviving to 2015 by Member State (aromatic amines, 1966-2005)				
Member State	Number of workers exposed over the period and surviving to 2015		% of current & at risk population	
	Min	Max	Min	Max
Netherlands	32,430	96,174	0.30%	0.90%
Poland	72,927	216,273	0.30%	0.90%
Portugal	19,908	59,038	0.30%	0.90%
Romania	38,129	113,075	0.30%	0.90%
Slovakia	10,403	30,850	0.30%	0.90%
Slovenia	3,958	11,739	0.30%	0.90%
Spain	89,129	264,323	0.30%	0.90%
Sweden	18,704	55,468	0.30%	0.90%
UK	124,485	369,175	0.30%	0.90%
Total	***975,636***	***2,893,362***	***0.30%***	***0.90%***

AFs per Member State

Table 4-204: Overall attributable fractions across all industries by Member State (aromatic amines)			
Cancer site/ scenario	Bladder		
	C-Low	C-Core	C-High
Austria	0.07%	0.14%	0.2%
Belgium	0.07%	0.14%	0.2%
Bulgaria	0.07%	0.14%	0.2%
Croatia	0.07%	0.14%	0.2%
Cyprus	0.07%	0.14%	0.2%
Czech Republic	0.07%	0.14%	0.2%
Denmark	0.07%	0.14%	0.2%
Estonia	0.07%	0.14%	0.2%
Finland	0.07%	0.14%	0.2%
France	0.07%	0.14%	0.2%
Germany	0.07%	0.14%	0.2%
Greece	0.07%	0.14%	0.2%
Hungary	0.07%	0.14%	0.2%
Ireland	0.07%	0.14%	0.2%
Italy	0.07%	0.14%	0.2%
Latvia	0.07%	0.14%	0.2%
Lithuania	0.07%	0.14%	0.2%
Luxembourg	0.07%	0.14%	0.2%
Malta	0.07%	0.14%	0.2%
Netherlands	0.07%	0.14%	0.2%
Poland	0.07%	0.14%	0.2%
Portugal	0.07%	0.14%	0.2%
Romania	0.07%	0.14%	0.2%
Slovakia	0.07%	0.14%	0.2%
Slovenia	0.07%	0.14%	0.2%
Spain	0.07%	0.14%	0.2%
Sweden	0.07%	0.14%	0.2%
UK	0.07%	0.14%	0.2%
EU-28	***0.07%***	***0.14%***	***0.2%***

4.25 Cytostatic drugs

4.25.1Methodology/assumptions

Summary of the relevant cancer endpoints and exposure period(s)

The relevant cancer endpoints are leukaemia and breast cancer (IARC, 2000[200]; Gunnarsdottir et al, 1997[201]).

IARC have examined a number of antineoplastic drugs (cytotoxic drugs) and concluded there is a sufficient evidence for leukaemia (short latency compared to alkylating agents) for two they studied: etoposide and tenoposide.[202]

There exist only very limited data from occupational studies for women that bear directly on the human carcinogenicity of cytostatic drugs.

Two latency periods are considered:

- Leukaemia, 0-20 years, 1996-2015;and
- Breast cancer, 10-50 years, 1966-2005.

Exposed population

HSE in UK list the following workers at risk of exposure to cytotoxic drugs (which can also be referred as antineoplastic drugs): pharmacists, pharmacy technicians, laboratory staff, nursing and medical staff and veterinary practitioners.[203]

The available data for estimating the occupationally exposed population include SUMER (France 2010) as and CAREX Canada (Canada). These data are summarised in the following table.

[200] IARC (2000): IARC Monographs Volume 76. Some Antiviral and antineoplastic agents, and other pharmaceutical agents. Available at http://monographs.iarc.fr/ENG/Monographs/vol76/

[201] Gunnarsdottir HK et al (1997): Occupational Risk Factors for Breast Cancer among Nurses. Int J Occup Environ Health, 3(4), pp 254-258.

[202] IARC (2000): IARC Monographs Volume 76. Some Antiviral and antineoplastic agents, and other pharmaceutical agents. Available at http://monographs.iarc.fr/ENG/Monographs/vol76/

[203] Health and Safety Executive: Safe handling of cytotoxic drugs in the workplace. Available at http://www.hse.gov.uk/healthservices/safe-use-cytotoxic-drugs.htm

Table 4-205: Published data – workforce exposed to cytostatic drugs				
Study	**Country**	**Year/period**	**No. of exposed workers**	**Notes**
SUMER	France	2010	49,400 (5,000 men, 44,400 women)	0.2% workforce (0.0% men, 0.5% women)
Carex	Canada	Assumed 2012	75,000 (over 75% are female-56,250)	Exposure in the following occupations: Pharmacy technicians, nurses, pharmacists, cleaning workers, veterinarians, veterinary technicians, home care workers, laundry workers and physician specialists

Extrapolations to the EU-28 are summarised below.

Table 4-206: Occupationally exposed population in the EU-28 (cytostatic drugs)	
Estimate and method of extrapolation	**Exposed population in the EU-28**
A: SUMER 2010, extrapolated on the basis of population	Men and women: 375,000 Women: 337,000
B: SUMER 2010, extrapolated based on % of EU workforce	Men and women: 420,000 Women: 380,000
C: CAREX Canada (assumed 2012), extrapolated on the basis of population	Men and women: 1.1 million Women 820,000

Estimate A in the table above forms the basis for the LOW scenario while estimate C is used for the HIGH scenario. The CENTRAL scenario is also based on estimate B.

Rate of change

No data is available in order to compare the rate of change in the number of workers exposed to cytotoxic drugs in the EU.

For this reason, two scenarios for the annual rate of change have been modelled:

- no decline in the number of workers exposed to cytotoxic drugs;
- an annual decline of 3% throughout the EU.

A generic staff turnover factor of 10% per annum has been used.

Relative risk

The relative risk estimates identified through literature review are summarised in the following table.

Table 4-207: Literature review of relative risk		
Study & summary of data/methodology	**Cancer site**	**Relative risk**
Gunnarsdottir et al (1997). Nested case-referent cohort study	Breast	OR 1.65 (95% CI 0.53-5.17) for nurses handling cytotoxic drugs
Skov T et al (1992). Study amongst nurses handling antineoplastic drugs	Leukaemia	RR 10.65, although the authors do note that this is only based on two cases
Sources: Gunnarsdottir HK et al (1997): Occupational Risk Factors for Breast Cancer among Nurses. Int J Occup Environ Health, 3(4), pp 254-258. Skov T et al (1992): Leukaemia and reproductive outcome among nurses handling antineoplastic drugs. Br J Ind Med, 49, pp 855-861.		

The lowest and highest relative risks identified through literature are summarised below.

Table 4-208: Summary of the relative risk		
Cancer site	**Lowest**	**Highest**
Breast	OR=1.65	OR=1.65
Leukaemia	RR=10.65	RR=10.65

Summary of the scenarios

The assumptions underpinning the different estimates are summarised below.

Table 4-209: Summary of the scenarios (cytostatic drugs)				
Aspect/scenario	**Low**	**High**	**Midpoint**	**Central**
Exposed population (EU-28) - point	Women and men: 375,000 Women: 337,000 (2010)	Women and men: 1.1 million Women: 820,000 (assumed 2012)	Women and men: 740,000 Women: 580,000 (assumed 2011)	Women and men: 420,000 Women: 380,000 (2010)
Relevant cancer sites	Leukaemia, breast cancer (1 more than IARC)	Leukaemia, breast cancer (1 more than IARC)	Leukaemia, breast cancer (1 more than IARC)	Leukaemia, breast cancer (1 more than IARC)
Relative risk	Breast: OR=1.65 Leukaemia: RR=10.65	Breast: OR=1.65 Leukaemia: RR=10.65	Breast: OR=1.65 Leukaemia: RR=10.65	Breast: OR=1.65 Leukaemia: RR=10.65
Change (p.a.)	0%	-3%	-1.5%	0%

4.25.2The results

Summary of the occupationally exposed population surviving to 2015

The total number of workers in the EU-28 exposed to cytostatic drugs between 1966 and 2005 and surviving to 2015 has been estimated to be between 1.2 million and 4.9 million. Between 1996 and 2015, the number of workers exposed to cytostatic drugs and surviving until 2015 has been estimated to have been between 1.1 and 4.1 million.

Table 4-210: Occupationally exposed population surviving to 2015 (cytostatic drugs)				
Scenario	1966-2005 (Women only)		1996-2015 (Women and men)	
	Number of female workers exposed (million)	Exposed female workers as % of current female population	Number of workers exposed over the period and surviving to 2015 (million)	% of current & at risk population
Low	1.2	0.7%	1.1	0.3%
High	4.9	3.1%	4.1	1.1%
Midpoint	2.4	1.5%	2.4	0.6%
Central	1.3	0.8%	1.2	0.3%

The break-down of these figures by Member State is provided below. The minimum and maximum values across all scenarios are presented for each Member State.

Table 4-211: Occupationally exposed female population by Member State (cytostatic drugs, 1966-2005)				
Member State	Number of female workers exposed		Exposed female workers as % of overall female population	
	Min	Max	Min	Max
Austria	20,087	82,441	0.7%	3.1%
Belgium	26,369	108,223	0.7%	3.1%
Bulgaria	16,869	69,232	0.7%	3.1%
Croatia	9,896	40,617	0.7%	3.1%
Cyprus	1,984	8,142	0.7%	3.1%
Czech Republic	24,682	101,301	0.7%	3.1%
Denmark	13,256	54,405	0.7%	3.1%
Estonia	3,076	12,624	0.7%	3.1%
Finland	12,816	52,598	0.7%	3.1%
France	155,554	638,426	0.7%	3.1%
Germany	190,176	780,524	0.7%	3.1%
Greece	25,431	104,374	0.7%	3.1%
Hungary	23,083	94,738	0.7%	3.1%
Ireland	10,842	44,496	0.7%	3.1%
Italy	142,392	584,407	0.7%	3.1%
Latvia	4,652	19,092	0.7%	3.1%
Lithuania	6,842	28,081	0.7%	3.1%
Luxembourg	1,319	5,412	0.7%	3.1%
Malta	1,006	4,127	0.7%	3.1%
Netherlands	39,584	162,461	0.7%	3.1%
Poland	89,015	365,335	0.7%	3.1%
Portugal	24,299	99,730	0.7%	3.1%
Romania	46,540	191,010	0.7%	3.1%
Slovakia	12,698	52,114	0.7%	3.1%
Slovenia	4,832	19,830	0.7%	3.1%
Spain	108,792	446,504	0.7%	3.1%
Sweden	22,830	93,698	0.7%	3.1%
UK	151,947	623,623	0.7%	3.1%
Total	***1,190,865***	***4,887,562***	***0.7%***	***3.1%***

Table 4-212: Occupationally exposed population surviving to 2015 by Member State (cytostatic drugs, women and men, 1996-2015				
Member State	Number of workers exposed over the period and surviving to 2015		% of current & at risk population	
	Min	Max	Min	Max
Austria	18,193	69,574	0.2%	0.8%
Belgium	23,883	91,333	0.2%	0.8%
Bulgaria	15,278	58,427	0.3%	1.1%
Croatia	8,963	34,277	0.3%	1.1%
Cyprus	1,797	6,871	0.3%	1.1%
Czech Republic	22,355	85,490	0.3%	1.1%
Denmark	12,006	45,914	0.3%	1.1%
Estonia	2,786	10,654	0.3%	1.1%
Finland	11,607	44,389	0.3%	1.1%
France	140,887	538,784	0.3%	1.1%
Germany	172,245	658,704	0.3%	1.1%
Greece	23,033	88,084	0.3%	1.1%
Hungary	20,907	79,952	0.3%	1.1%
Ireland	9,819	37,552	0.3%	1.1%
Italy	128,966	493,196	0.3%	1.1%
Latvia	4,213	16,112	0.3%	1.1%
Lithuania	6,197	23,698	0.3%	1.1%
Luxembourg	1,194	4,567	0.3%	1.1%
Malta	911	3,483	0.3%	1.1%
Netherlands	35,852	137,105	0.3%	1.1%
Poland	80,622	308,316	0.3%	1.1%
Portugal	22,008	84,164	0.3%	1.1%
Romania	42,152	161,198	0.3%	1.1%
Slovakia	11,500	43,980	0.3%	1.1%
Slovenia	4,376	16,735	0.3%	1.1%
Spain	98,534	376,816	0.3%	1.1%
Sweden	20,677	79,074	0.3%	1.1%
UK	137,620	526,291	0.3%	1.1%
Total	*1,078,583*	*4,124,740*	*0.3%*	*1.1%*

AFs per Member State

Table 4-213: Overall attributable fractions across all industries by Member State (cytostatic drugs)						
Cancer site/ scenario	Leukaemia			Breast cancer (women only)		
	C-Low	C-Core	C-High	C-Low	C-Core	C-High
Austria	0.1%	3.1%	11.0%	0%	0.5%	3.4%
Belgium	0.1%	3.1%	11.0%	0%	0.5%	3.4%
Bulgaria	0.1%	3.1%	11.0%	0%	0.5%	3.4%
Croatia	0.1%	3.1%	11.0%	0%	0.5%	3.4%
Cyprus	0.1%	3.1%	11.0%	0%	0.5%	3.4%
Czech Republic	0.1%	3.1%	11.0%	0%	0.5%	3.4%
Denmark	0.1%	3.1%	11.0%	0%	0.5%	3.4%
Estonia	0.1%	3.1%	11.0%	0%	0.5%	3.4%
Finland	0.1%	3.1%	11.0%	0%	0.5%	3.4%
France	0.1%	3.1%	11.0%	0%	0.5%	3.4%
Germany	0.1%	3.1%	11.0%	0%	0.5%	3.4%
Greece	0.1%	3.1%	11.0%	0%	0.5%	3.4%

Table 4-213: Overall attributable fractions across all industries by Member State (cytostatic drugs)						
Cancer site/ scenario	Leukaemia			Breast cancer (women only)		
	C-Low	C-Core	C-High	C-Low	C-Core	C-High
Hungary	0.1%	3.1%	11.0%	0%	0.5%	3.4%
Ireland	0.1%	3.1%	11.0%	0%	0.5%	3.4%
Italy	0.1%	3.1%	11.0%	0%	0.5%	3.4%
Latvia	0.1%	3.1%	11.0%	0%	0.5%	3.4%
Lithuania	0.1%	3.1%	11.0%	0%	0.5%	3.4%
Luxembourg	0.1%	3.1%	11.0%	0%	0.5%	3.4%
Malta	0.1%	3.1%	11.0%	0%	0.5%	3.4%
Netherlands	0.1%	3.1%	11.0%	0%	0.5%	3.4%
Poland	0.1%	3.1%	11.0%	0%	0.5%	3.4%
Portugal	0.1%	3.1%	11.0%	0%	0.5%	3.4%
Romania	0.1%	3.1%	11.0%	0%	0.5%	3.4%
Slovakia	0.1%	3.1%	11.0%	0%	0.5%	3.4%
Slovenia	0.1%	3.1%	11.0%	0%	0.5%	3.4%
Spain	0.1%	3.1%	11.0%	0%	0.5%	3.4%
Sweden	0.1%	3.1%	11.0%	0%	0.5%	3.4%
UK	0.1%	3.1%	11.0%	0%	0.5%	3.4%
EU-28	***0.1%***	***3.1%***	***11.0%***	***0%***	***0.5%***	***3.4%***

4.26 Organic solvents

4.26.1Methodology/assumptions

Summary of the relevant cancer endpoints and exposure period(s)

The relevant cancer endpoints are breast and liver cancer (liver and bile duct), NHL, leukaemia and/or lymphoma (Ekenga et al, 2014[204]; Hansen, 1999[205]; IARC, 2016[206]; Lindbohm et al, 2009[207]; Peplonska et al 2009[208]; Wang et al, 2009[209]).

Organic solvents include a number of chemical agents, e.g. dichloromethane (methylene chloride), ethanol and tetrahydrofuran (THF). In addition, the cancer risk from occupational exposure to benzene is considered separately in this study. Not all cancer sites are relevant to all chemical agents, for example IARC lists only liver and bile duct and leukaemia and/or lymphoma as relevant to methylene chloride.

[204] Ekenga CC (2014): Breast cancer risk after occupational solvent exposure: the influence of timing and setting. Cancer Res., 74(11), pp 3076-3083.

[205] Hansen J (1999): Breast cancer risk among relatively young women employed in solvent-using industries. Am J Ind Med, 36(1), pp 43-47.

[206] IARC (2016): List of classifications by cancer sites with sufficient or limited evidence in humans, available at https://monographs.iarc.fr/ENG/Classification/Table4.pdf

[207] Lindbohm M-L (2009): Risk of liver cancer and exposure to organic solvents and gasoline vapours among Finnish workers. Int J. Cancer, 124, pp 2954-2959.

[208] Peplonska B et al (2009): Occupational exposure to organic solvents and breast cancer in women. Occup Environ Med, 67, pp 722-729.

[209] Wang R et al (1999): Occupational Exposure to Solvents and Risk of Non-Hodgkin Lymphoma in Connecticut Women. American Journal of Epidemiology, 169(2), pp 176-185.

No risk estimate is available for leukaemia and no quantification for leukaemia is therefore provided. As a result, 75% (3 of 4) of relevant cancer sites have been quantified. 100% of cancer sites indicated in IARC (2016) as relevant to dichloromethane (methylene chloride) have been quantified.

All relevant cancer sites have a latency of 10 to 50 years (relevant exposure period 1966-2005).

Exposed population

Data are only available from the SUMER database. These estimates are summarised below.

Table 4-214: Published data – workforce exposed to organic solvents

Study	Country	Year/period	No. of exposed workers	% of exposed workforce	Notes
SUMER 2003	France	Ethanol	No data	No data	
		THF	61,700 (52,000 men, 9,700 women)	0.5% men	
		Methylene chloride	86,500 (70,300 men, 16,200 women)	0.7% men, 0.2% women	
SUMER 2010	France	Ethanol	961,400 (324,800 men, 636,600 women)	4.4% (2.7% men, 6.5% women)	
		THF	64,600 (57,400 men, 7,200 women)	0.3% (0.5% men, 0.1% women)	
		Methylene chloride	69,700 (58,500 men, 11,200 women)	0.3% (0.5% men, 0.1% women)	

Extrapolations to the EU-28 are summarised below. Please note that for the purposes of the extrapolation, it is assumed that there is no overlap between the groups exposed to the three chemical agents. As a result, the estimates presented below may represent the worst-case scenario. However, due to the fact that workers are likely to be also exposed to other organic solvents, it can be assumed that the totals most likely still underestimate the real level of exposure to organic solvents.

Since no data are available from SUMER 2003 for ethanol (which is likely to have the highest number of exposed workers), no extrapolations have been carried out on the basis of SUMER 2003.

Table 4-215: Occupationally exposed population in the EU-28 (organic solvents)

Estimate and method of extrapolation	Exposed population in the EU-28
A: SUMER 2010 total number of workers exposed, extrapolated on the basis of population	Women & men: 1.1 million Women: 0.655 million
B: SUMER 2010, 5% of workforce exposed in France, applied to EU-28 workforce	Women & men: 10.5 million Women: 6.3 million

Estimate A in the table above forms the basis for the LOW scenario while estimate B is used for the HIGH scenario. The CENTRAL scenario is also based on estimate A.

Rate of change

The SUMER data does not show a clear trend. Between 2003 and 2010, the number of workers exposed to THF was increasing by 0.7% p.a. whilst the number of workers exposed to methylene chloride was declining by 3% p.a.

Two rates of change are thus used as a basis for modelling:

- an annual decline of 3%; and
- an annual increase of 0.7%.

A generic staff turnover factor of 10% per annum has been used.

Relative risk

The relative risk estimates identified through literature review are summarised below.

Table 4-216: Literature review of relative risk for exposure to organic solvents for women

Study & summary of data/methodology	Cancer site	Relative risk
Ekenga et al (2014). Prospective cohort study of 47,661 women	Breast	HR 1.04 (95% CI: 0.88, 1.24)
Hansen (1999). Matched case-control study of 7,802 women with breast cancer	Breast	OR 1.4-2.4 for selected groups
Peplonska et al (2009). Large population-based case-control study	Breast	OR 1.16 (95% CI: 0.99, 1.4)
Lindbohm et al (2009). Cohort in Finland	Liver	RR 2.73 (95% CI: 1.21, 6.16) for other solvents (alcohols, ketones, esters and glycol ethers
Wang et al (2009). Population-based case-control study of 601 cases and 717 controls in Connecticut	NHL	Ever exposed: OR 1.3 (95% CI: 1.0,1.6) Medium-high level: OR 1.5 (95% CI: 1.1, 1.9)

The lowest and highest relative risks identified through literature are summarised below.

Table 4-217: Summary of relative risk – exposure to organic solvents

Cancer site	Lowest	Highest
Breast	1.04	OR=2.4
Liver	RR=2.73	RR=2.74
NHL	OR=1.3	OR=1.5

Summary of the scenarios

The assumptions underpinning the different estimates are summarised below. Please note that the estimates of the exposed population are point estimates for a specific year and do not represent the lowest and highest annual estimates over the whole assessment period since these also depend on the annual rate of change.

Table 4-218: Summary of the scenarios (organic solvents)				
Aspect/scenario	**Low**	**High**	**Midpoint**	**Central**
Exposed population (EU-28) - point	Women & men: 1.1 million Women: 0.655 million (2010)	Women & men: 10.5 million Women: 6.3 million (2010)	Women & men: 5.8 million Women: 3.5 million (2010)	Women & men: 1.1 million Women: 0.655 million (2010)
Relevant cancer sites	Breast, liver, NHL (3 of 4 but 1 more than IARC, 2016)	Breast, liver, NHL (3 of 4 but 1 more than IARC, 2016)	Breast, liver, NHL (3 of 4 but 1 more than IARC, 2016)	Breast, liver, NHL (3 of 4 but 1 more than IARC, 2016)
Relative risk	Breast: OR=1.04 Liver: RR=2.73 NHL: OR=1.3	Breast: OR=2.4 Liver: RR=2.73 NHL: OR=1.5	Breast: OR=1.72 Liver: RR=2.73 NHL: OR=1.4	Breast: OR=1.16 Liver: RR=2.73 NHL: OR=1.3
Change (p.a.)	0.7%	-3%	-1.15%	-3%

4.26.2The results

Summary of the occupationally exposed population surviving to 2015

The total number of workers in the EU-28 exposed to organic solvents between 1966 and 2005 and surviving to 2015 has been estimated to be between 3.5 and 58.6 million.

Table 4-219: Occupationally exposed population surviving to 2015 (organic solvents)		
Scenario	**No. of workers exposed 1966-2005 & surviving to 2015 (million)**	**% of current & at risk population**
Low	3.5 million	1.1% men & women (1.8% women only)
High	58.6 million	18.3% men & women (30.6% women only)
Midpoint	21.0 million	6.5% men & women (10.9% women only)
Central	6.1 million	1.9% men & women (3.2% women only)

The break-down of these figures by Member State is provided below. The minimum and maximum values across all scenarios are presented for each Member State.

Table 4-220: Occupationally exposed population surviving to 2015 by Member State (organic solvents, 1966-2005)				
Member State	**Number of workers exposed over the period and surviving to 2015**		**% of current & at risk population**	
	Min	**Max**	**Min**	**Max**
Austria	58,619	989,014	1.1%	18.3%
Belgium	76,952	1,298,321	1.1%	18.3%
Bulgaria	49,227	830,557	1.1%	18.3%
Croatia	28,880	487,263	1.1%	18.3%
Cyprus	5,789	97,677	1.1%	18.3%
Czech Republic	72,030	1,215,273	1.1%	18.3%
Denmark	38,685	652,678	1.1%	18.3%
Estonia	8,976	151,446	1.1%	18.3%
Finland	37,400	631,002	1.1%	18.3%
France	453,952	7,658,989	1.1%	18.3%
Germany	554,990	9,363,691	1.1%	18.3%

Table 4-220: Occupationally exposed population surviving to 2015 by Member State (organic solvents, 1966-2005)				
Member State	Number of workers exposed over the period and surviving to 2015		% of current & at risk population	
	Min	Max	Min	Max
Greece	74,215	1,252,145	1.1%	18.3%
Hungary	67,363	1,136,543	1.1%	18.3%
Ireland	31,639	533,810	1.1%	18.3%
Italy	415,542	7,010,944	1.1%	18.3%
Latvia	13,575	229,036	1.1%	18.3%
Lithuania	19,967	336,880	1.1%	18.3%
Luxembourg	3,848	64,920	1.1%	18.3%
Malta	2,935	49,512	1.1%	18.3%
Netherlands	115,518	1,948,990	1.1%	18.3%
Poland	259,771	4,382,803	1.1%	18.3%
Portugal	70,913	1,196,423	1.1%	18.3%
Romania	135,817	2,291,481	1.1%	18.3%
Slovakia	37,055	625,189	1.1%	18.3%
Slovenia	14,100	237,890	1.1%	18.3%
Spain	317,486	5,356,559	1.1%	18.3%
Sweden	66,624	1,124,064	1.1%	18.3%
UK	443,426	7,481,397	1.1%	18.3%
Total	***3,475,293***	***58,634,499***	***1.1%***	***18.3%***

A break down by Member State for occupationally exposed female populations is presented below.

Table 4-221: Occupationally exposed female population by Member State (organic solvents, 1966-2005)				
Member State	Number of women workers exposed		Exposed female workers as % of all women	
	Min	Max	Min	Max
Austria	97,894	1,651,653	1.8%	30.6%
Belgium	128,510	2,168,197	1.8%	30.6%
Bulgaria	82,210	1,387,030	1.8%	30.6%
Croatia	48,230	813,729	1.8%	30.6%
Cyprus	9,668	163,120	1.8%	30.6%
Czech Republic	120,290	2,029,506	1.8%	30.6%
Denmark	64,603	1,089,972	1.8%	30.6%
Estonia	14,990	252,915	1.8%	30.6%
Finland	62,458	1,053,773	1.8%	30.6%
France	758,099	12,790,512	1.8%	30.6%
Germany	926,834	15,637,365	1.8%	30.6%
Greece	123,939	2,091,083	1.8%	30.6%
Hungary	112,497	1,898,027	1.8%	30.6%
Ireland	52,837	891,463	1.8%	30.6%
Italy	693,955	11,708,276	1.8%	30.6%
Latvia	22,670	382,491	1.8%	30.6%
Lithuania	33,345	562,589	1.8%	30.6%
Luxembourg	6,426	108,417	1.8%	30.6%
Malta	4,901	82,685	1.8%	30.6%
Netherlands	192,914	3,254,813	1.8%	30.6%
Poland	433,817	7,319,282	1.8%	30.6%
Portugal	118,424	1,998,027	1.8%	30.6%
Romania	226,815	3,826,773	1.8%	30.6%

Table 4-221: Occupationally exposed female population by Member State (organic solvents, 1966-2005)				
Member State	Number of women workers exposed		Exposed female workers as % of all women	
	Min	Max	Min	Max
Slovakia	61,882	1,044,066	1.8%	30.6%
Slovenia	23,547	397,277	1.8%	30.6%
Spain	530,201	8,945,453	1.8%	30.6%
Sweden	111,262	1,877,187	1.8%	30.6%
UK	740,521	12,493,933	1.8%	30.6%
Total	***5,803,739***	***97,919,613***	***1.8%***	***30.6%***

AFs per Member State

The lowest and highest AFs per Member State are presented below. It should, however, be noted that these are highly uncertain[210] and have therefore not been included in the core assessment.

Table 4-222: Overall attributable fractions across all industries by Member State (organic solvents)						
Cancer site	Breast		Liver		NHL	
Min/max	Low	High	Low	High	Low	High
Austria	0.1%	30%	1.8%	24.1%	0.3%	8.4%
Belgium	0.1%	30%	1.8%	24.1%	0.3%	8.4%
Bulgaria	0.1%	30%	1.8%	24.1%	0.3%	8.4%
Croatia	0.1%	30%	1.8%	24.1%	0.3%	8.4%
Cyprus	0.1%	30%	1.8%	24.1%	0.3%	8.4%
Czech Republic	0.1%	30%	1.8%	24.1%	0.3%	8.4%
Denmark	0.1%	30%	1.8%	24.1%	0.3%	8.4%
Estonia	0.1%	30%	1.8%	24.1%	0.3%	8.4%
Finland	0.1%	30%	1.8%	24.1%	0.3%	8.4%
France	0.1%	30%	1.8%	24.1%	0.3%	8.4%
Germany	0.1%	30%	1.8%	24.1%	0.3%	8.4%
Greece	0.1%	30%	1.8%	24.1%	0.3%	8.4%
Hungary	0.1%	30%	1.8%	24.1%	0.3%	8.4%
Ireland	0.1%	30%	1.8%	24.1%	0.3%	8.4%
Italy	0.1%	30%	1.8%	24.1%	0.3%	8.4%
Latvia	0.1%	30%	1.8%	24.1%	0.3%	8.4%
Lithuania	0.1%	30%	1.8%	24.1%	0.3%	8.4%
Luxembourg	0.1%	30%	1.8%	24.1%	0.3%	8.4%
Malta	0.1%	30%	1.8%	24.1%	0.3%	8.4%
Netherlands	0.1%	30%	1.8%	24.1%	0.3%	8.4%
Poland	0.1%	30%	1.8%	24.1%	0.3%	8.4%
Portugal	0.1%	30%	1.8%	24.1%	0.3%	8.4%
Romania	0.1%	30%	1.8%	24.1%	0.3%	8.4%
Slovakia	0.1%	30%	1.8%	24.1%	0.3%	8.4%
Slovenia	0.1%	30%	1.8%	24.1%	0.3%	8.4%
Spain	0.1%	30%	1.8%	24.1%	0.3%	8.4%
Sweden	0.1%	30%	1.8%	24.1%	0.3%	8.4%
UK	0.1%	30%	1.8%	24.1%	0.3%	8.4%
EU-28	***0.1%***	***30%***	***1.8%***	***24.1%***	***0.3%***	***8.4%***

[210] For example, ethanol has been included in the analysis but this will be due to due to ingestion.

5 Annex 2: AFs/ANs and costs by Member State (central scenario)

The costs estimated under the Central-core scenario are set out below for each Member State.

Table 5-1: Present value costs of annual occupational cancer registrations							
Site	PV costs by member state (€)						
	Austria	Belgium	Bulgaria	Croatia	Cyprus	Czech Republic	Denmark
Bladder	390,000,000	780,000,000	300,000,000	190,000,000	41,000,000	440,000,000	320,000,000
Bone							
Brain	5,200,000	6,000,000	13,000,000	8,700,000	340,000	12,000,000	24,000,000
Breast	610,000,000	790,000,000	540,000,000	250,000,000	29,000,000	1,000,000,000	740,000,000
Cervix	310,000	540,000	1,100,000	280,000	26,000	870,000	310,000
CNS	330,000	460,000	640,000	440,000	16,000	630,000	28,000,000
Colon & rectum	11,000,000	10,000,000	38,000,000	24,000,000	820,000	63,000,000	10,000,000
Eye				0			
Kidney	17,000,000	19,000,000	17,000,000	15,000,000	370,000	62,000,000	25,000,000
Larynx	24,000,000	57,000,000	60,000,000	36,000,000	2,000,000	50,000,000	22,000,000
Leukaemia	75,000,000	100,000,000	47,000,000	35,000,000	9,900,000	78,000,000	81,000,000
Liver & bile duct	1,300,000	900,000	890,000	650,000	78,000	1,300,000	430,000
Lung	3,900,000,000	8,000,000,000	4,300,000,000	3,100,000,000	350,000,000	6,800,000,000	4,400,000,000
Lymphoma	290,000	490,000	150,000	140,000	21,000	300,000	11,000,000
Lymphoma and leukaemia							
Malignant melanoma	14,000,000	20,000,000	4,600,000	7,100,000	540,000	23,000,000	17,000,000
Mesothelium	180,000,000	470,000,000	250,000,000	160,000,000	25,000,000	370,000,000	210,000,000
NHL	5,700,000	10,000,00	2,600,000	2,600,000	560,000	6,200,000	5,000,000
NMSC							
Oesophagus	4,900,000	11,000,000	2,400,000	2,700,000	190,000	6,500,000	4,900,000
Ovary	620,000	440,000	3,100,000	1,500,000	46,000	3,700,000	5210,000
Pancreas	38,000,00	31,000,00	29,000,00	16,000,00	1,800,000	51,000,00	24,000,00

Table 5-1: Present value costs of annual occupational cancer registrations							
Site	**PV costs by member state (€)**						
	Austria	**Belgium**	**Bulgaria**	**Croatia**	**Cyprus**	**Czech Republic**	**Denmark**
	0	0	0	0		0	0
Pharynx incl. NFC	170,000,000	250,000,000	180,000,000	140,000,000	4,300,000	320,000,000	250,000,000
SNC		0					
Stomach	28,000,000	29,000,000	46,000,000	27,000,000	2,000,000	44,000,000	13,000,000
Thyroid	990,000	700,000	250,000	470,000	97,000	900,000	180,000
Total	**5,500,000,000**	**11,000,000**	**5,900,000,000**	**4,000,000,000**	470,000,000	9,400,000,000	6,200,000,000
Percentage of GDP	***1.6%***	***2.6%***	***12.9%***	***9.1%***	***2.6%***	***5.6%***	***2.3%***
Notes: all monetary values are presented to two significant figures so the total may not be exact sum of the costs for the different cancer sites. Calculations are based on 2015 GDP figures sourced from Eurostat							

Table 5-2: Present value costs of annual occupational cancer registrations							
Site	**PV costs by member state (€)**						
	Estonia	**Finland**	**France**	**Germany**	**Greece**	**Hungary**	**Ireland**
Bladder	38,000,000	200,000,000	2,000,000,000	5,100,000,000	500,000,000	480,000,000	120,000,000
Bone							
Brain	2,000,000	3,700,000	77,000,000	54,000,000	7,700,000	8,600,000	1,800,000
Breast	100,000,000	860,000,000	4,000,000,000	6,700,000,000	360,000,000	490,000,000	250,000,000
Cervix	160,000	120,000	2,400,000	4,300,000	360,000	1,000,000	300,000
CNS	71,000	360,000	11,000,000	6,000,000	340,000	430,000	110,000
Colon & rectum	1,500,000	4,900,000	110,000,000	160,000,000	6,800,000	62,000,000	3,900,000
Eye							
Kidney	3,300,000	5,700,000	96,000,000	300,000,000	8,700,000	28,000,000	4,600,000
Larynx	4,500,000	9,400,000	270,000,000	330,000,000	42,000,000	92,000,000	14,000,000
Leukaemia	15,000,000	46,000,000	730,000,000	770,000,000	150,000,000	85,000,000	40,000,000
Liver & bile duct	89,000	870,000	12,000,000	13,000,000	1,500,000	880,000	330,000
Lung	730,000,000	2,800,000,000	41,000,000,000	47,000,000,000	6,700,000,000	8,100,000,000	1,800,000,000
Lymphoma	38,000	310,000	10,000,000	4,200,000	160,000	210,000	140,000
Lymphoma							

Table 5-2: Present value costs of annual occupational cancer registrations							
Site	**PV costs by member state (€)**						
	Estonia	**Finland**	**France**	**Germany**	**Greece**	**Hungary**	**Ireland**
and leukaemia							
Malignant melanoma	1,700,000	13,000,000	100,000,000	180,000,000	4,900,000	12,000,000	9,000,000
Mesothelium	46,000,000	170,000,000	2,300,000,000	2,400,000,000	380,000,000	350,000,000	80,000,000
NHL	620,000	5,800,000	56,000,000	71,000,000	2,300,000	4,800,000	3,400,000
NMSC							
Oesophagus	590,000	3,100,000	49,000,000	76,000,000	2,400,000	6,600,000	4,700,000
Ovary	140,000	350,000	5,400,000	7,000,000	720,000	3,300,000	260,000
Pancreas	4,600,000	27,000,000	220,000,000	390,000,000	37,000,000	44,000,000	12,000,000
Pharynx incl. NFC	28,000,000	82,000,000	2,000,000,000	2,300,000,000	76,000,000	550,000,000	49,000,000
SNC							
Stomach	7,900,000	13,000,000	140,000,000	350,000,000	31,000,000	53,000,000	10,000,000
Thyroid	66,000	320,000	5,500,000	4,300,000	210,000	570,000	130,000
Total	**990,000,000**	**4,200,000,000**	**53,000,000,000**	**67,000,000,000**	**8,300,000,000**	**10,000,000,000**	**2,400,000,000**
Percentage of GDP	***4.9%***	***2.0%***	***2.4%***	***2.2%***	***4.7%***	***9.5%***	***0.95%***
Notes: all monetary values are presented to two significant figures so the total may not be exact sum of the costs for the different cancer sites. Calculations are based on 2015 GDP figures sourced from Eurostat							

Table 5-3: Present value costs of annual occupational cancer registrations							
Site	**PV costs by member state (€)**						
	Italy	**Latvia**	**Lithuania**	**Luxembourg**	**Malta**	**Netherlands**	**Poland**
Bladder	3,300,000,000	77,000,000	100,000,000	17,000,000	1,700,000	540,000,000	1,400,000,000
Bone							
Brain	56,000,000	3,100,000	4,000,000	250,000	3,000	6,700,000	68,000,000
Breast	2,900,000,000	320,000,000	490,000,000	16,000,000	730,000	1,300,000,000	2,300,000,000
Cervix	2,500,000	240,000	520,000	20,000	10	640,000	3,000,000
CNS	1,800,000	170,000	230,000	24,000	10	1,000,000	3,500,000
Colon & rectum	670,000,000	2,400,000	5,700,000	660,000	5,500	15,000,000	150,000,000
Eye					0		
Kidney	140,000,0	4,800,000	11,000,00	840,000	5,400	33,000,00	100,000,0

Table 5-3: Present value costs of annual occupational cancer registrations							
Site	**PV costs by member state (€)**						
	Italy	**Latvia**	**Lithuania**	**Luxembourg**	**Malta**	**Netherlands**	**Poland**
	00		0			0	00
Larynx	440,000,000	12,000,000	15,000,000	1,400,000	83,000	57,000,000	250,000,000
Leukaemia	620,000,000	19,000,000	33,000,000	4,200,000	170,000	120,000,000	260,000,000
Liver & bile duct	15,000,000	210,000	240,000	95,000	72	660,000	2,800,000
Lung	37,000,000,000	1,200,000,000	1,700,000,000	300,000,000	150,000,000	15,000,000,000	19,000,000,000
Lymphoma	4,000,000	54,000	130,000	13,000	1.0	920,000	760,000
Lymphoma and leukaemia					0		
Malignant melanoma	100,000,000	2,400,00	2,900,000	900,000	5,100	50,000,000	27,000,000
Mesothelium	2,100,000,000	70,000,000	100,000,000	20,000,000	19,000,000	1,000,000,000	480,000,000
NHL	61,000,000	900,000	1,700,000	330,000	870	16,000,000	13,000,000
NMSC							
Oesophagus	20,000,000	1,600,000	2,200,000	370,000	2,200	23,000,000	17,000,000
Ovary	37,000,000	280,000	610,000	35,000	120	490,000	15,000,000
Pancreas	250,000,000	8,800,000	11,000,000	1,600,000	21,000	51,000,000	120,000,000
Pharynx incl. NFC	1,400,000,000	34,000,000	66,000,000	8,800,000	1,200,00	260,000,000	1,100,000,000
SNC							
Stomach	450,000,000	14,000,000	20,000,000	1,400,000	28,000	40,000,000	170,000,000
Thyroid	7,800,000	140,000	470,000	51,000	23	460,000	1,500,000
Total	**49,000,000,000**	**1,800,000,000**	**2,600,000,000**	**380,000,000**	**170,000,000**	**18,000,000,000**	**26,000,000,000**
Percentage of GDP	***3.0%***	***7.4%***	***6.9%***	***0.7%***	***1.8%***	***2.7%***	***6.0%***
Notes: all monetary values are presented to two significant figures so the total may not be exact sum of the costs for the different cancer sites. Calculations are based on 2015 GDP figures sourced from Eurostat							

Table 5-4: Present value costs of annual occupational cancer registrations							
Site	**PV costs by member state (€)**						
	Portugal	**Romania**	**Slovakia**	**Slovenia**	**Spain**	**Sweden**	**United Kingdom**
Bladder	520,000,0	690,000,0	170,000,0	83,000,00	2,500,000,	420,000,0	1,600,000,

Table 5-4: Present value costs of annual occupational cancer registrations							
Site	PV costs by member state (€)						
	Portugal	Romania	Slovakia	Slovenia	Spain	Sweden	United Kingdom
	00	00	00	0	000	00	000
Bone							
Brain	12,000,000	26,000,000	7,600,000	2,400,00	28,000,000	8,200,000	34,000,000
Breast	2,400,000,000	1,000,000,000	240,000,000	180,000,000	1,200,000,000	700,000,000	8,300,000,000
Cervix	610,000	3,700,000	520,000	120,000	2,100,000	380,000	2,300,000
CNS	370,000	1,300,000	380,000	120,000	1,100,000	920,000	2,900,000
Colon & rectum	14,000,000	78,000,000	29,000,000	12,000,000	50,000,000	13,000,000	76,000,000
Eye							
Kidney	10,000,000	36,000,000	19,000,000	7,600,000	57,000,000	12,000,000	120,000,000
Larynx	67,000,000	150,000,000	26,000,000	9,400,000	250,000,000	15,000,000	180,000,000
Leukaemia	84,000,000	130,000,000	50,000,000	17,000,000	360,000,000	79,000,000	560,000,000
Liver & bile duct	1,400,000	3,100,000	560,000	300,000	7,700,000	680,000	5,800,000
Lung	5,200,000,000	12,000,000,000	3,000,000,000	1,400,000,000	27,000,000,000	3,900,000,000	60,000,000,000
Lymphoma	350,000	390,000	150,000	73,000	1,200,000	560,000	3,300,000
Lymphoma and leukaemia							
Malignant melanoma	12,000,000	12,000,000	8,400,000	5,600,000	52,000,000	30,000,000	150,000,000
Mesothelium	360,000,000	700,000,000	190,000,000	73,000,000	1,600,000,000	230,000,000	4,600,000,000
NHL	8,900,000	7,600,000	2,800,000	1,400,000	30,000,000	7,700,000	57,000,000
NMSC							
Oesophagus	6,700,000	8,400,000	3,100,000	920,000	23,000,000	5,100,000	97,000,000
Ovary	540,000	6,400,000	1,700,000	660,000	2,300,000	600,000	5,600,000
Pancreas	29,000,000	74,000,000	21,000,000	9,100,000	150,000,000	23,000,000	210,000,000
Pharynx incl. NFC	330,000,000	780,000,000	200,000,000	69,000,00	800,000,000	130,000,000	1,000,000,000
SNC							
Stomach	64,000,000	110,000,000	25,000,000	13,000,000	160,000,000	17,000,000	140,000,000
Thyroid	470,000	650,000	250,000	160,000	1,700,000	320,000	2,200,000
Total	**9,200,000,000**	**16,000,000,000**	**4,000,000,000**	**1,900,000,000**	**35,000,000,000**	**5,600,000,000**	**77,000,000,000**

Table 5-4: Present value costs of annual occupational cancer registrations							
Site	PV costs by member state (€)						
	Portugal	Romania	Slovakia	Slovenia	Spain	Sweden	United Kingdom
Percentage of GDP	***5.1%***	***10%***	***5.1%***	***4.8%***	***3.2%***	***1.3%***	***3.0%***
Notes: all monetary values are presented to two significant figures so the total may not be exact sum of the costs for the different cancer sites. Calculations are based on 2015 GDP figures sourced from Eurostat							

The central AFs and ANs for each Member State are provided in the following tables.

Table 5-5: Austria - AFs and ANs - CENTRAL scenario

Cancer site	Bladder	Bone	Brain	Breast	Cervix	CNS	Colon & rectum	Eye	Kidney	Larynx	Leukaemia	Liver & bile duct	Lung	Lymphoma	Lymphoma & leukaemia	Malignant melanoma	Mesothelium	NHL	NMSC	Oesophagus	Ovary	Pancreas	Pharynx incl. NFC	SNC	Stomach	Thyroid	Total incidence	OvAF
Incidence EUCAN	2,159		297	5,254	363	297	4,874		1,322	297	1,052	955	4,576	1,811		1,334	104	1,172		447	636	1,585	1,145		1,314	1,200	41,117	
Diesel exhaust	1.59%												3.06%															
Silica										2.03%			1.67%															
Asbestos							0.12%			0.31%			13.97%				95.00%				0.05%		0.99%		0.13%			
Formaldehyde			0.62%								0.32%		0.20%										1.22%	1.98%				
Benzene											0.34%																	
Mineral oils	7.20%												9.07%						2.27%									
Cd and Cd compounds									0.49%				0.18%															
Wood dust																							5.95%	2.68%				
Arsenic													0.16%															
Vinyl chloride												0.07%						0.10%										
Ethylene oxide											0.02%			0.00%														
PAHs	0.42%								0.20%				0.10%		1.16%		1.19%		0.63%			1.19%			0.81%			
Occupation as a welder								4.30%					1.52%															
Solar radiation																			9.36%									
ETS													2.45%															
Epichlorohydrine						0.06%							0.01%															
Tetrachloroethylene	0.18%				0.05%													0.16%		0.60%		0.11%						
Shift work				9.62%																								
Dioxins													1.14%															
Inorganic acid mists										2.08%			0.23%															
Rubber manufacturing	0.53%									0.05%	0.10%		0.67%	0%											0.24%			
Ionising radiation	0%	0.01%	0.34%	0.05%							0.03%	0%	0.02%			0.57%										0.04%		
Cr(VI) compounds													0.21%											1.90%				
Aromatic amines	0.14%																											
Cytostatic drugs				0.54%							3.09%																	
Total AF per site	9.82%	0.01%	0.96%	10.16%	0.05%	0.06%	0.12%	4.30%	0.69%	4.41%	3.87%	0.08%	30.44%	0.01%	1.16%	0.57%	95.06%	0.26%	11.98%	0.60%	0.05%	1.30%	8.01%	6.42%	1.17%	0.04%		
AN EUCAN	212		3	534	0	0	6		9	13	41	1	1,393	0		8	98	3		3	0	21	92		15	1	2,452	5.96%

Table 5-6: Belgium - AFs and ANs - CENTRAL scenario

Cancer site	Bladder	Bone	Brain	Breast	Cervix	CNS	Colon & rectum	Eye	Kidney	Larynx	Leukaemia	Liver & bile duct	Lung	Lymphoma	Lymphoma & leukaemia	Malignant melanoma	Mesothelium	NHL	NMSC	Oesophagus	Ovary	Pancreas	Pharynx incl. NFC	SNC	Stomach	Thyroid	Total incidence	OvAF
Incidence EUCAN	4,350		416	10,337	639	416	8,683		1,763	724	1,465	645	7,794	3,210		1,941	272	2,072		969	840	1,293	1,877		1,417	851	65,345	
Diesel exhaust	1.59%												3.06%															
Silica										2.03%			1.67%															
Asbestos							0.07%			0.17%			21.54%				95.00%				0.03%		0.54%		0.07%			
Formaldehyde			0.45%								0.23%		0.15%										0.89%	1.45%				
Benzene											0.34%																	
Mineral oils	7.20%												9.07%						2.27%									
Cd and Cd compounds									0.39%				0.14%															
Wood dust																							5.95%	2.68%				
Arsenic													0.14%															
Vinyl chloride												0.07%						0.10%										
Ethylene oxide											0.02%			0.00%														
PAHs	0.42%								0.20%				0.10%		1.16%		1.19%		0.63%			1.19%			0.81%			
Occupation as a welder								4.30%					1.52%															
Solar radiation																			6.28%									
ETS													2.03%															
Epichlorohydrine						0.06%							0.01%															
Tetrachloroethylene	0.18%				0.05%													0.16%		0.60%		0.11%						
Shift work				6.15%																								
Dioxins													1.14%															
Inorganic acid mists										2.08%			0.23%															
Rubber manufacturing	0.53%									0.05%	0.10%		0.67%	0.00%											0.24%			
Ionising radiation	0%	0.01%	0.34%	0.05%							0.03%	0.00%	0.02%			0.57%										0.04%		
Cr(VI) compounds													0.21%											1.90%				
Aromatic amines	0.14%																											
Cytostatic drugs				0.54%							3.09%																	
Total AF per site	9.82%	0.01%	0.79%	6.71%	0.05%	0.06%	0.07%	4.30%	0.59%	4.28%	3.78%	0.08%	36.21%	0.01%	1.16%	0.57%	95.06%	0.26%	8.99%	0.60%	0.03%	1.30%	7.29%	5.91%	1.11%	0.04%		
AN EUCAN	427		3	694	0	0	6		10	31	55	0	2,823	0		11	258	5		6	0	17	137		16	0	4,501	6.89%

Table 5-7: Bulgaria - AFs and ANs - CENTRAL scenario

Cancer site	Bladder	Bone	Brain	Breast	Cervix	CNS	Colon & rectum	Eye	Kidney	Larynx	Leukaemia	Liver & bile duct	Lung	Lymphoma	Lymphoma & leukaemia	Malignant melanoma	Mesothelium	NHL	NMSC	Oesophagus	Ovary	Pancreas	Pharynx incl. NFC	SNC	Stomach	Thyroid	Total incidence	OvAF
Incidence EUCAN	1,662		414	3,928	1,254	414	4,925		881	636	612	640	3,936	938		439	145	545		222	899	1,236	854		1,664	306	32,053	
Diesel exhaust	1.59%												3.06%															
Silica										2.03%			1.67%															
Asbestos							0.45%			1.09%			22.78%				95.00%				0.19%		3.47%		0.48%			
Formaldehyde			1.31%								0.67%		0.43%										2.55%	4.10%				
Benzene											0.34%																	
Mineral oils	7.20%												9.07%						2.27%									
Cd and Cd compounds									0.84%				0.30%															
Wood dust																							5.95%	2.68%				
Arsenic													0.36%															
Vinyl chloride												0.07%						0.10%										
Ethylene oxide											0.02%			0.00%														
PAHs	0.42%								0.20%				0.10%		1.16%		1.19%		0.63%			1.19%			0.81%			
Occupation as a welder								4.30%					1.52%															
Solar radiation																			13.00%									
ETS													3.65%															
Epichlorohydrine						0.08%							0.02%															
Tetrachloroethylene	0.18%				0.05%													0.16%		0.60%		0.11%						
Shift work				11.63%																								
Dioxins													1.14%															
Inorganic acid mists										2.08%			0.23%															
Rubber manufacturing	0.53%									0.05%	0.10%		0.67%	0.00%											0.24%			
Ionising radiation	0%	0.01%	0.34%	0.05%							0.03%	0.00%	0.02%			0.57%										0.04%		
Cr(VI) compounds													0.21%											1.90%				
Aromatic amines	0.14%																											
Cytostatic drugs				0.54%							3.09%																	
Total AF per site	9.82%	0.01%	1.65%	12.15%	0.05%	0.08%	0.45%	4.30%	1.04%	5.17%	4.21%	0.08%	38.67%	0.01%	1.16%	0.57%	95.06%	0.26%	15.52%	0.60%	0.19%	1.30%	11.52%	8.44%	1.51%	0.04%		
AN EUCAN	163		7	477	1	0	22		9	33	26	0	1,522	0		3	138	1		1	2	16	98		25	0	2,546	7.94%

Table 5-8: Croatia- AFs and ANs - CENTRAL scenario

Cancer site	Bladder	Bone	Brain	Breast	Cervix	CNS	Colon & rectum	Eye	Kidney	Larynx	Leukaemia	Liver & bile duct	Lung	Lymphoma	Lymphoma & leukaemia	Malignant melanoma	Mesothelium	NHL	NMSC	Oesophagus	Ovary	Pancreas	Pharynx incl. NFC	SNC	Stomach	Thyroid	Total incidence	OvAF
Incidence EUCAN	1,053		295	2,641	325	295	3,209		821	381	456	466	3,056	933		674	94	544		243	428	677	685		966	576	22,890	
Diesel exhaust	1.59%												3.06%															
Silica										2.03%			1.67%															
Asbestos							0.44%			1.07%			18.97%				95.00%				0.19%		3.38%		0.46%			
Formaldehyde			1.28%								0.66%		0.42%										2.48%	4.00%				
Benzene											0.34%																	
Mineral oils	7.20%												9.07%						2.27%									
Cd and Cd compounds									0.82%				0.30%															
Wood dust																							5.95%	2.68%				
Arsenic													0.35%															
Vinyl chloride												0.07%						0.10%										
Ethylene oxide											0.02%			0.00%														
PAHs	0.42%								0.20%				0.10%		1.16%		1.19%		0.63%			1.19%			0.81%			
Occupation as a welder								4.30%					1.52%															
Solar radiation																			12.71%									
ETS													3.56%															
Epichlorohydrine						0.08%							0.02%															
Tetrachloroethylene	0.18%				0.05%													0.16%		0.60%		0.11%						
Shift work				7.87%																								
Dioxins													1.14%															
Inorganic acid mists										2.08%			0.23%															
Rubber manufacturing	0.53%									0.05%	0.10%		0.67%	0.00%											0.24%			
Ionising radiation	0%	0.01%	0.34%	0.05%							0.03%	0.00%	0.02%			0.57%										0.04%		
Cr(VI) compounds													0.21%											1.90%				
Aromatic amines	0.14%																											
Cytostatic drugs				0.54%							3.09%																	
Total AF per site	9.82%	0.01%	1.61%	8.42%	0.05%	0.08%	0.44%	4.30%	1.01%	5.14%	4.19%	0.08%	35.56%	0.01%	1.16%	0.57%	95.06%	0.26%	15.23%	0.60%	0.19%	1.30%	11.38%	8.35%	1.50%	0.04%		
AN EUCAN	103		5	222	0	0	14		8	20	19	0	1,087	0		4	89	1		1	1	9	78		14	0	1,677	7.33%

Table 5-9: Cyprus- AFs and ANs - CENTRAL scenario

Cancer site	Bladder	Bone	Brain	Breast	Cervix	CNS	Colon & rectum	Eye	Kidney	Larynx	Leukaemia	Liver & bile duct	Lung	Lymphoma	Lymphoma & leukaemia	Malignant melanoma	Mesothelium	NHL	NMSC	Oesophagus	Ovary	Pancreas	Pharynx incl. NFC	SNC	Stomach	Thyroid	Total incidence	OvAF
Incidence EUCAN	227		29	604	31	29	442		46	25	146	56	276	182		52	14	116		17	56	77	32		94	118	3,438	
Diesel exhaust	1.59%												3.06%															
Silica										2.03 %			1.67%															
Asbestos							0.11%			0.26 %			32.03 %				95.00%				0.05 %		0.84%		0.11%			
Formaldehyde			0.30 %								0.15%		0.10%										0.59%	0.97 %				
Benzene											0.34%																	
Mineral oils	7.20%												9.07%						2.27%									
Cd and Cd compounds									0.24 %				0.09%															
Wood dust																							5.95%	2.68 %				
Arsenic													0.06%															
Vinyl chloride												0.07 %						0.10 %										
Ethylene oxide											0.01%			0.00%														
PAHs	0.42%								0.20 %				0.10%		1.16%		1.19%		0.63%			1.19%			0.81%			
Occupation as a welder								4.30 %					1.52%															
Solar radiation																			14.22 %									
ETS													2.04%															
Epichlorohydrine						0.03 %							0.01%															
Tetrachloroethylene	0.18%				0.05 %													0.16 %		0.60%		0.11%						
Shift work				3.71 %																								
Dioxins													1.14%															
Inorganic acid mists										2.08 %			0.23%															
Rubber manufacturing	0.53%									0.05 %	0.10%		0.67%	0.00%											0.24%			
Ionising radiation	0%	0.01 %	0.34 %	0.05 %							0.03%	0.00 %	0.02%			0.57%										0.04%		
Cr(VI) compounds													0.21%											1.90 %				
Aromatic amines	0.14%																											
Cytostatic drugs				0.54 %							3.09%																	
Total AF per site	9.82%	0.01 %	0.64 %	4.28 %	0.05 %	0.03 %	0.11%	4.30 %	0.44 %	4.37 %	3.70%	0.08 %	44.64 %	0.01%	1.16%	0.57%	95.06%	0.26 %	16.70 %	0.60%	0.05 %	1.30%	7.29%	5.45 %	1.15%	0.04%		
AN EUCAN	22		0	26	0	0	0		0	1	5	0	123	0		0	14	0		0	0	1	2		1	0	198	5.75 %

Table 5-10: Czech Republic- AFs and ANs - CENTRAL scenario

Cancer site	Bladder	Bone	Brain	Breast	Cervix	CNS	Colon & rectum	Eye	Kidney	Larynx	Leukaemia	Liver & bile duct	Lung	Lymphoma	Lymphoma & leukaemia	Malignant melanoma	Mesothelium	NHL	NMSC	Oesophagus	Ovary	Pancreas	Pharynx incl. NFC	SNC	Stomach	Thyroid	Total incidence	OvAF
Incidence EUCAN	2,462		419	6,854	1,016	419	8,336		3,313	530	1,016	919	6,683	1,953		2,194	212	1,278		593	1,092	2,118	1,510		1,595	1,094	57,627	
Diesel exhaust	1.59%												3.06%															
Silica										2.03 %			1.67%															
Asbestos							0.44%			1.07 %			19.63 %				95.00%				0.19 %		3.39%		0.47%			
Formaldehyde			1.28 %								0.66%		0.42%										2.49%	4.01 %				
Benzene											0.34%																	
Mineral oils	7.20%												9.07%						2.27%									
Cd and Cd compounds									0.82 %				0.30%															
Wood dust																							5.95%	2.68 %				
Arsenic													0.35%															
Vinyl chloride												0.07 %						0.10 %										
Ethylene oxide											0.02%			0.00%														
PAHs	0.42%								0.20 %				0.10%		1.16%		1.19%		0.63%			1.19%			0.81%			
Occupation as a welder								4.30 %					1.52%															
Solar radiation																			12.74 %									
ETS													3.57%															
Epichlorohydrine						0.08 %							0.02%															
Tetrachloroethylene	0.18%				0.05 %													0.16 %		0.60%		0.11%						
Shift work				12.94 %																								
Dioxins													1.14%															
Inorganic acid mists										2.08 %			0.23%															
Rubber manufacturing	0.53%									0.05 %	0.10%		0.67%	0.00%											0.24%			
Ionising radiation	0%	0.01 %	0.34 %	0.05%							0.03%	0.00 %	0.02%			0.57%										0.04%		
Cr(VI) compounds													0.21%											1.90 %				
Aromatic amines	0.14%																											
Cytostatic drugs				0.54%							3.09%																	
Total AF per site	9.82%	0.01 %	1.62 %	13.45 %	0.05 %	0.08 %	0.44%	4.30 %	1.02 %	5.14 %	4.19%	0.08 %	36.10 %	0.01%	1.16%	0.57%	95.06%	0.26 %	15.26 %	0.60%	0.19 %	1.30%	11.39 %	8.36 %	1.50%	0.04%		
AN EUCAN	242		7	922	0	0	36		34	27	43	1	2,413	0		13	202	3		4	2	28	172		24	0	4,172	7.24 %

Table 5-11: Denmark - AFs and ANs - CENTRAL scenario

Cancer site	Bladder	Bone	Brain	Breast	Cervix	CNS	Colon & rectum	Eye	Kidney	Larynx	Leukaemia	Liver & bile duct	Lung	Lymphoma	Lymphoma & leukaemia	Malignant melanoma	Mesothelium	NHL	NMSC	Oesophagus	Ovary	Pancreas	Pharynx incl. NFC	SNC	Stomach	Thyroid	Total incidence	OvAF
Incidence EUCAN	1,781		259	5,224	363	259	4,832		754	266	588	311	4,566	1,478		1,596	120	1,031		443	544	1,023	910		625	222	36,119	
Diesel exhaust	1.59%												3.06%															
Silica										2.03 %			1.67%															
Asbestos							0.12%			0.30 %			16.26 %				95.00%				0.05 %		0.97%		0.13%			
Formaldehyde			4.77 %								2.49%		1.59%										8.97%	13.88 %				
Benzene											0.34%																	
Mineral oils	7.20%												9.07%						2.27%									
Cd and Cd compounds									1.64 %				0.60%															
Wood dust																							5.95%	2.68%				
Arsenic													0.11%															
Vinyl chloride												0.07 %						0.10 %										
Ethylene oxide											1.69%			0.40%														
PAHs	0.42%								0.20 %				0.10%		1.16%		1.19%		0.63%			1.19%			0.81%			
Occupation as a welder								4.30 %					1.52%															
Solar radiation																			10.66 %									
ETS													2.20%															
Epichlorohydrine						5.83 %							1.34%															
Tetrachloroethylene	0.18%				0.05 %													0.16 %		0.60%		0.11%						
Shift work				12.03 %																								
Dioxins													1.14%															
Inorganic acid mists										2.08 %			0.23%															
Rubber manufacturing	0.53%									0.05 %	0.10%		0.67%	0.00%											0.24%			
Ionising radiation	0%	0.01 %	0.34 %	0.05%							0.03%	0.00 %	0.02%			0.57%										0.04%		
Cr(VI) compounds													0.21%											1.90%				
Aromatic amines	0.14%																											
Cytostatic drugs				0.54%							3.09%																	
Total AF per site	9.82%	0.01 %	5.10 %	12.55 %	0.05 %	5.83 %	0.12%	4.30 %	1.84 %	4.41 %	7.53%	0.08 %	34.19 %	0.40%	1.16%	0.57%	95.06%	0.26 %	13.24 %	0.60%	0.05 %	1.30%	15.21 %	17.78 %	1.17%	0.04%		
AN EUCAN	175		13	656	0	15	6		14	12	44	0	1,561	6		9	114	3		3	0	13	138		7	0	2,791	7.73 %

Table 5-12: Estonia- AFs and ANs - CENTRAL scenario

Cancer site	Bladder	Bone	Brain	Breast	Cervix	CNS	Colon & rectum	Eye	Kidney	Larynx	Leukaemia	Liver & bile duct	Lung	Lymphoma	Lymphoma & leukaemia	Malignant melanoma	Mesothelium	NHL	NMSC	Oesophagus	Ovary	Pancreas	Pharynx incl. NFC	SNC	Stomach	Thyroid	Total incidence	OvAF
Incidence EUCAN	209		45	658	186	45	789		284	56	175	64	632	225		166	26	128		54	156	191	143		370	80	6,117	
Diesel exhaust	1.59%												3.06%															
Silica										2.03 %			1.67%															
Asbestos							0.11%			0.27 %			25.87 %				95.00%				0.05 %		0.88%		0.12%			
Formaldehyde			2.11 %								1.09%		0.69%										4.07%	6.49%				
Benzene											0.34%																	
Mineral oils	7.20%												9.07%						2.27%									
Cd and Cd compounds									0.43 %				0.16%															
Wood dust																							5.95%	2.68%				
Arsenic													0.41%															
Vinyl chloride												0.07 %						0.10 %										
Ethylene oxide											0.02%			0.01%														
PAHs	0.42%								0.20 %				0.10%		1.16%		1.19%		0.63%			1.19%			0.81%			
Occupation as a welder								4.30 %					1.52%															
Solar radiation																			16.41 %									
ETS													3.27%															
Epichlorohydrine						0.09 %							0.02%															
Tetrachloroethylene	0.18%				0.05 %													0.16 %		0.60%		0.11%						
Shift work				13.24 %																								
Dioxins													1.14%															
Inorganic acid mists										2.08 %			0.23%															
Rubber manufacturing	0.53%									0.05 %	0.10%		0.67%	0.00%											0.24%			
Ionising radiation	0%	0.01 %	0.34 %	0.05%							0.03%	0.00 %	0.02%			0.57%										0.04%		
Cr(VI) compounds													0.21%											1.90%				
Aromatic amines	0.14%																											
Cytostatic drugs				0.54%							3.09%																	
Total AF per site	9.82%	0.01 %	2.44 %	13.75 %	0.05 %	0.09 %	0.11%	4.30 %	0.63 %	4.38 %	4.61%	0.08 %	40.99 %	0.01%	1.16%	0.57%	95.06%	0.26 %	18.82 %	0.60%	0.05 %	1.30%	10.57 %	10.72 %	1.16%	0.04%		
AN EUCAN	21		1	90	0	0	1		2	2	8	0	259	0		1	25	0		0	0	2	15		4	0	433	7.08 %

Table 5-13: Finland- AFs and ANs - CENTRAL scenario

Cancer site	Bladder	Bone	Brain	Breast	Cervix	CNS	Colon & rectum	Eye	Kidney	Larynx	Leukaemia	Liver & bile duct	Lung	Lymphoma	Lymphoma & leukaemia	Malignant melanoma	Mesothelium	NHL	NMSC	Oesophagus	Ovary	Pancreas	Pharynx incl. NFC	SNC	Stomach	Thyroid	Total incidence	OvAF
Incidence EUCAN	1,093		215	4,477	143	215	2,896		882	118	653	620	2,494	1,706		1,208	99	1,208		282	457	1,151	573		641	386	28,428	
Diesel exhaust	1.59%												3.06%															
Silica										2.03%			1.67%															
Asbestos							0.10%			0.24%			24.53%				95.00%				0.04%		0.77%		0.10%			
Formaldehyde			0.60%								0.31%		0.19%										1.17%	1.90%				
Benzene											0.34%																	
Mineral oils	7.20%												9.07%						2.27%									
Cd and Cd compounds									0.16%				0.06%															
Wood dust																							5.95%	2.68%				
Arsenic													0.31%															
Vinyl chloride												0.07%						0.10%										
Ethylene oxide											0.02%			0.01%														
PAHs	0.42%								0.20%				0.10%		1.16%		1.19%		0.63%			1.19%			0.81%			
Occupation as a welder								4.30%					1.52%															
Solar radiation																			11.15%									
ETS													2.41%															
Epichlorohydrine						0.09%							0.02%															
Tetrachloroethylene	0.18%				0.05%													0.16%		0.60%		0.11%						
Shift work				16.51%																								
Dioxins													1.14%															
Inorganic acid mists										2.08%			0.23%															
Rubber manufacturing	0.53%									0.05%	0.10%		0.67%	0.00%											0.24%			
Ionising radiation	0%	0.01%	0.34%	0.05%							0.03%	0.00%	0.02%			0.57%										0.04%		
Cr(VI) compounds													0.21%											1.90%				
Aromatic amines	0.14%																											
Cytostatic drugs				0.54%							3.09%																	
Total AF per site	9.82%	0.01%	0.94%	17.00%	0.05%	0.09%	0.10%	4.30%	0.36%	4.35%	3.86%	0.08%	38.97%	0.01%	1.16%	0.57%	95.06%	0.26%	13.71%	0.60%	0.04%	1.30%	7.77%	6.34%	1.14%	0.04%		
AN EUCAN	107		2	761	0	0	3		3	5	25	0	972	0		7	94	3		2	0	15	45		7	0	2,053	7.22%

Table 5-14: France- AFs and ANs - CENTRAL scenario

Cancer site	Bladder	Bone	Brain	Breast	Cervix	CNS	Colon & rectum	Eye	Kidney	Larynx	Leukaemia	Liver & bile duct	Lung	Lymphoma	Lymphoma & leukaemia	Malignant melanoma	Mesothelium	NHL	NMSC	Oesophagus	Ovary	Pancreas	Pharynx incl. NFC	SNC	Stomach	Thyroid	Total incidence	OvAF
Incidence EUCAN	11,175		2,384	48,763	2,862	2,384	40,825		11,023	3,344	9,180	8,332	40,043	19,291		9,871	1,339	11,512		4,415	4,592	9,149	11,240		6,507	6,703	349,426	
Diesel exhaust	1.59%												3.06%															
Silica										2.03 %			1.67%															
Asbestos							0.15%			0.37 %			20.65 %				95.00%				0.06 %		1.19%		0.16%			
Formaldehyde			1.43 %								0.73%		0.46%										2.77%	4.45 %				
Benzene											0.34%																	
Mineral oils	7.20%												9.07%						2.27%									
Cd and Cd compounds									0.28 %				0.10%															
Wood dust																							5.95%	2.68 %				
Arsenic													0.14%															
Vinyl chloride												0.07 %						0.10 %										
Ethylene oxide											0.10%			0.02%														
PAHs	0.42%								0.20 %				0.10%		1.16%		1.19%		0.63%			1.19%			0.81%			
Occupation as a welder								4.30 %					1.52%															
Solar radiation																			7.87%									
ETS													2.11%															
Epichlorohydrine						0.26 %							0.06%															
Tetrachloroethylene	0.18%				0.05 %													0.16 %		0.60%		0.11%						
Shift work				6.63 %																								
Dioxins													1.14%															
Inorganic acid mists										2.08 %			0.23%															
Rubber manufacturing	0.53%									0.05 %	0.10%		0.67%	0.00%											0.24%			
Ionising radiation	0%	0.01 %	0.34 %	0.05 %							0.03%	0.00 %	0.02%			0.57%										0.04%		
Cr(VI) compounds													0.21%											1.90 %				
Aromatic amines	0.14%																											
Cytostatic drugs				0.54 %							3.09%																	
Total AF per site	9.82%	0.01 %	1.76 %	7.18 %	0.05 %	0.26 %	0.15%	4.30 %	0.47 %	4.47 %	4.35%	0.08 %	35.75 %	0.03%	1.16%	0.57%	95.06%	0.26 %	10.53 %	0.60%	0.06 %	1.30%	9.64%	8.78 %	1.20%	0.04%		
AN EUCAN	1,098		42	3,502	1	6	61		52	150	399	6	14,315	5		56	1,273	30		26	3	119	1,084		78	3	22,311	6.38 %

Table 5-15: Germany - AFs and ANs - CENTRAL scenario

Cancer site	Bladder	Bone	Brain	Breast	Cervix	CNS	Colon & rectum	Eye	Kidney	Larynx	Leukaemia	Liver & bile duct	Lung	Lymphoma	Lymphoma & leukaemia	Malignant melanoma	Mesothelium	NHL	NMSC	Oesophagus	Ovary	Pancreas	Pharynx incl. NFC	SNC	Stomach	Thyroid	Total incidence	OvAF
Incidence EUCAN	28,405		3,558	71,623	4,995	3,558	63,572		18,615	4,064	11,038	9,202	50,813	22,561		16,884	1,372	14,597		6,950	6,673	16,451	15,891		16,015	5,229	493,780	
Diesel exhaust	1.59%												3.06%															
Silica										2.03 %			1.67%															
Asbestos							0.14%			0.35 %			16.68 %				95.00%				0.06 %		1.12%		0.15%			
Formaldehyde			0.49 %								0.25%		0.16%										0.96%	1.57 %				
Benzene											0.34%																	
Mineral oils	7.20%												9.07%						2.27%									
Cd and Cd compounds									0.68 %				0.25%															
Wood dust																							5.95%	2.68 %				
Arsenic													0.18%															
Vinyl chloride												0.07 %						0.10 %										
Ethylene oxide											0.03%			0.01%														
PAHs	0.42%								0.20 %				0.10%		1.16%		1.19%		0.63%			1.19%			0.81%			
Occupation as a welder								4.30 %					1.52%															
Solar radiation																			9.85%									
ETS													2.91%															
Epichlorohydrine						0.09 %							0.02%															
Tetrachloroethylene	0.18%				0.05 %													0.16 %		0.60%		0.11%						
Shift work				7.74 %																								
Dioxins													1.14%															
Inorganic acid mists										2.08 %			0.23%															
Rubber manufacturing	0.53%									0.05 %	0.10%		0.67%	0.00%											0.24%			
Ionising radiation	0%	0.01 %	0.34 %	0.05 %							0.03%	0.00 %	0.02%			0.57%										0.04%		
Cr(VI) compounds													0.21%											1.90 %				
Aromatic amines	0.14%																											
Cytostatic drugs				0.54 %							3.09%																	
Total AF per site	9.82%	0.01 %	0.83 %	8.28 %	0.05 %	0.09 %	0.14%	4.30 %	0.88 %	4.45 %	3.81%	0.08 %	32.98 %	0.01%	1.16%	0.57%	95.06%	0.26 %	12.46 %	0.60%	0.06 %	1.30%	7.89%	6.02 %	1.19%	0.04%		
AN EUCAN	2,791		30	5,933	2	3	90		163	181	420	7	16,757	2		96	1,305	38		42	4	214	1,254		190	2	29,525	5.98 %

Table 5-16: Greece - AFs and ANs - CENTRAL scenario

Cancer site	Bladder	Bone	Brain	Breast	Cervix	CNS	Colon & rectum	Eye	Kidney	Larynx	Leukaemia	Liver & bile duct	Lung	Lymphoma	Lymphoma & leukaemia	Malignant melanoma	Mesothelium	NHL	NMSC	Oesophagus	Ovary	Pancreas	Pharynx incl. NFC	SNC	Stomach	Thyroid	Total incidence	OvAF
Incidence EUCAN	2,777		667	4,934	421	667	3,885		1,094	527	2,247	1,054	6,884	1,412		472	219	467		217	915	1,539	570		1,478	253	40,971	
Diesel exhaust	1.59%												3.06%															
Silica										2.03%			1.67%															
Asbestos							0.10%			0.25%			19.64%				95.00%				0.04%		0.80%		0.11%			
Formaldehyde			0.30%								0.15%		0.10%										0.58%	0.94%				
Benzene											0.34%																	
Mineral oils	7.20%												9.07%						2.27%									
Cd and Cd compounds									0.24%				0.09%															
Wood dust																							5.95%	2.68%				
Arsenic													0.06%															
Vinyl chloride												0.07%						0.10%										
Ethylene oxide											0.01%			0.00%														
PAHs	0.42%								0.20%				0.10%		1.16%		1.19%		0.63%			1.19%			0.81%			
Occupation as a welder								4.30%					1.52%															
Solar radiation																			13.58%									
ETS													1.91%															
Epichlorohydrine						0.03%							0.01%															
Tetrachloroethylene	0.18%				0.05%													0.16%		0.60%		0.11%						
Shift work				5.80%																								
Dioxins													1.14%															
Inorganic acid mists										2.08%			0.23%															
Rubber manufacturing	0.53%									0.05%	0.10%		0.67%	0.00%											0.24%			
Ionising radiation	0%	0.01%	0.34%	0.05%							0.03%	0.00%	0.02%			0.57%										0.04%		
Cr(VI) compounds													0.21%											1.90%				
Aromatic amines	0.14%																											
Cytostatic drugs				0.54%							3.09%																	
Total AF per site	9.82%	0.01%	0.63%	6.36%	0.05%	0.03%	0.10%	4.30%	0.43%	4.35%	3.69%	0.08%	34.46%	0.01%	1.16%	0.57%	95.06%	0.26%	16.08%	0.60%	0.04%	1.30%	7.24%	5.43%	1.15%	0.04%		
AN EUCAN	273		4	314	0	0	4		5	23	83	1	2,372	0		3	208	1		1	0	20	41		17	0	3,371	8.23%

Table 5-17: Hungary- AFs and ANs - CENTRAL scenario

Cancer site	Bladder	Bone	Brain	Breast	Cervix	CNS	Colon & rectum	Eye	Kidney	Larynx	Leukaemia	Liver & bile duct	Lung	Lymphoma	Lymphoma & leukaemia	Malignant melanoma	Mesothelium	NHL	NMSC	Oesophagus	Ovary	Pancreas	Pharynx incl. NFC	SNC	Stomach	Thyroid	Total incidence	OvAF
Incidence EUCAN	2,689		298	5,094	1,178	298	8,442		1,554	986	1,111	630	9,288	1,398		1,117	199	987		603	999	1,856	2,696		1,951	686	50,475	
Diesel exhaust	1.59%												3.06%															
Silica										2.03%			1.67%															
Asbestos							0.42%			1.03%			13.21%				95.00%				0.18%		3.26%		0.45%			
Formaldehyde			1.24%								0.63%		0.40%										2.40%	3.86%				
Benzene											0.34%																	
Mineral oils	7.20%												9.07%						2.27%									
Cd and Cd compounds									0.79%				0.29%															
Wood dust																							5.95%	2.68%				
Arsenic													0.34%															
Vinyl chloride												0.07%						0.10%										
Ethylene oxide											0.02%			0.00%														
PAHs	0.42%								0.20%				0.10%		1.16%		1.19%		0.63%			1.19%			0.81%			
Occupation as a welder								4.30%					1.52%															
Solar radiation																			12.31%									
ETS													3.44%															
Epichlorohydrine						0.08%							0.02%															
Tetrachloroethylene	0.18%				0.05%													0.16%		0.60%		0.11%						
Shift work				7.91%																								
Dioxins													1.14%															
Inorganic acid mists										2.08%			0.23%															
Rubber manufacturing	0.53%									0.05%	0.10%		0.67%	0.00%											0.24%			
Ionising radiation	0%	0.01%	0.34%	0.05%							0.03%	0.00%	0.02%			0.57%										0.04%		
Cr(VI) compounds													0.21%											1.90%				
Aromatic amines	0.14%																											
Cytostatic drugs				0.54%							3.09%																	
Total AF per site	9.82%	0.01%	1.57%	8.46%	0.05%	0.08%	0.42%	4.30%	0.98%	5.10%	4.17%	0.08%	30.87%	0.01%	1.16%	0.57%	95.06%	0.26%	14.85%	0.60%	0.18%	1.30%	11.20%	8.22%	1.48%	0.04%		
AN EUCAN	264		5	431	1	0	35		15	50	46	0	2,868	0		6	189	3		4	2	24	302		29	0	4,275	8.47%

Table 5-18: Ireland - AFs and ANs - CENTRAL scenario

Cancer site	Bladder	Bone	Brain	Breast	Cervix	CNS	Colon & rectum	Eye	Kidney	Larynx	Leukaemia	Liver & bile duct	Lung	Lymphoma	Lymphoma & leukaemia	Malignant melanoma	Mesothelium	NHL	NMSC	Oesophagus	Ovary	Pancreas	Pharynx incl. NFC	SNC	Stomach	Thyroid	Total incidence	OvAF
Incidence EUCAN	666		175	2,899	357	175	2,560		571	179	594	239	2,273	1,127		859	46	711		424	380	510	384		487	155	20,808	
Diesel exhaust	1.59%												3.06%															
Silica										2.03%			1.67%															
Asbestos							0.09%			0.22%			12.45%				95.00%				0.04%		0.70%		0.09%			
Formaldehyde			0.23%								0.12%		0.07%										0.44%	0.72%				
Benzene											0.34%																	
Mineral oils	7.20%												9.07%						2.27%									
Cd and Cd compounds									0.25%				0.09%															
Wood dust																							5.95%	2.68%				
Arsenic													0.06%															
Vinyl chloride												0.07%						0.10%										
Ethylene oxide											0.01%			0.00%														
PAHs	0.42%								0.20%				0.10%		1.16%		1.19%		0.63%			1.19%			0.81%			
Occupation as a welder								4.30%					1.52%															
Solar radiation																			7.95%									
ETS													1.51%															
Epichlorohydrine						0.03%							0.01%															
Tetrachloroethylene	0.18%				0.05%													0.16%		0.60%		0.11%						
Shift work				7.14%																								
Dioxins													1.14%															
Inorganic acid mists										2.08%			0.23%															
Rubber manufacturing	0.53%									0.05%	0.10%		0.67%	0.00%											0.24%			
Ionising radiation	0%	0.01%	0.34%	0.05%							0.03%	0.00%	0.02%			0.57%										0.04%		
Cr(VI) compounds													0.21%											1.90%				
Aromatic amines	0.14%																											
Cytostatic drugs				0.54%							3.09%																	
Total AF per site	9.82%	0.01%	0.56%	7.69%	0.05%	0.03%	0.09%	4.30%	0.44%	4.32%	3.66%	0.08%	28.29%	0.01%	1.16%	0.57%	95.06%	0.26%	10.61%	0.60%	0.04%	1.30%	7.02%	5.22%	1.13%	0.04%		
AN EUCAN	65		1	223	0	0	2		3	8	22	0	643	0		5	44	2		3	0	7	27		6	0	1,059	5.09%

Table 5-19: Italy - AFs and ANs - CENTRAL scenario

Cancer site	Bladder	Bone	Brain	Breast	Cervix	CNS	Colon & rectum	Eye	Kidney	Larynx	Leukaemia	Liver & bile duct	Lung	Lymphoma	Lymphoma & leukaemia	Malignant melanoma	Mesothelium	NHL	NMSC	Oesophagus	Ovary	Pancreas	Pharynx incl. NFC	SNC	Stomach	Thyroid	Total incidence	OvAF
Incidence EUCAN	18,284		2,464	50,658	2,918	2,464	48,110		11,300	4,049	8,369	10,733	37,238	19,494		10,012	1,226	12,548		1,809	5,911	10,688	5,835		13,001	9,459	354,456	
Diesel exhaust	1.59%												3.06%															
Silica										2.03 %			1.67%															
Asbestos							0.80%			1.94 %			20.33 %				95.00%				0.34 %		6.03%		0.85%			
Formaldehyde			0.90 %								0.46%		0.29%										1.75%	2.83 %				
Benzene											0.34%																	
Mineral oils	7.20%												9.07%						2.27 %									
Cd and Cd compounds									0.46 %				0.17%															
Wood dust																							5.95%	2.68 %				
Arsenic													0.11%															
Vinyl chloride												0.07 %						0.10 %										
Ethylene oxide											0.03%			0.01%														
PAHs	0.42%								0.20 %				0.10%		1.16%		1.19%		0.63 %			1.19%			0.81%			
Occupation as a welder								4.30 %					1.52%															
Solar radiation																			3.33 %									
ETS													1.53%															
Epichlorohydrine						0.04 %							0.01%															
Tetrachloroethylene	0.18%				0.05 %													0.16 %		0.60%		0.11%						
Shift work				4.40 %																								
Dioxins													1.14%															
Inorganic acid mists										2.08 %			0.23%															
Rubber manufacturing	0.53%									0.05 %	0.10%		0.67%	0.00%											0.24%			
Ionising radiation	0%	0.01 %	0.34 %	0.05 %							0.03%	0.00 %	0.02%			0.57%										0.04%		
Cr(VI) compounds													0.21%											1.90 %				
Aromatic amines	0.14%																											
Cytostatic drugs				0.54 %							3.09%																	
Total AF per site	9.82%	0.01 %	1.23 %	4.96 %	0.05 %	0.04 %	0.80%	4.30 %	0.65 %	5.98 %	4.01%	0.08 %	34.99 %	0.01%	1.16%	0.57%	95.06%	0.26 %	6.12 %	0.60%	0.34 %	1.30%	13.16 %	7.22 %	1.88%	0.04%		
AN EUCAN	1,796		30	2,515	1	1	383		74	242	336	8	13,028	2		57	1,165	33		11	20	139	768		244	4	20,859	5.88 %

Table 5-20: Latvia- AFs and ANs - CENTRAL scenario

Cancer site	Bladder	Bone	Brain	Breast	Cervix	CNS	Colon & rectum	Eye	Kidney	Larynx	Leukaemia	Liver & bile duct	Lung	Lymphoma	Lymphoma & leukaemia	Malignant melanoma	Mesothelium	NHL	NMSC	Oesophagus	Ovary	Pancreas	Pharynx incl. NFC	SNC	Stomach	Thyroid	Total incidence	OvAF
Incidence EUCAN	425		128	1,145	284	128	1,152		449	143	254	154	1,183	313		225	40	186		142	304	371	215		640	168	10,347	
Diesel exhaust	1.59%												3.06%															
Silica										2.03 %			1.67%															
Asbestos							0.12%			0.29 %			20.90 %				95.00%				0.05 %		0.95%		0.13%			
Formaldehyde			0.96 %								0.49%		0.31%										1.88%	3.04 %				
Benzene											0.34%																	
Mineral oils	7.20%												9.07%						2.27%									
Cd and Cd compounds									0.38 %				0.14%															
Wood dust																							5.95%	2.68 %				
Arsenic													0.32%															
Vinyl chloride												0.07 %						0.10 %										
Ethylene oxide											0.02%			0.01%														
PAHs	0.42%								0.20 %				0.10%		1.16%		1.19%		0.63%			1.19%			0.81%			
Occupation as a welder								4.30 %					1.52%															
Solar radiation																			20.22 %									
ETS													2.92%															
Epichlorohydrine						0.07 %							0.02%															
Tetrachloroethylene	0.18%				0.05 %													0.16 %		0.60%		0.11%						
Shift work				24.29 %																								
Dioxins													1.14%															
Inorganic acid mists										2.08 %			0.23%															
Rubber manufacturing	0.53%									0.05 %	0.10%		0.67%	0.00%											0.24%			
Ionising radiation	0%	0.01 %	0.34 %	0.05%							0.03%	0.00 %	0.02%			0.57%										0.04%		
Cr(VI) compounds													0.21%											1.90 %				
Aromatic amines	0.14%																											
Cytostatic drugs				0.54%							3.09%																	
Total AF per site	9.82%	0.01 %	1.30 %	24.74 %	0.05 %	0.07 %	0.12%	4.30 %	0.58 %	4.40 %	4.04%	0.08 %	36.50 %	0.01%	1.16%	0.57%	95.06%	0.26 %	22.53 %	0.60%	0.05 %	1.30%	8.59%	7.43 %	1.17%	0.04%		
AN EUCAN	42		2	283	0	0	1		3	6	10	0	432	0		1	38	0		1	0	5	18		7	0	851	8.22 %

Table 5-21: Lithuania - AFs and ANs - CENTRAL scenario

Cancer site	Bladder	Bone	Brain	Breast	Cervix	CNS	Colon & rectum	Eye	Kidney	Larynx	Leukaemia	Liver & bile duct	Lung	Lymphoma	Lymphoma & leukaemia	Malignant melanoma	Mesothelium	NHL	NMSC	Oesophagus	Ovary	Pancreas	Pharynx incl. NFC	SNC	Stomach	Thyroid	Total incidence	OvAF
Incidence EUCAN	569		154	1,479	615	154	1,558		773	183	435	175	1,555	604		275	59	349		198	369	480	382		867	567	14,520	
Diesel exhaust	1.59%												3.06%															
Silica										2.03 %			1.67%															
Asbestos							0.21%			0.52 %			23.39 %				95.00%				0.09 %		1.66%		0.22%			
Formaldehyde			1.08 %								0.55%		0.35%										2.10%	3.39 %				
Benzene											0.34%																	
Mineral oils	7.20%												9.07%						2.27%									
Cd and Cd compounds									0.55 %				0.20%															
Wood dust																							5.95%	2.68 %				
Arsenic													0.25%															
Vinyl chloride												0.07 %						0.10 %										
Ethylene oxide											0.03%			0.01%														
PAHs	0.42%								0.20 %				0.10%		1.16%		1.19%		0.63%			1.19%			0.81%			
Occupation as a welder								4.30 %					1.52%															
Solar radiation																			23.24 %									
ETS													3.77%															
Epichlorohydrine						0.08 %							0.02%															
Tetrachloroethylene	0.18%				0.05 %													0.16 %		0.60%		0.11%						
Shift work				28.88 %																								
Dioxins													1.14%															
Inorganic acid mists										2.08 %			0.23%															
Rubber manufacturing	0.53%									0.05 %	0.10%		0.67%	0.00%											0.24%			
Ionising radiation	0%	0.01 %	0.34 %	0.05%							0.03%	0.00 %	0.02%			0.57%										0.04%		
Cr(VI) compounds													0.21%											1.90 %				
Aromatic amines	0.14%																											
Cytostatic drugs				0.54%							3.09%																	
Total AF per site	9.82%	0.01 %	1.42 %	29.30 %	0.05 %	0.08 %	0.21%	4.30 %	0.74 %	4.61 %	4.10%	0.08 %	39.05 %	0.01%	1.16%	0.57%	95.06%	0.26 %	25.46 %	0.60%	0.09 %	1.30%	9.45%	7.77 %	1.26%	0.04%		
AN EUCAN	56		2	433	0	0	3		6	8	18	0	607	0		2	56	1		1	0	6	36		11	0	1,248	8.60 %

Table 5-22: Luxembourg - AFs and ANs - CENTRAL scenario

Cancer site	Bladder	Bone	Brain	Breast	Cervix	CNS	Colon & rectum	Eye	Kidney	Larynx	Leukaemia	Liver & bile duct	Lung	Lymphoma	Lymphoma & leukaemia	Malignant melanoma	Mesothelium	NHL	NMSC	Oesophagus	Ovary	Pancreas	Pharynx incl. NFC	SNC	Stomach	Thyroid	Total incidence	OvAF
Incidence EUCAN	96		20	360	24	20	310		70	17	62	68	261	102		86	11	68		34	36	67	64		67	62	2,476	
Diesel exhaust	1.59%												3.06%															
Silica										2.03 %			1.67%															
Asbestos							0.12%			0.30 %			26.85 %				95.00%				0.05 %		0.98%		0.13%			
Formaldehyde			0.36 %								0.18%		0.12%										0.70%	1.14 %				
Benzene											0.34%																	
Mineral oils	7.20%												9.07%						2.27%									
Cd and Cd compounds									0.46 %				0.17%															
Wood dust																							5.95%	2.68 %				
Arsenic													0.19%															
Vinyl chloride												0.07 %						0.10 %										
Ethylene oxide											0.01%			0.00%														
PAHs	0.42%								0.20 %				0.10%		1.16%		1.19%		0.63%			1.19%			0.81%			
Occupation as a welder								4.30 %					1.52%															
Solar radiation																			8.29%									
ETS													2.40%															
Epichlorohydrine						0.07 %							0.01%															
Tetrachloroethylene	0.18%				0.05 %													0.16 %		0.60%		0.11%						
Shift work				3.28 %																								
Dioxins													1.14%															
Inorganic acid mists										2.08 %			0.23%															
Rubber manufacturing	0.53%									0.05 %	0.10%		0.67%	0.00%											0.24%			
Ionising radiation	0%	0.01 %	0.34 %	0.05 %							0.03%	0.00 %	0.02%			0.57%										0.04%		
Cr(VI) compounds													0.21%											1.90 %				
Aromatic amines	0.14%																											
Cytostatic drugs				0.54 %							3.09%																	
Total AF per site	9.82%	0.01 %	0.70 %	3.85 %	0.05 %	0.07 %	0.12%	4.30 %	0.65 %	4.41 %	3.73%	0.08 %	40.78 %	0.01%	1.16%	0.57%	95.06%	0.26 %	10.94 %	0.60%	0.05 %	1.30%	7.52%	5.62 %	1.17%	0.04%		
AN EUCAN	9		0	14	0	0	0		0	1	2	0	106	0		0	11	0		0	0	1	5		1	0	152	6.14 %

Table 5-23: Malta- AFs and ANs - CENTRAL scenario

Cancer site	Bladder	Bone	Brain	Breast	Cervix	CNS	Colon & rectum	Eye	Kidney	Larynx	Leukaemia	Liver & bile duct	Lung	Lymphoma	Lymphoma & leukaemia	Malignant melanoma	Mesothelium	NHL	NMSC	Oesophagus	Ovary	Pancreas	Pharynx incl. NFC	SNC	Stomach	Thyroid	Total incidence	OvAF
Incidence EUCAN	132		16	314	12	16	268		57	25	48	19	181	79		36	11	49		20	46	75	52		68	32	1,902	
Diesel exhaust	1.59%												3.06%															
Silica										2.03 %			1.67%															
Asbestos							0.83%			2.02 %			36.78 %				95.00%				0.35 %		6.27%		0.88%			
Formaldehyde			0.89 %								0.45%		0.29%										1.73%	2.80 %				
Benzene											0.34%																	
Mineral oils	7.20%												9.07%						2.27 %									
Cd and Cd compounds									0.45 %				0.16%															
Wood dust																							5.95%	2.68 %				
Arsenic													0.11%															
Vinyl chloride												0.07 %						0.10 %										
Ethylene oxide											0.03%			0.01%														
PAHs	0.42%								0.20 %				0.10%		1.16%		1.19%		0.63 %			1.19%			0.81%			
Occupation as a welder								4.30 %					1.52%															
Solar radiation																			3.39 %									
ETS													1.59%															
Epichlorohydrine						0.04 %							0.01%															
Tetrachloroethylene	0.18%				0.05 %													0.16 %		0.60%		0.11%						
Shift work				4.07 %																								
Dioxins													1.14%															
Inorganic acid mists										2.08 %			0.23%															
Rubber manufacturing	0.53%									0.05 %	0.10%		0.67%	0.00%											0.24%			
Ionising radiation	0%	0.01 %	0.34 %	0.05 %							0.03%	0.00 %	0.02%			0.57%										0.04%		
Cr(VI) compounds													0.21%											1.90 %				
Aromatic amines	0.14%																											
Cytostatic drugs				0.54 %							3.09%																	
Total AF per site	9.82%	0.01 %	1.22 %	4.64 %	0.05 %	0.04 %	0.83%	4.30 %	0.65 %	6.05 %	4.01%	0.08 %	48.44 %	0.01%	1.16%	0.57%	95.06%	0.26 %	6.18 %	0.60%	0.35 %	1.30%	13.37 %	7.20 %	1.92%	0.04%		
AN EUCAN	1		0	1	0	0	0		0	0	0	0	52	0		0	10	0		0	0	0	1		0	0	64	3.38 %

Table 5-24: Netherlands- AFs and ANs - CENTRAL scenario

Cancer site	Bladder	Bone	Brain	Breast	Cervix	CNS	Colon & rectum	Eye	Kidney	Larynx	Leukaemia	Liver & bile duct	Lung	Lymphoma	Lymphoma & leukaemia	Malignant melanoma	Mesothelium	NHL	NMSC	Oesophagus	Ovary	Pancreas	Pharynx incl. NFC	SNC	Stomach	Thyroid	Total incidence	OvAF
Incidence EUCAN	2,999		583	13,895	750	583	13,918		2,679	733	1,775	475	11,968	4,861		4,804	582	3,241		2,091	1,025	2,141	2,063		1,953	560	93,448	
Diesel exhaust	1.59%												3.06%															
Silica										2.03 %			1.67%															
Asbestos							0.06%			0.15 %			30.00 %				95.00%				0.03 %		0.49%		0.07%			
Formaldehyde			0.29 %								0.15%		0.09%										0.57%	0.94 %				
Benzene											0.34%																	
Mineral oils	7.20%												9.07%						2.27 %									
Cd and Cd compounds									0.48 %				0.17%															
Wood dust																							5.95%	2.68 %				
Arsenic													0.10%															
Vinyl chloride												0.07 %						0.10 %										
Ethylene oxide											0.03%			0.01%														
PAHs	0.42%								0.20 %				0.10%		1.16%		1.19%		0.63 %			1.19%			0.81%			
Occupation as a welder								4.30 %					1.52%															
Solar radiation																			6.03 %									
ETS													2.48%															
Epichlorohydrine						0.10 %							0.02%															
Tetrachloroethylene	0.18%				0.05 %													0.16 %		0.60%		0.11%						
Shift work				7.99 %																								
Dioxins													1.14%															
Inorganic acid mists										2.08 %			0.23%															
Rubber manufacturing	0.53%									0.05 %	0.10%		0.67%	0.00%											0.24%			
Ionising radiation	0%	0.01 %	0.34 %	0.05 %							0.03%	0.00 %	0.02%			0.57%										0.04%		
Cr(VI) compounds													0.21%											1.90 %				
Aromatic amines	0.14%																											
Cytostatic drugs				0.54 %							3.09%																	
Total AF per site	9.82%	0.01 %	0.63 %	8.53 %	0.05 %	0.10 %	0.06%	4.30 %	0.67 %	4.26 %	3.71%	0.08 %	43.33 %	0.01%	1.16%	0.57%	95.06%	0.26 %	8.75 %	0.60%	0.03 %	1.30%	6.94%	5.42 %	1.11%	0.04%		
AN EUCAN	295		4	1,186	0	1	9		18	31	66	0	5,186	1		27	553	9		13	0	28	143		22	0	7,589	8.12 %

Table 5-25: Poland - AFs and ANs - CENTRAL scenario

Cancer site	Bladder	Bone	Brain	Breast	Cervix	CNS	Colon & rectum	Eye	Kidney	Larynx	Leukaemia	Liver & bile duct	Lung	Lymphoma	Lymphoma & leukaemia	Malignant melanoma	Mesothelium	NHL	NMSC	Oesophagus	Ovary	Pancreas	Pharynx incl. NFC	SNC	Stomach	Thyroid	Total incidence	OvAF
Incidence EUCAN	7,961		2,234	17,259	3,513	2,234	19,438		5,244	2,657	3,304	1,998	26,230	4,803		2,583	275	2,659		1,506	4,456	5,004	5,010		6,105	1,769	152,216	
Diesel exhaust	1.59%												3.06%															
Silica										2.03 %			1.67%															
Asbestos							0.44%			1.09 %			6.48%				95.00%				0.19 %		3.44%		0.47%			
Formaldehyde			1.32 %								0.67%		0.43%										2.55%	4.11 %				
Benzene											0.34%																	
Mineral oils	7.20%												9.07%						2.27%									
Cd and Cd compounds									0.84 %				0.30%															
Wood dust																							5.95%	2.68 %				
Arsenic													0.36%															
Vinyl chloride												0.07 %						0.10 %										
Ethylene oxide											0.02%			0.00%														
PAHs	0.42%								0.20 %				0.10%		1.16%		1.19%		0.63%			1.19%			0.81%			
Occupation as a welder								4.30 %					1.52%															
Solar radiation																			13.02 %									
ETS													3.66%															
Epichlorohydrine						0.08 %							0.02%															
Tetrachloroethylene	0.18%				0.05 %													0.16 %		0.60%		0.11%						
Shift work				11.33 %																								
Dioxins													1.14%															
Inorganic acid mists										2.08 %			0.23%															
Rubber manufacturing	0.53%									0.05 %	0.10%		0.67%	0.00%											0.24%			
Ionising radiation	0%	0.01 %	0.34 %	0.05%							0.03%	0.00 %	0.02%			0.57%										0.04%		
Cr(VI) compounds													0.21%											1.90 %				
Aromatic amines	0.14%																											
Cytostatic drugs				0.54%							3.09%																	
Total AF per site	9.82%	0.01 %	1.65 %	11.85 %	0.05 %	0.08 %	0.44%	4.30 %	1.04 %	5.16 %	4.21%	0.08 %	25.73 %	0.01%	1.16%	0.57%	95.06%	0.26 %	15.54 %	0.60%	0.19 %	1.30%	11.50 %	8.45 %	1.51%	0.04%		
AN EUCAN	782		37	2,046	2	2	86		54	137	139	2	6,750	0		15	262	7		9	8	65	576		92	1	11,072	7.27 %

Table 5-26: Portugal - AFs and ANs - CENTRAL scenario

Cancer site	Bladder	Bone	Brain	Breast	Cervix	CNS	Colon & rectum	Eye	Kidney	Larynx	Leukaemia	Liver & bile duct	Lung	Lymphoma	Lymphoma & leukaemia	Malignant melanoma	Mesothelium	NHL	NMSC	Oesophagus	Ovary	Pancreas	Pharynx incl. NFC	SNC	Stomach	Thyroid	Total incidence	OvAF
Incidence EUCAN	2,876		466	6,088	720	466	7,129		1,004	830	1,124	1,004	4,192	2,642		1,101	209	1,842		608	616	1,225	2,082		3,018	576	49,174	
Diesel exhaust	1.59%												3.06%															
Silica										2.03 %			1.67%															
Asbestos							0.11%			0.27 %			30.81 %				95.00%				0.05 %		0.88%		0.12%			
Formaldehyde			1.07 %								0.55%		0.35%										2.08%	3.37 %				
Benzene											0.34%																	
Mineral oils	7.20%												9.07%						2.27%									
Cd and Cd compounds									0.34 %				0.12%															
Wood dust																							5.95%	2.68 %				
Arsenic													0.16%															
Vinyl chloride												0.07 %						0.10 %										
Ethylene oxide											0.01%			0.00%														
PAHs	0.42%								0.20 %				0.10%		1.16%		1.19%		0.63%			1.19%			0.81%			
Occupation as a welder								4.30 %					1.52%															
Solar radiation																			11.61 %									
ETS													2.45%															
Epichlorohydrine						0.04 %							0.01%															
Tetrachloroethylene	0.18%				0.05 %													0.16 %		0.60%		0.11%						
Shift work				34.34 %																								
Dioxins													1.14%															
Inorganic acid mists										2.08 %			0.23%															
Rubber manufacturing	0.53%									0.05 %	0.10%		0.67%	0.00%											0.24%			
Ionising radiation	0%	0.01 %	0.34 %	0.05%							0.03%	0.00 %	0.02%			0.57%										0.04%		
Cr(VI) compounds													0.21%											1.90 %				
Aromatic amines	0.14%																											
Cytostatic drugs				0.54%							3.09%																	
Total AF per site	9.82%	0.01 %	1.41 %	34.73 %	0.05 %	0.04 %	0.11%	4.30 %	0.53 %	4.38 %	4.08%	0.08 %	44.10 %	0.01%	1.16%	0.57%	95.06%	0.26 %	14.16 %	0.60%	0.05 %	1.30%	8.72%	7.74 %	1.16%	0.04%		
AN EUCAN	283		7	2,114	0	0	8		5	36	46	1	1,849	0		6	199	5		4	0	16	182		35	0	4,796	9.75 %

Table 5-27: Romania - AFs and ANs - CENTRAL scenario

Cancer site	Bladder	Bone	Brain	Breast	Cervix	CNS	Colon & rectum	Eye	Kidney	Larynx	Leukaemia	Liver & bile duct	Lung	Lymphoma	Lymphoma & leukaemia	Malignant melanoma	Mesothelium	NHL	NMSC	Oesophagus	Ovary	Pancreas	Pharynx incl. NFC	SNC	Stomach	Thyroid	Total incidence	OvAF
Incidence EUCAN	3,825		858	8,981	4,343	858	10,256		1,940	1,618	1,750	2,214	11,644	2,528		1,121	401	1,566		768	1,850	3,082	3,728		4,075	788	78,760	
Diesel exhaust	1.59%												3.06%															
Silica										2.03 %			1.67%															
Asbestos							0.44%			1.08 %			21.25 %				95.00%				0.19 %		3.41%		0.47%			
Formaldehyde			1.29 %								0.66%		0.42%										2.51%	4.04 %				
Benzene											0.34%																	
Mineral oils	7.20%												9.07%						2.27%									
Cd and Cd compounds									0.83 %				0.30%															
Wood dust																							5.95%	2.68 %				
Arsenic													0.35%															
Vinyl chloride												0.07 %						0.10 %										
Ethylene oxide											0.02%			0.00%														
PAHs	0.42%								0.20 %				0.10%		1.16%		1.19%		0.63%			1.19%			0.81%			
Occupation as a welder								4.30 %					1.52%															
Solar radiation																			12.82 %									
ETS													3.60%															
Epichlorohydrine						0.08 %							0.02%															
Tetrachloroethylene	0.18%				0.05 %													0.16 %		0.60%		0.11%						
Shift work				9.50%																								
Dioxins													1.14%															
Inorganic acid mists										2.08 %			0.23%															
Rubber manufacturing	0.53%									0.05 %	0.10%		0.67%	0.00%											0.24%			
Ionising radiation	0%	0.01 %	0.34 %	0.05%							0.03%	0.00 %	0.02%			0.57%										0.04%		
Cr(VI) compounds													0.21%											1.90 %				
Aromatic amines	0.14%																											
Cytostatic drugs				0.54%							3.09%																	
Total AF per site	9.82%	0.01 %	1.63 %	10.03 %	0.05 %	0.08 %	0.44%	4.30 %	1.02 %	5.15 %	4.20%	0.08 %	37.41 %	0.01%	1.16%	0.57%	95.06%	0.26 %	15.34 %	0.60%	0.19 %	1.30%	11.43 %	8.38 %	1.50%	0.04%		
AN EUCAN	376		14	901	2	1	45		20	83	73	2	4,356	0		6	381	4		5	3	40	426		61	0	6,800	8.63 %

Table 5-28: Slovakia - AFs and ANs - CENTRAL scenario

Cancer site	Bladder	Bone	Brain	Breast	Cervix	CNS	Colon & rectum	Eye	Kidney	Larynx	Leukaemia	Liver & bile duct	Lung	Lymphoma	Lymphoma & leukaemia	Malignant melanoma	Mesothelium	NHL	NMSC	Oesophagus	Ovary	Pancreas	Pharynx incl. NFC	SNC	Stomach	Thyroid	Total incidence	OvAF
Incidence EUCAN	933		261	2,643	607	261	3,963		1,063	280	650	398	2,531	983		806	109	574		284	518	881	988		901	300	24,045	
Diesel exhaust	1.59%												3.06%															
Silica										2.03%			1.67%															
Asbestos							0.42%			1.04%			26.67%				95.00%				0.18%		3.29%		0.45%			
Formaldehyde			1.25%								0.64%		0.40%										2.42%	3.90%				
Benzene											0.34%																	
Mineral oils	7.20%												9.07%						2.27%									
Cd and Cd compounds									0.80%				0.29%															
Wood dust																							5.95%	2.68%				
Arsenic													0.34%															
Vinyl chloride												0.07%						0.10%										
Ethylene oxide											0.02%			0.00%														
PAHs	0.42%								0.20%				0.10%		1.16%		1.19%		0.63%			1.19%			0.81%			
Occupation as a welder								4.30%					1.52%															
Solar radiation																			12.42%									
ETS													3.47%															
Epichlorohydrine						0.08%							0.02%															
Tetrachloroethylene	0.18%				0.05%													0.16%		0.60%		0.11%						
Shift work				7.54%																								
Dioxins													1.14%															
Inorganic acid mists										2.08%			0.23%															
Rubber manufacturing	0.53%									0.05%	0.10%		0.67%	0.00%											0.24%			
Ionising radiation	0%	0.01%	0.34%	0.05%							0.03%	0.00%	0.02%			0.57%										0.04%		
Cr(VI) compounds													0.21%											1.90%				
Aromatic amines	0.14%																											
Cytostatic drugs				0.54%							3.09%																	
Total AF per site	9.82%	0.01%	1.58%	8.08%	0.05%	0.08%	0.42%	4.30%	0.99%	5.11%	4.17%	0.08%	41.62%	0.01%	1.16%	0.57%	95.06%	0.26%	14.95%	0.60%	0.18%	1.30%	11.25%	8.25%	1.49%	0.04%		
AN EUCAN	92		4	214	0	0	17		11	14	27	0	1,053	0		5	104	2		2	1	11	111		13	0	1,681	6.99%

Table 5-29: Slovenia - AFs and ANs - CENTRAL scenario

Cancer site	Bladder	Bone	Brain	Breast	Cervix	CNS	Colon & rectum	Eye	Kidney	Larynx	Leukaemia	Liver & bile duct	Lung	Lymphoma	Lymphoma & leukaemia	Malignant melanoma	Mesothelium	NHL	NMSC	Oesophagus	Ovary	Pancreas	Pharynx incl. NFC	SNC	Stomach	Thyroid	Total incidence	OvAF
Incidence EUCAN	463		80	1,258	139	80	1,621		400	99	226	216	1,360	468		533	42	294		84	192	383	326		468	200	11,457	
Diesel exhaust	1.59%									2.03 %			3.06%															
Silica										1.08 %			1.67%															
Asbestos							0.44%						18.88 %				95.00%				0.19 %		3.43%		0.47%			
Formaldehyde			1.31 %								0.67%		0.43%										2.54%	4.09 %				
Benzene											0.34%																	
Mineral oils	7.20%												9.07%						2.27%									
Cd and Cd compounds									0.84 %				0.30%															
Wood dust																							5.95%	2.68 %				
Arsenic													0.36%															
Vinyl chloride												0.07 %						0.10 %										
Ethylene oxide											0.02%			0.00%														
PAHs	0.42%								0.20 %				0.10%		1.16%		1.19%		0.63%			1.19%			0.81%			
Occupation as a welder								4.30 %					1.52%															
Solar radiation																			12.98 %									
ETS													3.64%															
Epichlorohydrine						0.08 %							0.02%															
Tetrachloroethylene	0.18%				0.05 %													0.16 %		0.60%		0.11%						
Shift work				11.80 %																								
Dioxins													1.14%															
Inorganic acid mists										2.08 %			0.23%															
Rubber manufacturing	0.53%									0.05 %	0.10%		0.67%	0.00%											0.24%			
Ionising radiation	0%	0.01 %	0.34 %	0.05%							0.03%	0.00 %	0.02%			0.57%										0.04%		
Cr(VI) compounds													0.21%											1.90 %				
Aromatic amines	0.14%																											
Cytostatic drugs				0.54%							3.09%																	
Total AF per site	9.82%	0.01 %	1.64 %	12.33 %	0.05 %	0.08 %	0.44%	4.30 %	1.03 %	5.15 %	4.21%	0.08 %	35.57 %	0.01%	1.16%	0.57%	95.06%	0.26 %	15.49 %	0.60%	0.19 %	1.30%	11.48 %	8.44 %	1.51%	0.04%		
AN EUCAN	45		1	155	0	0	7		4	5	10	0	484	0		3	40	1		1	0	5	37		7	0	806	7.03 %

Table 5-30: Spain - AFs and ANs - CENTRAL scenario

Cancer site	Bladder	Bone	Brain	Breast	Cervix	CNS	Colon & rectum	Eye	Kidney	Larynx	Leukaemia	Liver & bile duct	Lung	Lymphoma	Lymphoma & leukaemia	Malignant melanoma	Mesothelium	NHL	NMSC	Oesophagus	Ovary	Pancreas	Pharynx incl. NFC	SNC	Stomach	Thyroid	Total incidence	OvAF
Incidence EUCAN	13,789		1,859	25,215	2,511	1,859	32,240		6,474	3,182	5,190	5,522	26,715	9,700		5,004	937	6,130		2,090	3,236	6,367	5,978		7,810	2,059	215,534	
Diesel exhaust	1.59%												3.06%															
Silica										2.03 %			1.67%															
Asbestos							0.09%			0.22 %			21.65 %				95.00%				0.04 %		0.71%		0.09%			
Formaldehyde			0.48 %								0.24%		0.15%										0.94%	1.52 %				
Benzene											0.34%																	
Mineral oils	7.20%												9.07%						2.27%									
Cd and Cd compounds									0.29 %				0.10%															
Wood dust																							5.95%	2.68 %				
Arsenic													0.09%															
Vinyl chloride												0.07 %						0.10 %										
Ethylene oxide											0.01%			0.00%														
PAHs	0.42%								0.20 %				0.10%		1.16%		1.19%		0.63%			1.19%			0.81%			
Occupation as a welder								4.30 %					1.52%															
Solar radiation																			8.00%									
ETS													1.74%															
Epichlorohydrine						0.03 %							0.01%															
Tetrachloroethylene	0.18%				0.05 %													0.16 %		0.60%		0.11%						
Shift work				3.45 %																								
Dioxins													1.14%															
Inorganic acid mists										2.08 %			0.23%															
Rubber manufacturing	0.53%									0.05 %	0.10%		0.67%	0.00%											0.24%			
Ionising radiation	0%	0.01 %	0.34 %	0.05 %							0.03%	0.00 %	0.02%			0.57%										0.04%		
Cr(VI) compounds													0.21%											1.90 %				
Aromatic amines	0.14%																											
Cytostatic drugs				0.54 %							3.09%																	
Total AF per site	9.82%	0.01 %	0.82 %	4.03 %	0.05 %	0.03 %	0.09%	4.30 %	0.48 %	4.33 %	3.79%	0.08 %	36.06 %	0.01%	1.16%	0.57%	95.06%	0.26 %	10.66 %	0.60%	0.04 %	1.30%	7.49%	5.98 %	1.13%	0.04%		
AN EUCAN	1,355		15	1,015	1	1	29		31	138	197	4	9,634	1		29	890	16		13	1	83	448		89	1	13,988	6.49 %

Table 5-31: Sweden - AFs and ANs - CENTRAL scenario

Cancer site	Bladder	Bone	Brain	Breast	Cervix	CNS	Colon & rectum	Eye	Kidney	Larynx	Leukaemia	Liver & bile duct	Lung	Lymphoma	Lymphoma & leukaemia	Malignant melanoma	Mesothelium	NHL	NMSC	Oesophagus	Ovary	Pancreas	Pharynx incl. NFC	SNC	Stomach	Thyroid	Total incidence	OvAF
Incidence EUCAN	2,350		654	6,624	451	654	6,358		1,125	186	1,147	490	3,891	2,401		2,911	129	1,602		461	659	964	971		811	387	50,481	
Diesel exhaust	1.59%												3.06%															
Silica										2.03%			1.67%															
Asbestos							0.12%			0.29%			20.54%				95.00%				0.05%		0.93%		0.12%			
Formaldehyde			0.35%								0.18%		0.11%										0.68%	1.11%				
Benzene											0.34%																	
Mineral oils	7.20%												9.07%						2.27%									
Cd and Cd compounds									0.41%				0.15%															
Wood dust																							5.95%	2.68%				
Arsenic													0.15%															
Vinyl chloride												0.07%						0.10%										
Ethylene oxide											0.04%			0.01%														
PAHs	0.42%								0.20%				0.10%		1.16%		1.19%		0.63%			1.19%			0.81%			
Occupation as a welder								4.30%					1.52%															
Solar radiation																			8.28%									
ETS													2.47%															
Epichlorohydrine						0.08%							0.02%															
Tetrachloroethylene	0.18%				0.05%													0.16%		0.60%		0.11%						
Shift work				8.81%																								
Dioxins													1.14%															
Inorganic acid mists										2.08%			0.23%															
Rubber manufacturing	0.53%									0.05%	0.10%		0.67%	0.00%											0.24%			
Ionising radiation	0%	0.01%	0.34%	0.05%							0.03%	0.00%	0.02%			0.57%										0.04%		
Cr(VI) compounds													0.21%											1.90%				
Aromatic amines	0.14%																											
Cytostatic drugs				0.54%							3.09%																	
Total AF per site	9.82%	0.01%	0.69%	9.35%	0.05%	0.08%	0.12%	4.30%	0.60%	4.39%	3.75%	0.08%	35.69%	0.01%	1.16%	0.57%	95.06%	0.26%	10.92%	0.60%	0.05%	1.30%	7.45%	5.59%	1.16%	0.04%		
AN EUCAN	231		4	619	0	1	7		7	8	43	0	1,389	0		17	123	4		3	0	13	72		9	0	2,551	5.05%

Table 5-32: United Kingdom - AFs and ANs - CENTRAL scenario

Cancer site	Bladder	Bone	Brain	Breast	Cervix	CNS	Colon & rectum	Eye	Kidney	Larynx	Leukaemia	Liver & bile duct	Lung	Lymphoma	Lymphoma & leukaemia	Malignant melanoma	Mesothelium	NHL	NMSC	Oesophagus	Ovary	Pancreas	Pharynx incl. NFC	SNC	Stomach	Thyroid	Total incidence	OvAF
Incidence EUCAN	8,778		2,327	52,399	2,659	2,327	40,755		9,714	2,201	8,011	4,186	40,382	18,182		14,445	2,663	11,836		8,803	6,692	8,747	7,495		6,684	2,654	327,812	
Diesel exhaust	1.59%												3.06%															
Silica										2.03 %			1.67%															
Asbestos							0.11%			0.26 %			40.72 %				95.00%				0.05 %		0.85%		0.11%			
Formaldehyde			0.45 %								0.23%		0.15%										0.88%	1.44 %				
Benzene											0.34%																	
Mineral oils	7.20%												9.07%						2.27 %									
Cd and Cd compounds									0.46 %				0.17%															
Wood dust																							5.95%	2.68 %				
Arsenic													0.14%															
Vinyl chloride												0.07 %						0.10 %										
Ethylene oxide											0.02%			0.01%														
PAHs	0.42%								0.20 %				0.10%		1.16%		1.19%		0.63 %			1.19%			0.81%			
Occupation as a welder								4.30 %					1.52%															
Solar radiation																			6.79 %									
ETS													2.43%															
Epichlorohydrine						0.07 %							0.01%															
Tetrachloroethylene	0.18%				0.05 %													0.16 %		0.60%		0.11%						
Shift work				13.48 %																								
Dioxins													1.14%															
Inorganic acid mists										2.08 %			0.23%															
Rubber manufacturing	0.53%									0.05 %	0.10%		0.67%	0.00%											0.24%			
Ionising radiation	0%	0.01 %	0.34 %	0.05%							0.03%	0.00 %	0.02%			0.57%										0.04%		
Cr(VI) compounds													0.21%											1.90 %				
Aromatic amines	0.14%																											
Cytostatic drugs				0.54%							3.09%																	
Total AF per site	9.82%	0.01 %	0.79 %	13.99 %	0.05 %	0.07 %	0.11%	4.30 %	0.66 %	4.37 %	3.79%	0.08 %	52.02 %	0.01%	1.16%	0.57%	95.06%	0.26 %	9.48 %	0.60%	0.05 %	1.30%	7.57%	5.90 %	1.15%	0.04%		
AN EUCAN	862		18	7,330	1	2	44		64	96	303	3	21,006	2		82	2,531	31		53	3	114	567		77	1	33,192	10.13 %

6 Annex 3: Summary of EUCAN and EUREG data

6.1 EUREG

Data on cancer incidence broken down by site are available for the majority of EU Member States from the EUREG database[211]. However, there are several caveats with using these data including:

- Data are not available for all Member States. For cancer incidence, data are not available for Greece, Hungary and Luxembourg;
- The most recent data have been extracted for each Member State. However, it is important to note that there is some variation between Member States in terms of the latest year for which data are available. For example, the data for Belgium are for 2006 but those from Sweden are for 2009;
- Data for some Member States appear to be partial. For example, for France data on cancer incidence are provided for some administrative areas but not others;
- For some Member States, there are two entries for a single carcinogen. In such instances, the total of the two rows has been taken;
- For each Member State, the source provides an overall total for "all sites excluding other skin". However, if the data for the individual cancer sites are summed, the resultant total is generally less than the overall total provided (by 2-9%). This suggests that there are cancer registrations that have not been allocated to a specific cancer site. Some of this difference could be explained by mesothelioma related cases, which may not be included within the totals; and
- Mesothelioma has been added in as a cancer site to ensure that it can be referred to in the later analysis. Note that for the majority of Member States, the difference between the EUREG totals and the totals calculated through summing the cases by cancer site is greater than the number of mesothelioma cases. Therefore, the addition of these data does not have any implications for the overall number of incidences.

Mesothelioma incidence across the EU has been estimated by extrapolating the UK data over the EU because the UK appears to have the most comprehensive dataset on mesothelioma incidence. The UK data suggest that there are currently around 40 cases of mesothelioma per year per million inhabitants whilst data for other countries[212] suggest a similar or lower order of magnitude. A review of mesothelioma incidence data carried out by Bianchi & Bianchi (2014)[213] shows that the highest incidence rates are reported for United Kingdom, the Netherlands, Malta, and Belgium whilst lower incidence/mortality rates are reported for Central Europe. It is, however expected that this may reflect a lack of reliable data collection rather than lower incidence of mesothelioma per se. For this reason, the use of UK data for extrapolation to the EU-28 is seen as appropriate. The UK data have been extrapolated to the other EU Member States using per capita incidence rates provided in Bianchi & Bianchi (2014). Where not data on national incidence was available, the average of all available national rates was applied.

[211] See EUREG, accessed at: http://eco.iarc.fr/EUREG/AnalysisT.aspx on 6th September 2016.

[212] For example, see http://www.google.co.uk/url?sa=t&rct=j&q=&esrc=s&source=web&cd=9&cad=rja&uact=8&sqi=2&ved=0ahUKEwjYzYvv6p7SAhULBcAKHZ7uD3wQFghSMAg&url=http%3A%2F%2Fec.europa.eu%2Fsocial%2FBlobServlet%3FdocId%3D11280%26langId%3Den&usg=AFQjCNGeTbkYFSLDPsFMLj2Pt0zXRiDj3Q&bvm=bv.147448319,d.d24

[213] Bianchi & Bianchi (2014): Global mesothelioma epidemic: Trend and features, Indian J Occup Environ Med 2014;18:82-8, available at http://www.ijoem.com/text.asp?2014/18/2/82/146897

For Member States where data are missing or partial, additional data have been derived from the Global Cancer Observatory (GCO) Cancer Today dataset[214] as follows:

- For Member States where no data are available from the EUREG database, the Cancer Today data have been used. These provide total cancer incidence by Member State, as well as the numbers for the ten most common cancer sites. Data for the remaining cancer sites have therefore been extrapolated by calculating cancer incidence not accounted for by the ten most common sites, and sharing these cases out between the remaining sites according to the EU level share. For example, summing the available data from the EUREG database suggests that 0.2% of cancer incidence across the EU is eye related. This percentage can be used to extrapolate the number of eye cancer incidents for Greece by normalising it according to the sum of the percentages for the cancer sites for which Greek data are lacking. The resultant figure is then multiplied by the number of cancer incidents that have not been allocated to a cancer site. This process has been used to extrapolate numbers for Greece, Hungary and Luxembourg; and

- For Member States for which data are only partially available (e.g. for some administrative areas but not others, or where particular cancer sites are missing), the Cancer Today data were used to provide the total number of cancers and also the numbers for the ten most common cancer sites. EUREG data were then used to identify percentages to distribute the remaining cancer cases amongst the cancer sites. This process has been used to extrapolate numbers for cancer incidences for France, Germany, Italy, Poland, Portugal, Romania, Spain and the UK.

The resulting cancer incidence data are provided in the following tables:

- the first two tables provide data for the 17 MSs for which full data are available from EUREG;
- the third table provides data for the eight MSs for which EUREG and Cancer Today datasets were combined; and
- the last table provides cancer incidence data and estimates for the three MSs for which all data have been sourced from Cancer Today. Where data are not available for specific cancer sites, estimates have been derived using EU wide percentages from EUREG.

[214] See Cancer Today (IARC), accessed at: http://gco.iarc.fr/today/online-analysis-multi-bars?mode=cancer&mode_population=continents&population=40&sex=0&cancer=29&type=0&statistic=0&prevalence=0&color_palette=default on 6th September 2016.

Table 6-1: Cancer incidence data (EUREG)									
Cancer site	Number of cases by Member State for year for which latest data are available								
	2009	2006	2007	2007	2007	2007	2007	2009	2007
	Austria	Belgium	Bulgaria	Croatia	Cyprus	CZ	Denmark	Estonia	Finland
All sites	37,387	57,372	33,725	21,569	2,578	72,553	32,073	6,933	32,723
All sites excl. other skin & mesothelioma	37,387	57,355	29,991	21,515	2,578	53,790	30,883	5,939	24,853
Bladder	1,627	1,986	1,393	913	124	2,507	1,692	203	751
Bone	109	142	84	67	7	105	41	8	39
Breast	5,062	10,088	3,649	2,701	472	6,633	4,114	695	4,160
Cervix uteri	398	603	1,130	403	29	1,005	388	187	145
CNS	589	725	706	507	53	808	482	93	381
Colon	2,985	5,233	2,725	1,663	263	4,520	2,584	463	1,552
Corpus uteri	903	1,321	1,235	620	65	1,750	656	199	789
Endocrine glands	43	58	41	42	3	46	58	4	34
Eye	82	78	55	29	2	99	81	3	60
Gallbladder	388	308	301	337	24	956	200	43	261
Hodgkin lymphoma	166	300	150	158	19	256	145	34	126
Kidney	1,347	1,684	737	726	38	3,090	724	290	805
Larynx	292	617	624	370	23	515	259	66	131
Leukaemia	894	1,117	651	486	84	1,003	685	181	599
Lip	29	75	205	92	8	97	43	21	78
Liver	911	494	618	431	47	922	271	63	417
Lung	4,250	6,993	3,896	2,962	200	6,533	4,285	709	2,297
Multiple myeloma	441	730	199	183	46	417	334	60	307
Non-Hodgkin lymphoma	1,145	1,943	536	444	89	1,164	980	136	1,057
Nose & sinuses	75	96	47	38	5	80	88	12	45
Oesophagus	369	918	201	229	13	522	395	55	235

Table 6-1: Cancer incidence data (EUREG)									
Cancer site	Number of cases by Member State for year for which latest data are available								
	2009	2006	2007	2007	2007	2007	2007	2009	2007
	Austria	Belgium	Bulgaria	Croatia	Cyprus	CZ	Denmark	Estonia	Finland
Oral cavity	237	407	135	145	11	271	216	27	114
Other female sites	208	289	197	122	10	345	162	36	146
Other skin	0	17	3,734	54	-	18,763	1,190	994	7,870
Ovary	705	907	856	485	43	1,127	555	138	445
Pancreas	1,433	1,172	1,099	682	64	1,973	926	179	1,032
Penis	58	76	45	23	4	80	55	6	32
Pharynx	460	640	327	276	8	573	321	45	107
Prostate	4,902	9,254	1,566	1,661	330	5,188	3,727	837	4,197
Rectum	1,696	2,688	1,900	1,352	95	3,397	1,545	269	1,008
Salivary glands	73	105	83	58	7	120	50	8	74
Skin melanoma	1,302	1,573	437	527	53	2,041	1,462	151	919
Small intestine	153	212	49	38	4	143	74	14	110
Soft tissue	263	290	177	132	25	277	264	33	150
Stomach	1,356	1,362	1,776	1,071	71	1,627	553	395	683
Testis	350	270	201	146	21	489	316	24	132
Thyroid gland	938	693	247	477	98	873	184	84	381
Tongue	214	327	142	136	2	280	152	28	128
Mesothelioma	104	272	145	94	14	212	120	26	99

Source: all data from EUREG (http://eco.iarc.fr/EUREG/AnalysisT.aspx) except numbers for mesothelioma (extrapolated from UK data) Note: grey shaded cells are extrapolated numbers

Table 6-2: Cancer incidence data (EUREG)								
Cancer site	Number of cases by Member State for year for which latest data are available							
	2009	2007	2006	2009	2007	2007	2007	2009
	Ireland	Latvia	Lithuania	Malta	Netherlands	Slovakia	Slovenia	Sweden
All sites	26,674	10,323	17,286	2,114	87,999	26,674	11,334	51,150
All sites excl. other skin & mesothelioma	18,720	9,403	15,346	1,655	81,831	21,674	9,525	47,682
Bladder	442	364	417	72	2,740	796	279	2,269
Bone	31	25	35	3	259	54	16	101
Breast	2,788	1,059	1,447	300	13,892	2,445	1,154	6,474
Cervix uteri	350	235	544	10	738	627	153	441
CNS	322	226	307	32	1,116	368	127	614
Colon	1,593	604	806	140	8,043	1,845	785	3,864
Corpus uteri	418	397	522	57	1,785	932	296	1,448
Endocrine glands	22	22	29	2	54	21	9	31
Eye	38	20	24	1	190	66	16	131
Gallbladder	126	55	105	14	661	384	155	361
Hodgkin lymphoma	140	45	83	10	411	128	48	192
Kidney	546	476	654	57	2,565	955	314	1,130
Larynx	133	125	196	20	660	299	121	174
Leukaemia	490	256	368	32	1,705	605	227	1,073
Lip	17	17	52	2	231	78	26	131
Liver	201	147	141	17	418	376	179	510
Lung	2,058	1,211	1,581	168	10,858	2,396	1,223	3,711
Multiple myeloma	265	113	135	18	1,083	261	111	675
Non-Hodgkin lymphoma	641	167	316	55	2,822	502	249	1,572
Nose & sinuses	22	17	22	4	170	24	24	83
Oesophagus	377	136	187	15	1,658	266	97	453
Oral cavity	95	35	77	10	523	214	80	196
Other female sites	97	71	74	23	403	129	74	299
Other skin	7,954	920	1,940	459	6,168	5,000	1,809	3,468
Ovary	349	292	391	42	1,160	442	175	730
Pancreas	469	356	468	66	1,804	793	301	961
Penis	27	21	16	2	113	28	6	107
Pharynx	138	91	141	15	567	430	155	315
Prostate	3,090	889	3,233	181	9,649	1,581	1,036	10,578
Rectum	858	464	709	87	4,314	1,505	636	2,123
Salivary glands	38	32	37	7	147	65	12	80
Skin melanoma	770	165	241	4	3,913	658	440	2,735
Small intestine	59	16	26	4	270	51	23	262

Table 6-2: Cancer incidence data (EUREG)								
Cancer site	Number of cases by Member State for year for which latest data are available							
	2009	2007	2006	2009	2007	2007	2007	2009
	Ireland	Latvia	Lithuania	Malta	Netherlands	Slovakia	Slovenia	Sweden
Soft tissue	126	65	72	9	513	129	48	304
Stomach	539	649	927	63	1,907	939	463	905
Testis	171	32	36	14	625	230	89	321
Thyroid gland	177	168	336	28	464	278	135	408
Tongue	88	36	60	10	418	177	47	203
Mesothelioma	46	40	59	11	582	109	42	129
Source: all data from EUREG (http://eco.iarc.fr/EUREG/AnalysisT.aspx) except numbers for mesothelioma (extrapolated based on UK data) Note: grey shaded cells are extrapolated numbers								

Table 6-3: Cancer incidence data and estimates for France, Germany, Italy, Poland, Portugal, Romania, Spain and the UK (EUREG and Cancer Today)								
Cancer site	Number of cases by Member State (data and extrapolations for 2012)							
	France	Germany	Italy	Poland	Portugal	Romania	Spain	UK
All sites	349,426	493,780	354,456	152,216	49,174	78,760	215,534	327,812
Bladder	11,175	28,405	18,284	7,961	2,876	3,825	2,494	8,778
Bone	594	485	365	318	72	419	70	368
Breast	48,763	71,623	50,658	17,259	6,088	8,981	4,911	52,399
Cervix uteri	2,669	2,968	2,001	2,493	587	4,343	445	1,623
CNS	4,285	3,959	3,047	4,467	631	1,231	715	2,679
Colon	40,825	63,572	48,110	19,438	7,129	10,256	4,137	40,755
Corpus uteri	6,285	6,730	4,910	5,912	1,485	1,739	1,113	4,283
Endocrine glands	361	218	185	348	30	134	37	150
Eye	526	451	348	226	67	134	63	291
Gallbladder	2,601	2,890	2,736	1,845	288	500	499	937
Hodgkin lymphoma	1,925	1,150	1,149	570	258	196	284	1,013
Kidney	11,023	18,615	11,300	5,244	659	1,940	1,209	9,714
Larynx	3,015	2,218	2,491	2,058	501	1,490	770	1,232
Leukaemia	9,180	6,504	4,730	2,924	586	1,249	961	4,146
Lip	353	227	396	318	1,294	330	288	182
Liver	9,578	4,742	10,733	1,270	396	2,214	928	2,000
Lung	40,043	50,813	37,238	26,230	4,192	11,644	4,758	40,382
Multiple myeloma	5,548	3,268	2,735	1,192	389	294	492	2,560
Non-Hodgkin lymphoma	11,512	14,597	12,548	2,384	1,842	830	1,358	11,836
Nose & sinuses	684	409	260	170	68	134	66	264
Oesophagus	6,097	3,656	1,448	883	442	723	472	8,803
Oral cavity	2,511	1,940	1,043	618	271	401	292	929
Other female sites	1,225	2,268	1,148	631	254	401	215	1,034
Other skin	60	46,854	37,549	7,992	2,269	3,639	3,280	37,261
Ovary	4,090	4,949	3,054	2,797	361	1,463	578	3,397

Table 6-3: Cancer incidence data and estimates for France, Germany, Italy, Poland, Portugal, Romania, Spain and the UK (EUREG and Cancer Today)								
Cancer site	Number of cases by Member State (data and extrapolations for 2012)							
	France	Germany	Italy	Poland	Portugal	Romania	Spain	UK
Pancreas	9,149	16,451	10,688	5,004	1,225	3,082	1,058	8,747
Penis	353	430	244	178	83	107	82	268
Pharynx	5,811	3,447	1,762	1,162	459	1,293	423	1,147
Prostate	56,841	68,262	44,525	11,029	6,622	4,532	5,398	45,406
Rectum	16,254	14,662	9,082	5,617	2,184	3,220	2,103	8,385
Salivary glands	504	503	434	291	83	134	100	346
Skin melanoma	9,871	16,884	5,191	2,019	678	794	1,051	14,445
Small intestine	1,376	985	595	200	140	125	155	584
Soft tissue	1,661	1,593	1,099	605	234	392	239	1,010
Stomach	8,142	16,015	13,001	6,105	3,018	4,075	1,633	4,445
Testis	2,210	2,480	1,212	692	131	330	255	1,183
Thyroid gland	7,127	3,618	4,684	1,710	985	910	552	1,229
Tongue	2,481	1,605	978	483	280	446	277	940
Mesothelioma	1,339	1,372	1,226	275	209	401	937	2,663
Source: overall totals and data for the 10 most common cancer sites for each member state from Cancer Today (http://gco.iarc.fr/today/online-analysis-multi-bars?mode=cancer&mode_population=continents&population=40&sex=0&cancer=29&type=0&statistic=0&prevalence=0&color_palette=default). Data for other sites extrapolated based on the distribution of incidence across cancer sites given by country specific data on the EUREG (http://eco.iarc.fr/EUREG/AnalysisT.aspx). Numbers for Mesothelioma are extrapolated based on UK data Note: grey shaded cells are extrapolated numbers Note: extrapolated figures are given in shaded boxes, non-shaded boxes represent actual data								

Table 6-4: Cancer incidence data and estimates for Greece, Hungary and Luxembourg (Cancer Today)			
Cancer site	Number of cases by Member State (data and extrapolations for 2012)		
	Greece	Hungary	Luxembourg
All sites	40,971	50,475	2,476
Bladder	2,777	2,689	96
Bone	51	58	3
Breast	4,934	5,094	360
Cervix uteri	302	1,178	19
CNS	1,334	429	23
Colon	3,885	8,442	310
Corpus uteri	619	712	115
Endocrine glands	24	27	1
Eye	43	50	3
Gallbladder	229	264	14
Hodgkin lymphoma	126	145	8
Kidney	1,094	1,554	70
Larynx	234	269	14
Leukaemia	2,247	638	34
Lip	47	54	3
Liver	398	458	68

Table 6-4: Cancer incidence data and estimates for Greece, Hungary and Luxembourg (Cancer Today)			
Cancer site	Number of cases by Member State (data and extrapolations for 2012)		
	Greece	Hungary	Luxembourg
Lung	6,884	9,288	261
Multiple myeloma	302	347	19
Non-Hodgkin lymphoma	756	870	68
Nose & sinuses	39	45	2
Oesophagus	364	418	23
Oral cavity	146	1,524	9
Other female sites	150	172	9
Other skin	3,672	4,223	227
Ovary	428	492	26
Pancreas	1,539	1,856	43
Penis	36	42	2
Pharynx	239	275	15
Prostate	3,244	3,167	336
Rectum	1,219	1,401	75
Salivary glands	49	56	3
Skin melanoma	788	906	86
Small intestine	80	92	5
Soft tissue	140	161	9
Stomach	1,478	1,951	51
Testis	173	199	11
Thyroid gland	327	376	20
Tongue	132	152	8
Mesothelioma (mixed data sources)	219	199	11
Source: Overall totals and data for the 10 most common cancer sites for each Member State from Cancer Today (http://gco.iarc.fr/today/online-analysis-multi-bars?mode=cancer&mode_population=continents&population=40&sex=0&cancer=29&type=0&statistic=0&prevalence=0&color_palette=default). Data for other sites extrapolated based on the distribution of incidences across cancer sites for the EU (with proportions calculated from EUREG (http://eco.iarc.fr/EUREG/AnalysisT.aspx). Numbers for mesothelioma are extrapolated based on UK data. *Note: extrapolated figures are given in shaded boxes, non-shaded boxes represent actual data*			

6.2 EUCAN

The EUCAN data for cancer incidence and mortality are presented in the following tables.

Table 6-5: Incidence 2012														
MEN AND WOMEN	Year	Lip, oral cavity & pharynx	Oesophagus	Stomach	Large bowel	Liver & intraheptic bile ducts	Gallbladder & biliary tract	Pancreas	Larynx	Lung incl trachea & bronchus	Malignant melanoma of skin	Breast (women only!)	Cervix uteri (women only!)	Corpus uteri (women only!)
Austria	2012	1,145	447	1,314	4,874	955	359	1,585	297	4,576	1,334	5,254	363	908
Belgium	2012	1,877	969	1,417	8,683	645	370	1,293	724	7,794	1,941	10,337	639	1,517
Bulgaria	2012	854	222	1,664	4,925	640	303	1,236	636	3,936	439	3,928	1,254	1,280
Croatia	2012	685	243	966	3,209	466	345	677	381	3,056	674	2,641	325	598
Cyprus	2012	32	17	94	442	56	28	77	25	276	52	604	31	92
Czech Republic	2012	1,510	593	1,595	8,336	919	966	2,118	530	6,683	2,194	6,854	1,016	1,892
Denmark	2012	910	443	625	4,832	311	255	1,023	266	4,566	1,596	5,224	363	754
Estonia	2012	143	54	370	789	64	44	191	56	632	166	658	186	205
Finland	2012	573	282	641	2,896	620	256	1,151	118	2,494	1,208	4,477	143	860
France	2012	11,240	4,415	6,507	40,825	8,332	2,512	9,149	3,344	40,043	9,871	48,763	2,862	6,852
Germany	2012	15,891	6,950	16,015	63,572	9,202	5,340	16,451	4,064	50,813	16,884	71,623	4,995	11,196
Greece	2012	570	217	1,478	3,885	1,054	413	1,539	527	6,884	472	4,934	421	865
Hungary	2012	2,696	603	1,951	8,442	630	646	1,856	986	9,288	1,117	5,094	1,178	788
Ireland	2012	384	424	487	2,560	239	152	510	179	2,273	859	2,899	357	372
Italy	2012	5,835	1,809	13,001	48,110	10,733	3,945	10,688	4,049	37,238	10,012	50,658	2,918	8,471
Latvia	2012	215	142	640	1,152	154	60	371	143	1,183	225	1,145	284	394
Lithuania	2012	382	198	867	1,558	175	106	480	183	1,555	275	1,479	615	572
Luxembourg	2012	64	34	67	310	68	5	67	17	261	86	360	24	115
Malta	2012	52	20	68	268	19	15	75	25	181	36	314	12	64
Netherlands	2012	2,063	2,091	1,953	13,918	475	635	2,141	733	11,968	4,804	13,895	750	2,039
Poland	2012	5,010	1,506	6,105	19,438	1,998	2,296	5,004	2,657	26,230	2,583	17,259	3,513	5,912
Portugal	2012	2,082	608	3,018	7,129	1,004	496	1,225	830	4,192	1,101	6,088	720	1,485
Romania	2012	3,728	768	4,075	10,256	2,214	632	3,082	1,618	11,644	1,121	8,981	4,343	1,539
Slovakia	2012	988	284	901	3,963	398	394	881	280	2,531	806	2,643	607	927
Slovenia	2012	326	84	468	1,621	216	198	383	99	1,360	533	1,258	139	306
Spain	2012	5,978	2,090	7,810	32,240	5,522	2,002	6,367	3,182	26,715	5,004	25,215	2,511	5,121
Sweden	2012	971	461	811	6,358	490	368	964	186	3,891	2,911	6,624	451	1,427
UK	2012	7,495	8,803	6,684	40,755	4,186	750	8,747	2,201	40,382	14,445	52,399	2,659	8,378

Table 6-5: Incidence 2012														
MEN AND WOMEN	Year	Lip, oral cavity & pharynx	Oesophagus	Stomach	Large bowel	Liver & intraheptic bile ducts	Gallbladder & biliary tract	Pancreas	Larynx	Lung incl trachea & bronchus	Malignant melanoma of skin	Breast (women only!)	Cervix uteri (women only!)	Corpus uteri (women only!)
EU28	2012	73,699	34,777	81,592	345,346	51,785	23,891	79,331	28,336	312,645	82,749	361,608	33,679	64,929

Table 6-6: Incidence 2012													
MEN AND WOMEN	Year	Ovary (women only!)	Prostate (men only!)	Testis (men only!)	Kidney incl renal pelvis & urether	Bladder	Brain & central nervous system	Thyroid	Hodgkin lymphoma	Non-Hodgkin lymphomas	Multiple myeloma	Leukaemias	All sites but non-melanoma skin
Austria	2012	636	5,833	368	1,322	2,159	593	1,200	163	1,172	476	1,052	41,117
Belgium	2012	840	9,393	300	1,763	4,350	831	851	303	2,072	835	1,465	65,345
Bulgaria	2012	899	1,818	220	881	1,662	827	306	153	545	240	612	32,053
Croatia	2012	428	2,021	194	821	1,053	589	576	160	544	229	456	22,890
Cyprus	2012	56	480	28	46	227	58	118	22	116	44	146	3,438
Czech Republic	2012	1,092	6,848	496	3,313	2,462	838	1,094	249	1,278	426	1,016	57,627
Denmark	2012	544	5,205	336	754	1,781	518	222	136	1,031	311	588	36,119
Estonia	2012	156	1,021	23	284	209	89	80	27	128	70	175	6,117
Finland	2012	457	5,366	144	882	1,093	430	386	140	1,208	358	653	28,428
France	2012	4,592	56,841	2,332	11,023	11,175	4,767	6,703	1,757	11,512	6,022	9,180	349,426
Germany	2012	6,673	68,262	4,031	18,615	28,405	7,116	5,229	2,017	14,597	5,947	11,038	493,780
Greece	2012	915	3,244	157	1,094	2,777	1,334	253	378	467	567	2,247	40,971
Hungary	2012	999	3,167	566	1,554	2,689	595	686	154	987	257	1,111	50,475
Ireland	2012	380	3,788	216	571	666	350	155	122	711	294	594	20,808
Italy	2012	5,911	44,525	2,664	11,300	18,284	4,928	9,459	1,584	12,548	5,362	8,369	354,456
Latvia	2012	304	1,484	55	449	425	256	168	45	186	82	254	10,347
Lithuania	2012	369	1,516	34	773	569	308	567	68	349	187	435	14,520
Luxembourg	2012	36	336	22	70	96	39	62	10	68	24	62	2,476
Malta	2012	46	202	16	57	132	31	32	11	49	19	48	1,902
Netherlands	2012	1,025	13,300	709	2,679	2,999	1,166	560	419	3,241	1,201	1,775	93,448

Table 6-6: Incidence 2012													
MEN AND WOMEN	Year	Ovary (women only!)	Prostate (men only!)	Testis (men only!)	Kidney incl renal pelvis & urether	Bladder	Brain & central nervous system	Thyroid	Hodgkin lymphoma	Non-Hodgkin lymphomas	Multiple myeloma	Leukaemias	All sites but non-melanoma skin
Poland	2012	4,456	11,029	939	5,244	7,961	4,467	1,769	723	2,659	1,421	3,304	152,216
Portugal	2012	616	6,622	302	1,004	2,876	932	576	287	1,842	513	1,124	49,174
Romania	2012	1,850	4,532	340	1,940	3,825	1,715	788	318	1,566	644	1,750	78,760
Slovakia	2012	518	1,934	284	1,063	933	521	300	125	574	284	650	24,045
Slovenia	2012	192	1,573	111	400	463	160	200	40	294	134	226	11,457
Spain	2012	3,236	27,853	823	6,474	13,789	3,717	2,059	1,150	6,130	2,420	5,190	215,534
Sweden	2012	659	11,596	329	1,125	2,350	1,307	387	174	1,602	625	1,147	50,481
UK	2012	6,692	45,406	2,163	9,714	8,778	4,654	2,654	1,696	11,836	4,650	8,011	327,812
EU28	2012	44,577	345,195	18,202	85,215	124,188	43,136	37,440	12,431	79,312	33,642	62,678	2,635,222

Table 6-7: Incidence 2012														
MEN	Year	Lip, oral cavity & pharynx	Oesophagus	Stomach	Large bowel	Liver & intraheptic bile ducts	Gallbladder & biliary tract	Pancreas	Larynx	Lung incl trachea & bronchus	Malignant melanoma of skin	Breast (women only!)	Cervix uteri (women only!)	Corpus uteri (women only!)
Austria	2012	820	372	760	2790	644	148	785	253	2851	661	-	-	-
Belgium	2012	1384	721	884	4797	446	167	667	620	5757	758	-	-	-
Bulgaria	2012	649	183	990	2711	418	125	686	602	3246	227	-	-	-
Croatia	2012	515	200	588	1803	329	124	352	344	2262	309	-	-	-
Cyprus	2012	24	12	63	231	36	12	41	22	211	25	-	-	-
Czech Republic	2012	1070	482	944	4978	581	325	1086	478	4624	1146	-	-	-
Denmark	2012	605	298	440	2535	227	111	513	214	2303	731	-	-	-
Estonia	2012	100	43	196	369	34	17	99	52	481	60	-	-	-
Finland	2012	338	194	368	1551	407	105	555	104	1682	670	-	-	-
France	2012	8070	3256	4261	21524	6500	1158	4555	2825	28033	4720	-	-	-
Germany	2012	12052	5539	10081	36567	6396	2180	7972	3613	34159	8514	-	-	-
Greece	2012	399	175	903	2074	708	214	829	485	5680	263	-	-	-

Table 6-7: Incidence 2012														
MEN	Year	Lip, oral cavity & pharynx	Oesophagus	Stomach	Large bowel	Liver & intraheptic bile ducts	Gallbladder & biliary tract	Pancreas	Larynx	Lung incl trachea & bronchus	Malignant melanoma of skin	Breast (women only!)	Cervix uteri (women only!)	Corpus uteri (women only!)
Hungary	2012	2060	506	1115	4751	434	234	906	866	5893	566	-	-	-
Ireland	2012	264	283	306	1478	152	58	257	149	1246	402	-	-	-
Italy	2012	3839	1337	7549	26568	7188	1666	4946	3714	26931	4888	-	-	-
Latvia	2012	165	112	383	527	96	19	174	132	947	87	-	-	-
Lithuania	2012	298	167	538	767	111	43	246	173	1275	117	-	-	-
Luxembourg	2012	45	25	42	180	46	2	33	14	172	44	-	-	-
Malta	2012	36	14	43	153	13	9	41	20	149	16	-	-	-
Netherlands	2012	1277	1560	1228	7597	338	341	1137	606	6987	2196	-	-	-
Poland	2012	3794	1147	3936	11072	1071	618	2549	2341	17905	1192	-	-	-
Portugal	2012	1683	533	1834	4209	772	305	670	800	3215	464	-	-	-
Romania	2012	3241	655	2711	5760	1485	261	1692	1542	9317	528	-	-	-
Slovakia	2012	823	241	534	2347	258	132	440	258	1804	399	-	-	-
Slovenia	2012	249	67	292	932	157	71	176	89	980	255	-	-	-
Spain	2012	4505	1756	4866	19261	4006	947	3335	2914	21780	2286	-	-	-
Sweden	2012	579	339	497	3297	319	135	483	154	1928	1456	-	-	-
UK	2012	5000	5972	4169	22597	2721	204	4211	1811	21845	6900	-	-	-
EU28	2012	53,884	26,189	50,521	193,426	35,893	9,731	39,436	25,195	213,663	39,880	-	-	-

Table 6-8: Incidence 2012													
MEN	Year	Ovary (women only!)	Prostate (men only!)	Testis (men only!)	Kidney incl renal pelvis & urether	Bladder	Brain & central nervous system	Thyroid	Hodgkin lymphoma	Non-Hodgkin lymphomas	Multiple myeloma	Leukaemias	All sites but non-melanoma skin
Austria	2012	-	5,833	368	818	1625	294	334	91	621	245	578	22273
Belgium	2012	-	9,393	300	1128	3482	469	243	179	1108	470	872	36103
Bulgaria	2012	-	1,818	220	581	1282	439	48	83	284	117	339	16480
Croatia	2012	-	2,021	194	519	751	298	112	83	261	108	256	12220
Cyprus	2012	-	480	28	30	202	30	23	13	61	25	88	1809

Table 6-8: Incidence 2012													
MEN	Year	Ovary (women only!)	Prostate (men only!)	Testis (men only!)	Kidney incl renal pelvis & urether	Bladder	Brain & central nervous system	Thyroid	Hodgkin lymphoma	Non-Hodgkin lymphomas	Multiple myeloma	Leukaemias	All sites but non-melanoma skin
Czech Republic	2012	-	6,848	496	2116	1774	422	214	147	634	226	571	30716
Denmark	2012	-	5,205	336	489	1311	293	71	73	568	165	346	18555
Estonia	2012	-	1,021	23	167	153	50	15	16	67	35	87	3236
Finland	2012	-	5,366	144	477	869	242	95	76	641	199	374	15204
France	2012	-	56,841	2,332	7358	9283	2670	1647	874	6282	3287	5454	194552
Germany	2012	-	68,262	4,031	11353	21656	3977	1568	1081	7674	3311	6271	270401
Greece	2012	-	3,244	157	719	2303	704	44	184	257	293	1248	23319
Hungary	2012	-	3,167	566	1027	1873	300	154	80	470	120	593	26973
Ireland	2012	-	3,788	216	355	468	205	44	66	389	160	386	11304
Italy	2012	-	44,525	2,664	7681	14674	2762	2648	919	6951	2775	4902	192151
Latvia	2012	-	1,484	55	260	305	120	35	23	88	36	125	5390
Lithuania	2012	-	1,516	34	467	385	131	75	34	163	78	211	7251
Luxembourg	2012	-	336	22	49	71	26	16	3	36	9	33	1296
Malta	2012	-	202	16	37	100	18	7	4	24	11	29	1005
Netherlands	2012	-	13,300	709	1682	2249	689	164	238	1771	700	990	49403
Poland	2012	-	11,029	939	3054	6113	2086	350	417	1224	610	1894	77710
Portugal	2012	-	6,622	302	665	2339	488	127	148	1015	268	618	28476
Romania	2012	-	4,532	340	1250	3151	915	126	135	797	323	1009	43149
Slovakia	2012	-	1,934	284	649	716	273	67	57	267	123	376	12612
Slovenia	2012	-	1,573	111	253	352	92	42	23	142	74	124	6339
Spain	2012	-	27,853	823	4346	11584	2056	698	616	3379	1311	3028	128550
Sweden	2012	-	11,596	329	684	1776	581	101	100	878	350	638	27736
UK	2012	-	45,406	2,163	6067	6346	2799	654	975	6447	2614	4761	165502
EU28	2012	-	345,195	18,202	54,281	97,193	23,429	9,722	6,738	42,499	18,043	36,201	1,429,715

Table 6-9: Incidence 2012														
WOMEN	Year	Lip, oral cavity & pharynx	Oesophagus	Stomach	Large bowel	Liver & intraheptic bile ducts	Gallbladder & biliary tract	Pancreas	Larynx	Lung incl trachea & bronchus	Malignant melanoma of skin	Breast (women only!)	Cervix uteri (women only!)	Corpus uteri (women only!)
Austria	2012	325	75	554	2,084	311	211	800	44	1,725	673	5,254	363	908
Belgium	2012	493	248	533	3,886	199	203	626	104	2,037	1,183	10,337	639	1,517
Bulgaria	2012	205	39	674	2,214	222	178	550	34	690	212	3,928	1,254	1,280
Croatia	2012	170	43	378	1,406	137	221	325	37	794	365	2,641	325	598
Cyprus	2012	8	5	31	211	20	16	36	3	65	27	604	31	92
Czech Republic	2012	440	111	651	3,358	338	641	1,032	52	2,059	1,048	6,854	1,016	1,892
Denmark	2012	305	145	185	2,297	84	144	510	52	2,263	865	5,224	363	754
Estonia	2012	43	11	174	420	30	27	92	4	151	106	658	186	205
Finland	2012	235	88	273	1,345	213	151	596	14	812	538	4,477	143	860
France	2012	3,170	1,159	2,246	19,301	1,832	1,354	4,594	519	12,010	5,151	48,763	2,862	6,852
Germany	2012	3,839	1,411	5,934	27,005	2,806	3,160	8,479	451	16,654	8,370	71,623	4,995	11,196
Greece	2012	171	42	575	1,811	346	199	710	42	1,204	209	4,934	421	865
Hungary	2012	636	97	836	3,691	196	412	950	120	3,395	551	5,094	1,178	788
Ireland	2012	120	141	181	1,082	87	94	253	30	1,027	457	2,899	357	372
Italy	2012	1,996	472	5,452	21,542	3,545	2,279	5,742	335	10,307	5,124	50,658	2,918	8,471
Latvia	2012	50	30	257	625	58	41	197	11	236	138	1,145	284	394
Lithuania	2012	84	31	329	791	64	63	234	10	280	158	1,479	615	572
Luxembourg	2012	19	9	25	130	22	3	34	3	89	42	360	24	115
Malta	2012	16	6	25	115	6	6	34	5	32	20	314	12	64
Netherlands	2012	786	531	725	6,321	137	294	1,004	127	4,981	2,608	13,895	750	2,039
Poland	2012	1,216	359	2,169	8,366	927	1,678	2,455	316	8,325	1,391	17,259	3,513	5,912
Portugal	2012	399	75	1,184	2,920	232	191	555	30	977	637	6,088	720	1,485
Romania	2012	487	113	1,364	4,496	729	371	1,390	76	2,327	593	8,981	4,343	1,539
Slovakia	2012	165	43	367	1,616	140	262	441	22	727	407	2,643	607	927
Slovenia	2012	77	17	176	689	59	127	207	10	380	278	1,258	139	306
Spain	2012	1,473	334	2,944	12,979	1,516	1,055	3,032	268	4,935	2,718	25,215	2,511	5,121
Sweden	2012	392	122	314	3,061	171	233	481	32	1,963	1,455	6,624	451	1,427
UK	2012	2,495	2,831	2,515	18,158	1,465	546	4,536	390	18,537	7,545	52,399	2,659	8,378

Table 6-9: Incidence 2012														
WOMEN	Year	Lip, oral cavity & pharynx	Oesophagus	Stomach	Large bowel	Liver & intraheptic bile ducts	Gallbladder & biliary tract	Pancreas	Larynx	Lung incl trachea & bronchus	Malignant melanoma of skin	Breast (women only!)	Cervix uteri (women only!)	Corpus uteri (women only!)
EU28	2012	19,815	8,588	31,071	151,920	15,892	14,160	39,895	3,141	98,982	42,869	361,608	33,679	64,929

Table 6-10: Incidence 2012													
WOMEN	Year	Ovary (women only!)	Prostate (men only!)	Testis (men only!)	Kidney incl renal pelvis & urether	Bladder	Brain & central nervous system	Thyroid	Hodgkin lymphoma	Non-Hodgkin lymphomas	Multiple myeloma	Leukaemias	All sites but non-melanoma skin
Austria	2012	636	-	-	504	534	299	866	72	551	231	474	18844
Belgium	2012	840	-	-	635	868	362	608	124	964	365	593	29242
Bulgaria	2012	899	-	-	300	380	388	258	70	261	123	273	15573
Croatia	2012	428	-	-	302	302	291	464	77	283	121	200	10670
Cyprus	2012	56	-	-	16	25	28	95	9	55	19	58	1629
Czech Republic	2012	1,092	-	-	1,197	688	416	880	102	644	200	445	26911
Denmark	2012	544	-	-	265	470	225	151	63	463	146	242	17564
Estonia	2012	156	-	-	117	56	39	65	11	61	35	88	2881
Finland	2012	457	-	-	405	224	188	291	64	567	159	279	13224
France	2012	4,592	-	-	3,665	1,892	2,097	5,056	883	5,230	2,735	3,726	154874
Germany	2012	6,673	-	-	7,262	6,749	3,139	3,661	936	6,923	2,636	4,767	223379
Greece	2012	915	-	-	375	474	630	209	194	210	274	999	17652
Hungary	2012	999	-	-	527	816	295	532	74	517	137	518	23502
Ireland	2012	380	-	-	216	198	145	111	56	322	134	208	9504
Italy	2012	5,911	-	-	3,619	3,610	2,166	6,811	665	5,597	2,587	3,467	162305
Latvia	2012	304	-	-	189	120	136	133	22	98	46	129	4957
Lithuania	2012	369	-	-	306	184	177	492	34	186	109	224	7269
Luxembourg	2012	36	-	-	21	25	13	46	7	32	15	29	1180
Malta	2012	46	-	-	20	32	13	25	7	25	8	19	897
Netherlands	2012	1,025	-	-	997	750	477	396	181	1,470	501	785	44045

Table 6-10: Incidence 2012													
WOMEN	Year	Ovary (women only!)	Prostate (men only!)	Testis (men only!)	Kidney incl renal pelvis & urether	Bladder	Brain & central nervous system	Thyroid	Hodgkin lymphoma	Non-Hodgkin lymphomas	Multiple myeloma	Leukaemias	All sites but non-melanoma skin
Poland	2012	4,456	-	-	2,190	1,848	2,381	1,419	306	1,435	811	1,410	74506
Portugal	2012	616	-	-	339	537	444	449	139	827	245	506	20698
Romania	2012	1,850	-	-	690	674	800	662	183	769	321	741	35611
Slovakia	2012	518	-	-	414	217	248	233	68	307	161	274	11433
Slovenia	2012	192	-	-	147	111	68	158	17	152	60	102	5118
Spain	2012	3,236	-	-	2,128	2,205	1,661	1,361	534	2,751	1,109	2,162	86984
Sweden	2012	659	-	-	441	574	726	286	74	724	275	509	22745
UK	2012	6,692	-	-	3,647	2,432	1,855	2,000	721	5,389	2,036	3,250	162310
EU28	2012	44,577	-	-	30,934	26,995	19,707	27,718	5,693	36,813	15,599	26,477	1,205,507

Table 6-11: Mortality														
MEN AND WOMEN	Year	Lip, oral cavity & pharynx	Oesophagus	Stomach	Large bowel	Liver & intraheptic bile ducts	Gallbladder & biliary tract	Pancreas	Larynx	Lung incl trachea & bronchus	Malignant melanoma of skin	Breast (women only!)	Cervix uteri (women only!)	Corpus uteri (women only!)
Austria	2012	430	351	853	2185	894	224	1486	118	3658	354	1512	178	234
Belgium	2012	585	721	962	3503	761	193	1596	266	7179	294	2523	219	346
Bulgaria	2012	585	183	1354	2728	858	174	1052	436	3659	189	1391	437	318
Croatia	2012	373	219	786	2010	447	275	711	205	2793	206	920	140	186
Cyprus	2012	10	14	72	133	47	13	88	17	258	14	132	17	20
Czech Republic	2012	724	469	1099	3628	697	760	1928	236	5228	336	1617	315	349
Denmark	2012	360	487	351	1996	303	128	877	112	3806	228	1198	97	169
Estonia	2012	110	67	286	425	92	49	229	31	665	56	258	80	44
Finland	2012	182	240	479	1161	484	203	1052	37	2138	220	860	53	179
France	2012	3758	3826	4412	17148	8050	1132	9588	1100	31434	1831	11933	1167	2148
Germany	2012	5016	5169	9714	25473	7725	2913	16188	1412	43420	2671	16828	1566	2133

Table 6-11: Mortality														
MEN AND WOMEN	Year	Lip, oral cavity & pharynx	Oesophagus	Stomach	Large bowel	Liver & intraheptic bile ducts	Gallbladder & biliary tract	Pancreas	Larynx	Lung incl trachea & bronchus	Malignant melanoma of skin	Breast (women only!)	Cervix uteri (women only!)	Corpus uteri (women only!)
Greece	2012	302	208	1323	2526	1398	348	1630	361	6434	203	2138	208	277
Hungary	2012	1458	539	1570	4651	621	538	1828	512	8070	343	1914	461	208
Ireland	2012	136	361	325	984	237	44	488	70	1778	140	704	101	99
Italy	2012	2699	1746	9917	19279	9198	3364	10637	1651	33531	1807	12796	1016	1955
Latvia	2012	149	128	484	682	135	51	366	89	1002	85	433	135	149
Lithuania	2012	286	188	668	995	181	74	458	157	1292	108	607	221	133
Luxembourg	2012	10	24	32	126	66	0	67	5	218	11	72	13	32
Malta	2012	20	13	33	114	22	5	60	6	139	6	77	3	16
Netherlands	2012	591	1811	1391	5239	678	353	2489	206	10609	853	3163	242	405
Poland	2012	2441	1421	5197	11350	2068	1894	4846	1488	23371	1350	5373	1858	1311
Portugal	2012	751	540	2285	3797	908	303	1268	368	3441	218	1570	390	304
Romania	2012	2197	712	3366	5675	2830	466	2782	1009	10071	364	3244	1909	359
Slovakia	2012	618	255	633	1787	347	296	815	168	1981	188	698	232	207
Slovenia	2012	146	79	335	813	189	147	374	46	1131	128	420	64	71
Spain	2012	2070	1728	5389	14700	4536	1174	5720	1321	21118	967	6075	848	1211
Sweden	2012	320	430	635	2736	621	456	1640	56	3695	565	1450	187	292
UK	2012	2259	7929	4534	16202	4059	687	8406	765	35581	2195	11679	979	1711
EU28	2012	28,586	29,858	58,485	152,046	48,452	16,264	78,669	12,248	267,700	15,930	91,585	13,136	14,866

Table 6-12: Mortality													
MEN AND WOMEN	Year	Ovary (women only!)	Prostate (men only!)	Testis (men only!)	Kidney incl renal pelvis & urether	Bladder	Brain & central nervous system	Thyroid	Hodgkin lymphoma	Non-Hodgkin lymphomas	Multiple myeloma	Leukaemias	All sites but non-melanoma skin
Austria	2012	504	1105	25	536	486	475	69	30	580	331	769	20440
Belgium	2012	731	1913	13	728	989	599	79	67	712	484	1029	29815
Bulgaria	2012	440	860	41	470	558	643	50	60	344	108	405	18059
Croatia	2012	321	756	18	377	367	402	35	21	277	140	354	13313
Cyprus	2012	37	103	2	17	47	42	8	5	48	30	64	1467

Table 6-12: Mortality													
MEN AND WOMEN	Year	Ovary (women only!)	Prostate (men only!)	Testis (men only!)	Kidney incl renal pelvis & urether	Bladder	Brain & central nervous system	Thyroid	Hodgkin lymphoma	Non-Hodgkin lymphomas	Multiple myeloma	Leukaemias	All sites but non-melanoma skin
Czech Republic	2012	708	1268	30	1095	741	637	72	40	512	328	786	26911
Denmark	2012	401	1316	11	352	558	396	33	24	340	241	437	15669
Estonia	2012	97	253	3	142	106	93	16	6	80	54	133	3613
Finland	2012	329	832	4	333	276	318	39	19	418	274	342	11400
France	2012	3389	8606	98	4186	4774	3286	392	305	4280	2764	5712	154572
Germany	2012	5379	12548	146	7540	5404	5664	649	296	5491	3780	7358	217636
Greece	2012	578	1821	27	602	1117	1163	74	208	249	380	1470	28480
Hungary	2012	644	1031	50	673	822	467	84	37	503	203	828	30255
Ireland	2012	264	524	5	230	194	268	18	19	243	159	274	8354
Italy	2012	3617	7814	82	4203	5745	4002	590	422	4768	3194	6185	170030
Latvia	2012	223	365	6	225	198	183	24	19	125	73	163	5971
Lithuania	2012	301	611	5	309	239	250	32	15	154	116	269	8278
Luxembourg	2012	27	58	0	12	27	31	1	0	25	15	43	1020
Malta	2012	32	35	0	27	51	19	1	0	31	13	24	822
Netherlands	2012	1019	2650	26	1463	1253	1055	104	83	1007	641	1228	42539
Poland	2012	2692	4242	116	2721	3276	3029	255	219	1564	1215	2656	94958
Portugal	2012	381	1582	18	368	854	718	93	59	685	365	761	24112
Romania	2012	1020	2018	63	886	1471	1594	162	116	735	344	1168	48252
Slovakia	2012	280	535	18	388	257	360	30	29	212	127	342	11783
Slovenia	2012	150	423	5	171	198	145	14	9	161	102	178	5867
Spain	2012	1878	5481	42	2295	5007	2668	286	212	2337	1675	3212	102762
Sweden	2012	609	2444	9	635	685	649	73	30	580	507	753	22062
UK	2012	4040	10595	64	4150	4935	3792	356	344	4269	2799	4526	157849
EU28	2012	30,091	71,789	927	35,134	40,635	32,948	3,639	2,694	30,730	20,462	41,469	1,276,289

Table 6-13: Mortality														
MEN	Year	Lip, oral cavity & pharynx	Oesophagus	Stomach	Large bowel	Liver & intraheptic bile ducts	Gallbladder & biliary tract	Pancreas	Larynx	Lung incl trachea & bronchus	Malignant melanoma of skin	Breast (women only!)	Cervix uteri (women only!)	Corpus uteri (women only!)
Austria	2012	317	294	467	1210	588	85	728	101	2341	220	-	-	-
Belgium	2012	452	524	587	1837	459	80	793	238	5639	159	-	-	-
Bulgaria	2012	424	155	830	1523	527	70	599	411	3015	107	-	-	-
Croatia	2012	323	182	479	1149	284	101	359	188	2124	111	-	-	-
Cyprus	2012	8	10	42	76	31	5	53	16	204	10	-	-	-
Czech Republic	2012	560	385	648	2181	437	256	953	212	3660	198	-	-	-
Denmark	2012	248	357	219	1017	231	54	462	90	2001	125	-	-	-
Estonia	2012	89	54	165	204	51	17	111	29	509	25	-	-	-
Finland	2012	112	159	270	607	299	75	504	32	1474	146	-	-	-
France	2012	2965	2996	2847	8991	5926	482	4909	972	22907	1055	-	-	-
Germany	2012	3770	3898	5584	13464	5054	1120	7900	1201	28702	1470	-	-	-
Greece	2012	214	168	805	1345	920	178	863	331	5295	121	-	-	-
Hungary	2012	1200	454	891	2585	409	191	888	454	5238	190	-	-	-
Ireland	2012	97	240	202	586	133	15	252	62	1048	86	-	-	-
Italy	2012	1857	1308	5723	10253	6010	1395	5074	1502	24686	1070	-	-	-
Latvia	2012	117	109	275	326	75	18	178	84	837	35	-	-	-
Lithuania	2012	241	163	400	504	107	25	236	150	1102	57	-	-	-
Luxembourg	2012	7	19	19	66	42	0	32	5	146	7	-	-	-
Malta	2012	15	10	24	60	15	3	30	6	116	5	-	-	-
Netherlands	2012	393	1339	822	2761	430	153	1241	158	6392	462	-	-	-
Poland	2012	1922	1113	3368	6370	1104	508	2459	1307	16529	700	-	-	-
Portugal	2012	619	467	1387	2240	655	167	690	353	2638	108	-	-	-
Romania	2012	1957	599	2217	3229	1818	201	1546	949	8024	189	-	-	-
Slovakia	2012	536	219	366	1047	213	102	376	156	1509	99	-	-	-
Slovenia	2012	120	63	205	458	129	52	168	42	795	55	-	-	-
Spain	2012	1576	1457	3335	8742	3049	483	3003	1235	17430	527	-	-	-
Sweden	2012	199	315	395	1394	389	166	756	49	1833	336	-	-	-
UK	2012	1496	5374	2821	8734	2496	238	4095	623	19395	1245	-	-	-

Table 6-13: Mortality														
MEN	Year	Lip, oral cavity & pharynx	Oesophagus	Stomach	Large bowel	Liver & intraheptic bile ducts	Gallbladder & biliary tract	Pancreas	Larynx	Lung incl trachea & bronchus	Malignant melanoma of skin	Breast (women only!)	Cervix uteri (women only!)	Corpus uteri (women only!)
EU28	2012	21,834	22,431	35,393	82,959	31,881	6,240	39,258	10,956	185,589	8,918	-	-	-

Table 6-14: Incidence 2012													
MEN	Year	Ovary (women only!)	Prostate (men only!)	Testis (men only!)	Kidney incl renal pelvis & urether	Bladder	Brain & central nervous system	Thyroid	Hodgkin lymphoma	Non-Hodgkin lymphomas	Multiple myeloma	Leukaemias	All sites but non-melanoma skin
Austria	2012	-	1105	25	314	327	254	28	18	298	166	416	11041
Belgium	2012	-	1913	13	456	734	332	27	43	370	243	569	17342
Bulgaria	2012	-	860	41	324	443	357	23	41	184	54	214	10553
Croatia	2012	-	756	18	261	276	207	13	12	138	57	186	7754
Cyprus	2012	-	103	2	10	38	23	4	3	27	17	38	837
Czech Republic	2012	-	1268	30	669	509	338	28	21	268	147	408	14797
Denmark	2012	-	1316	11	222	375	220	13	16	175	145	242	8258
Estonia	2012	-	253	3	82	78	45	2	2	37	19	67	1956
Finland	2012	-	832	4	180	205	169	15	12	208	143	199	6091
France	2012	-	8606	98	2894	3654	1940	158	175	2310	1416	3196	90111
Germany	2012	-	12548	146	4713	3543	3104	256	164	2964	1980	3977	117607
Greece	2012	-	1821	27	397	915	620	30	118	138	195	844	17107
Hungary	2012	-	1031	50	437	559	237	32	22	250	93	432	16762
Ireland	2012	-	524	5	148	132	155	9	11	134	90	165	4439
Italy	2012	-	7814	82	2803	4547	2261	234	258	2611	1570	3532	94986
Latvia	2012	-	365	6	125	156	88	4	9	57	31	72	3180
Lithuania	2012	-	611	5	201	184	115	10	7	78	52	132	4691
Luxembourg	2012	-	58	0	8	18	20	1	0	14	7	23	548
Malta	2012	-	35	0	17	19	12	0	0	19	6	16	447
Netherlands	2012	-	2650	26	964	857	609	34	48	540	353	683	22937
Poland	2012	-	4242	116	1691	2583	1506	76	127	825	556	1457	53031

Table 6-14: Incidence 2012													
MEN	Year	Ovary (women only!)	Prostate (men only!)	Testis (men only!)	Kidney incl renal pelvis & urether	Bladder	Brain & central nervous system	Thyroid	Hodgkin lymphoma	Non-Hodgkin lymphomas	Multiple myeloma	Leukaemias	All sites but non-melanoma skin
Portugal	2012	-	1582	18	240	658	370	33	35	371	181	402	14304
Romania	2012	-	2018	63	591	1180	862	53	61	398	176	667	28875
Slovakia	2012	-	535	18	233	186	192	9	18	110	51	183	6651
Slovenia	2012	-	423	5	112	139	85	7	7	82	49	103	3267
Spain	2012	-	5481	42	1531	4102	1469	100	117	1266	849	1834	63579
Sweden	2012	-	2444	9	385	486	374	29	16	322	273	419	11477
UK	2012	-	10595	64	2549	3295	2249	140	180	2345	1525	2633	82881
EU28	2012	-	71,789	927	22,557	30,198	18,213	1,368	1,541	16,539	10,444	23,109	715,509

Table 6-15: Incidence 2012														
WOMEN	Year	Lip, oral cavity & pharynx	Oesophagus	Stomach	Large bowel	Liver & intraheptic bile ducts	Gallbladder & biliary tract	Pancreas	Larynx	Lung incl trachea & bronchus	Malignant melanoma of skin	Breast (women only!)	Cervix uteri (women only!)	Corpus uteri (women only!)
Austria	2012	113	57	386	975	306	139	758	17	1,317	134	1512	178	234
Belgium	2012	133	197	375	1,666	302	113	803	28	1,540	135	2523	219	346
Bulgaria	2012	161	28	524	1,205	331	104	453	25	644	82	1391	437	318
Croatia	2012	50	37	307	861	163	174	352	17	669	95	920	140	186
Cyprus	2012	2	4	30	57	16	8	35	1	54	4	132	17	20
Czech Republic	2012	164	84	451	1,447	260	504	975	24	1,568	138	1617	315	349
Denmark	2012	112	130	132	979	72	74	415	22	1,805	103	1198	97	169
Estonia	2012	21	13	121	221	41	32	118	2	156	31	258	80	44
Finland	2012	70	81	209	554	185	128	548	5	664	74	860	53	179
France	2012	793	830	1,565	8,157	2,124	650	4,679	128	8,527	776	11933	1167	2148
Germany	2012	1,246	1,271	4,130	12,009	2,671	1,793	8,288	211	14,718	1,201	16828	1566	2133
Greece	2012	88	40	518	1,181	478	170	767	30	1,139	82	2138	208	277
Hungary	2012	258	85	679	2,066	212	347	940	58	2,832	153	1914	461	208
Ireland	2012	39	121	123	398	104	29	236	8	730	54	704	101	99

Table 6-15: Incidence 2012														
WOMEN	Year	Lip, oral cavity & pharynx	Oesophagus	Stomach	Large bowel	Liver & intraheptic bile ducts	Gallbladder & biliary tract	Pancreas	Larynx	Lung incl trachea & bronchus	Malignant melanoma of skin	Breast (women only!)	Cervix uteri (women only!)	Corpus uteri (women only!)
Italy	2012	842	438	4,194	9,026	3,188	1,969	5,563	149	8,845	737	12796	1016	1955
Latvia	2012	32	19	209	356	60	33	188	5	165	50	433	135	149
Lithuania	2012	45	25	268	491	74	49	222	7	190	51	607	221	133
Luxembourg	2012	3	5	13	60	24	0	35	0	72	4	72	13	32
Malta	2012	5	3	9	54	7	2	30	0	23	1	77	3	16
Netherlands	2012	198	472	569	2,478	248	200	1,248	48	4,217	391	3163	242	405
Poland	2012	519	308	1,829	4,980	964	1,386	2,387	181	6,842	650	5373	1858	1311
Portugal	2012	132	73	898	1,557	253	136	578	15	803	110	1570	390	304
Romania	2012	240	113	1,149	2,446	1,012	265	1,236	60	2,047	175	3244	1909	359
Slovakia	2012	82	36	267	740	134	194	439	12	472	89	698	232	207
Slovenia	2012	26	16	130	355	60	95	206	4	336	73	420	64	71
Spain	2012	494	271	2,054	5,958	1,487	691	2,717	86	3,688	440	6075	848	1211
Sweden	2012	121	115	240	1,342	232	290	884	7	1,862	229	1450	187	292
UK	2012	763	2,555	1,713	7,468	1,563	449	4,311	142	16,186	950	11679	979	1711
EU28	2012	6,752	7,427	23,092	69,087	16,571	10,024	39,411	1,292	82,111	7,012	91,585	13,136	14,866

Table 6-16: Incidence 2012													
WOMEN	Year	Ovary (women only!)	Prostate (men only!)	Testis (men only!)	Kidney incl renal pelvis & urether	Bladder	Brain & central nervous system	Thyroid	Hodgkin lymphoma	Non-Hodgkin lymphomas	Multiple myeloma	Leukaemias	All sites but non-melanoma skin
Austria	2012	504	-	-	222	159	221	41	12	282	165	353	9399
Belgium	2012	731	-	-	272	255	267	52	24	342	241	460	12473
Bulgaria	2012	440	-	-	146	115	286	27	19	160	54	191	7506
Croatia	2012	321	-	-	116	91	195	22	9	139	83	168	5559
Cyprus	2012	37	-	-	7	9	19	4	2	21	13	26	630
Czech Republic	2012	708	-	-	426	232	299	44	19	244	181	378	12114
Denmark	2012	401	-	-	130	183	176	20	8	165	96	195	7411

Table 6-16: Incidence 2012													
WOMEN	Year	Ovary (women only!)	Prostate (men only!)	Testis (men only!)	Kidney incl renal pelvis & urether	Bladder	Brain & central nervous system	Thyroid	Hodgkin lymphoma	Non-Hodgkin lymphomas	Multiple myeloma	Leukaemias	All sites but non-melanoma skin
Estonia	2012	97	-	-	60	28	48	14	4	43	35	66	1657
Finland	2012	329	-	-	153	71	149	24	7	210	131	143	5309
France	2012	3389	-	-	1,292	1120	1,346	234	130	1,970	1,348	2,516	64461
Germany	2012	5379	-	-	2,827	1861	2,560	393	132	2,527	1,800	3,381	100029
Greece	2012	578	-	-	205	202	543	44	90	111	185	626	11373
Hungary	2012	644	-	-	236	263	230	52	15	253	110	396	13493
Ireland	2012	264	-	-	82	62	113	9	8	109	69	109	3915
Italy	2012	3617	-	-	1,400	1198	1,741	356	164	2,157	1,624	2,653	75044
Latvia	2012	223	-	-	100	42	95	20	10	68	42	91	2791
Lithuania	2012	301	-	-	108	55	135	22	8	76	64	137	3587
Luxembourg	2012	27	-	-	4	9	11	0	0	11	8	20	472
Malta	2012	32	-	-	10	32	7	1	0	12	7	8	375
Netherlands	2012	1019	-	-	499	396	446	70	35	467	288	545	19602
Poland	2012	2692	-	-	1,030	693	1,523	179	92	739	659	1,199	41927
Portugal	2012	381	-	-	128	196	348	60	24	314	184	359	9808
Romania	2012	1020	-	-	295	291	732	109	55	337	168	501	19377
Slovakia	2012	280	-	-	155	71	168	21	11	102	76	159	5132
Slovenia	2012	150	-	-	59	59	60	7	2	79	53	75	2600
Spain	2012	1878	-	-	764	905	1,199	186	95	1,071	826	1,378	39183
Sweden	2012	609	-	-	250	199	275	44	14	258	234	334	10585
UK	2012	4040	-	-	1,601	1640	1,543	216	164	1,924	1,274	1,893	74968
EU28	2012	30,091	-	-	12,577	10,437	14,735	2,271	1,153	14,191	10,018	18,360	560,780

7 Annex 4: Attributable Fractions (incl. by gender and cancer site)

7.1 Central scenarios – women

Table 7-1: AFs per cancer site (CENTRAL- low) WOMEN

Carcinogen	Bladder	Bone	Brain	Breast	Cervix	CNS	Colon & rectum	Eye	Kidney	Larynx	Leukaemia	Liver & bile duct	Lung	Lymphoma	Lymphoma and leukaemia	Malignant melanoma	Mesothelium	NHL	NMSC	Oesophagus	Ovary	Pancreas	Pharynx incl. NFC	Sinonasal (SNC)	Stomach	Thyroid
Diesel exhaust	0.01 %												0.2%													
Silica										0.1%			0.1%													
Asbestos							0.001 %			0.01 %			10.9%				95 %				0.1 %		0.01 %		0.01 %	
Formaldehyde			0.9 %								0.5%		0.2%										0.1%	1.3%		
Benzene											0.02 %															
Mineral oils	0.1%												0.1%						0%							
Cd and Cd compounds									0%				0%													
Wood dust																							0.1%	0.07 %		
Arsenic													0.003 %													
Vinyl chloride												0.01%						0.01 %								
Ethylene oxide											0%			0 %												
PAHs	0.1%								0.06 %				0.03%		0.01 %		0%		0.02 %			0.03 %			0.04 %	
Occupation as a welder								0.06 %					0%													
Solar radiation																			1.8%							
ETS													2.4%													
Epichlorohydrine						0 %							0%													
Tetrachloroethylen	0.05				0													0%		0.3		0%				

Table 7-1: AFs per cancer site (CENTRAL- low) WOMEN																									
Carcinogen	Bladder	Bone	Brain	Breast	Cervix	CNS	Colon & rectum	Eye	Kidney	Larynx	Leukaemia	Liver & bile duct	Lung	Lymphoma	Lymphoma and leukaemia	Malignant melanoma	Mesothelium	NHL	NMSC	Oesophagus	Ovary	Pancreas	Pharynx incl. NFC	Sinonasal (SNC)	Stomach	Thyroid
e	%				%															%						
Shift work				6.72 %																						
Dioxins													1%													
Inorganic acid mists										0.7%			0%													
Rubber manufacturing	0.03 %									0%	0%		0%	0 %											0.01 %	
Ionising radiation	0%	0.01 %	0%	0.03 %							0.01 %	0.005 %	0.003 %			0.3 %										0.04 %
Cr(VI) compounds													0%											0%		
Aromatic amines	0.07 %																									
Cytostatic drugs				0%							0.2%															
OvAF	***0.4%***	***0.01 %***	***0.9 %***	***6.7%***	***0 %***	***0 %***	***0.001 %***	***0.1%***	***0.1%***	***0.9%***	***0.7%***	***0.02%***	***14.5%***	***0 %***	***0.01 %***	***0.3 %***	***95 %***	***0.01 %***	***1.8%***	***0.3 %***	***0.1 %***	***0.03 %***	***0.2%***	***1.4%***	***0.1%***	***0.04 %***

Table 7-2: AFs per cancer site (CENTRAL- core) WOMEN																									
Carcinogen	Bladder	Bone	Brain	Breast	Cervix	CNS	Colon & rectum	Eye	Kidney	Larynx	Leukaemia	Liver & bile duct	Lung	Lymphoma	Lymphoma and leukaemia	Malignant melanoma	Mesothelium	NHL	NMSC	Oesophagus	Ovary	Pancreas	Pharynx incl. NFC	Sinonasal (SNC)	Stomach	Thyroid
Diesel exhaust	0.2 %												0.3%													
Silica										0.3%			0.3%													
Asbestos							0.02 %			0.03%			10.9%				95 %				0.1 %		0.2 %		0.02 %	
Formaldehyde			0.9 %								0.5%		0.3%										1.8 %	3%		
Benzene											0.1%															

Table 7-2: AFs per cancer site (CENTRAL- core) WOMEN																									
Carcinogen	Bladder	Bone	Brain	Breast	Cervix	CNS	Colon & rectum	Eye	Kidney	Larynx	Leukaemia	Liver & bile duct	Lung	Lymphoma	Lymphoma and leukaemia	Malignant melanoma	Mesothelium	NHL	NMSC	Oesophagus	Ovary	Pancreas	Pharynx incl. NFC	Sinonasal (SNC)	Stomach	Thyroid
Mineral oils	0.7 %												0.9%						0.2 %							
Cd and Cd compounds									0.2 %				0.1%													
Wood dust																							1%	0.4 %		
Arsenic													0.04%													
Vinyl chloride												0.02%						0.05 %								
Ethylene oxide											0.1%			0.01%												
PAHs	0.1 %								0.1 %				0.03%		0.3 %		0.3 %		0.2 %			0.3 %			0.2%	
Occupation as a welder								0.3 %					0.1%													
Solar radiation																			3.4 %							
ETS													3.2%													
Epichlorohydrine						0.1 %							0.02%													
Tetrachloroethylene	0.3 %				0.05 %													0.3%		1.1 %		0.2 %				
Shift work				9.3 %																						
Dioxins													1.0%													
Inorganic acid mists										2.1%			0.2%													
Rubber manufacturing	0.1 %									0.006 %	0.01 %		0.1%	0.0004 %											0.02 %	
Ionising radiation	0%	0.01 %	0.3 %	0.1 %							0.03 %	0.005 %	0.003 %			0.6 %										0.04 %
Cr(VI) compounds													0.05%											0.4 %		
Aromatic amines	0.1 %																									
Cytostatic drugs				0.5 %							5.1%															
OvAF	***1.5 %***	***0.01 %***	***1.3 %***	***9.8 %***	***0.05 %***	***0.1 %***	***0.02 %***	***0.3 %***	***0.2 %***	***2.4%***	***5.7%***	***0.03%***	***16.6%***	***0.01%***	***0.3 %***	***0.6 %***	***95 %***	***0.3%***	***3.8 %***	***1.1 %***	***0.1 %***	***0.5 %***	***3%***	***3.8 %***	***0.3%***	***0.04 %***

Table 7-3: AFs per cancer site (CENTRAL- high) WOMEN																									
Carcinogen	Bladder	Bone	Brain	Breast	Cervix	CNS	Colon & rectum	Eye	Kidney	Larynx	Leukaemia	Liver & bile duct	Lung	Lymphoma	Lymphoma and leukaemia	Malignant melanoma	Mesothelium	NHL	NMSC	Oesophagus	Ovary	Pancreas	Pharynx incl. NFC	Sinonasal (SNC)	Stomach	Thyroid
Diesel exhaust	0.3 %												0.4%													
Silica										0.5%			0.4%													
Asbestos							0.05 %			0.04 %			10.9%				95%				0.2 %		0.5 %		0.04 %	
Formaldehyde			0.9 %								0.5%		0.3%										5.2 %	5.3 %		
Benzene											0.1%															
Mineral oils	1.4 %												2.1%						1.9 %							
Cd and Cd compounds									0.2 %				0.03%													
Wood dust																							2.4 %	1%		
Arsenic													0.1%													
Vinyl chloride												0.03%						0.1 %								
Ethylene oxide											0.2%			0.05%												
PAHs	0.1 %								0.1 %				0.03%		1 %		1.2%		0.4 %			1%			0.6%	
Occupation as a welder								0.7 %					0.3%													
Solar radiation																			5.3 %							
ETS													3.8%													
Epichlorohydrine						0.6 %							0.04%													
Tetrachloroethylene	0.7 %				0.3 %													1.4 %		2.3 %		0.7 %				
Shift work				12%																						
Dioxins													1%													
Inorganic acid mists										4.7%			0.6%													

Table 7-3: AFs per cancer site (CENTRAL- high) WOMEN																									
Carcinogen	Bladder	Bone	Brain	Breast	Cervix	CNS	Colon & rectum	Eye	Kidney	Larynx	Leukaemia	Liver & bile duct	Lung	Lymphoma	Lymphoma and leukaemia	Malignant melanoma	Mesothelium	NHL	NMSC	Oesophagus	Ovary	Pancreas	Pharynx incl. NFC	Sinonasal (SNC)	Stomach	Thyroid
Rubber manufacturing	0.1 %									0.02 %	0.02 %		0.3%	0.004 %											0.1%	
Ionising radiation	0%	0.01 %	1.3 %	0.1 %							0.05 %	0.005 %	0.003 %			0.9 %										0.04 %
Cr(VI) compounds													0.1%											1.7 %		
Aromatic amines	0.2 %																									
Cytostatic drugs				3.4 %							17.4 %															
OvAF	***2.7 %***	***0.01 %***	***2.2 %***	***15%***	***0.3 %***	***0.6 %***	***0.05 %***	***0.7 %***	***0.3 %***	***5.3%***	***18.1 %***	***0.04%***	***19.3%***	***0.1%***	***1 %***	***0.9 %***	***95.1 %***	***1.5 %***	***7.5 %***	***2.3 %***	***0.2 %***	***1.8 %***	***8%***	***7.8 %***	***0.6%***	***0.04 %***

7.2 Central scenarios - men

Table 7-4: AFs per cancer site (CENTRAL-low SCENARIO) MEN																									
Carcinogen	Bladder	Bone	Brain	Breast	Cervix	CNS	Colon & rectum	Eye	Kidney	Larynx	Leukaemia	Liver & bile duct	Lung	Lymphoma	Lymphoma and leukaemia	Malignant melanoma	Mesothelium	NHL	NMSC	Oesophagus	Ovary	Pancreas	Pharynx incl. NFC	Sinonasal (SNC)	Stomach	Thyroid
Diesel exhaust	0.1 %												3.6%													
Silica										1.5 %			1.4%													
Asbestos							0.03 %			0.6 %			26.6 %				95%				0%		0.3 %		0.1 %	
Formaldehyde			0.8 %								0.4%		0.2%										0.1 %	1.1 %		
Benzene											0.2%															
Mineral oils	2.1 %												2.1%						0%							
Cd and Cd compounds									0%				0%													
Wood dust																							0.8 %	0.8 %		

Table 7-4: AFs per cancer site (CENTRAL-low SCENARIO) MEN																									
Carcinogen	Bladder	Bone	Brain	Breast	Cervix	CNS	Colon & rectum	Eye	Kidney	Larynx	Leukaemia	Liver & bile duct	Lung	Lymphoma	Lymphoma and leukaemia	Malignant melanoma	Mesothelium	NHL	NMSC	Oesophagus	Ovary	Pancreas	Pharynx incl. NFC	Sinonasal (SNC)	Stomach	Thyroid
Arsenic													0.02 %													
Vinyl chloride												0.1%						0.1 %								
Ethylene oxide											0%			0%												
PAHs	0.7 %								0.3 %				0.2%		0.1 %		0%		0.1 %			0.2 %			0.2 %	
Occupation as a welder								1.6 %					0%													
Solar radiation																			7.7 %							
ETS													1.4%													
Epichlorohydrine						0%							0%													
Tetrachloroethylene	0.1 %				0%													0%		0.5 %		0%				
Shift work				0%																						
Dioxins													1.3%													
Inorganic acid mists										0.7 %			0%													
Rubber manufacturing	0.6 %									0%	0%		0%	0%											0.1 %	
Ionising radiation	0%	0.01 %	0%	0%							0.01 %	0.005 %	0.04 %			0.3 %										0.04 %
Cr(VI) compounds													0%											0%		
Aromatic amines	0.1 %																									
Cytostatic drugs				0%							0.03 %															
OvAF	***3.6 %***	***0.01 %***	***0.8 %***	***0 %***	***0 %***	***0%***	***0.03 %***	***1.6 %***	***0.3 %***	***2.8 %***	***0.6%***	***0.1%***	***33.7 %***	***0%***	***0.1 %***	***0.3 %***	***95.0 %***	***0.1 %***	***7.8 %***	***0.5 %***	***0%***	***0.2 %***	***1.2 %***	***1.9 %***	***0.5 %***	***0.04 %***

Table 7-5: AFs per cancer site (CENTRAL-core SCENARIO) MEN																									
Carcinogen	Bladder	Bone	Brain	Breast	Cervix	CNS	Colon & rectum	Eye	Kidney	Larynx	Leukaemia	Liver & bile duct	Lung	Lymphoma	Lymphoma and leukaemia	Malignant melanoma	Mesothelium	NHL	NMSC	Oesophagus	Ovary	Pancreas	Pharynx incl. NFC	Sinonasal (SNC)	Stomach	Thyroid
Diesel exhaust	3%												5.7%													
Silica										3.7 %			3%													
Asbestos							0.5 %			1.2 %			26.6 %				95%				0 %		3.9%		0.5 %	
Formaldehyde			0.8 %								0.4%		0.3%										1.5%	2.5%		
Benzene											0.6%															
Mineral oils	12.9 %												16%						4.3%							
Cd and Cd compounds									0.9 %				0.3%													
Wood dust																							10.4 %	4.8%		
Arsenic													0.3%													
Vinyl chloride												0.1%						0.3 %								
Ethylene oxide											0.05 %			0.01 %												
PAHs	0.7%								0.3 %				0.2%		2%		2%		1.1%			2%			1.4 %	
Occupation as a welder								8 %					2.9%													
Solar radiation																			13.9 %							
ETS													1.8%													
Epichlorohydrine						0.2 %							0.1%													
Tetrachloroethylene	0.6%				0 %													0.5 %		1.9 %		0.4 %				
Shift work				0 %																						
Dioxins													1.3%													
Inorganic acid mists										2.1 %			0.2%													
Rubber manufacturing	1%									0.1 %	0.2%		0.7%	0.01 %											0.4 %	

Table 7-5: AFs per cancer site (CENTRAL-core SCENARIO) MEN																									
Carcinogen	Bladder	Bone	Brain	Breast	Cervix	CNS	Colon & rectum	Eye	Kidney	Larynx	Leukaemia	Liver & bile duct	Lung	Lymphoma	Lymphoma and leukaemia	Malignant melanoma	Mesothelium	NHL	NMSC	Oesophagus	Ovary	Pancreas	Pharynx incl. NFC	Sinonasal (SNC)	Stomach	Thyroid
Ionising radiation	0%	0.01 %	0.3 %	0 %							0.03 %	0.005 %	0.04 %			0.6 %										0.04 %
Cr(VI) compounds													0.4%											3.3%		
Aromatic amines	0.1%																									
Cytostatic drugs				0 %							1%															
OvAF	***17.6 %***	***0.01 %***	***1.1 %***	***0 %***	***0 %***	***0.2 %***	***0.5 %***	***8 %***	***1.2 %***	***6.9 %***	***2.2%***	***0.1%***	***48.2 %***	***0.02 %***	***2.0 %***	***0.6 %***	***95.1 %***	***0.8 %***	***18.4 %***	***1.9 %***	***0 %***	***2.4 %***	***15.2 %***	***10.3 %***	***2.3 %***	***0.04 %***

Table 7-6: AFs per cancer site (CENTRAL-high SCENARIO) MEN																									
Carcinogen	Bladder	Bone	Brain	Breast	Cervix	CNS	Colon & rectum	Eye	Kidney	Larynx	Leukaemia	Liver & bile duct	Lung	Lymphoma	Lymphoma and leukaemia	Malignant melanoma	Mesothelium	NHL	NMSC	Oesophagus	Ovary	Pancreas	Pharynx incl. NFC	Sinonasal (SNC)	Stomach	Thyroid
Diesel exhaust	5%												7.9%													
Silica										6.5%			4.9%													
Asbestos							1 %			2%			26.6 %				95%				0 %		10.5 %		0.9 %	
Formaldehyde			0.8 %								0.4 %		0.3%										4.4%	4.5%		
Benzene											1.3 %															
Mineral oils	24.1 %												32.8 %						30.4 %							
Cd and Cd compounds									1.1 %				0.2%													
Wood dust																							22.6 %	10.2 %		
Arsenic													0.8%													
Vinyl chloride												0.2%						0.8 %								

Table 7-6: AFs per cancer site (CENTRAL-high SCENARIO) MEN																										
Carcinogen	Bladder	Bone	Brain	Breast	Cervix	CNS	Colon & rectum	Eye	Kidney	Larynx	Leukaemia	Liver & bile duct	Lung	Lymphoma	Lymphoma and leukaemia	Malignant melanoma	Mesothelium	NHL	NMSC	Oesophagus	Ovary	Pancreas	Pharynx incl. NFC	Sinonasal (SNC)	Stomach	Thyroid
Ethylene oxide											0.2 %			0.04 %												
PAHs	0.7%								0.3 %				0.2%		5.5 %		6.5%		2.4%			5.8 %			3.2 %	
Occupation as a welder								17.2 %					6.6%													
Solar radiation																			20.4 %							
ETS													2.2%													
Epichlorohydrine						1.9 %							0.1%													
Tetrachloroethylene	1.2%				0 %													2.4 %		4 %		1.3 %				
Shift work				0 %																						
Dioxins													1.3%													
Inorganic acid mists										4.7%			0.6%													
Rubber manufacturing	1.6%									0.3%	0.4 %		2.1%	0.1%											0.9 %	
Ionising radiation	0%	0.01 %	1.3 %	0 %							0%	0.005 %	0.04 %			0.9 %										0.04 %
Cr(VI) compounds													0.9%											12.3 %		
Aromatic amines	0.2%																									
Cytostatic drugs				0 %							3.6 %															
OvAF	***30.5 %***	***0.01 %***	***2.1 %***	***0 %***	***0 %***	***1.9 %***	***1 %***	***17.2 %***	***1.4 %***	***12.9 %***	***5.8 %***	***0.2%***	***63%***	***0.1%***	***5.5 %***	***0.9 %***	***95.3 %***	***3.1 %***	***45.9 %***	***4 %***	***0 %***	***7.1 %***	***33.7 %***	***24.8 %***	***5%***	***0.04 %***

7.3 Mid-point, low and high scenarios (both genders)

Table 7-7: AFs per cancer site (MIDPOINT SCENARIO) EU28

Carcinogen	Bladder	Bone	Brain	Breast	Cervix	CNS	Colon & rectum	Eye	Kidney	Larynx	Leukaemia	Liver & bile duct	Lung	Lymphoma	Lymphoma and leukaemia	Malignant melanoma	Mesothelium	NHL	NMSC	Oesophagus	Ovary	Pancreas	Pharynx incl. NFC	Sinonasal (SNC)	Stomach	Thyroid
Diesel exhaust	1.5 %												9.8%													
Silica										2%			4%													
Asbestos							3.8 %			3.4 %			20% (39.1%)				95%				0.5 %		5.2 %		11.3 %	
Formaldehyde			0.5 %								0.3%		0.2%										1%	1.7%		
Benzene											0.9%															
Mineral oils	5.9 %												5.2%						0.8 %							
Cd and Cd compounds									0.3 %				0.1%													
Wood dust																							2.9 %	10.5 %		
Arsenic													0.5%													
Vinyl chloride												0.3 %						0.1 %								
Ethylene oxide											0.01 %			0.01%												
PAHs	0.4 %								0.6 %				0.3%		0.7 %		0.9 %		0.5 %			0.9 %			0.6%	
Occupation as a welder								3.3 %					0.7%													
Solar radiation																			4.9 %							
ETS													4.4%													
Epichlorohydrine						0.1 %							0.02%													
Tetrachloroethylene	0.2 %				0.2 %													0.1 %		0.5 %		0.1 %				
Shift work				17.6 %																						
Dioxins													0.6%													

Table 7-7: AFs per cancer site (MIDPOINT SCENARIO) EU28																									
Carcinogen	Bladder	Bone	Brain	Breast	Cervix	CNS	Colon & rectum	Eye	Kidney	Larynx	Leukaemia	Liver & bile duct	Lung	Lymphoma	Lymphoma and leukaemia	Malignant melanoma	Mesothelium	NHL	NMSC	Oesophagus	Ovary	Pancreas	Pharynx incl. NFC	Sinonasal (SNC)	Stomach	Thyroid
Inorganic acid mists										2.1 %			0.2%													
Rubber manufacturing	1.1 %									0.1 %	0.1%		0.4%	0.004 %											0.4%	
Ionising radiation	0%	1.9 %	0.6 %	0.1%							0.4%	0.3 %	0.7%			0.6 %										0.6 %
Cr(VI) compounds													0.2%											2.8%		
Aromatic amines	0.7 %																									
Cytostatic drugs				0.9%							5.8%															
OvAF	***9.3 %***	***1.9 %***	***1.1 %***	***18.5 %***	***0.2 %***	***0.1 %***	***3.8 %***	***3.3 %***	***0.9 %***	***7.3 %***	***7.4%***	***0.6 %***	***39.6% (54.1%)***	***0.01%***	***0.7 %***	***0.6 %***	***95%***	***0.2 %***	***6.1 %***	***0.5 %***	***0.5 %***	***1%***	***8.9 %***	***14.5 %***	***12.1 %***	***0.6 %***

Table 7-8: AFs per cancer site (LOW SCENARIO) EU28																									
Carcinogen	Bladder	Bone	Brain	Breast	Cervix	CNS	Colon & rectum	Eye	Kidney	Larynx	Leukaemia	Liver & bile duct	Lung	Lymphoma	Lymphoma and leukaemia	Malignant melanoma	Mesothelium	NHL	NMSC	Oesophagus	Ovary	Pancreas	Pharynx incl. NFC	Sinonasal (SNC)	Stomach	Thyroid
Diesel exhaust	1.2%												0.7%													
Silica										0.8%			0%													
Asbestos							0.03 %			0%			6.7% (13%)				95%				0 %		0.1 %		0.02 %	
Formaldehyde			0%								0%		0%										0%	0%		
Benzene											0.0005 %															
Mineral oils	0%												0%						0%							
Cd and Cd compounds									0.1%				0.01%													
Wood dust																							2.1 %	1.2 %		

Table 7-8: AFs per cancer site (LOW SCENARIO) EU28																									
Carcinogen	Bladder	Bone	Brain	Breast	Cervix	CNS	Colon & rectum	Eye	Kidney	Larynx	Leukaemia	Liver & bile duct	Lung	Lymphoma	Lymphoma and leukaemia	Malignant melanoma	Mesothelium	NHL	NMSC	Oesophagus	Ovary	Pancreas	Pharynx incl. NFC	Sinonasal (SNC)	Stomach	Thyroid
Arsenic													0.1%													
Vinyl chloride												0.01 %						0.01 %								
Ethylene oxide											0.0002 %			0.001 %												
PAHs	0%								0.0035 6%				0%		0.01 %		0.01 %		0.003 %			0.01 %			0.003 %	
Occupation as a welder								0.4 %					0.03%													
Solar radiation																			1.4%							
ETS													0.3%													
Epichlorohydrine						0 %							0%													
Tetrachloroethylene	0.04 %				0.01 %													0.03 %		0.1 %		0.03 %				
Shift work				0%																						
Dioxins													0.01%													
Inorganic acid mists										1.4%			0.2%													
Rubber manufacturing	0.01 %									0.01 %	0.003 %		0.04%	0.002 %											0%	
Ionising radiation	0%	0.004 %	0.1 %	0.02 %							0%	0%	0%			0.1 %										0.1 %
Cr(VI) compounds													0%											1.1 %		
Aromatic amines	0%																									
Cytostatic drugs				0.5%							2.8%															
OvAF	***1.2 %***	***0.004 %***	***0.1 %***	***0.5 %***	***0.01 %***	***0 %***	***0.03 %***	***0.4 %***	***0.1%***	***2.2 %***	***2.8%***	***0.01 %***	***7.9% (14.2 %)***	***0.002 %***	***0.01 %***	***0.1 %***	***95%***	***0.04 %***	***1.4%***	***0.1 %***	***0 %***	***0.03 %***	***2.2 %***	***2.3 %***	***0.02 %***	***0.1 %***

Table 7-9: AFs per cancer site (HIGH SCENARIO) EU28																									
Carcinogen	Bladder	Bone	Brain	Breast	Cervix	CNS	Colon & rectum	Eye	Kidney	Larynx	Leukaemia	Liver & bile duct	Lung	Lymphoma	Lymphoma and leukaemia	Malignant melanoma	Mesothelium	NHL	NMSC	Oesophagus	Ovary	Pancreas	Pharynx incl. NFC	Sinonasal (SNC)	Stomach	Thyroid
Diesel exhaust	2.1%												16.4%													
Silica										3.1 %			10.2%													
Asbestos							11.8 %			12%			33.3% (65.2%)				95%				1.8 %		13.9 %		32.5 %	
Formaldehyde			2.2 %								0.9 %		0.7%										4.3%	6.8%		
Benzene											5.5 %															
Mineral oils	15.4 %												12.9%						2.3%							
Cd and Cd compounds									0.7 %				0.2%													
Wood dust																							7.3%	21.7 %		
Arsenic													1%													
Vinyl chloride												0.9 %						0.2 %								
Ethylene oxide											0.1 %			0.01 %												
PAHs	1.4%								1.3 %				1.3%		1 %		1.8%		1%			1.8 %			1.2%	
Occupation as a welder								6.6 %					2.4%													
Solar radiation																			9%							
ETS													9.8%													
Epichlorohydrine						0.2 %							0.04%													
Tetrachloroethylene	0.3%				0.4 %													0.2 %		0.9 %		0.2 %				
Shift work				39.8 %																						
Dioxins													2.3%													
Inorganic acid mists										2.5 %			0.3%													
Rubber manufacturing	3.8%									0.1 %	0.2 %		1.3%	0.01 %											1.4%	

Table 7-9: AFs per cancer site (HIGH SCENARIO) EU28																										
Carcinogen	Bladder	Bone	Brain	Breast	Cervix	CNS	Colon & rectum	Eye	Kidney	Larynx	Leukaemia	Liver & bile duct	Lung	Lymphoma	Lymphoma and leukaemia	Malignant melanoma	Mesothelium	NHL	NMSC	Oesophagus	Ovary	Pancreas	Pharynx incl. NFC	Sinonasal (SNC)	Stomach	Thyroid
Ionising radiation	0%	6.1 %	1.3 %	0.2%							1.5 %	1.5 %	1.5%			1.5 %										2.1 %
Cr(VI) compounds													0.7%											6.6%		
Aromatic amines	2%																									
Cytostatic drugs				1.9%							9.8 %															
OvAF	***23.3 %***	***6.1 %***	***3.5 %***	***41.1 %***	***0.4 %***	***0.2 %***	***11.8 %***	***6.6 %***	***1.9 %***	***17%***	***17%***	***2.4 %***	***65% (81.7 %)***	***0.02 %***	***1 %***	***1.5 %***	***95.1 %***	***0.4 %***	***11.9 %***	***0.9 %***	***1.8 %***	***2%***	***23.6 %***	***31.9 %***	***34.3 %***	***2.1 %***

8 Annex 5: Additional information

8.1 Prioritisation of 25 carcinogens – scoring system

The results of the different studies are combined by means of a scoring system that assigns a weight to each study based on the following attributes:

a) Risk and number of workers exposed
b) Age of the underlying data
c) Specificity
d) Geographic scope
e) Scope in terms of the breadth of carcinogenic agents

The scores (max: 5, min: 0) are summarised in the table below.

Table 8-1: Weights for scoring

Attribute	Rushton et al (2010)	CAREX (2010)	RIVM(2015)	SUMER	Wriedt (2015)
Risk based	5	2	2	2	3
Age of data	2	1	5	4	5
Specificity	3	1	3	2	2
Geographic scope	1	3	3	1	3
Breadth of agents	5	1	1	1	1
Total	***16***	***8***	***14***	***10***	***14***

The weighted scores for the relevant chemical carcinogens are set out below.

Table 8-2: Carcinogen weighted scores

Carcinogenic agent	Score
Diesel exhaust	44
Silica	41
Asbestos	37
Formaldehyde	36
Benzene	35
Mineral oils	31
Cadmium and cadmium compounds	30
Wood dust	28
Arsenic	27
1,3-Butadiene	27
Vinyl chloride	27
Ethylene oxide	27
Acrylamide	27
PAHs (from coal tars and pitches)	26
Occupation as a welder	26
Solar radiation	24
Environmental tobacco smoke (ETS)	24
Occupation as a painter	23
Epichlorohydrine	22
Radon	19

Table 8-2: Carcinogen weighted scores	
Carcinogenic agent	**Score**
Tetrachloroethylene	19
Shift work	16
Dioxins	16
Inorganic acid mists containing sulphuric acid	16
Rubber manufacturing industry	15
Petroleum refining	15
Isopropyl alcohol manufacture	10
Note: Scoring based on the following system: maximum score awarded when the carcinogen is among the top 10 in that study, for ranks between 10 and 20, two-thirds of the maximum score has been given, for carcinogens that received rankings above 20 or were simply deemed relevant, one-third of the maximum score has been given.	

8.2 Gender relevance – overview of literature

The available literature shows that the 15 carcinogens in the table above are relevant to both men and women, with two being predominantly relevant to men (silica and PAHs) and one being predominantly relevant to women (breast cancer and shift/night work). It is also of note that the table above covers the key carcinogens of relevance to women in terms of the number of female workers exposed. In the CAREX database, the most important carcinogens, in terms of the number of women workers exposed, were diesel engine exhaust, solar radiation and environmental tobacco smoke (EU-OSHA, 2014).

It has also been argued that female workers may be more exposed than male workers by factors such as formaldehyde, cytostatic drugs, biocides, hair dyes and some biological agents, with these exposures being particularly relevant to service workers and professions where the majority of workers are women (e.g. healthcare, cleaning, hairdressing and the textile industry) (EU-OSHA, 2014). Exposures to biological agents in the food processing industry or in waste management and recycling also severely impact female workers, but there is very little data on patterns and levels of exposure.

17 studies have been identified that assessed cancer with specific focus on women. The relevant carcinogens, occupations and sectors are summarised below.

Table 8-3: The most significant occupational carcinogens - women		
Carcinogenic agent	**Sector/use/profession**	**Studies**
Shift work	Hospitality, flight attendants, nurses	Åkerstedt T et al (2015) Hansen J & Lassen CF (2012) Hansen & Stevens (2012) Menegaux F et al (2012) Davis & Mirick (2006) Straif K et al (2007)
	Nurses	Kjaer TK and Hansen J (2009)
Cosmic radiation	Aviation/airline crew	Buja et al (2006) Koja K et al (2013)
Second hand tobacco smoke	Hospitality	Malhotra J et al (2015)
Ionising radiation	Electricity generation/transmission	Sarahan T (2012)
	Offshore workers	Stenehjem JS et al (2014)
Asbestos		Boffetta P et al (2010)

Table 8-3: The most significant occupational carcinogens - women		
Carcinogenic agent	**Sector/use/profession**	**Studies**
		Lacourt A et al (2014)
PAHs		Boffetta P et al (2010)
Chromium VI		
	Pulp and paper production	Andersson E et al (2013)
Softwood dust		Smailtye G (2012)
	Electroplating	Panizza C (2011)
	Agriculture	Heck JE (2009)
Alcohols, Ketones, Esters and Glycol ethers		Lindbohm ML et al (2009)

Sources:

Åkerstedt T et al (2015): Night work and breast cancer in women: a Swedish cohort study. BMJ Open, 5, ee008127, available at http://bmjopen.bmj.com/content/5/4/e008127.info

Andersson E et al (2013): Cancer incidence among Swedish pulp and paper mill workers: a cohort study of sulphate and sulphite mills. International Archives of Occupational and Environmental Health, 86(5), pp 529-540, available at http://link.springer.com/article/10.1007%2Fs00420-012-0785-1

Boffetta P et al (2010): An estimate of cancers attributable to occupational exposures in France. J Occup Environ Med., 52(4), pp 399-406, available at https://www.ncbi.nlm.nih.gov/pubmed/20357680

Buja A et al (2006): Cancer Incidence among Female Flight Attendants: A Meta-Analysis of Published Data. Journal of Women's Health, 15(1), pp 98-105, available at http://online.liebertpub.com/doi/abs/10.1089/jwh.2006.15.98

Davis S and Mirick DK (2006): Circadian disruption, shift work and the risk of cancer: a summary of the evidence and studies in Seattle. Cancer Courses Control, 17(4), pp 539-545, available at https://www.ncbi.nlm.nih.gov/pubmed/16596308

Hansen C and Lassen CF (2012): Nested case-control study of night shift work and breast cancer risk among women in the Danish military. Occup Environ Med, 69(8), 551-556, available at http://oem.bmj.com/content/69/8/551

Hansen J and Stevens RG (2012): Case-control study of shift-work and breast cancer risk in Danish nurses: impact of shift systems. Eur J Cancer, 48(11), pp 1722-1729, available at https://www.ncbi.nlm.nih.gov/pubmed/21852111

Heck JE (2009): Occupation and renal cell cancer in Central and Eastern Europe. Occup Environ Med., 67(1), pp 47-53, available at https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2879053/

Kjaer TK and Hansen J (2009): Cancer incidence among large cohort of female Danish registered nurses. Scand J Work Environ Health, 35(6), pp 446-453, available at http://www.sjweh.fi/show_abstract.php?abstract_id=1358

Koja K et al (2013): Risk Factors for Skin cancer among Finnish Airline Crew. Ann Occup Hyg, 57(6), pp 695-704, available at https://academic.oup.com/annweh/article/57/6/695/148797/Risk-Factors-for-Skin-Cancer-among-Finnish-Airline

Lacourt A et al (2014): Occupational and non-occupational attributable risk of asbestos exposure for malignant pleural mesothelioma. Thorax, 69, pp 532-539, available at http://thorax.bmj.com/content/69/6/532.info

Lindbohm ML et al (2009): Risk of liver cancer and exposure to organic solvents and gasoline vapors among Finnish workers. International Journal of Cancer, 124(12), pp 2954-2959, available at http://onlinelibrary.wiley.com/doi/10.1002/ijc.24309/abstract

Malhorta J et al (2015): Risk factors for lung cancer worldwide. Eur Respir J., 48(3), pp 899-902, available at https://www.ncbi.nlm.nih.gov/pubmed/27174888

Menegaux F et al (2012): Night work and breast cancer: A population based case-control study in France (the CECILE study). International Journal of Cancer, 132(4), pp 924-931, available at http://onlinelibrary.wiley.com/doi/10.1002/ijc.27669/abstract

Panizza C (2011): Lung cancer risk in the electroplating industry in Lombardy, Italy, using the Italian occupational cancer monitoring (OCCAM) information system. American Journal of Industrial Medicine, 55(1), pp 1-4, available at http://onlinelibrary.wiley.com/doi/10.1002/ajim.21004/abstract

Sarahan T (2012): Cancer incidence in UK electricity generation and transmission workers, 1973-2008. Occup Med (Lond), 62(7), pp 496-505, available at

Table 8-3: The most significant occupational carcinogens - women		
Carcinogenic agent	**Sector/use/profession**	**Studies**
https://academic.oup.com/occmed/article/62/7/496/1536629/Cancer-incidence-in-UK-electricity-generation-and Smailtye G (2012): Cancer incidence among workers exposed to softwood dust in Lithuania. Occup Environ Med., 69(6), pp 449-451, available at https://www.ncbi.nlm.nih.gov/pubmed/22241843 Stenehjem JS et al (2014): Cancer incidence among 41,000 offshore oil industry workers. Occup Med (Lond), 64 (7), pp 539-545, available at https://academic.oup.com/occmed/article/64/7/539/2750752/Cancer-incidence-among-41-000-offshore-oil Straif K et al (2007): Carcinogenicity of shift-work, painting, and fire-fighting. Lancet Oncology, 8(12), pp 1065-1066, available at http://www.thelancet.com/journals/lanonc/article/PIIS1470-2045(07)70373-X/abstract		

SUMER (2010) also assessed occupational exposure to hazardous chemical agents in France separately for men and women. Carcinogens among the top 25 chemical risks to female employees are given in the table below.

Table 8-4: Carcinogens among the top 25 occupational chemical risks for women in France	
Carcinogen	**Number of exposed employees**
Ethanol	636,600
Other alcohols	398,600
Mineral acids excluding hydrocyanic acid, hydrofluoric acid and chromic acid	177,300
Organic acids	167,900
Other amines and derivatives	111,900
Formaldehyde	73,300
Bromine, chlorine, iodine, fluorine	59,500
Other fuels	50,500
Diesel exhaust	43,600
Other exhaust fumes	41,000
Source: SUMER (2010)	

In addition, the most significant carcinogens in Rushton et al (2010) are relevant to both men and women, as summarised in the table below.

Table 8-5: The most significant occupational carcinogens - UK		
Carcinogen	**Men/women***	**Notes**
Asbestos	Men & women	
Shift work	Women	Key occupational carcinogen for women
Mineral oils	Men & women	Primarily metal workers (15% of attributable registrations are women)
Solar radiation	Men & women	
Silica	Men	
Diesel exhaust	Men & women	
PAHs (from coal tars and pitches)	Men	
Occupation as a painter	Men & women	
Dioxins	Men & women	
Environmental tobacco smoke (ETS)	Men & women	60% of cancer registrations in the 'wholesale and retail trade and restaurants and hotels sector' are women

Table 8-5: The most significant occupational carcinogens - UK		
Carcinogen	**Men/women***	**Notes**
Radon	Men & women	
Welders	Men & women	
Tetrachloroethylene	Men & women	
Arsenic	Men & women	
Inorganic acid mists containing sulphuric acid	Men & women	
Source: Rushton et al (2010) [215], *based on Rushton and initial literature review of 80 studies		

8.3 Share of men/women in exposed workforce in ASA and SUMER

Table 8-6: Exposed population: MEN and WOMEN								
Carcinogen	**Study**	**Country and Year**	**No. of exposed workers (MEN)**	**% of exposed workers**	**% of workforce**	**No. of exposed workers (WOMEN)**	**% of exposed workers**	**% of workforce**
01 DEE	SUMER	France; 1994	NA	NA	NA	NA	NA	NA
		France; 2003	699,300	96.1%	4.2%	28,200	3.9%	0.4%
		France; 2010	754,300	94.5%	6.4%	43,600	5.5%	0.4%
	ASA	Finland; 2005	NA	NA	NA	NA	NA	NA
		Finland; 2011	NA	NA	NA	NA	NA	NA
		Finland; 2014	NA	NA	NA	NA	NA	NA
02 Silica	SUMER	France; 1994	85,000	88.5%	1.2%	11,000	11.5%	0.2%
		France; 2003	254,100	94.5%	2.5%	14,900	5.5%	0.2%
		France; 2010	279,200	94.7%	2.4%	15,600	5.3%	0.2%
	ASA	Finland; 2005	NA	NA	NA	NA	NA	NA
		Finland; 2011	NA	NA	NA	NA	NA	NA
		Finland; 2014	NA	NA	NA	NA	NA	NA
03 Asbestos	SUMER	France; 1994	91,000	98.9%	1.3%	1,000	1.1%	NA
		France; 2003	104,400	97.9%	1.0%	2,200	2.1%	<0.1%
		France; 2010	75,700	93.0%	0.6%	5,700	7.0%	0.1%
	ASA	Finland; 2005	1,805	96.7%	NA	62	3.3%	NA

[215] Rushton et al. (2010): Occupation and cancer in Britain, available at: http://www.ncbi.nlm.nih.gov/pubmed/20424618

Table 8-6: Exposed population: MEN and WOMEN								
Carcinogen	Study	Country and Year	No. of exposed workers (MEN)	% of exposed workers	% of workforce	No. of exposed workers (WOMEN)	% of exposed workers	% of workforce
		Finland; 2011	900	93.8%	NA	59	6.2%	NA
		Finland; 2014	1,234	94.8%	NA	68	5.2%	NA
04 Formaldehyde	SUMER	France; 1994	NA	NA	NA	NA	NA	NA
		France; 2003	66,800	43.5%	0.7%	86,800	56.5%	1.2%
		France; 2010	66,100	47.4%	0.6%	73,300	52.6%	0.7%
	ASA	Finland; 2005	NA	NA	NA	NA	NA	NA
		Finland; 2011	NA	NA	NA	NA	NA	NA
		Finland; 2014	NA	NA	NA	NA	NA	NA
05 Benzene	SUMER	France; 1994	61,000	92.4%	0.9%	5,000	7.6%	NA
		France; 2003	43,400	91.6%	0.4%	4,000	8.4%	<0.1%
		France; 2010	28,800	78.0%	0.2%	8,100	22.0%	0.1%
	ASA	Finland; 2005	1,374	91.4%	NA	129	8.6%	NA
		Finland; 2011	1,573	93.6%	NA	107	6.4%	NA
		Finland; 2014	1,935	94.7%	NA	108	5.3%	NA
06 Mineral oils	SUMER	France; 1994	490,000	93.9%	6.9%	32,000	6.1%	0.7%
		France; 2003	639,700	95.6%	6.4%	29,400	4.4%	0.4%
		France; 2010	525,000	97.7%	4.4%	12,500	2.3%	0.1%
	ASA	Finland; 2005	NA	NA	NA	NA	NA	NA
		Finland; 2011	NA	NA	NA	NA	NA	NA
		Finland; 2014	NA	NA	NA	NA	NA	NA
07 Cd and Cd compounds	SUMER	France; 1994	8,000	80.0%	0.1%	2,000	20.0%	NA
		France; 2003	21,200	76.5%	0.2%	6,500	23.5%	NA
		France; 2010	37,500	93.7%	0.3%	2,500	6.3%	0.1%
	ASA	Finland; 2005	964	81.6%	NA	217	18.4%	NA
		Finland	798	82.5%	NA	169	17.5%	NA

Table 8-6: Exposed population: MEN and WOMEN								
Carcinogen	Study	Country and Year	No. of exposed workers (MEN)	% of exposed workers	% of workforce	No. of exposed workers (WOMEN)	% of exposed workers	% of workforce
		; 2011						
		Finland ; 2014	1,375	88.7%	NA	175	11.3%	NA
08 Wood dust	SUMER	France; 1994	177,000	95.7%	2.5%	8,000	4.3%	0.2%
		France; 2003	357,500	94.1%	3.6%	22,400	5.9%	0.3%
		France; 2010	351,000	95.1%	3.0%	18,100	4.9%	0.2%
	ASA	Finland ; 2005	957	86.8%	NA	146	13.2%	NA
		Finland ; 2011	465	89.3%	NA	56	10.7%	NA
		Finland ; 2014	661	91.7%	NA	60	8.3%	NA
09 Arsenic	SUMER	France; 1994	NA	NA	NA	NA	NA	NA
		France; 2003	NA	NA	NA	NA	NA	NA
		France; 2010	NA	NA	NA	NA	NA	NA
	ASA	Finland ; 2005	1,070	86.2%	NA	171	13.8%	NA
		Finland ; 2011	1,826	87.5%	NA	262	12.5%	NA
		Finland ; 2014	2,210	89.4%	NA	262	10.6%	NA
10 Vinyl chloride	SUMER	France; 1994	8,000	80.0%	0.1%	2,000	20.0%	NA
		France; 2003	NA	NA	NA	NA	NA	NA
		France; 2010	NA	NA	NA	NA	NA	NA
	ASA	Finland ; 2005	90	83.3%	NA	18	16.7%	NA
		Finland ; 2011	42	91.3%	NA	4	8.7%	NA
		Finland ; 2014	33	80.5%	NA	8	19.5%	NA
11 Ethylene oxide	SUMER	France; 1994	NA	NA	NA	NA	NA	NA
		France; 2003	NA	NA	NA	NA	NA	NA
		France; 2010	NA	NA	NA	NA	NA	NA
	ASA	Finland ; 2005	133	50.8%	NA	129	49.2%	NA
		Finland ; 2011	13	24.5%	NA	40	75.5%	NA

Table 8-6: Exposed population: MEN and WOMEN								
Carcinogen	Study	Country and Year	No. of exposed workers (MEN)	% of exposed workers	% of workforce	No. of exposed workers (WOMEN)	% of exposed workers	% of workforce
		Finland; 2014	16	59.3%	NA	11	40.7%	NA
12 PAHs	SUMER	France; 1994	63,000	86.3%	0.9%	10,000	13.7%	NA
		France; 2003	NA	NA	NA	NA	NA	NA
		France; 2010	NA	NA	NA	NA	NA	NA
	ASA	Finland; 2005	55	79.7%	NA	14	20.3%	NA
		Finland; 2011	1,890	93.4%	NA	134	6.6%	NA
		Finland; 2014	84	84.0%	NA	16	16.0%	NA
13 Occupation as a welder	SUMER	France; 1994	342,000	95.0%	4.8%	18,000	5.0%	0.4%
		France; 2003	567,100	95.3%	0.7%	27,700	4.7%	1.2%
		France; 2010	573,900	96.0%	5.7%	23,800	4.0%	0.4%
	ASA	Finland; 2005	4,243	98.5%	NA	63	1.5%	NA
		Finland; 2011	3,694	97.0%	NA	115	3.0%	NA
		Finland; 2014	4,550	97.6%	NA	110	2.4%	NA
14 Solar radiation	SUMER	France; 1994	NA	NA	NA	NA	NA	NA
		France; 2003	NA	NA	NA	NA	NA	NA
		France; 2010	NA	NA	NA	NA	NA	NA
	ASA	Finland; 2005	NA	NA	NA	NA	NA	NA
		Finland; 2011	NA	NA	NA	NA	NA	NA
		Finland; 2014	NA	NA	NA	NA	NA	NA
15 ETS	SUMER	France; 1994	NA	NA	NA	NA	NA	NA
		France; 2003	NA	NA	NA	NA	NA	NA
		France; 2010	NA	NA	NA	NA	NA	NA
	ASA	Finland; 2005	3,824	33.0%	NA	7,763	67.0%	NA
		Finland; 2011	58	43.6%	NA	75	56.4%	NA
		Finland	36	30.3%	NA	83	69.7%	NA

Table 8-6: Exposed population: MEN and WOMEN								
Carcinogen	Study	Country and Year	No. of exposed workers (MEN)	% of exposed workers	% of workforce	No. of exposed workers (WOMEN)	% of exposed workers	% of workforce
		; 2014						
16 Epichlorohydrine	SUMER	France; 1994	NA	NA	NA	NA	NA	NA
		France; 2003	NA	NA	NA	NA	NA	NA
		France; 2010	NA	NA	NA	NA	NA	NA
	ASA	Finland; 2005	185	72.3%	NA	71	27.7%	NA
		Finland; 2011	159	81.1%	NA	37	18.9%	NA
		Finland; 2014	144	77.0%	NA	43	23.0%	NA
17 Tetrachloroethylene	SUMER	France; 1994	NA	NA	NA	NA	NA	NA
		France; 2003	27,800	58.6%	0.3%	19,600	41.4%	0.3%
		France; 2010	20,700	68.3%	0.2%	9,600	31.7%	0.1%
	ASA	Finland; 2005	NA	NA	NA	NA	NA	NA
		Finland; 2011	NA	NA	NA	NA	NA	NA
		Finland; 2014	NA	NA	NA	NA	NA	NA
18 Shift work	SUMER	France; 1994	NA	NA	NA	NA	NA	NA
		France; 2003	NA	NA	NA	NA	NA	NA
		France; 2010	NA	NA	NA	NA	NA	NA
	ASA	Finland; 2005	NA	NA	NA	NA	NA	NA
		Finland; 2011	NA	NA	NA	NA	NA	NA
		Finland; 2014	NA	NA	NA	NA	NA	NA
19 Dioxins	SUMER	France; 1994	NA	NA	NA	NA	NA	NA
		France; 2003	NA	NA	NA	NA	NA	NA
		France; 2010	NA	NA	NA	NA	NA	NA
	ASA	Finland; 2005	33	52.4%	NA	30	47.6%	NA
		Finland; 2011	12	46.2%	NA	14	53.8%	NA
		Finland; 2014	11	68.8%	NA	5	31.3%	NA

Table 8-6: Exposed population: MEN and WOMEN								
Carcinogen	Study	Country and Year	No. of exposed workers (MEN)	% of exposed workers	% of workforce	No. of exposed workers (WOMEN)	% of exposed workers	% of workforce
20 Inorganic acid mists	SUMER	France; 1994	NA	NA	NA	NA	NA	NA
		France; 2003	NA	NA	NA	NA	NA	NA
		France; 2010	NA	NA	NA	NA	NA	NA
	ASA	Finland; 2005	NA	NA	NA	NA	NA	NA
		Finland; 2011	NA	NA	NA	NA	NA	NA
		Finland; 2014	NA	NA	NA	NA	NA	NA
21 Rubber manufacturing	SUMER	France; 1994	23,000	92.0%	0.3%	2,000	8.0%	NA
		France; 2003	35,000	91.4%	0.3%	3,300	8.6%	NA
		France; 2010	15,500	95.7%	0.1%	700	4.3%	NA
	ASA	Finland; 2005	52	98.1%	NA	1	1.9%	NA
		Finland; 2011	69	94.5%	NA	4	5.5%	NA
		Finland; 2014	78	97.5%	NA	2	2.5%	NA
22 Ionising radiation	SUMER	France; 1994	NA	NA	NA	NA	NA	NA
		France; 2003	NA	NA	NA	NA	NA	NA
		France; 2010	NA	NA	NA	NA	NA	NA
	ASA	Finland; 2005	NA	NA	NA	NA	NA	NA
		Finland; 2011	NA	NA	NA	NA	NA	NA
		Finland; 2014	NA	NA	NA	NA	NA	NA
23 Cr(VI) compounds	SUMER	France; 1994	42,000	82.4%	0.6%	9,000	17.6%	0.2%
		France; 2003	93,700	86.8%	0.9%	14,300	13.2%	0.2%
		France; 2010	84,200	87.6%	0.7%	11,900	12.4%	0.1%
	ASA	Finland; 2005	6,762	92.4%	NA	556	7.6%	NA
		Finland; 2011	6,253	92.3%	NA	519	7.7%	NA
		Finland; 2014	6,268	92.9%	NA	476	7.1%	NA
24 Aromatic	SUMER	France;	22,000	62.9%	0.3%	13,000	37.1%	0.3%

Table 8-6: Exposed population: MEN and WOMEN								
Carcinogen	Study	Country and Year	No. of exposed workers (MEN)	% of exposed workers	% of workforce	No. of exposed workers (WOMEN)	% of exposed workers	% of workforce
amines		1994						
		France; 2003	33,600	47.5%	0.3%	37,200	52.5%	0.5%
		France; 2010	27,900	44.4%	0.2%	35,000	55.6%	0.4%
	ASA	Finland; 2005	NA	NA	NA	NA	NA	NA
		Finland; 2011	NA	NA	NA	NA	NA	NA
		Finland; 2014	NA	NA	NA	NA	NA	NA
25 Cytostatic drugs	SUMER	France; 1994	NA	NA	NA	NA	NA	NA
		France; 2003	14,000	20.2%	0.1%	55,200	79.8%	0.7%
		France; 2010	5,000	10.1%	<0.1%	44,400	89.9%	0.5%
	ASA	Finland; 2005	NA	NA	NA	NA	NA	NA
		Finland; 2011	NA	NA	NA	NA	NA	NA
		Finland; 2014	NA	NA	NA	NA	NA	NA
26 Organic solvents: Ethanol	SUMER	France; 1994	NA	NA	NA	NA	NA	NA
		France; 2003	NA	NA	NA	NA	NA	NA
		France; 2010	324,800	33.8%	2.7%	636,600	66.2%	6.5%
	ASA	Finland; 2005	NA	NA	NA	NA	NA	NA
		Finland; 2011	NA	NA	NA	NA	NA	NA
		Finland; 2014	NA	NA	NA	NA	NA	NA
26 Organic solvents: tetrahydrofuran THF	SUMER	France; 1994	18,000	78.3%	0.3%	5,000	21.7%	NA
		France; 2003	52,000	84.3%	0.5%	9,700	15.7%	NA
		France; 2010	57,400	88.9%	0.5%	7,200	11.1%	0.1%
	ASA	Finland; 2005	NA	NA	NA	NA	NA	NA
		Finland; 2011	NA	NA	NA	NA	NA	NA
		Finland; 2014	NA	NA	NA	NA	NA	NA
26 Organic solvents:	SUMER	France; 1994	NA	NA	NA	NA	NA	NA

Table 8-6: Exposed population: MEN and WOMEN								
Carcinogen	Study	Country and Year	No. of exposed workers (MEN)	% of exposed workers	% of workforce	No. of exposed workers (WOMEN)	% of exposed workers	% of workforce
Methylene chloride		France; 2003	70,300	81.3%	0.7%	16,200	18.7%	0.2%
		France; 2010	58,500	83.9%	0.5%	11,200	16.1%	0.1%
	ASA	Finland; 2005	NA	NA	NA	NA	NA	NA
		Finland; 2011	NA	NA	NA	NA	NA	NA
		Finland; 2014	NA	NA	NA	NA	NA	NA

8.4 Assessment of the limitations of the analysis (WP1-Step 7)

The AFs and ANs in this study are subject to some uncertainty. The implications of this are evaluated in this section.

The key limitations relate to the following issues:

- Focus on suspected or confirmed carcinogenic agents, including issues regarding the definition of what is covered by specific agents and reliance on experimental animal data rather than epidemiological data;
- Selection of the Relative Risks for the purposes of the analysis, particularly as it has not been possible to undertake an exhaustive review of the literature and statistics can vary significantly across studies and over time;
- Exposure patterns, including the potential for threshold effects and the need for relative risks to correspond to real exposure levels in the workplace;
- The framework for the analysis, i.e. whether the starting point is a carcinogenic agent, tumour site, or a specific occupation;
- Gender differences of occupational cancer; and
- Focussing on the selected 25 carcinogenic agents, with those selected not including many high tonnage chemicals which have been registered under REACH, leading to a potentially significant underestimate of the total occupational burden of cancer (an example of an additional carcinogenic agent, organic solvents, is provided).

8.4.1 Suspected or confirmed carcinogenic agents

Regulatory classification is an important consideration for the designation of substances as contributors to carcinogenic risk at the workplace. The IARC[216] and the CLP (EC, 2008)[217] classifications of the 25 carcinogenic agents selected for detailed assessment in this study are summarised in Annex 4. However, these classifications were derived for specific purposes and may not fully and consistently capture the real cancer potential of these agents. Different regulatory bodies may have different scientific perspectives and discussions on classifications may have been carried out at different points in time (and thus be based on different information). In addition, the definitions of the specific agents used may have differed.

The classification and evidence of carcinogenicity varies between the different carcinogenic agents in Table 8-7.

Table 8-7: Cancer Classification of 25 carcinogenic agents

Carcinogenic agent	Classification IARC	Classification EU(CLP)
Diesel exhaust	1	Not assessed for classification
Silica dust	1	Not classified
Asbestos	1	All: Carc. 1A
Formaldehyde	1	Carc. 1B
Benzene	1	Carc. 1A

[216] See http://monographs.iarc.fr/ENG/Classification/latest_classif.php

[217] EC, European Commission (2008): Regulation (EC) No 1272/2008 of the European Parliament and of the Council of 16 December 2008 on classification, labelling and packaging of substances and mixtures, amending and repealing Directives 67/548/EEC and 1999/45/EC, and amending Regulation (EC) No 1907/2006, Official Journal of the European Union, L 353, 1-1355

Table 8-7: Cancer Classification of 25 carcinogenic agents		
Carcinogenic agent	**Classification IARC**	**Classification EU(CLP)**
Mineral oils[$]	1/3	Different classifications; depends on identity (e.g. highly/mildly refined)
Cd and Cd compounds	1	Carc. 1B*
Wood dust	1	Not assessed for classification
Arsenic	1	Carc. 1A*
Vinyl chloride	1	Carc. 1A
Ethylene oxide	1	Carc. 1B
PAHs (from coal tars and pitches)	1	Carc. 1A
Occupation as a welder: Welding fumes	2B	Not assessed for classification
Solar radiation	1	Not assessed for classification
Environmental tobacco smoke (ETS) (Tobacco smoke, second hand)	1	Not assessed for classification
Epichlorohydrine	2A	Carc. 1B
Tetrachloroethylene	2A	Carc. 2
Shift work that involves circadian disruption	2A	Not assessed for classification
Dioxins [++])	1/3	Not assessed for classification
Inorganic acid mists containing sulphuric acid	1	Classified single substances
Rubber manufacturing industry	1	Not assessed for classification
Ionizing radiation	1	Not assessed for classification
Cr(VI) compounds	1	Carc. 1B*
Aromatic Amines	2A [&]	Different classifications; depends on identity
Cytostatic drugs	Different classifications; depends on identity	Different classifications; depends on identity

IARC: Group 1 = carcinogenic to humans, Group 2A: probably carcinogenic to humans, Group 2B: possibly carcionogenic to humans, Group 3: not classifiable as to its carcinogenicity to humans
CLP: Group 1A = Substances known to have carcinogenic potential for humans ; Group 1B = Substances presumed to have carcinogenic potential for humans ; Group 2 = Suspected human carcinogens
$) mineral oils, highly refined group 1, mineral oils, untreated or mildly treated group 3
*) may differ for some arsenic-, cadmium-, or chromium compounds
++) 1 for 2,3,7,8-Tetrachloro-para-dibenzodioxine, 3 for others dioxins
&) Some, not all aromatic amines are classified as “probably” carcinogenic (2A), others as “possibly” (2B); occupational exposures as hairdressers or barbers: “probably” (2A).

The prioritisation phase of this study (WP1-Step 1) predominantly focused on IARC Group 1 and 2A carcinogens (carcinogenic and probably carcinogenic to humans). Due to the fact that Group 2B (possibly carcinogenic to humans) comprises a very large number of entries, it was not possible to consider the vast majority of these agents within the prioritisation exercise. In addition, limited human data and other information are available for Group 2B carcinogens. There is a number of high tonnage carcinogens in IARC Group 2 or CLP Carc. 2 but these are often not considered in published literature because they are only ‘suspected’ carcinogens by one or the other classification.

The 25 agents considered in this study include some that are classed as ‘suspected carcinogens’ rather than ‘probable or known carcinogens. The implication for this study is that, should the carcinogenic property of these agents not be confirmed, this would reduce the overall AFs across the 25 agents estimated in this study.

In conclusion, classification is a significant factor of uncertainty. For example, shift work is currently not classified as a human carcinogen. In addition, conclusions drawn for tetrachloroethylene (CLP Carc. 2), mineral oils, aromatic amines, cytostatic drugs, inorganic mists and organic solvents should be considered more uncertain because of the definitional issues.

Mineral oils are a very heterogeneous group of compounds, with classifications depending on the degree of refining. In CLP, different mineral oil fractions have different classifications. For example, lubricating oil (CAS-No: 74869-22-0) is classified Carc. Cat. 1B, Distillates (petroleum), light paraffinic (CAS-No: 64741-50-0) is Carc. Cat. 1A, and distillates (petroleum), light hydrocracked (CAS-No. 64741-77-1) are Carc. Cat. 2. Therefore, workers exposed to "mineral oils" belong to different subgroups with different probability that they are really exposed to a carcinogenic agent.

8.4.2 Cancer risk estimates from experimental animal data or from epidemiological data

This report only uses relative risk estimates from epidemiological studies. Whilst this is a widely accepted procedure, it gives rise to further uncertainty in the AFs estimated in this study. For all substances classified as Carc. 1B (CLP), cancer potential and potency were mainly evaluated based on experimental animal data. If there had been adequate epidemiological data, those substances (or activities) could potentially have been assigned Carc. 1A (CLP). Therefore, information from epidemiological studies for about 600 single chemical substances from CLP-classification may be too weak to be adequately used to estimate AFs. For genotoxic carcinogens, one may not be certain that tumour localisations in animal studies are identical to the ones in humans. However, as a weight of evidence approach, it may be more appropriate to assume identical tumour sites for interspecies extrapolation than to rely on elevated relative risks from questionable epidemiology for a Carc. 1B carcinogen (specifically, if those relative risks were only insignificantly elevated). In general, epidemiological data for Carc. Cat. 1B may not provide sufficient potency and relative risk information.

For example, tetrachloroethylene is classified as a probable carcinogen (Group 2A) by IARC and as suspected carcinogen (Carc. Cat. 2) under CLP. US-EPA (2012)[218] has classified the agent as "likely to be carcinogenic to humans". However, both bodies note that there is sufficient evidence for carcinogenicity only in animal studies, whereas human data provide only "associations" (IARC) or "suggestive evidence" (EPA). Therefore, animal data may be more appropriate quantitative assessments of the cancer risk. In this report, only epidemiological data were used to calculate the AFs, using relative risks for bladder cancer, cervical cancer, non-Hodgkin lymphoma, oesophagus and pancreas cancer. In animal studies, mainly liver tumours, kidney tumours and leukaemia were shown. A consideration of different target organs would result in different AFs, if animal data were taken into consideration. Please note that for trichloroethylene, a very similar chlorinated hydrocarbon with identical metabolites, kidney cancer is a confirmed cancer site from human epidemiological data (not included in the considered cancer sites for tetrachloroethylene in this project because there is some but less evidence than for the cancer sites considered for tetrachloroethylene).

Therefore, the use of epidemiological data contributed to the overall uncertainty in the case of carcinogens classified Carc. 1B or Carc. 2 (CLP). Information from animal experimental data (cancer sites and risk potency) is not taken into account in this study.

[218] EPA, Environmental Protection Agency (2012): Toxicological Review of Tetrachloroethylene (CAS No. 127-18-4). In Support of Summary Information on the Integrated Risk Information System (IRIS), February 2012, http://www.epa.gov/iris/toxreviews/0106tr.pdf

8.4.3 Selection of relative risks

As indicated above, this report uses relative risks (e.g., SMR, RR, OR, etc.) to calculate the AFs. However, these relative risk estimates may differ in quality and validation. Within the framework of this report it was not possible to perform an exhaustive search for all relevant studies with relative risk quantifications or to perform meta-analyses. It is emphasised in this report that incidence relative risks from meta-analyses are preferred but those are not always available or suffer from substantial study heterogeneity or sometimes are outdated. There are examples, where this uncertainty is limited or negligible. There are others, where the selection of the RR contributes significantly to the overall uncertainty.

In order to illustrate how additional research going beyond the budgetary and time constraints of this study could potentially identify additional relative risk estimates and thus impact on the study results, a more extensive search was carried out for tetrachloroethylene.

Table 8-8: Examples of additional RR for tetrachlorethylene, currently not considered in this report

Endpoint/study	RR	Comment
Bladder cancer		Currently used: RR 1.44 [1.07-1.93] (Lynge et al., 2006)
Calvert et al. (2011)	SMR 1.35 [0.16-4.89]	Dry-Cleaners, USA
Seldén et al. (2011)	SIR 0.92 [0.65-1.26]	Male plus female, data from Sweden (dry-cleaners, laundry workers), prospec. cohort study
Oesophagus		Current RR used: RR 2.47 [1.35,4.14] (Ruder et al., 2001)
Lynge et al. (2006)	RR 0.76 [0.34-1.69]	Dry-Cleaners, Nordic Countries
Seldén et al. (2011)	SIR 0.67 [0.22-1.56]	Male plus female, females separate: SIR 1.33 [0.43-3.1], data from Sweden (dry-cleaners, laundry workers), prospec. cohort study
Calvert et al. (2011)	SMR 2.68 [0.98-5.83]	Dry-Cleaners, USA, includes the data by Ruder et al. (2001)
Lung cancer		Currently not covered as cancer endpoint for tetrachloroethylene
Mattei et al., (2014)	OR 3.57 female [0.54-23.55]	Significant after co-exposure to other chlorinated hydrocarbon solvents, higher OR for women than for men
Seldén et al. (2011)	SIR 1.32 [1.07-1.6]	Male plus female, males separate: SIR 1.45 [1.03-1.98], data from Sweden (dry-cleaners, laundry workers), prospec. cohort study
NHL		Current RR used: RR 1.29 [1.00 – 1.66] (Mandel et al., 2006)
Calvert et al. (2011)	SMR 2.46 [0.9-5.36]	Dry-Cleaners, USA
Seldén et al. (2011)	SIR 1.38 [1.02-1.82]	Male plus female, males separate: SIR 2.05 [1.3-3.07], data from Sweden (dry-cleaners, laundry workers), prospec. cohort study
Cervical cancer		Current RR used: RR 1.95 [1.00,3.4] (Ruder et al., 2001)
Calvert et al. (2011)	SMR 2.1 [0.68-4.9]	Dry-Cleaners, USA, includes the data by Ruder et al. (2001)
Seldén et al. (2011)	SIR 1.25 [0.81-1.85]	Data from Sweden (dry-cleaners, laundry workers), prospec. cohort study

Table 8-8: Examples of additional RR for tetrachlorethylene, currently not considered in this report		
Endpoint/study	**RR**	**Comment**
Sources: Calvert et al (2011): Mortality and end-stage renal disease incidence among dry cleaning workers, Occupational and Environmental Medicine, 68, 709-716 Lynge et al (2006): Cancer in persons working in dry cleaning in the nordic countries, Environmental Health Perspectives, 114, 213-219 Mattei et al (2014): Exposure to chlorinated solvents and lung cancer: results of the ICARE study, Occupational and Environmental Medicine, 71, 681-689 Seldén & Ahlborg (2011): Cancer morbidity in Swedish dry-cleaners and laundry workers: historically prospective cohort study, International Archives of Occupational and Environmental Health, 84, 435-443		

Table 8-8 provides some additional risk figures, which are not included in the analysis in the main report and Annex 1. This table shows suggests that there are other sources of additional relative risk estimates which, if used, could potentially change the AFs estimated in this report.

Shift-work provides another example. Bhatti et al (2013)[219] found a significantly elevated risk of ovarian cancer for shift workers. Similarly, endometrial cancer was increased according to Viswanthan et al (2009)[220]. Rao et al (2015)[221] report a significantly elevated risk in prostate cancer from 8 epidemiological studies on shift work and Wang et al (2015)[222] performed a meta-analysis on colorectal cancer with significant odds ratio. This list contributes to an analysis of gender differences, attributable fractions and overall insight into occupational carcinogens.

8.4.4 Exposure patterns

Substances with a non-genotoxic mode of action (MoA) are often regarded as threshold carcinogens (and tend to be classified only as suspected carcinogens). The European Scientific Committee on Occupational Exposure Limits (SCOEL) often describes carcinogens as having "a practical threshold", if factors other than genotoxicity are significantly contributing to the carcinogenic MoA. Overall, genotoxicity was indicated for only for 38% (n=105) of 278 carcinogenic chemicals tested within the National Toxicology Program (NTP) of the United States (Kardekar et al., 2012)[223]. This indicates that many carcinogens in the workplace should be considered non-genotoxic or with only partial contributions of genotoxicity to the carcinogenic MoA. For these (frequently occurring) carcinogens with a sublinear exposure risk relationship or a threshold, there will be significant uncertainties in calculations of the attributed risk as the AFs will only be correct if the exposure level fits to the calculated relative risk. This can be illustrated using the examples of benzene and sulphuric acid.

The genotoxic **benzene** is associated with an RR of 1.64 at low exposure levels (Khalade et al 2010)[224] and with an RR of 3.6 at high exposure levels (Guénel et al 2002) [225] (see Annex 1). The study by

[219] Bhatti, P.; Cushing-Haugen, K.L.; Wicklund, K.G.; Doherty, J.A.; Rossing, M.A. (2013): Nightshift work and risk of ovarian cancer, Occupational and Environmental Medicine, 70, 231-237

[220] Viswanathan, A.N.; Schernhammer, E.S. (2009): Circulating melatonin and the risk of breast and endometrial cancer in women, Cancer Letters, 281, 1-7

[221] Rao, D.; Yu, H.; Bai, Y.; Zheng, X.; Xie, L. (2015): Does night-shift work increase the risk of prostate cancer? a systematic review and meta-analysis, Onco Targets Ther, 8, 2817-2826

[222] Wang, X.; Ji, A.; Zhu, Y.; Liang, Z.; Wu, J.; Li, S.; Meng, S.; Zheng, X.; Xie, L. (2015): A meta-analysis including dose-response relationship between night shift work and the risk of colorectal cancer, Oncotarget, 6, 25046-25060

[223] Kardekar et al (2012): Gender differences, Toxicologic Pathology, available at http://www.ncbi.nlm.nih.gov/pubmed/22585941

[224] Khalade, A.; Jaakkola, M.S.; Pukkala, E.; Jaakkola, J.J. (2010): Exposure to benzene at work and the risk of leukaemia: a systematic review and meta-analysis, Environmental Health, 9:31

Khalade et al (2010) is based on a systematic review and meta-analysis. The RR found by Guénel et al (2002) is restricted to exposure levels above 16.8 ppm-years. Over a 40-year working life, this corresponds to average air concentrations of 1.4 mg/m³ (16.8 ppm x 3.25 mg/m³ x ppm / 40 years). However, IARC (2012)[226] provides exposure data for occupational scenarios which indicate that often much lower concentrations than 1.4 mg/m³ are present at the workplace. Therefore, excluding exposure considerations may possibly lead to application of an RR that may overestimate risk at lower (but realistic conditions) at the workplace.

The non-genotoxic **sulfuric acid** will probably be a threshold carcinogen, with exposure levels below the threshold not being associated with an increased cancer risk. The RR of 4.28 for larynx cancer or the RR of 1.36 for lung cancer attributed to "inorganic acid mists containing sulphuric acid" (see Annex I) is therefore suitable to high exposures. The RR is based on data from exposure prior to 1965[227]. Bradveit et al (2004)[228] report that exposures to sulphuric acid prior to 1975 may have been very high but that "today's exposure levels are lower than those reported to be associated with an increased prevalence of laryngeal cancer".

The robustness of the AFs estimated in this study therefore depends on the exposure levels corresponding to the relative risks used. However, this report does not consider exposure concentrations. It is not feasible to quantify exposure concentrations, duration of exposure, protection measures to lower exposure and other factors influencing the exposure patterns in a single European country or, more than ever, differentiated across all EU countries. RRs are used for the calculation formula for AF without any differentiation of the specific activity and associated exposure levels. This contributes to the overall uncertainty.

8.4.5 Different starting points: 'carcinogenic agents' or 'tumour sites' or 'cancer profiles for specific occupations'

Most of the 25 carcinogenic agents considered in this report are chemical substances but some are occupations/activities. However, it is important to recognise that:

- not all relevant cancer risks associated with the top 25 carcinogenic agents are covered;
- taking 'tumour sites' as a starting point (instead of carcinogenic agents) may increase respective associations; and
- taking 'cancer profiles for specific occupations' as a starting point may increase respective associations.

Specific examples of the implications of this are provided below.

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[225] Guénel, P.; Imbernon, E.; Chevalier, A.; Crinquand-Calastreng, A.; Goldberg, M. (2002): Leukaemia in relation to occupational exposures to benzene and other agents: a case-control study nested in a cohort of gas and electric utility workers, American Journal of Industrial Medicine, 42, 87-97, cited in Roller et al., 2006

[226] IARC, International Agency for Research on Cancer (2012): IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. Vol. 100F. A Review of Human Carcinogens. Chemical Agents and Related Occupations, WHO, World Health Organization, Lyon, France

[227] Steenland et al., Incidence of laryngeal cancer and exposure to acid mists, British Journal of Industrial Medicine, 1988, 45, 766-776

[228] Bratveit, M.; Haaland, I.M.; Moen, B.E.; Malsnes, A. (2004): Exposure to sulfuric acid in zinc production Annals of Occupational Hygiene, 48, 159-170

Example 1: tumour sites as a starting point – breast cancer, sinonasal cancer, thyroid cancer and bladder cancer as examples

From the top 25 agents, only shift-work, ionising radiation and cytostatic drugs also contribute to occupational breast cancer risk. However, these are just few of the agents, which can be linked to this tumour site.

216 chemicals have been identified from experimental animal studies, which cause **mammary tumours** (Brophy et al, 2012).[229] This indicates that occupational conditions with influence on breast cancer incidence are not sufficiently covered by the selected 25 carcinogenic agents.

From epidemiological evidence, also **cadmium** (one of the 25 agents) should be linked to breast cancer. According to a recent analysis by Byrne et al (2013)[230] breast cancer risk is significantly elevated already from low (environmental) exposures to cadmium and AGS (2014)[231], Fenga (2016)[232] and Zumel et al (2016) [233] also report occupational exposure to cadmium possibly leading to breast cancer.

These and further substances have been linked to mammary tumours, some of which are listed in Table 8-9.

Table 8-9: Selected carcinogenic agents associated with breast cancer
• Ionising Radiation • Non-ionising radiation • Organochlorine pesticides • Organophosphate pesticides • Polycyclic aromatic hydrocarbons • Night-shift work • Metals
Source: Fenga et al (2016)

This analysis can be extended to further cancer sites, when related to occupations and carcinogenic agents. There is an overlap of occupations and carcinogenic agents. Both links will lead to different numbers of workers with elevated risk. Some examples are provided in Table 8-10.

Table 8-10: Selected occupations and carcinogenic agents associated with bladder cancer, thyroid cancer or sinonasal cancer		
Occupation, RR, tumour site analysis (listed only, if significantly elevated)	**This report (RR), chemical factor analysis**	**Source**
Bladder cancer		
Cumberbatch et al., 2017	Diesel motor	Cumberbatch et al (2017);

[229] Brophy, J.T.; Keith, M.M.; Watterson, A.; Park, R.; Gilbertson, M.; Maticka-Tyndale, E.; Beck, M.; Abu-Zahra, H.; Schneider, K.; Reinhartz, A.; DeMatteo, R.; Luginaah, I. (2012): Breast cancer risk in relation to occupations with exposure to carcinogens and endocrine disruptors: a Canadian case–control study, Environmental Health, 11, 1-17

[230] Byrne, C.; Divekar, S.D.; Storchan, G.B.; Parodi, D.A.; Martin, M.B. (2013): Metals and breast cancer, Journal of Mammary Gland Biology and Neoplasia, 18, 63-73

[231] AGS (2014): Begründung zu Expositions-Risiko-Beziehung für Cadmium in TRGS 910. Ausgabe: Oktober 2014. Stand: Mai 2014 http://www.baua.de/de/Themen-von-A-Z/Gefahrstoffe/TRGS/Begruendungen-910.html

[232] Fenga, C. (2016): Occupational exposure and risk of breast cancer, Biomed Rep, 4, 282-292

[233] Zumel et al (2016): Occupational exposure to metals and risk of breast cancer, BMJ, 2016, Vol. 73, Suppl.1

Table 8-10: Selected occupations and carcinogenic agents associated with bladder cancer, thyroid cancer or sinonasal cancer		
Occupation, RR, tumour site analysis (listed only, if significantly elevated)	**This report (RR), chemical factor analysis**	**Source**
Waiters RR 1.3 (1.01-1.65) Smelting workers 1.49 (1.05-2.25) Electrical workers 1.6 (1.09-2.36) Glass workers 1.66 (1.21-2.27) Textiles 1.74 (1.45-2.08) Dye workers 1.8 (1.07-3.04) Rubber workers 1.82 (1.4-2.38) Chemical process workers 1.87 (1.5-2.34) Noon et al., 2016 Male building caretakers SMR 1.39 (1.09-1.76) Transport workers 1.27 (1.01-1.59) Engine operators 1.23 (1.00-1.49) Female assistant nurses 1.55 (1.01-2.27) Hairdressers 1.99 (1.03-3.47) Hadkhale et al., 2016 Tobacco workers SIR 1.57 (1.24-1.96) Chimney Sweeps 1.48 (1.21-1.80) Waiters 1.43 (1.33-1.53) Hairdressers 1.28 (1.19-1.40) Seamen 1.22 (1.16-1.30) Printers 1.21 (1.14-1.30) Plumbers 1.20 (1.13-1.30)	emissions 1.24 Mineral oil 2.6 PAH 2.09 Tetrachloroethylene 1.44 Rubber manufacturing 8.25 Aromatic amines 2.15	Noon et al (2016); Hadkhale et al (2016)
Thyroid cancer		
Health care practitioners and technical occupations 1.71 (1.09-2.7) Health diagnosing and treating practitioners 1.80 (1.05-3.08) Cooks and food preparation workers 4.13 (1.04-16.39) Building cleaning and pest control workers 2.36 (1.02-5.05) Retail sales persons 3.13 (1.27-7.67)	Ionising radiation 2.1	Ba et al (2016)
Sinonasal cancer		
Formaldehyde RR 1.68 (1.37-2.06) Wood dust 5.91 (4.31-8.11) Leather dust 11.89 (7.69-18.36) Textile industry 2.03 (1.47-2.8) construction 1.62 (1.11-2.36) Nickel/chromium compounds 18.0 (14.55-22.27)	Formaldehyde 2.8 Wood dust 5.91	Binazzi et al (2015)
Sources: Ba et al (2016): Occupation and thyroid cancer: a population-based, case-control study in Connecticut, In: Journal of Occupational and Environmental Medicine, 58, 299-305 Binazzi, A.; Ferrante, P.; Marinaccio, A. (2015): Occupational exposure and sinonasal cancer: a systematic review and meta-analysis, BMC Cancer, 15, 49 Cumberbatch, M.G.; Windsor-Shellard, B.; Catto, J.W.F. (2017): The contemporary landscape of occupational		

Table 8-10: Selected occupations and carcinogenic agents associated with bladder cancer, thyroid cancer or sinonasal cancer		
Occupation, RR, tumour site analysis (listed only, if significantly elevated)	**This report (RR), chemical factor analysis**	**Source**
bladder cancer within the United Kingdom: a meta-analysis of risks over the last 80 years, BJU International, 119, 100-109 Hadkhale, K., et al., Occupation and risk of bladder cancer in Nordic countries, JOEM, 2016 Noon, A.P.; Martinsen, J.I.; Catto, J.W.F.; Pukkala, E. (2016): Occupation and bladder cancer phenotype: identification of workplace patterns that increase the risk of advanced disease beyond overall incidence, European Urology Focus		

Example 2: occupational profiles as a starting point

Another starting point could be to compile all types of cancer associated with a given occupation. Such a study has been carried out for 15 million people in Nordic Countries by Pukkala et al (2009).[234] From this study, which has not been directly evaluated in this analysis, additional cancer sites, occupations and carcinogenic agents can be derived. The three occupations with an overall increased significant SIR above 2 were

- Beverage workers SIR 2.07 (1.4-3.0);
- Tobacco workers SIR 2.28 (1.0-4.5); and
- Launderers SIR 2.22 (1.5-3.2).

8.4.6 Gender differences of occupational cancer

With respect to gender differences in occupational cancer in general but also with respect to this study:

e) The relevance of sex-specific cancer may be underestimated because of insufficient studies with female cohorts, e.g. there are other studies highlighting ovarian cancer for female welders (Pukkala et al, 2009) and linking shift work to endometrial cancer (Viswanathan and Schernhammer, 2009). In addition, an increased risk for male reproductive organs was not quantified for any of the 25 carcinogenic agents which demonstrates another uncertainty of this assessment.

f) Significant disparities also exist for other than reproductive organ sites, with these referred to as being "enigmatic sex disparities" (Edgren et al, 2012). Some of these may reflect some endocrine influences on cancer occurrence which is an area that has not yet been studied in sufficient detail (Del Pup et al, 2015).

g) Due to resource limitations, it has not been possible to reflect gender differences across all cancer sites, with a single relative risk figure applied to both males and females. This is a simplification and leads to uncertainty. This simplification should be noted when gender specific AFs are discussed.

h) This report mainly addresses exposure related differences in cancer attributable to men or women. Biases in gender-linked reporting on exposure may contribute to uncertainty.

[234] Pukkala, E.; Martinsen, J.I.; Lynge, E.; Gunnarsdottir, H.K.; Sparén, P.; Tryggvadottir, L.; Weiderpass, E.; Kjaerheim, K. (2009): Occupation and cancer - follow-up of 15 million people in five Nordic countries, Acta Oncologica, 48, 646-790

8.4.7 Focus on the selected 25 carcinogenic agents

Section 2.2 of the report provides a detailed description of the process by which the 25 carcinogenic agents, used in this study, were chosen. It is possible that these 25 agents may cover the majority of occupational cancer but this is not certain.

A grouping exercise on **high tonnage chemicals registered under REACH** which have not been included among the 'priority 25' lists some substances, which are registered for a marketed volume with more than 1 million tonnes (full registration, not only intermediate use), shows that these include, e.g. 1,2-dichloroethane, acrylonitrile (both Carc. Cat. 1B, CLP) and chloromethane, vinyl acetate and aniline (all Carc. Cat. 2, CLP). Similarly, naphthalene, dichloromethane, trichloromethane, tetrahydrofurane, nitrobenzene, and some isocyanates are classified suspected carcinogens within the tonnage band of 100,000 to 1 million tonnes. Although their precise effect on the AFs calculated in this study depends on the RRs, even if each of them would only contribute with a small percentage to occupational cancer risk, this could – also depending on the respective cancer site – change calculated AFs.

8.4.8 Organic solvents (carcinogenic agent no. 26)

Although organic solvents were not included in the core assessment due to significant uncertainties associated with the input data, an additional assessment is provided here.

Assumptions used to estimate the AF

Occupationally exposed population

The annual estimates of the exposed populations and the rates of change used for the different scenarios are summarised below. The estimates of the exposed populations in the table below are extrapolations from published sources, i.e. annual estimates for the year assessed in the relevant study, and, as a result, do not represent the lowest or highest annual estimates over the whole reference period, since these also depend on the annual rate of change applied.

Table 8-11: Summary of the scenarios (exposed populations and annual rate of change)

Carcinogen	Parameter	Low	High	Mid-point	Central
26 Organic solvents	Exposed population (EU-28) - point	Women & men: 1.1 million Women: 0.655 million (2010)	Women & men: 10.5 million Women: 6.3 million (2010)	Women & men: 5.8 million Women: 3.5 million (2010)	Women & men: 1.1 million Women: 0.655 million (2010)
	Rate of change (per annum)	0.7%	-3%	-1.15%	-3%

The exposed populations (over the relevant exposure period) estimated using the methodology set out in Section 2.3 of the main report (and Annex I) are summarised below for the EU-28.

Table 8-12: Summary of the results (exposed population over the relevant reference period)

Carcinogen	Reference period	Low	High	Mid-point	Central
26 Organic solvents	1966-2005	3.5	58.6	21.0	6.1
	% share of EU population	0.90%	24.90%	7.80%	2.60%

Relative Risk

The cancer sites for which risk estimates have been identified (thus enabling the calculation for an AF) are summarised below, compared with the cancer sites listed in IARC (2016)[235] to show the potential gaps in our analysis (i.e. cancer sites for which AFs could not be calculated due to a lack of risk estimates).

Table 8-13: Summary of the scenarios (cancer sites, share of cancer sites in IARC 2016)		
Carcinogen	**Relevant cancer sites**	**Remaining gaps**
26 Organic solvents	Breast Liver NHL	3 of 4 but 1 more than IARC 2016

The Relative Risks set out below have been used to calculate the AF for organic solvents under the different scenarios.

Table 8-14: Summary of the scenarios (relative risk)				
Carcinogen	**Low**	**High**	**Mid-point**	**Central**
26 Organic solvents	Breast: OR=1.04 Liver: RR=2.73 NHL: OR=1.3	Breast: OR=2.4 Liver: RR=2.73 NHL: OR=1.5	Breast: OR=1.72 Liver: RR=2.73 NHL: OR=1.4	Breast: OR=1.16 Liver: RR=2.73 NHL: OR=1.3

Men/women

Table 8-15: Exposed population: MEN and WOMEN		
Carcinogen	**% of exposed workers (MEN)**	**% of exposed workers (WOMEN)**
26 Organic solvents	84%	16%

Attributable fractions

The AFs for organic solvents by scenario and cancer site are given below.

Table 8-16: AFs per cancer site (High, Low, Central and Mid-point scenarios)			
Carcinogen	**Breast**	**Liver & bile duct**	**NHL**
26 Organic solvents (HIGH)	30.0%	24.1%	8.4%
26 Organic solvents (LOW)	0.1%	1.8%	0.3%
26 Organic solvents (CENTRAL)	0.5%	3.2%	0.6%
26 Organic solvents (MID-POINT)	7.3%	10.2%	2.5%

8.4.9 Use of different population adjustment factors

As regards the HIGH scenario for both genders, the inclusion of organic solvents among the list of top carcinogenic agents increases the overall attributable fraction by 7.14%. The increase is mainly caused by large attributable fractions for organic solvents-induced breast and liver cancers (29.97% and 24.05%, respectively). Moreover, breast cancer applies to women only, which coincides with the 6.93% increase in women's overall attributable fraction under the HIGH scenario compared to

[235] IARC (2016): List of classifications by cancer sites with sufficient or limited evidence in humans, available at https://monographs.iarc.fr/ENG/Classification/Table4.pdf

the 6.80% increase in men's attributable fraction. For all remaining scenarios, the increase in overall attributable fractions is of lesser magnitude, i.e. between 0.38% and 3.66%.

Table 8-17: AFs per cancer site across the 25 and 26 carcinogenic agents				
Attributable fractions	**High**	**Low**	**Central**	**Mid-point**
Across 26 carcinogenic agents (including organic solvents)				
Overall AF (OvAF) - BOTH	22.18%	1.68%	7.31%	10.68%
Overall AF (OvAF) - WOMEN	21.93%	0.78%	4.91%	9.52%
Overall AF (OvAF) - MEN	23.33%	2.66%	10.27%	12.83%
Across 25 carcinogenic agents (without organic solvents)				
Overall AF (OvAF) - BOTH	15.04%	1.17%	5.53%	7.39%
Overall AF (OvAF) - WOMEN	15.00%	0.40%	3.85%	6.78%
Overall AF (OvAF) - MEN	16.53%	1.97%	8.20%	9.17%

OvAF: Population adjustment factor = 0.53 for both time periods

The overall attributable fraction under the HIGH scenario for both genders has increased by 2.96%. Women's and men's overall attributable fraction under the HIGH scenario has increased by 6.12% and 1.23% respectively. For all other scenarios, the increase fluctuates between 0.04% and 1.79%.

Table 8-18: AFs per cancer site across the 25 and 26 carcinogenic agents				
Attributable fractions	**High**	**Low**	**Central**	**Mid-point**
Across 26 carcinogenic agents (including organic solvents)				
Overall AF (OvAF) - BOTH	23.89%	1.77%	8.01%	11.76%
Overall AF (OvAF) - WOMEN	23.32%	0.86%	5.56%	10.53%
Overall AF (OvAF) - MEN	25.15%	2.79%	11.13%	14.01%
Across 25 carcinogenic agents (without organic solvents)				
Overall AF (OvAF) - BOTH	20.93%	1.71%	7.87%	10.69%
Overall AF (OvAF) - WOMEN	18.20%	0.82%	5.40%	8.74%
Overall AF (OvAF) - MEN	23.92%	2.65%	10.97%	13.52%

Table 8-19: AFs per cancer site across the 25 and 26 carcinogenic agents				
Attributable fractions	**High**	**Low**	**Central**	**Mid-point**
Across 26 carcinogenic agents (including organic solvents)				
Overall AF (OvAF) - BOTH	20.16%	1.33%	6.50%	9.70%
Overall AF (OvAF) - WOMEN	22.54%	0.53%	4.70%	9.95%
Overall AF (OvAF) - MEN	19.62%	2.31%	9.44%	10.92%
Across 25 carcinogenic agents (without organic solvents)				
Overall AF (OvAF) - BOTH	16.82%	1.26%	6.33%	8.46%
Overall AF (OvAF) - WOMEN	16.78%	0.48%	4.52%	7.85%
Overall AF (OvAF) - MEN	18.23%	2.11%	9.25%	10.32%

8.4.10Conclusion

Calculated attributable fractions (AFs), attributable cancer cases (ANs), associated costs and country specific breakdown derived in this project are inevitably subject to considerable uncertainties, as are estimates of the costs associated with a cancer registration. The study has attempted to provide *ranges* for the estimates (Max, Min, Central, Mid-point). However, these ranges reflect only parts of the variability and uncertainty, where "true" numbers may spread over an even larger range. As a

result, the central estimate should only be regarded as a qualified *order of magnitude* figure instead of an exact number.

More generally, it is important that the limitations of the analysis presented here are recognised. Importantly, gender differences in cancer attributable to occupation could only partly be addressed. This analysis focused on the gender-specific exposure profiles, whereas the intrinsic different biological potency of the carcinogenic agents, leading to sex discrepancies, was not (or only marginally) addressed.

There are some parameters which may *increase* the overall estimated AF:

- If selection were not restricted to 25 carcinogenic agents;
- If selection were not limited to only a few cancer sites and risk quantifications (as "relative risk"), which were restricted to the most relevant ones according to IARC plus some additional - not necessarily representative - information sources;
- If many suspected carcinogens, "possible" carcinogens, and carcinogens found to only be carcinogenic in animal studies, were not examined, including those with high production tonnages;
- Moreover, no extended and systematic supplemental assessment could be performed from different starting points apart from the "carcinogenic agents". Starting from "cancers attributed to occupations" and "occupations and carcinogenic agents attributed to cancer sites" would have provided a more complete coverage of carcinogens impact on workers in EU28.

There are some parameters which may *decrease* the overall estimated AF:

- Relative risks may often be quantified at elevated exposure levels and risks at lower exposures may be associated with a significantly lower cancer risk. Because a realistic exposure concentration was not assessed for the "top 25" carcinogenic agents, because the exposure level associated with the RR was not explicitly taken into account and because some non-genotoxic carcinogens (but even genotoxic carcinogens) may be associated with a sublinear exposure risk relationship or even a threshold type of carcinogenicity, these elements may contribute to a significant overestimation of the final overall AF.
- Because some suspected carcinogens were included as if they were confirmed carcinogens (e.g., tetrachloroethylene or organic solvents or shift work), new data may disprove suspicion and lead to lower carcinogenic impact by occupational exposures.

There are some parameters leading to significant uncertainties, even though the direction (higher or lower estimate) could not be clearly described:

- Not all of the carcinogenic agents are well-defined, which leads to significant uncertainties on all subsequent input figures (cancer sites, RR, AF, exposure, AN, and costs). Examples are mineral oil or organic solvents;
- Only epidemiological data were used for risk quantification. The large pool of "additional risk" data from experimental animals may have been more appropriate for some substances and may lead to quantitative changes; and
- A more exhaustive search for epidemiological data including meta-analyses would have improved the reliability of the finally adopted RRs, but was not feasible within the framework of this project.

The overall result of cancer incidence attributed to occupation is not far away from other similar assessments. This provides some confidence in the overall result even though described

uncertainties have to be acknowledged. Therefore this estimate of the overall AF (and the composition of the overall AF) is considered to provide a reasonable starting point for the subsequent steps in this project (i.e., the estimate of the cost of cancer).

8.5 Additional cost data (Task 2)

Table 8-20: Estimates of the annual cost per patient of cancer				
Mortality rate after 5 years	**Cancer**	**Health care**	**Informal care**	**Total cost per case (€)**
22%	Prostate	€ 4,027	€ 1,390	€ 5,417
80%	Lung	€ 6,952	€ 6,278	€ 13,230
24%	Breast	€ 4,378	€ 2,086	€ 6,464
44%	Colorectal	€ 5,037	€ 2,567	€ 7,604
47%	All cancers	€ 6,047	€ 2,753	€ 8,800
Source: Luengo-Fernandez, R. et al (2013): Economic burden of cancer across the European Union: a population-based cost analysis; Lancet Oncology; 14: 1165–74, published online October 14: http://dx.doi.org/10.1016/S1470-2045(13)70442-X				

Table 8-21: Estimates of the annual cost per patient of cancer						
Mortality rate after 5 years	**Cancer**	**Health care**	**Productivity losses**	**Lost working days**	**Informal care**	**Total cost per case (€)**
22%	Prostate	€ 4,027	€ 543	€ 290	€ 1,390	€ 6,250
80%	Lung	€ 6,952	€ 16,319	€ 1,337	€ 6,278	€ 30,887
24%	Breast	€ 4,378	€ 2,118	€ 1,164	€ 2,086	€ 9,747
44%	Colorectal	€ 5,037	€ 3,411	€ 833	€ 2,567	€ 11,849
47%	All cancers	€ 6,047	€ 5,047	€ 1,118	€ 2,753	€ 14,966
Source: Luengo-Fernandez, R. et al (2013): Economic burden of cancer across the European Union: a population-based cost analysis; Lancet Oncology; 14: 1165–74, published online October 14: http://dx.doi.org/10.1016/S1470-2045(13)70442-X						

Table 8-22: Average unit cost (€), by country, in 2009									
Country	Mortality losses (Yearly earnings)		Morbidity losses (Daily earnings)	Informal care (Hourly earnings)		Health care unit costs			
	Males	Females		Carers in employment	Carers not in employment	GP visit	Outpatient visit	A&E visit	Inpatient day
Austria	34,982	21,520	125	16	10	45	58	121	446
Belgium	41,748	35,659	170	21	9	26	53	70	499
Bulgaria	4,181	3,357	17	2	1	6	17	27	74
Cyprus	25,333	20,307	100	13	6	15	21	44	284
Czech Rep.	12,108	9,096	47	6	2	9	14	71	187
Denmark	58,747	46,344	230	29	11	18	81	144	663
Estonia	11,602	8,254	43	5	2	16	44	116	166
Finland	39,000	31,908	154	19	11	62	240	252	656
France	34,146	25,118	130	16	9	33	125	85	843
Germany	46,697	35,654	181	23	10	22	81	105	545
Greece	31,935	21,611	121	15	6	23	53	57	378
Hungary	11,270	7,964	42	5	2	4	5	62	91
Ireland	45,405	33,073	173	22	10	49	168	203	826
Italy	29,325	23,735	118	15	7	22	71	72	643
Latvia	8,623	7,218	34	4	2	8	32	36	98
Lithuania	7,734	6,711	31	4	2	9	22	38	70
Luxembourg	57,576	47,363	231	29	11	36	56	72	830

Table 8-22: Average unit cost (€), by country, in 2009									
Country	Mortality losses (Yearly earnings)		Morbidity losses (Daily earnings)	Informal care (Hourly earnings)		Health care unit costs			
	Males	Females		Carers in employment	Carers not in employment	GP visit	Outpatient visit	A&E visit	Inpatient day
Malta	17,647	14,712	72	9	4	32	50	98	325
Netherlands	45,163	33,738	174	22	9	39	109	148	531
Poland	10,334	8,404	41	5	2	13	53	30	185
Portugal	19,276	16,815	79	10	3	31	85	86	194
Romania	5,436	5,025	23	3	1	8	11	61	58
Slovakia	11,291	8,396	44	5	2	17	24	33	150
Slovenia	18,048	16,043	74	9	4	23	34	96	330
Spain	25,437	21,188	103	13	5	35	74	139	363
Sweden	36,246	29,721	144	18	12	115	381	237	468
UK	35,706	20,519	124	16	7	37	131	116	516
Source: Luengo-Fernandez et al (2013)									

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