WORKING FOR A HEALTHY FUTURE

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Health, socio-economic and environmental aspects of possible amendments to the EU Directive on the protection of workers from the risks related to exposure to carcinogens and mutagens at work

Benzo[a]pyrene

Authors:

JW Cherrie, M Gorman Ng, A Sánchez Jiménez, A Shafrir and M van Tongeren (IOM)

R Mistry, M Sobey and C Corden (AMEC Environment & Infrastructure UK Ltd)

L Rushton (Imperial College, MRC-HPA Centre for Environment and Health)

S Hutchings (Imperial College)

Other project team members:

A Searl (IOM), O Warwick and M-H Bouhier (AMEC Environment & Infrastructure UK Ltd), T Kaupinnen and P Heikkila (Finnish Institute of Occupational Health), H Kromhout (IRAS, University of Utrecht), L Levy (IEH, Cranfield University)

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SUMMARY

Benzo[a]pyrene (B[a]P) has been classified by the International Agency for Research on Cancer (IARC) as carcinogenic to humans based on animal toxicity and other supporting information (IARC category 1). Under the classification and labelling legislation in Europe it is classified as a Cat 2 carcinogen and is therefore within the scope of the EU Carcinogens Directive. However, there is no occupational exposure limit (OEL) for benzo[a]pyrene specified in the Directive.

Benzo[a]pyrene is a polycyclic aromatic hydrocarbon (PAH), which is generally only found as part of a complex mixture in emissions from combustion or other similar sources. It is often used as a marker of exposure to the PAH mixture and it is in this way that we have evaluated it in this report. This report considers the likely health, socioeconomic and environmental impacts associated with possible changes to the Carcinogens Directive, in particular the possible introduction of an occupational exposure limit (OEL) of 0.002 mg/m^3 for benzo[a]pyrene (2 µg/m^3).

There is potential exposure to benzo[a]pyrene in aluminium, iron and steel production plants, foundries, waste incineration, mining or oil refining, coke and tar production plants, coal gasification sites, bitumen and asphalt production plants, road and roof tarring operations, and other facilities that burn carbonaceous materials. While benzo[a]pyrene may be found in diesel engine exhaust emissions we have excluded this source as we have considered these emissions in a separate report (P937/13).

We estimated that in 2006 in the EU there were 234,000 workers who were potentially exposed to high levels of benzo[a]pyrene and about 7 million to low levels. The overall geometric mean exposure level was 0.000023 mg/m^3 with a geometric standard deviation of 6.29. According to these data exposure concentrations are below the suggested OEL in all EU countries and it is unlikely that many workers are exposed above the potential OEL of 0.002 mg/m^3. We assume exposure levels have been decreasing by about 6% per annum and that this reduction will continue for at least the next 20-years.

Exposure to PAH may cause lung and bladder cancer and skin contact with tar or pitch containing PAH may cause non-melanoma skin cancer (NMSC). For bladder cancer we identified a relative risk of 1.44 for high exposed work groups and 1.0 for low exposed groups. In the case of lung cancer we have identified four risk categories as shown in the following table.

Exposure category (µg/m^3)	<0.01	0.01 - <0.75	0.75 - <2.0	2.0+
RR estimate	1.00	1.02	1.08	1.25

The low exposed were assumed to have a RR=1.0 for lung cancer, corresponding to <0.00001 mg/m^3 (i.e. 0.01µg/m^3) B[a]P 8-h average. The main risk from NMSC appears to be from dermal contact with coal tars and pitches in road workers and roofers. The combined risk estimate of 1.74 was selected for groups where such exposure was likely.

We estimate that in 2010 in the EU there will be about 151 incident cases of bladder cancer and 466 cases of lung cancer that might be attributable to past exposure to

PAH mixtures containing benzo[a]pyrene (corresponding to 0.114% of all bladder cancer cases and 0.153% of lung cancers amongst the exposed workers). There are estimated to be 47 bladder and 430 lung cancer deaths in the same year attributable to past PAH exposure. Future attributable incidence and mortality are expected to decreases from the identified decline in exposures. By the decade starting 2060 it is judged there will be three bladder cancer registrations per year and five lung cancer registrations per year that are attributable to exposure to PAH containing benzo[a]pyrene. DALYs decrease from 6,978 to 64 per year and 703 to 17 each year for lung and bladder cancer, respectively.

For NMSC there are 254 incident cases in 2010 attributed to past exposure to PAH containing benzo[a]pyrene with two deaths and 24 DALYs. The number of NMSC each year from PAH exposure is estimated to rise slowly so that by the decade starting 2060 there are 299 incident cases, three deaths and 29 DALYs, per year. The main cause of the increase is the increase in survival amongst the population as a consequence of improving general health and our assumption of continued exposure to benzo[a]pyrene in remediation of roads and roofs containing tar or pitch. Total estimated health costs over the period up to 2069 that are associated with inaction range from €6,292m to €19,438m.

The impacts of NMSC are relatively limited compared to the total health costs (€6-19bn), with total NMSC health costs over the period 2010-69 being between €45m and €453m. The rest of the health costs relate to bladder and lung cancer.

Current exposures in the EU are judged to be well below 0.002 mg/m^3 and so there are no predicted health benefits and no important costs associated with compliance with the suggested OEL. There are also no social or macro-economic costs associated with introducing an OEL at the suggested level.

There are no significant environmental impacts foreseen.

PROBLEM DEFINITION

1.1 OUTLINE OF THE INVESTIGATION

Benzo[a]pyrene (B[a]P) is a polycyclic aromatic hydrocarbon (PAH), which is generally only found as part of a complex mixture in emissions from combustion or other similar sources. It is often used as a marker of exposure to the PAH mixture and it is in this way that we have evaluated it in this report. PAHs containing benzo[a]pyrene may cause lung, bladder and non-melanoma skin cancer. Exposure to benzo[a]pyrene has been classified as a group 1 carcinogen (Carcinogenic to humans) by the International Agency for Research on Cancer (IARC)[1], based on the available toxicology data plus mechanistic and other relevant data. It is also classified as a Cat 2 carcinogen in the EU under the classification and labelling legislation[2]. Benzo[a]pyrene is therefore already regulated as a carcinogen throughout the EU. In this assessment we consider the impacts of introducing an exposure limit for benzo[a]pyrene within the EU Carcinogens and Mutagens Directive.

The key objectives of the present study are to identify the technical feasibility and the socioeconomic, health and environmental impacts of introducing a regulatory exposure limit of 0.002 mg/m^3.

1.2 OELS/EXPOSURE CONTROL

National occupational exposure limits (OELs) in EU member states are presented in Table 1.1. These are expressed as long-term limits, averaged over an 8-hour working day or short-term exposure limits (STELs), i.e. 15 minutes. OELs from selected countries outside the EU are also presented for comparison.

[1] Available at: http://monographs.iarc.fr/ENG/Classification/ClassificationsAlphaOrder.pdf
[2] Available at: http://ecb.jrc.ec.europa.eu/esis/

Table 1.1 Occupational exposure limits in various EU member states and selected countries outside the EU

Country	8-hrs long term mg/m^3	STELs mg/m^3
Austria	(0.005 certain uses in coking plants) 0.002 (other uses)	0.008 (certain uses in coking plants) 0.02 (other uses)
Czech Republic	0.005	0.025
Estonia	0.002	0.02
Hungary		0.002
Finland	0.01	
Lithuania	0.002	0.02
Latvia	0.00015	
Poland	0.002	
Sweden	0.002	0.02
Slovakia	0.005 (coke) 0.002 (other)	
Slovenia	0.005 (coke) 0.002 (other)	0.02 (coke) 0.008 (other)
The Netherlands	0.0005507	
Canada - Quebec	0.005	
Switzerland	0.002	
USA - OSHA	0.2	

Source: http:www.dguv.de/bgia/en/gestis/limit_values/index.jsp

The long-term OELs from the EU member states range from 0.00015 to 0.01 mg/m^3. Austria, Czech Republic, Estonia, Hungary, Lithuania, Sweden and Slovenia have STELs ranging from 0.002 – 0.02 mg/m^3. The terms of reference for this project specify that, where they exist, the most commonly adopted value or range of values of OELs adopted at national level in the EU Member States and elsewhere should be assessed. For the purposes of this report an OEL of 0.002 mg/m^3 is considered typical for the EU.

1.3 DESCRIPTION OF DIFFERENT SOURCES OF EMISSION

Benzo[a]pyrene is usually present as a component of PAH mixtures. PAHs are a group of over 100 different chemicals that are formed during the incomplete burning of organic material (coal, oil, wood, gas, garbage, or other organic substances like tobacco or charbroiled meat).

Emissions of benzo[a]pyrene have been estimated as a function of SNAP sectors in the UK (see Table 1.2). This reveals that, in 2004, emissions from non-industrial combustion plants (domestic space, water heating and in other non-residential buildings) was the largest emitting sector, contributing to nearly one quarter of the national total. This consists principally of the estimates of emissions from domestic wood and coal combustion. The next largest emission sector was ‘Other Sources and Sinks’, which includes emissions resulting from natural fires, accidental fires and bonfires.

Table 1.2 Estimated UK Benzo[a]pyrene emissions for 2004 and projected emissions from 2005 to 2020

SNAP Code	Source Description	Benzo[a]pyrene emissions (kg)				
		2004	**2005**	**2010**	**2015**	**2020**
01	Combustion in energy production	57	67	67	66	64
02	Non-industrial combustion plants	3790	3526	2953	3010	3203
03	Combustion in industry	2266	2266	2601	2532	2566
04	Production processes	1027	1294	1342	1342	1342
06	Solvent and other product use	25	44	51	51	51
07	Road transport	442	341	245	204	196
08	Other mobile sources	59	681	681	681	681
09	Waste treatment and disposal	681	681	681	681	681
11	Other sources and sinks	3185	3185	3185	3185	3185
Total		11533	11463	11182	11128	11346

Source: AEA (2007) Assessment of benzo[a]pyrene concentrations in the UK

Therefore, potential exposure to benzo[a]pyrene occurs in aluminium, iron and steel production plants, foundries, waste incineration, mining or oil refining, coke and tar production plants, coal gasification sites, bitumen and asphalt production plants, road and roof tarring operations, and other facilities that burn carbonaceous materials.[3]

Benzo[a]pyrene may be used in biochemical, biomedical, laboratory, and/or cancer research. Here it is used in very small quantities and in controlled ways and so exposure is likely to be very low.

Exposure is mostly via inhalation but dermal exposure may also occur.

The highest levels of exposure occur during the production of coke. Most of the data compiled on occupational exposure in coke production plants dated from 1990s, with very few studies since 2000. There has been a decrease in the production of coke in the EU since the 1990 as a result of the increase production in China (60 % of the overall production in 2008). Currently there are very few coke production plants in the EU, mostly located in England, Germany, Belgium and France.[4]

1.4 RISKS TO HUMAN HEALTH

1.4.1 Introduction

Bladder cancer

Bladder cancer is a relatively common cancer that is generally diagnosed on people over 60 years of age. There are about twice as many cases diagnosed on men

[3] ATSDR (1995) Agency of Toxic Substances and Disease Registry Public Health Statement for Polycyclic Aromatic Hydrocarbons Available online at URL: http://www.atsdr.cdc.gov/toxprofiles/phs69.html
[4] Available at: www.allbusiness.com

compared to women. In the EU it comprises about 5% of all cancer incidences (Ferlay *et al*, 2007). Key environmental risk factors are cigarette smoking, some industrial chemicals, diet and genetic factors. Mortality amongst European men, especially younger men, has been dropping steadily since the mid-1970s, which is probably due to changes in smoking prevalence and reductions in occupational exposure to aromatic amines such as benzidine and α-and ß-naphthylamine (Levi *et al*, 2004).

Early symptoms of bladder cancer include intermittent haematuria (blood in the urine), changes in the frequency of urination and pain when urinating, although all of these symptoms are also associated with other non-malignant conditions. About three quarters of people diagnosed with bladder cancer can be treated by relatively minor surgery (transurethral resection of superficial bladder cancer), with chemotherapy and/or immunotherapy, giving a relatively good prognosis. For more serious cases of bladder cancer (muscle invasive tumours) the treatment options include surgery, chemotherapy and radiotherapy. Survival rates are lower for these types of tumours.

Lung cancer

Lung cancer is the most common malignant neoplasm among men in most countries and incidence has been steadily increasing among women. In the EU the incidence is about 30 per 100,000 persons, with about 290,000 new cases each year[5]. The main environmental cause is cigarette smoking, although other factors, such as genetic susceptibility, poor diet, and indoor air pollution, may act in conjunction with tobacco consumption as risks for lung cancer. Among both men and women, the incidence of lung cancer is low in individuals aged less than 40 years and increases up to age 70 or 75 (Quinn *et al*, 2001). In most European countries, the risk of lung cancer among men is regularly two to three times higher in lower than higher socio-economic classes (Quinn *et al*, 2005).

Lung cancer is highly fatal, so the trends in incidence and mortality are closely similar. In Europe about 10% of lung cancer patients survive for more than 5-years post diagnosis (Verdecchia *et al* 2007). Lung cancer accounted for 15.5% of all cancers in men in Europe, and 6.9% of such cases in females (Ferlay *et al*, 2007).

There are a number of occupational agents that are known or suspected of causing lung cancer. Rushton *et al*, (2010) estimated that in Great Britain occupational exposures account for about 21% of male lung cancers and 5% of female lung cancers.

Non-melanoma skin cancer

Skin cancer can be classified depending on the type of cells that are affected:

- Melanoma occurs in the cells that produce skin pigment (melanocytes) and is the less common but more dangerous than the other forms;
- Basal cell carcinoma arises in the cells in the lowest layer of the epidermis and is the commonest type of skin cancer;
- Squamous cell carcinoma involves cells in the middle layer of the epidermis.

[5] Available at: http://globocan.iarc.fr/factsheets/populations/factsheet.asp?uno=990

Squamous and basal cell skin cancer are grouped as non-melanoma skin cancer (NMSC). Non-melanoma skin cancer is the most common malignant neoplasm in Caucasian populations around the world. The main environmental cause is exposure to sunlight (UV radiation) and as a consequence the disease shows marked variation between and within countries. The incidence is increasing rapidly in white populations in Europe, the US, Canada and Australia; the average increase of NMSC has been 3-8% per year since the 1960s.

If detected early, NMSC is rarely fatal; the cure rates are close to 99%. Treatment is relatively simple with the tumour often being excised in an outpatient clinic. Radiation therapy and/or chemotherapy may also be necessary depending on the stage of tumour development at diagnosis. A consequence of the straightforward treatment is that incidence statistics are less reliable than for other forms of cancer, i.e. cancers with a higher rate of fatality.

There are no reliable statistics about the incidence of NMSC in Europe. Trakatelli *et al* (2007) present data for NMSC incidence in Italy, UK, Slovakia and some other European countries that suggests the incidence is about 100 per 100,000 population per year, which would imply there could be about 500,000 incident cases in the EU each year.

The risk of NMSC is increased among workers in a number of industries and occupations. The responsible agent or agents have been identified for several, but not all of these high-risk workplaces. These include: solar radiation, arsenic and arsenic compounds, coal tar and pitch, soot, benzo(a)pyrene, shale oils, and some mineral oils.

1.4.2 Summary of the available epidemiological literature on risk

Through animal experiments and other toxicological studies benzo[a]pyrene has been established as a carcinogen for skin and lung cancers. It is thought to be the component of coal tars and shale oils responsible for these cancers in occupational groups such as chimney sweeps and machinists. However, because it is usually only one of several potential carcinogens in coal tars and pitches and fumes and gases containing PAHs it has been difficult to quantify the risks specifically due to B[a]P using epidemiological studies. For this reason and because it is thought to be one of the most important carcinogens within PAHs it has been decided that the risk estimates for B[a]P will be derived from epidemiological studies of PAHs as a whole.

Bladder Cancer

There have been many studies reporting excess risk from bladder cancer due to exposure to PAHs in a wide range of industries. In an Italian population-based case-control study of 121 male bladder cancer cases and 342 matched controls exposure to PAH and aromatic amine (AA) was assessed using a job-exposure matrix (JEM) (Bonassi *et al* 1989). An increased risk was found with both possible and definite exposure to PAH. The risk associated with possible exposure to PAHs was not affected by adjustment for smoking, whereas it was greatly reduced after adjustment for AA exposure. For definite exposure to PAH there was little change in the OR estimates when the analysis was adjusted for smoking and AA. The risk was also relatively constant irrespective of the level of AA exposure.

Boffetta *et al* (1997) reviewed the cancer risk from occupational and environmental exposure to PAHs, in aluminium production, coal gasification, coke production, iron and steel foundry, diesel engine exhaust exposure, and workers exposed to coal tars and related products, which included tar distillation, shale oil extraction, creosote exposure, carbon black manufacture, carbon and graphite electrode manufacture, chimney sweeps, and calcium carbide production. Increased risks from bladder cancer were found for most industry sectors except coke production.

In a meta-analysis combining data from 11 case-control studies (3,346 incident cases and 6,840 controls) conducted between 1976 and 1996 in six European countries a number of occupations with known exposure to PAHs showed an increased risk of bladder cancer (Kogevinas *et al*, 2003). A JEM was applied to evaluate exposure to PAHs. In the JEM, prevalence of exposure and average levels of exposure were evaluated for each occupation in different time periods. Overall exposure was defined as the product of these two continuous variables, and exposed subjects were classified in tertiles of maximum achieved exposure during their job history. Bladder cancer risk was shown to increase with higher exposure to PAHs with an OR for the highest exposure tertile of 1.23 (95%CI=1.07-1.4). In the lowest tertile the risk was just above one. The risk attributable to occupation ranged from 4.2 to 7.4%, with an estimated 4.3% for exposure to PAHs.

Lung cancer

There have been several reviews of epidemiological studies investigating the effects of exposure to PAHs and lung cancer. In a review by Mastrangelo *et al* (1996) an exposure-response relationship was observed between lung cancer risk and exposure as measured as benzene soluble matter (BSM), benzo(a)pyrene or PAHs. The overall findings suggested exposure at 0.2 mg/m^3 of BSM (which indicates PAH exposure) for 40 years gives a RR of 1.2-1.4 for lung cancer.

In the review by Boffetta *et al* (1997) the authors concluded the lung was the major target organ of PAH carcinogenicity and the increased risk was present in most of the industries and occupations they reviewed.

A review and meta-analysis of 39 cohorts estimated meta-RRs for different industry sectors (Armstrong *et al,* 2004). The average estimated unit RR (URR) at 100μg/m^3-years B[a]P was estimated to be 1.20 (95%CI=1.11-1.29) and was not sensitive to particular studies or analytic methods. However, the URR varied by industry (Table 1.3).

Table 1.3 Relative risks at 100 μg/m^3 B[a]P years; from Armstrong *et al* (2004)

Industry	Mean Unit Relative Risk (95%CI)	
Coke ovens	1.17	(1.12-1.22)
Gas workers	1.15	(1.11-1.20)
Aluminium smelter	1.16	(1.05-1.28)
Above 3 combined	1.17	(1.12-1.22)
Carbon anode	4.30	(0.81-22.79)
Asphalt	17.50	(4.21-72.78)
Tar distillery	12.28	(0.48-314.4)
Chimney sweep	16.24	(1.64-160.7)
Power	>1000	(0->1000)
Carbon black	0	(0->1000)

Bosetti *et al* (2007) also reviewed the results from cohort studies on workers exposed to PAHs in various industries. To obtain a quantitative overall estimate the observed and expected number of deaths/cases in each study were summed and the overall SMR calculated as an un-weighted ratio. Pooled RRs and the corresponding 95%CIs were computed as a weighted average of the SMR/SIR, using the inverse of the variance of the logarithm of the SMR/SIR as weight. The results of this analysis are given in Table 1.4.

Table 1.4 SMR and pooled RR for exposure to PAHs in various industries and occupations (source: Bosetti *et al*, 2007)

Industry	No. of cohorts	SMR	Pooled RR* (95%CI)
Aluminium production	8	1.01	1.03 (0.95-1.11)
Coal gasification	4	2.14	2.29 (1.98-2.64)
Coke production	10	1.49	1.58 (1.47-1.69)
Iron and steel foundry	9	1.39	1.40 (1.32-1.49)
Tar distillation	3	1.19	1.21 (0.95-1.55)
Creosote	2	1.11	1.14 (0,85-1.51)
Roofers	2	1.50	1.51 (1.28-1.78)
Asphalt workers	2	1.12	1.14 (1.07-1.22)
Carbon black production	2	1.21	1.30 (1.06-1.59)
Carbon electrode manufacture	6	0.96	1.00 (0.82-1.23)

* Weighted average of the study SMRs, using the inverse of the variance as weight

Non-melanoma skin cancer

The risk of non-melanoma skin cancer (NMSC) from exposure to PAHs has been difficult to assess because most studies have only analysed mortality, and the risk only increases after heavy dermal exposures (Boffetta *et al*, 1997). Partanen and Boffetta (1994) published a review and meta-analysis of 20 epidemiological studies for cancer risk in asphalt workers and roofers of which 4 reported results for skin cancer. The results are somewhat ambiguous, however, as, although results are reported as NMSC within the individual study description it is apparent that melanoma is also included for at least 1 study (Maizlish *et al* 1988). Maizlish reported a significantly increased risk of skin cancer mortality in Californian highway maintenance workers (RR=2.18, 95% CI=1.19-3.66, n=14). A study on US roofers and water proofers (Hammond *et al* 1976) employed for more than 20-years also observed an elevated risk of skin cancer mortality (RR=4.00, 95%CI=0.83-11.7, n=3). Pukkala *et al* (1992) found an increased risk for skin cancer incidence among Finish asphalt workers (RR=2.48, 95%CI=0.06-13.8, n=1). A reduced incidence risk was observed in Danish mastic asphalt workers in road paving and flooring (RR=0.67, 95%CI=0.14-1.96, n=3). Combining these results gave, a significantly increased risk was observed for all asphalt workers (RR=1.74, 95% CI=1.07-2.65, n=21).

1.4.3 Choice of risk estimates to assess health impact

Bladder Cancer

Results from all the industry sectors reviewed by Bofetta *et al* (1997), with the exception of diesel exposure and coke production (for which no evidence was found for a raised risk of bladder cancer), have been used by the study team to calculate an inverse variance weighted combined estimate of RR (random effects model; Q test indicated significant heterogeneity, Q = 48.75, p < 0.0001). In the present study we have estimated the resulting RR based on 26 studies as 1.44 (95%CI=1.2-1.7), which has been used for the high exposed group. Estimates of a combined OR from population based case control studies covered in the same review (again excluding diesel exposures and drivers, and mineral oils (cutting fluids)) result in lower relative risks for broader based definitions of workplace exposure, of 0.9 (95%CI=0.8–1.1) for a large Montreal case control study, and 1.2 (95%CI=1.1-1.4) for a range of other smaller studies (both random effects model). The RR for the ‘low exposed’ group has been set to 1 to reflect these results, and the lowest tertile group from Kogevinas *et al* (2003).

Lung cancer

The risk estimate used is an adaptation of the Unit Relative Risk (URR) estimate for all the industrial cohorts from the paper by Armstrong *et al* (2004) meta-analysis, adjusted for smoking. A 20 year exposed working lifetime is assumed and the RR is given by ((URR) to the power of (x * 20/100)) where “x” is the mean benzo[a]pyrene level (e.g. 8 hour time weighted average (TWA)) in μg/m^3 for the exposed. This is 1.31 (95%CI=1.16–1.48), mean RR at 100 μg/m^3 B[a]P years.

Unwin *et al* (2006) gives an indication from airborne monitoring of PAHs in an HSE commissioned cross-industry occupational hygiene survey, of the 8 h TWA levels of benzo[a]pyrene in a range of workplaces. 8 h TWA B[a]P levels ranged from <0.01 to 6.21 μg/m^3, with 50% of the samples below 0.01 μg/m^3, 90% below 0.75 μg/m^3, and 95% below 2.0 μg/m^3. For the present study the above calculation was used to derive a RR estimate at the mean (class mid-point) exposure levels give the following (Table 1.5):

Table 1.5 Lung cancer risk estimates for different exposure categories

8 h TWA category (µg/m^3)	<0.01	0.01 - <0.75	0.75 - <2.0	2.0+
Mid-point B[a]P level (µg/m^3)	0.005	0.38	1.375	4.105
RR estimate	1.00	1.02	1.08	1.25

The low exposed were assumed to have a RR=1.0, corresponding to <0.00001 mg/m^3 (i.e. 0.01µg/m^3) B[a]P 8-h average.

Non-melanoma skin cancer

The main risk from NMSC appears to be from dermal contact with coal tars and pitches in road workers and roofers. The combined risk estimate of 1.74 (95%CI=1.07-2.65) from Partanen & Boffetta (1994) has been chosen to be applied to this industry sector only.

2 BASELINE SCENARIOS

2.1 SOURCES OF BENZO[A]PYRENE

Benzo[a]pyrene is not generally produced intentionally but is an unintentional by-product of combustion in various processes and is a component of products such as coal tars.

As indicated above, the main sectors where exposure is likely to occur are aluminium, iron and steel production plants, foundries, waste incineration, mining or oil refining, coke and tar production plants, coal gasification sites, bitumen and asphalt production plants, road and roof tarring operations, and other facilities that burn carbonaceous materials.

2.2 PREVALENCE OF BENZO[A]PYRENE EXPOSURE IN THE EU

The prevalence of exposure to B[a]P was estimated from the Finnish CAREX estimate of 2007 as this was the only available source. The proportion of exposed workers was multiplied by the number of workers employed in each industry in each country. The number of employees in each industry was obtained from the structural business statistics (SBS) and the labour force survey (LFS) available on the Eurostat database[6] for the year 2006. When data for 2006 was not available data from other years (1998-2005) was used. For Finland we used the data provide in the Finnish CAREX database.

The estimated exposure prevalence for the EU member states based on 2006 employment data is shown in Table 2.1. Approximately 234,000 workers in the EU in 2006 were potentially exposed to high levels of benzo[a]pyrene and 7 million to low levels of benzo[a]pyrene.

[6] Available at: http://epp/ec/europa.eu/

The estimated number of male and female employees in each industry group in each EU member state is shown in Appendix 8.1. The estimates were obtained by applying the average male to female employee ratio for the industry group for each country to the total number of employees. Male to female employee ratios were calculated with data from the LFS.

Table 2.1 Number of workers exposed to benzo[a]pyrene by country and NACE code

	NACE Code															
Country	**13**	**14**	**15**	**20**	**21**	**22**	**23**	**24**	**26**	**27**	**28**	**29**	**34**	**35**	**40**	**45**
Austria	NA[1]	27	348	121	48	7	NA	230	135	5,535	541	461	1,125	385	847	545
Belgium	NA	NA	441	43	38	9	504	599	123	5,648	512	247	1,599	321	489	567
Bulgaria	502	42	502	63	30	5	407	222	112	3,753	315	397	95	384	1,131	400
Cyprus	0	3	58	10	2	1	11	16	13	61	29	6	8	5	NA	74
Czech Republic	2	37	NA	230	54	12	258	354	293	9,604	1,260	923	3,822	739	1,090	849
Denmark	0	7	390	47	20	10	NA	256	69	897	358	354	217	268	406	438
Estonia	0	5	79	61	5	2	92	26	22	69	98	31	76	97	196	108
Finland	45	14	178	100	83	9	230	160	73	2,450	369	378	222	552	390	375
France	27	160	NA	273	212	52	2,347	2,353	528	16,694	3,238	1,728	9,096	5,044	4,705	3,564
Germany	0	200	3,763	448	388	100	1,781	3,917	923	43,022	5,949	5,970	28,558	4,738	6,904	3,235
Greece	56	35	393	45	20	8	351	155	98	2,297	304	129	97	475	NA	668
Hungary	21	25	558	84	47	9	548	274	109	3,205	562	388	1,741	275	967	518
Ireland	NA	21	226	22	9	4	NA	212	42	410	99	65	131	129	287	156
Italy	23	174	2,019	529	213	45	1,454	1,709	936	22,741	5,336	3,206	5,644	3,685	2,616	3,982
Latvia	0	5	161	101	4	3	4	37	24	601	73	41	42	185	384	158
Lithuania	0	9	235	104	6	3	304	52	46	154	139	62	40	244	569	269
Luxembourg	0	2	NA	2	NA	NA	0	9	11	1,012	32	14	NA	NA	28	77
Malta	NA	2	NA	NA	1	1	NA	8	NA	NA	NA	2	2	127	NA	28
Netherlands	NA	12	581	62	59	22	568	545	112	3,499	743	506	765	855	565	1,038
Poland	NA	NA	2,051	431	119	27	1,280	924	539	12,026	2,095	1,172	4,086	2,416	4,617	1,511
Portugal	82	79	490	146	32	10	183	184	230	1,613	665	269	786	NA	310	1,066
Romania	676	63	943	253	44	10	597	417	230	10,144	775	584	2,124	2,052	2,824	922
Slovakia	49	14	215	46	21	3	15	110	80	4,430	260	256	988	249	761	156
Slovenia	NA	NA	89	38	14	3	8	120	37	1,521	257	153	302	90	227	155
Spain	39	165	1,786	324	149	43	757	1,193	765	12,292	2,834	1,094	5,377	1,971	1,153	6,037
Sweden	409	15	NA	133	111	14	280	372	78	7,825	642	663	2,917	756	858	586
United Kingdom	0	171	2,018	267	199	91	2,065	1,834	430	12,212	2,508	1,572	6,064	5,002	3,254	3,007
Total	1,931	1,286	17,524	3,983	1,929	502	14,044	16,290	6,058	183,715	29,993	20,671	75,924	31,043	35,578	30,490

[1] NA = Not Available

Country	NACE Code 50	51	60	63	73	74	75	80	Grand Total
Austria	2,259	1,429	433	10,963	23	24,656	58,690	18,989	127,335
Belgium	2,071	1,634	341	9,843	26	34,696	97,608	32,599	189,713
Bulgaria	NA	NA	336	7,649	1	10,488	52,123	18,735	97,293
Cyprus	232	143	17	1,346	0	1,161	6,939	1,948	12,076
Czech Republic	2,351	1,721	756	8,086	26	30,125	74,355	24,395	160,419
Denmark	1,603	1,235	280	6,406	27	21,301	38,570	18,419	91,223
Estonia	321	292	83	2,152	2	3,491	9,027	5,081	21,383
Finland	1,309	700	269	6,600	106	15,200	27,100	14,600	71,134
France	11,620	7,730	2,620	52,696	180	203,482	558,263	154,029	1,038,914
Germany	18,555	9,148	2,411	97,923	403	276,721	667,567	180,390	1,357,044
Greece	2,762	2,413	456	7,918	38	23,492	88,256	26,220	156,556
Hungary	2,080	1,210	585	6,066	28	27,232	66,209	27,598	139,952
Ireland	1,064	625	109	3,873	10	11,986	24,182	11,223	54,822
Italy	12,228	7,944	1,975	64,210	114	165,859	328,585	133,057	765,078
Latvia	555	394	171	3,208	5	3,678	20,260	7,626	37,678
Lithuania	1,188	560	234	3,008	3	4,727	17,568	11,495	40,960
Luxembourg	213	104	47	517	NA	3,381	5,152	1,307	11,893
Malta	96	70	8	912	0	688	3,249	1,053	6,245
Netherlands	3,879	3,415	703	17,348	145	105,505	129,889	46,648	316,957
Poland	6,848	5,182	1,759	14,907	18	56,927	212,435	98,360	428,558
Portugal	3,343	2,088	376	7,493	5	39,541	81,502	27,045	167,269
Romania	2,816	2,525	747	13,233	99	24,655	112,646	35,908	214,703
Slovakia	423	632	222	2,108	19	5,915	37,595	14,426	68,737
Slovenia	412	312	115	1,710	11	4,552	13,135	6,529	29,636
Spain	10,434	8,332	2,068	45,768	72	160,828	283,495	92,454	638,336
Sweden	2,215	1,649	488	11,444	NA	29,951	58,504	42,085	161,331
United Kingdom	15,546	8,473	2,027	72,681	443	274,188	467,548	219,939	1,099,966
Total	106,423	69,960	19,635	480,067	1,806	1,564,425	3,540,451	1,272,159	7,505,213

Classification of Industries by Exposure Level

Industries in which exposure to b[a]p occurs have been classified as high or low exposure compared to data from 1975, based on an evaluation of the peer-reviewed literature, information from industry and expert judgement. The industries, grouped by NACE code were identified from the CAREX data. The exposure classification by industry and total number of people exposed is presented in Table 2.2.

There was not data in the Spanish, Italian and Finnish CAREX databases on the prevalence of exposure in the Sewage and refuse disposal, sanitation and similar activities industry (NACE code 90). Prevalence on exposure to diesel, in the Sewage industry was not included in the CAREX database. Since, most of the exposure to benzo[a]pyrene in this industry is likely to be due to exposure to diesel (B[a]P is contained in diesel emissions) we assumed that the number of people exposed in this industry is very low.

Table 2.2 Classification of industries by exposure level to benzo[a]pyrene in 1975

Industry	NACE (rev 1.1)	Historical Exposure Classification[1]	Prevalence of exposure[2]
Mining of metal ores	13	L	1,931
Other mining and quarrying	14	L	1,286
Manufacture of Food Products and Beverages	15	L	17,524
Manufacture of textiles	17	L	0
Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting mater	20	L	3,983
Manufacture of pulp, paper and paper products	21	L	1,929
Publishing, printing and reproduction of recorded media	22	L	502
Manufacture of coke, refined petroleum products and nuclear fuel	23	H	14,044
Manufacture of printing inks	24	L	16,290
Manufacture of other non-metallic mineral products	26	H	6,058
Manufacture of basic metals	27	H	183,715
Manufacture of fabricated metal products, except machinery and equipment	28	H	29,993
Manufacture of machinery and equipment	29	L	20,671

Industry	NACE (rev 1.1)	Historical Exposure Classification[1]	Prevalence of exposure[2]
Manufacture of motor vehicles, trailers and semi-trailers	34	L	75,924
Manufacture of other transport equipment	35	L	31,043
Electricity, gas, steam and hot water supply	40	L	35,578
Construction	45	L	30,490
Sale, maintenance and repair of motor vehicles and motorcycles; retail sale of automotive fuel	50	L	106,423
Wholesale trade and commission trade, except of motor vehicles and motorcycles	51	L	69,960
Hotels and restaurants	55	L	0
Land transport; transport via pipelines	60	L	19,635
Supporting and auxiliary transport activities; activities of travel agencies	63	L	480,067
Post and telecommunications	64	L	0
Research and development	73	L	1,806
Other business activities	74	L	1,564,425
Public Administration and Defence	75	L	3,540,451
Education	80	L	1,272,159
Health and social work	85	L	0
Sewage and refuse disposal, sanitation and similar activities	90	L	unknown

[1] Relevant to 1975 Exposure Levels
[2] Data retrieved from the 2007 Finnish CAREX database. Prevalence estimation methods are described in section 2.2

2.3 LEVEL OF EXPOSURE TO BENZO[A]PYRENE

2.3.1 Estimation of exposure levels

No occupational exposure data were available from the industry. A literature review was carried out in PubMed using the terms occupational exposure and benzo[a]pyrene. The peer-reviewed literature with exposure data relevant to the industries classified as high exposure levels is summarised in the sections below.

The geometric standard deviation (GSD) and geometric mean (GM) were not always reported. In those cases where information on the arithmetic mean (AM) and standard deviation was available, GM and GSD were calculated as described in Lavoué *et al* (2007). When the median was reported this was taken as an approximate estimation of the GM.

There were insufficient data on exposure to estimate exposure concentration values for each EU country, so it is assumed that concentrations in each industry are similar for all EU countries.

Manufacture of coke, refined petroleum products and nuclear fuel (NACE code 23)

Six studies, in the EU were identified with exposure data on the manufacture of coke. Exposure data to PAHs in coke production plants in the 1990s were reported in several studies. However, most of the reviewed studies reported concentrations of 1-hydroxypyrene (a urinary metabolic of pyrene) (see Strunk *et al* 2002 for a review).

Buchet *et al* (1992) reported a GM=0.000585 mg/m^3 in a coke production plant in Belgium (personal TWA). In Finland Pyy *et al* (1997) reported concentrations ranging from 0.0003 to 0.0025 mg/m^3 in a coke plant in Finland between 1988 and 1994. These concentrations are also in line with data from another cokery plant in Finland: 0.0014 - 0.0025 mg/m^3 (as reported in Kuljuka *et al* (1996)). Although this might not be representative for the rest of EU at that period as it is recognised that coke production was reduced in the 1990 in Finland due to the economic slump in the region.

Armstrong *et al* (2004) estimated personal exposure to benzo[a]pyrene for a number of industries based on published exposure estimates in the IARC report (1983) and data reported by Lindstedt and Sollenberg (1982). Typical plant concentrations in a coke plant were estimated to be 0.000010 mg/m^3. For tar distillation plants the estimated concentrations were 0.0005 mg/m^3.

Pyy *et al* (1997) reported personal concentrations ranging form 0.0003 mg/m^3 to 0.0025 mg/m^3 with most of the concentrations being below 0.001 mg/m^3 in 1994 in a coke production plant in Finland. (AM or GM were not reported).

Kuljuka *et al* (1996) measured personal exposure (TWA) concentration of coke production workers in an oil shale processing plant in Estonia in 1996. Benzo[a]pyrene was measured in the solid (i.e. particulates) and gas phase. Concentrations ranged from below the LOD (0.00000 mg/m^3) to 0.03960 mg/m^3 (n=37). The AM was 0.05700 mg/m^3. Dermal exposure was also assessed by wiping the skin at the beginning and end of the work shift. The AM was 1.2 ng/cm^2.

Three of the studies were in Germany (Förster *et al* 2008, Rossbach *et al* 2007 and Strunk *et al* 2002). Förster *et al* (2008) assessed personal exposure (8-hrs TWA) to coke oven gas in Germany. A total of 79 workers from three different coking plants participated in the study. Concentrations for the period 1998-2004 ranged from below the limit of detection (LOD=0.00000 mg/m^3) to 0.0292 mg/m^3 with an arithmetic mean (AM) of 0.00224 mg/m^3 and median concentration of 890 mg/m^3.

Rossbach *et al* (2007) measured exposure concentrations on workers in coke production plants in Germany (the year is not specified but it is believed it was in 2000s). The median exposure was 0.000760 mg/m^3. The maximum exposure concentration was 0.029290 mg/m^3 and the 95th percentile 0.015720 mg/m^3.

The most recent exposure data were collected by Strunk *et al* (2002) in 2000 in a coke plant in Germany. Concentrations ranged from below the LOD to 0.000029 mg/m^3. The weighed AM was 0.002911 mg/m^3, GM = 001603 mg/m^3 and GSD = 2.26.

Exposure data were very limited, and although they suggest that levels across EU countries can vary, there was no sufficient information to estimate exposure concentration for individual countries. Data from Strunk *et al* and Rossbach *et al* was considered the most representative as it was based on actual exposure measurements (not estimated as in Armstrong *et al*) and the studies reported AM or median concentration. The weighed GM was 0.000973 mg/m^3 represents exposure in 2000. Assuming a reduction of 6 % per year, exposure concentrations in 2010 would be 0.000524 mg/m^3. GSD was only reported by Strunk *et al* (2002) (GSD = 2.26). Due to the large range of concentrations reported the GSD was assumed to be 4, which is higher than GSD for typical occupational exposure data (GSD=3).

Manufacture of other non-metallic mineral products (NACE code 26)

Eight studies were identified that reported information in the manufacture of other non-metallic products (including production of refractory materials (n=2), carbon electrodes (n=5) and fire proof materials (n=1). Overall concentrations in the production of carbon electrodes were higher than those reported in the production of refractory materials and fireproof materials.

In the production of refractory materials Förster *et al* (2007) reported exposure concentrations (AM) for 1999-2001 of 0.00154 mg/m^3 in Germany. Median concentrations were 0.000014 mg/m^3. Higher median concentrations were reported by Rossbach *et al* (2007) in another refractory production plant in Germany: median personal concentrations were 0.001270 mg/m^3 with maximum concentrations of 0.56052 mg/m^3.

Concentrations reported in the production of carbon electrodes were higher. Most of the studies were based in Germany. Förster *et al* (2007) reported exposure concentrations (AM) of 0.0049 mg/m^3 in Germany. Petry *et al* (1996) in another study in Germany reported average personal concentrations (AM) between 1999 and 2004 of 0.00244 mg/m^3, with concentrations ranging from 0.00017 to 0.00488 mg/m^3. Rossbach *et al* (2007) reported maximum concentrations of 0.30061 mg/m^3 with a median of 0.0014 mg/m^3 in another electrode production plant in Germany (the year when measurements were taken was not indicated but it is believed it was in 2000s).

In another carbon electrode production plant in the Netherlands van Delft *et al* (1998) reported personal exposure concentrations (median) of 0.00037 mg/m^3 for low exposed workers and 0.0012 mg/m^3 for high exposed workers in 1995. Armstrong *et al* (2004) estimated personal exposure concentrations (AM) in the EU for the period 1999-2001 in carbon anode plants of 0.001 mg/m^3. Concentrations in the carbon black production industry were 0.00005 mg/m^3.

Preuss *et al* (2006) reported exposure concentrations from lower than the LOD to 0.03815 mg/m^3 with a median exposure concentration of 0.0001 mg/m^3 in a fireproof material production plant in Germany between 1999 and 2004.

Lafountaine *et al* (2000) in a study in an artificial shotting plant in France in the 1990 reported personal exposure (AM) of 0.00012 mg/m^3. Concentrations ranged from 0.000037 to 0.00027 mg/m^3.

There were not sufficient data to estimate an individual exposure concentration for each country. An averaged weighed GM was calculated from the previous studies that reported the AM, median or GM (Förster *et al*, Preuss *et al*, van Delft *et al* and Rossbach *et al*). The calculated GM=0.000788 mg/m^3. This data applies for data from 2000. We assumed a reduction of 6.0 % per year as estimated by Friesen *et al* in a coke plant in Canada between 1977 and 2000 (see section 1.6 for more details). Therefore, exposure concentrations (GM) in 2010 are estimated to be 0.000424 mg/m^3. The GSD was calculated from Forster *et al*'s study as this was the only study that reported GSD values. The averaged GSD=5.

Manufacture of basic metals (NACE code 27)

Ten studies were identified in the literature review with exposure data. Data were collected in aluminium smelters and foundries in Finland, Denmark, Belgium, the UK and Canada.

Friesen *et al* (2006) developed a model to estimate exposure concentrations in an aluminium smelter in Canada. The estimated personal annual exposure concentration (AM) in 1980 for three different potline areas was approximately 0.0025, 0.004 and 0.002 mg/m^3, which results in a GM= 0.002714 mg/m^3 and GSD=1.42. Annual estimation for 2000 for the same potline areas was 0.001, 0.001 and 0.0005 mg/m^3. This results in a GM= 0.000793 mg/m^3 and GSD=1.50.

Armstrong *et al* (2004) estimated similar concentrations than those reported by Friesen *et al* in the 1980s. Data were compiled from the IARC (1983) and Lindstedt and Sollenberg (1982). Typical concentrations in two plants in the pot room of aluminium smelters were 0.003 mg/m^3 for those plants where aluminium reduction was done using a Soderberg cell and 0.0005 mg/m^3 when the reduction was done using pre-bake cell. The GM of both exposure values is 0.0012 mg/m^3 and the GSD=3.5

Exposure data from iron foundries were lower than that reported for aluminium smelters for the same time period. Median concentrations in the 1980s (personal TWA exposure) in a foundry in Finland in 1980 ranged from 0.00005 to 0.0002 mg/m^3 (Hemminki *et al* 1997). In the 1990s exposure concentrations were lower (5 ng/m^3, Hemminki *et al* 1997) as a result of a reduction in production due to the economic slump in Finland in the 1990. Omland *et al* (1994) reported personal exposures (AM) of

0.0000089 mg/m^3 in another iron foundry in Finland in 1990s. In Denmark the AM exposure between 1988-1994 for a group of workers in an iron foundry was 0.00002 mg/m^3 (Omland *et al* 1994).

Current values are of the order of ng/m^3. Exposure concentrations from 2005-2006 from an electric arc furnace steelmaking plant in the UK in 2008 ranged from 1.7 to 24.5 ng/m^3 with an AM=1.4 ng/m^3.

Another study in a foundry in Taiwan in 2000 reported AM of 30 ng/m^3 (Liu *et al* 2010).

It is difficult with the available data to estimate a GM of exposure as data from Finland are not representative of the rest of EU in that period due to the reduction in production. The current GM was calculated as the GM between data provided by Friesen *et al* for 2000 (GM=0.00080 mg/m^3) after applying a reduction of 6% per year (0.000431 mg/m^3) and the GM=0.65 ng/m^3 provided by Aries *et al* (2008). Therefore the estimated exposure concentration for 2010 in aluminium foundries is 0.000017mg/m^3. The GSD is assumed to be the same as for NACE code 26 (GSD=5).

Manufacture of fabricated metal products, except machinery and equipment (NACE code 28)

There were no exposure data in the reviewed literature for manufacture of fabricated metal products. It is likely that exposure in this sector is lower than that for NACE code 27. However, we assumed a conservative approach and estimated that exposure was the same in both industries. Therefore, the GM and GSD were assumed to be 0.000017 mg/m^3 and 5, respectively.

Estimated GM and GSD

The overall weighted GM and GSD were estimated across all high exposure industries across the EU using @Risk©. We assumed exposure is constant across all EU countries.

The overall GM and GSD were 0.0000229 mg/m^3 and 6.29 respectively. According to these results exposure concentrations are below the suggested OEL in all EU countries. Based on these data it is unlikely that many workers are exposed above the potential OEL of 0.002 mg/m^3.

2.3.2 Temporal change in exposure

In 1980s exposure concentrations to b[a]p were classified as follows (Lindstedt and Sollenberg, 1982):

- very high (0.01 mg/m^3): coke work (topside work);
- fairly high (0.001-0.01 mg/m^3): coke works in general (non-topside work), blast furnaces, steel works (some jobs);
- moderate (0.0001-0.001 mg/m^3: steel works (in general), foundries (some jobs); and
- low (0.000001-0.0001 mg/m^3: foundries (in general).

We estimated a reduction in exposure concentrations of 6% per year for all industries based in a study by Friessen *et al* 2006 on concentrations between 1977 and 2000 in an aluminium smelter in Canada.

We calculated the GM of the exposure data presented in Figures 2 and 3 in Friesen *et al* (2006) for the potroom operators and potroom repairmen for the years 1977, 1980, 1985 and 2000 (Figure 2.1).

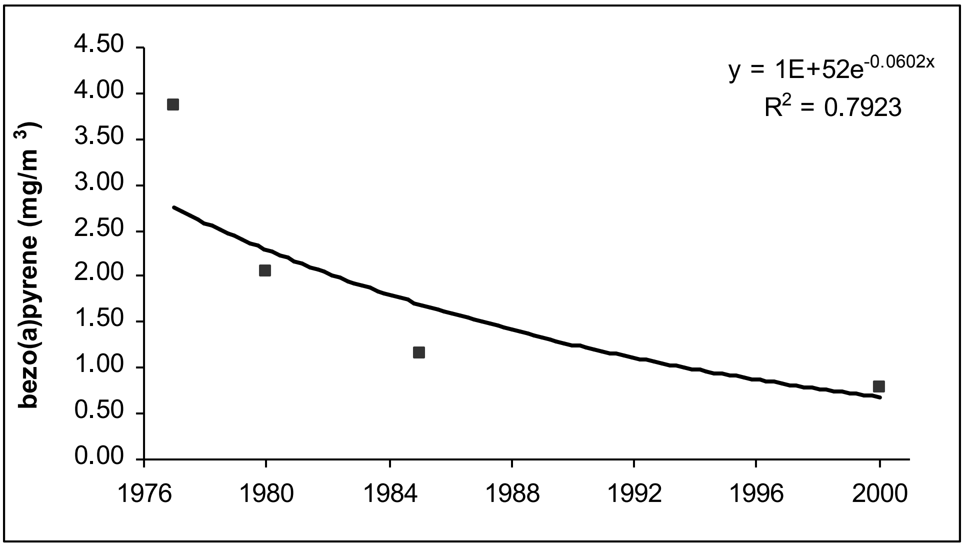


Figure 2.1 Exposure trend of benzo(a)pyrene in an Aluminium smelter (Data from Friesen *et al* 2006)

The temporal trend in benzo[a]pyrene concentrations was expressed as the annual change in exposure using the following expression:

$$\% \text{ change per year} = 100 \text{ x } (\exp [\beta_1] - 1)$$

The resulting annual reduction was 6%. Our estimate is similar to exposure reductions reported in industrial settings (5-10%) % (Symanski *et al*, 2001; Creely *et al*, 2007; Galea *et al* 2009).

2.4 HEALTH IMPACT FROM CURRENT EXPOSURES

2.4.1 Background data

The occupational cancers associated with exposure to benzo(a)pyrene are shown in Table 2.3, along with a summary of the information used in the health impact assessment.

Table 2.3 Occupational cancers associated with exposure to Benzo(a)pyrene

Cancer site	**Bladder**		**Lung**			**NMSC**	
ICD-10 code	C67		C33-C34				
IARC group for carcinogen	2A		2A			2A	
Strength of evidence for cancer site (1)	Suggestive		Suggestive			Suggestive	
Latency assumption	10-50 yrs		10-50 yrs			10-50 yrs	
Source of forecast numbers - deaths	Eurostat, 2006		Eurostat, 2006 for C32-C34			Estimate based on GB data, adjusted to EU countries on 2006 population estimates	
Source of forecast numbers - registrations	GLOBOCAN, 2002[7]		GLOBOCAN 2002			Estimate based on GB data, adjusted to EU countries on 2006 population estimates	
Exposure levels	*Relative Risk (RR)*	*Source of RR*	*Relative Risk (RR)*		*Source of RR*	*Relative Risk (RR)*	*Source of RR*
H (coal tars and pitches only for NMSC, in the coke industry NACE 23)	1.44 (1.2, 1.7)	Bofetta *et al* (1997), inverse variance weighted combined estimate based on 26 studies excluding DEE exposure and coke production	8 h TWA category (µg/m^3)* H4 = <0.01 H3 = 0.01 - <0.75 H2 = 0.75 - <2.0 H1 = 2.0+	RR estimate** 1.00 1.02 1.08 1.25	* Unwin *et al* (2006) **Armstrong *et al.* (2004) meta-analysis	1.74 (1.07-2.65)	Partanen and Bofetta (1994)

[7] IARC, GLOBOCAN database, available at: http://www-dep.iarc.fr/globocan/database.htm

Cancer site	Bladder		Lung			NMSC	
L (coal tars and pitches only for NMSC, roofers, road workers and paviours in construction NACE 45)	Set to 1	Bofetta *et al* (1997), combined estimate from population based case control studies excluding diesel exposures and drivers, and mineral oils (cutting fluids), and Kogevinas *et al* (2003)	=<0.01µg/m^3 B[a]P 8 h TWA	1	Armstrong *et al* (2004) meta-analysis	1.74 (1.07-2.65)	

[(1)] Based on Siemiatycki *et al*, 2004

2.4.2 Exposed numbers and exposure levels

Industry sectors, their NACE codes, classifications to High/Medium/Low/Background exposure as applicable for the mid 1970's and numbers exposed in 2006 are given in Table 2.2 in the previous section on the exposure. The estimated average exposure level (GM) and measure of variability (GSD) for NACE industries exposed to benzo(a)pyrene are 0.0000229 mg/m^3 and 6.29 respectively for 2010 and a 6% decline over the period 1977-2000 is assumed. These estimates of GM and GSD, which are actually for high exposed industries, were used to estimate the proportions of the high exposed workers in each country falling into each of the risk categories H1 to H4 for lung cancer shown in Table 2.3 above. The estimated proportions exposed in each of the 'high risk' exposure categories across the EU are given in Table 2.4 below

Table 2.4 Estimated proportions exposed in each of the high risk exposure categories across the EU member states

8 h TWA category (µg/m^3)	2.0+	0.75 - <2.0	0.01 - <0.75	<0.01
Estimated proportion in 1975 (EU average)	0.11	0.13	0.71	0.05
Estimated proportion in 2006 (EU average)	0.01	0.02	0.64	0.33
GB study proportions (Unwin *et al* 2006)	0.05	0.05	0.4	0.5

For lung and bladder cancers the estimates have assumed that there is no excess risk (RR=1) for the 'low' exposed (Table 2.3 above). The threshold below which excess risk is zero has been estimated for lung cancer to be at 0.01 µg/m^3 (Armstrong *et al*, 2004). This threshold has been used as a low/baseline boundary for estimating attributable skin cancers (NMSC) below which excess risk for NMSC is also assumed to be zero, as in the case of NMSC the low exposed (roofers, road workers and pavers in construction) did not have zero excess risk.

We present data for a "baseline" scenario which for all industries assumes the annual declines as above in exposure levels and standard change in employed numbers up to the 2001-10 estimation interval and constant levels thereafter.

2.4.3 Forecast cancer numbers

Separate estimates for total numbers of deaths for bladder (C67) and lung (C32-C34, including larynx) cancer by age band are available from EUROSTAT for the 27 countries of the EU, for 2006, and for registrations for bladder and lung (C33-C34) cancer from GLOBOCAN for 2002. No European estimates were available for NMSC (ICD10 C44). Therefore deaths (for 2005) and registrations (for 2004) for Great Britain were used, uprated in proportion to individual EU country populations in 2005 by age and sex. The forecast numbers of deaths and registrations by country used to estimate attributable numbers are in Appendix 8.2.

2.4.4 Results

The cancer deaths and registrations attributed to occupational exposure to Benzo(a)pyrene for the baseline scenario are presented per year for the target years given and are based on the all working age cohort of currently (2006) exposed workers. Attributable fractions and numbers of deaths and registrations, and Years of Life Lost

(YLLs), Years Lived with Disability (YLDs) and Disability-Adjusted Life Years (DALYs), are estimated.

As the exposure data suggests that exposure declines over time, a dynamic baseline scenario has been used.

A summary of the results for the total EU is in Table 2.5 below.

Table 2.5 Results for the baseline forecast scenario, total EU (27 countries), Benzo(a)pyrene, men plus women

Scenario	**All scenarios**		**Baseline (trend) scenario (1) - Linear employment and exposure level trends assumed to 2021-30, constant thereafter.**			
EU Total	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Numbers ever exposed	23,465,839	27,888,781	34,142,463	40,440,316	44,963,543	47,763,566
Proportion of the population exposed	6.495%	7.325%	8.781%	10.268%	11.471%	12.436%
Bladder cancer						
Attributable Fraction	0.114%	0.074%	0.033%	0.013%	0.005%	0.002%
Attributable deaths	47	37	20	9	4	1
Attributable registrations 'Avoided' cancers	151	115	59	25	9	3
YLLs	544	418	216	95	36	13
DALYs	703	539	277	121	46	17
Lung cancer						
Attributable Fraction	0.153%	0.092%	0.032%	0.009%	0.003%	0.001%
Attributable deaths	430	302	121	38	15	5
Attributable registrations 'Avoided' cancers	466	325	129	39	15	5
YLLs	6,689	4,564	1,744	512	190	61
DALYs	6,978	4,763	1,821	535	199	64
NMSC						
Numbers ever exposed	194,305	197,765	202,083	203,188	203,740	204,546
Proportion of the population exposed	0.054%	0.052%	0.052%	0.052%	0.052%	0.053%
Attributable Fraction	0.044%	0.043%	0.041%	0.037%	0.034%	0.031%
Attributable deaths	2	2	3	3	3	3
Attributable registrations 'Avoided' cancers	254	286	319	330	320	299
YLLs	24	27	31	33	33	29
DALYs	24	27	31	33	33	29

The attributable deaths in the EU 2010 from previous benzo(a)pyrene exposures were 47 deaths from bladder cancer, 430 deaths from lung cancer and 2 deaths from NMSC. The estimated deaths and cancer registrations decrease steadily over the following 50 years for bladder and lung cancer to 1 attributable death in 2060 for bladder cancer and 5 attributable deaths in 2060 for lung cancer. For NMSC, the number of attributable deaths is predicted to slightly increase to 3 deaths in 2060. The corresponding estimated attributable fraction (AF) for all three types of cancers decreases from 0.114% in 2010 to 0.002% in 2060 for bladder cancer, from 0.153% in 2010 to 0.001% in 2060 for lung cancer and from 0.044% to 0.031% for NMSC. DALYs are also expected to decrease for bladder and lung cancers in the baseline scenario from 703 years in 2010 to 17 years in 2060 for bladder cancer and from 6,978 years in 2010 to 64 years in 2060 for lung cancer. Over the same time period, DALYs are predicted to increase slightly for NMSC with 24 years in 2010 and 29 years in 2060.

2.5 POSSIBLE COSTS ASSOCIATED WITH NOT MODIFYING THE DIRECTIVE

2.5.1 Health impacts – possible costs under the baseline scenario

Introduction

The health data (cancer registrations and Years of Life Lost - 'YLL') for the baseline in which there are no further modifications to the Carcinogens Directive are shown in section 2.4 of this report. These data show that there are predicted to be a significant number of cancer registrations and YLLs from non-melanoma skin cancer (NMSC) and cancers of the bladder and lung resulting from predicted future exposure to B[a]p. There is predicted to be a decline in registrations and YLLs over time of both bladder and lung cancer as a result of predicted exposure reduction owing to implementation of existing and ongoing risk management measures across the EU. However, registrations and YLLs of NMSC are predicted to increase over time.

Method in brief

Using the health data (cancer registrations and Years of Life Lost - 'YLL'), it is possible to monetise the costs under the baseline by estimating the:

- Life years lost – This is calculated by using the YLL and multiplying this by a valuation of the Value of Life Year Lost (VLYL). This gives a value for the time (in years) lost as a result of premature death.
- Cost of Illness (COI) –This is a monetary cost of the time spent with cancer. In this study, a unit COI estimate is multiplied by the number of cancer registrations, give a total value for COI. (COI is often the main market-based approach in relation to health impact[8]). COI includes the direct and indirect costs of cancer but not the intangible costs (see below).
- Willingness to Pay (WTP) to avoid cancer – WTP in this study is used as an alternative method (high cost scenario) based on publicly available, peer reviewed studies on what people would be willing to pay to avoid having cancer. This includes various intangible costs (such as disfigurement, functional limitations, pain and fear) and includes the costs associated with life years lost.

[8] ECHA (2008) "Applying SEA as part of restriction proposals under REACH" Available at: http://echa.europa.eu/doc/reach/sea_workshop_proceedings_20081021.pdf

Because exposure to benzo[a]pyrene can lead to NMSC (as well as lung and bladder cancer), a modification of the method used to estimate costs of health impacts was required as compared to other substances assessed in the current project. The standard method (as set out in the method paper) was used for lung and bladder cancer, whilst a different set of cost estimates was used for NMSC, as set out below.

The cost variables used in this study for lung and bladder cancer are presented in Table 2.6 in 2010 prices. Costs for NMSC are presented in Table 2.7. Costs for NMSC are based on a simple meta-analysis of various studies examining the economic costs of NMSC. Of particular relevance was a study by Miljoministeriet (2004) in which the direct costs of NMSC and willingness to pay (WTP) studies to avoid the permanent scars were reviewed. The study (along with other studies) suggests that NMSC can typically be treated within a year and is assumed, in general, to not result in death. Therefore, the costs associated with NMSC are much lower than those for bladder and lung cancer (Table 2.6) which are based on avoiding life-threatening cancer.

The cost that includes WTP to avoid scarring (249,424 Danish kroner (DKK) in 2002 prices) is taken from the Miljoministeriet (2004) study and converted to Euros (€38,827 in 2009 prices) and is used as a high estimate. The study also provides a possible low COI estimate of €2,926 (18,795 DKK in 2002 prices). A comparable estimate is also derived from Morris *et al* (2005) which estimates COI at €2,601 in 2009 prices (based on an estimate of £1,413 in 2002 GBP prices). The latter is used as the low estimate in the current analysis.

Another study by O'Dea (2009) estimated the overall costs of NMSC to New Zealand. If divided by the number of incidents, this gives a broad estimate of €538 (867 NZD in 2007/08 prices) per incident. However this was excluded as the per-registration costs was not explicitly estimated and also may not necessarily be representative of costs for the EU.

For the purposes of this study, all valuations are increased by 2% each year in the future in part to present costs in real terms (i.e. adjusting for inflation in prices) and to reflect the increasing value society attaches to its health (as economic growth typically increases over a long period of time)[9].

Table 2.6 Summary of cost variables used in this study for bladder and lung cancer (€ 2009 prices)

Cost/ benefit elements	Low scenario	High scenario
VLYL - Each year lost	€ 50,393	€ 0 (note 1)
COI or WTP - Unit cost (per cancer registration)	€ 49,302 (COI)	€ 1,793,776 (WTP)

(Note 1) – By using WTP (€1.8m) in the high scenario instead of COI, the WTP can include the costs of premature death and therefore there was a risk of double counting benefits if VLYL costs were included.

[9] This is consistent with some other European Commission studies and is standard practice for air quality under the Clean Air for Europe (CAFE) programme.

Table 2.7 Summary of cost variables used in this study for NMSC (€ 2009 prices)

Cost/ benefit elements	Low scenario	High scenario
VLYL - Each year lost	€ 50,393	€ 50,393
COI or WTP - Unit cost (per cancer registration)	€ 2,601 (COI)	€ 38,827 (WTP)

All costs and benefits over time in this study are also discounted using a 4% discount rate as recommended by the European Commission's Impact Guidelines[10]. In order to assess the effect that discounting has on the results ('sensitivity analysis), we have also presented estimates that take into consideration a declining discount rate for impacts occurring after 30 years and no discounting.

The health data shown in section 2.4 are 'snap-shots' (i.e. an estimation for the initial year of a ten year period) of the number of cancer registrations, deaths, YLLs in future years at 10 year intervals. In calculating the costs associated with these effects, each 'snap-shot' result is multiplied by 10 in order to derive an estimate for the whole assessment time period (for example, 2020 results are multiplied by 10 to give results over the period 2020-2029). This assumes that each snap-shot year is representative of the following 10 years.

The method to valuing health benefits is explained in more detail in the method paper titled *"Valuing health benefits – Method paper".*

Results

The health costs under the baseline scenario are presented in Table 2.8. Health-related costs of benzo[a]pyrene exposure are predicted to decline over time and are predominately the result of past exposure. In Section 2.4.3 the number of cancer registrations and YLLs are estimated to decline over time, accounted for by risk management measures (RMMs) already imposed (as applied at production and end use) over the past 10-20 years (exposure is expected to decline at 6% per year, as described above).

Table 2.8 shows the ranges of health costs for each representative decade. The ranges are based on the high and low cost scenarios (see Table 2.6). The results are also illustrated in Figure 2.2.

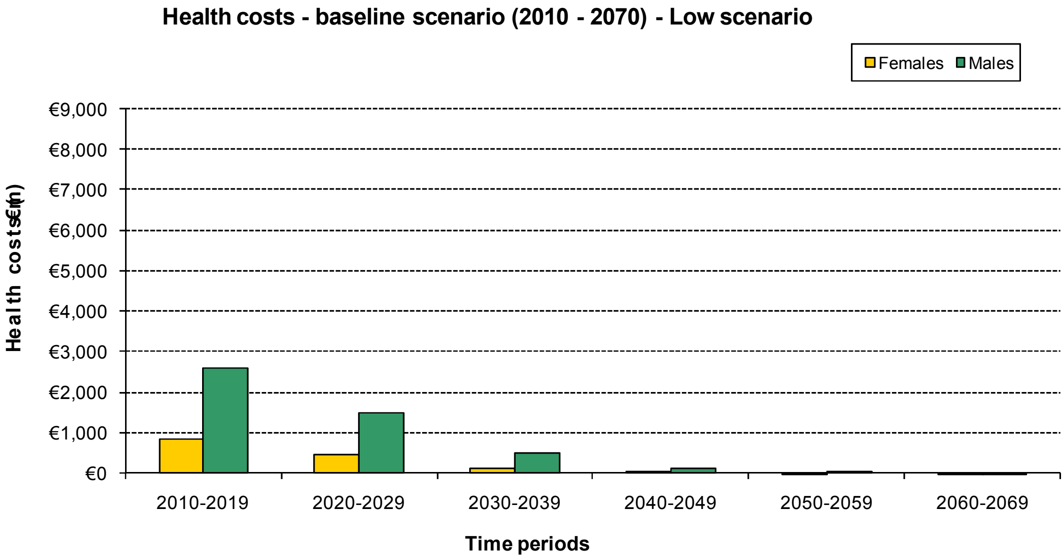
[10] European Commission impact Assessment Guidelines (Jan 2009) - http://ec.europa.eu/governance/impact/commission_guidelines/docs/iag_2009_en.pdf

Table 2.8 Health costs - baseline scenario – 2010 to 2070 (Present Value – 2010 €m prices)

Costs by Gender (€m)	**2010-2019**	**2020-2029**	**2030-2039**	**2040-2049**	**2050-2059**	**2060-2069**	**Total**
Female	839 to 1744	450 to 963	126 to 300	27 to 77	9 to 29	3 to 12	1455 to 3126
Male	2596 to 8469	1508 to 5073	517 to 1876	147 to 592	51 to 216	18 to 86	4837 to 16312
Total	3435 to 10213	1958 to 6037	643 to 2176	174 to 669	60 to 245	22 to 98	6292 to 19438

Notes:
- All costs are presented in present value using a discount rate of 4%. The low range is based on low estimates for costs of illness and life years lost. The upper range of costs relate to WTP estimates to avoid having cancer, which include intangible costs associated with having cancer. Costs include cancers that are assumed to be non-fatal (NMSC) as well as cancers that are fatal in some/many instances.
- Totals may not match to sums of females and male costs due to underlying small differences in raw data and rounding to whole number

The impacts of NMSC are relatively limited compared to the total costs (€6-19bn), with total costs over the period 2010-69 being between €45m and €453m. The rest of the health costs relate to bladder and lung cancer.



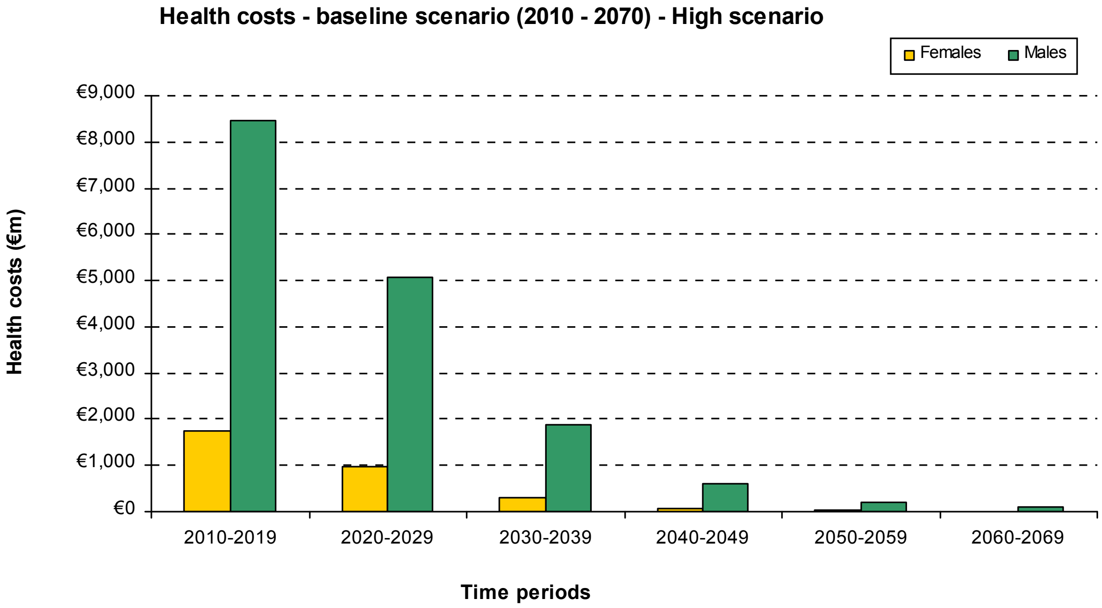


Figure 2.2 Health costs - baseline scenario – 2010 to 2070 (Present Value – 2010 €m prices)

These costs will affect Member States differently depending upon the overall number of workers within affected industry groups, existing RMMs and the proportion of males and females within these groups. Figure 2.3 shows that France, Germany and Italy are predicted to have relatively high health costs, given the higher number of workers likely to be exposed in these countries. The industrial sector estimated to be most affected under the baseline is the manufacture of basic metals, which relates to workers exposed to benzo[a]pyrene in the aluminium smelting sector. This is shown in Figure 2.4. Health costs are also predicted in three service sectors – other business activities, public administration and defence, and education – whilst relative risk is low in these sectors, there are a high number of workers potentially exposed (at some level).

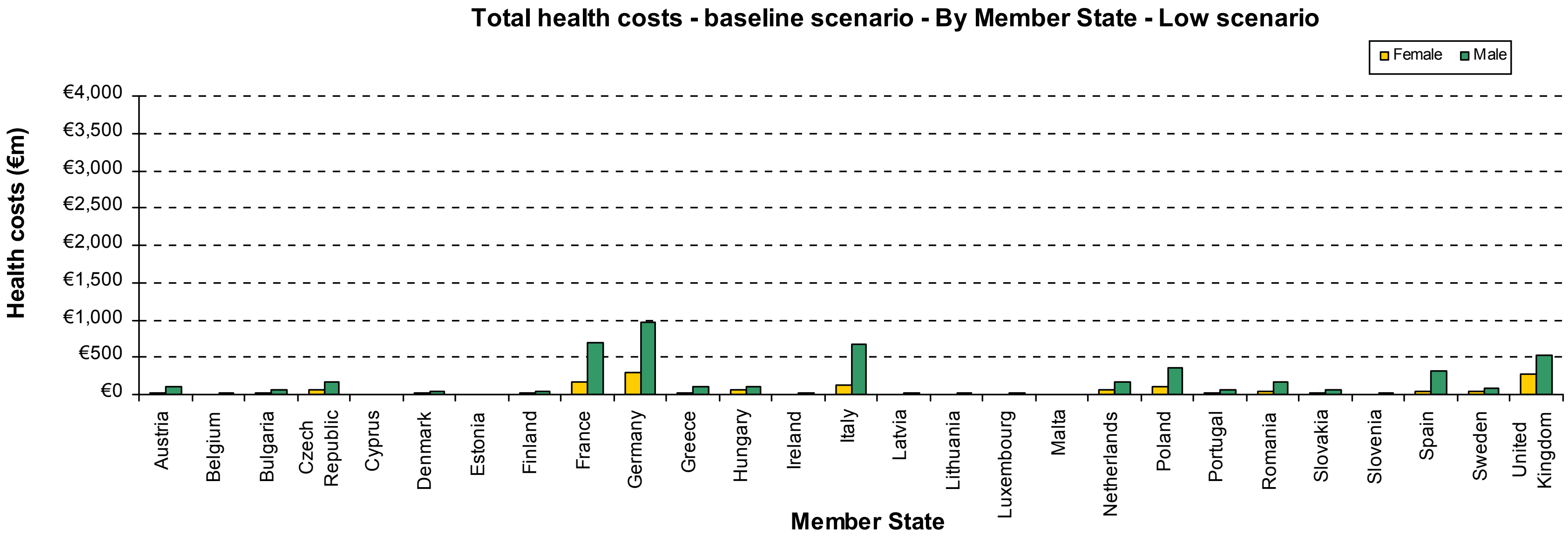


Figure 2.3a Total health costs - baseline scenario – By Member State (Present Value – 2010 €m prices)

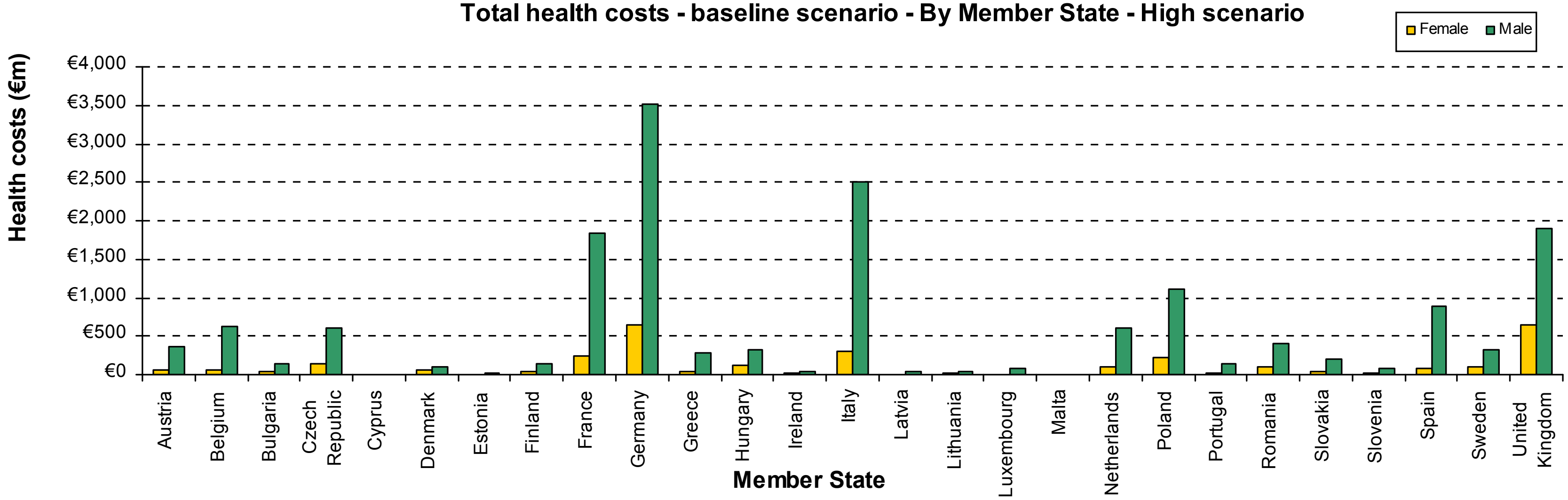


Figure 2.4b Total health costs - baseline scenario – By Member State (Present Value – 2010 €m prices)

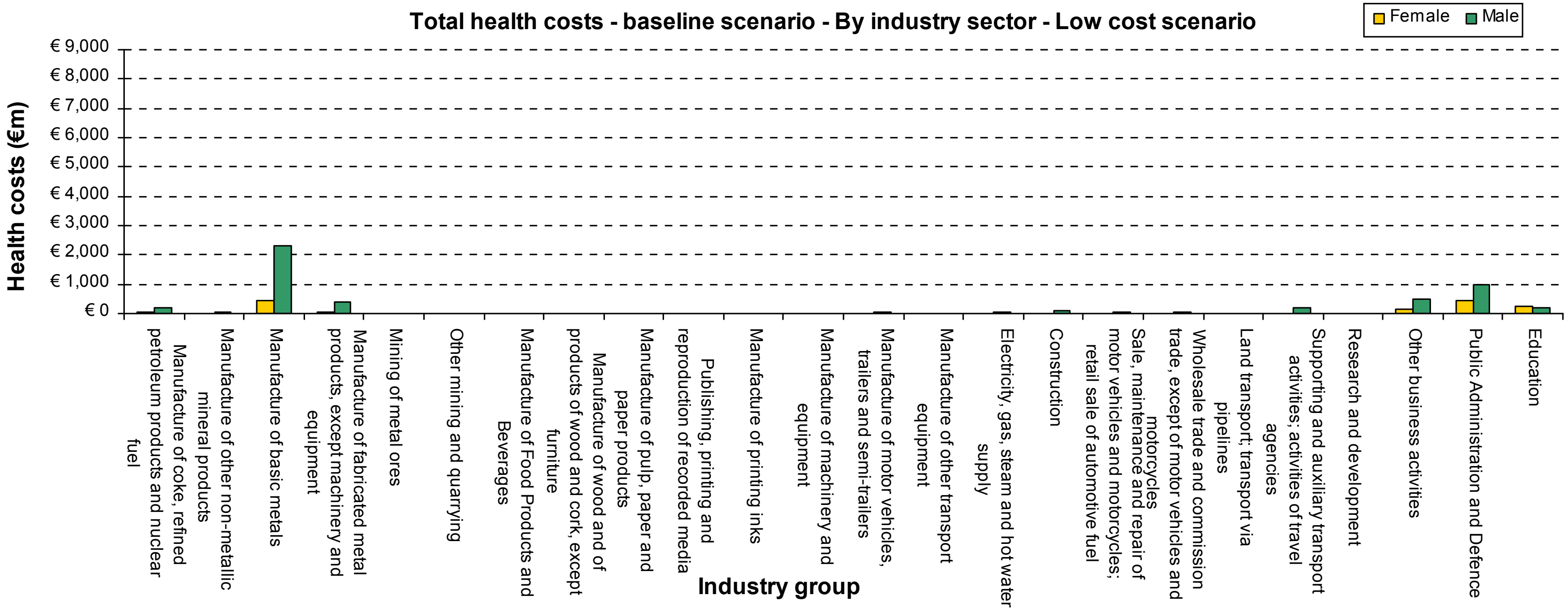


Figure 2.5a Total health costs - baseline scenario - by industry group (Present Value – 2010 €m prices) [11]

[11] Charts exclude industries for which zero costs are estimated.

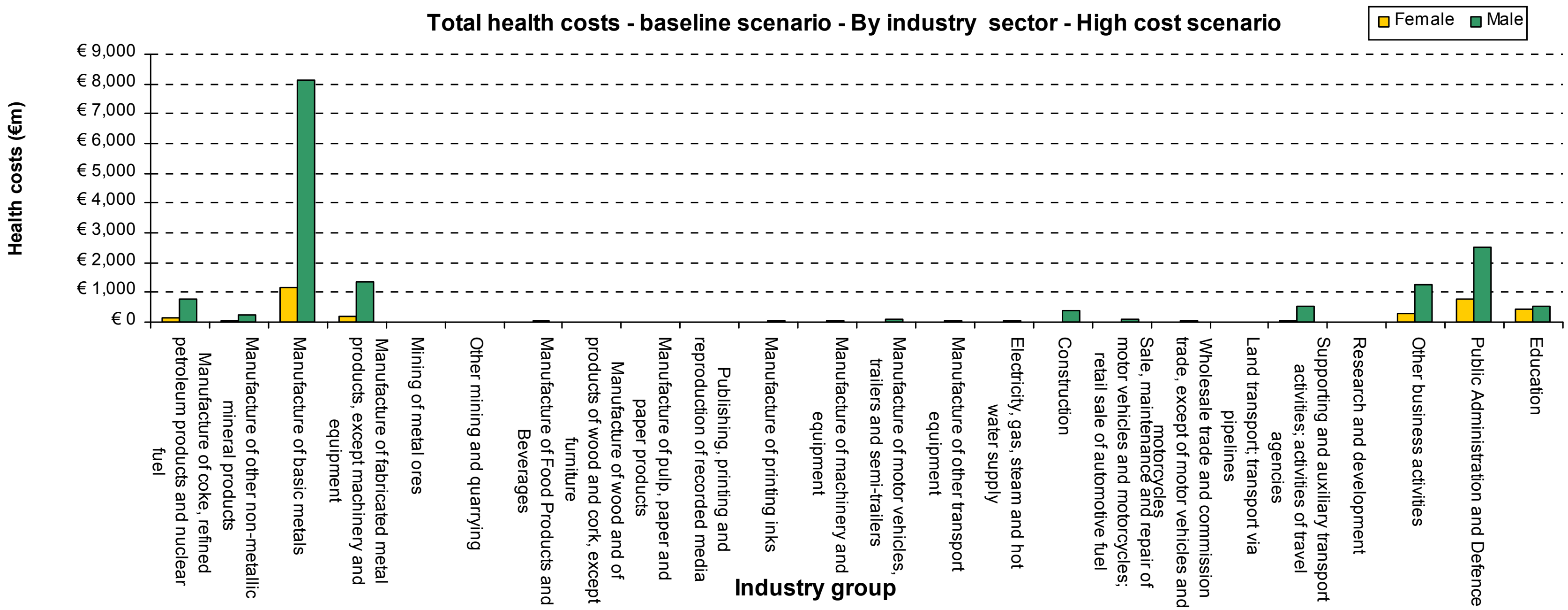
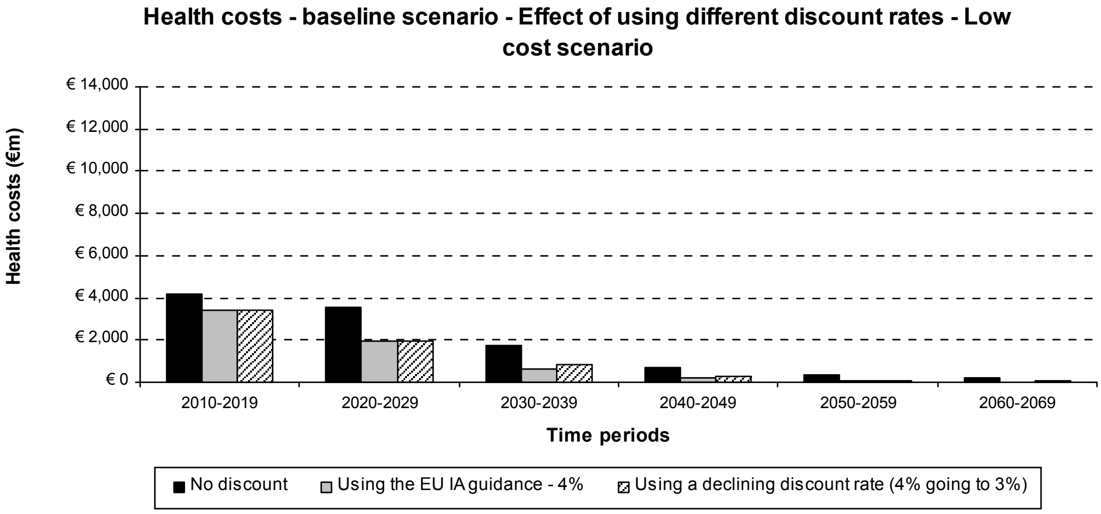


Figure 2.6b Total health costs - baseline scenario - by industry group (Present Value – 2010 €m prices) [12]

[12] Charts exclude industries for which zero costs are estimated.

In order to present all socio-economic costs and benefits consistently in present value terms, all future costs and benefits have been discounted. The primary approach was to apply the European Commission IA recommended 4% discount rate. Since most health impacts occur over a long period of time relative to costs, the impacts of discounting are significant.

In Figure 2.5, the effects of different discount rates on the overall results are shown, indicating that the impacts of discounting become more pronounced the further in the future that the impact occurs.



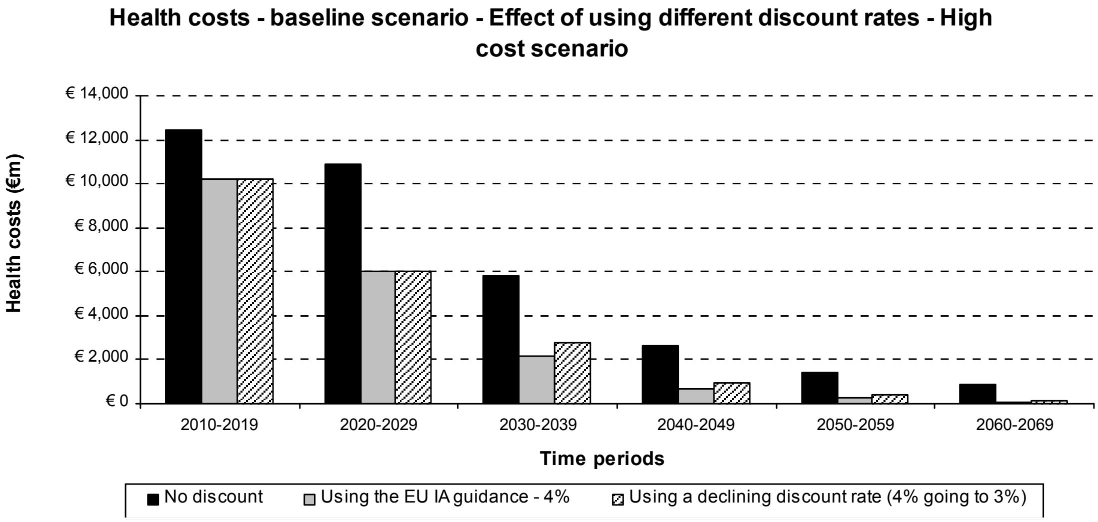


Figure 2.7 Impacts of discounting

3 POLICY OPTIONS

3.1 DESCRIPTION OF MEASURES

Workers may be exposed to benzo[a]pyrene through:

- Breathing air containing benzo[a]pyrene in the workplace. This man occur in coking plants, coal-tar and asphalt production plants, coal gasification sites, smoke houses, where rubbish is incinerated or on construction projects.
- Contact with benzo[a]pyrene in the air, water, or soil near a waste site, or another polluted site.[13,14]

Possible risk management measures include:

- Closed systems,
- Local exhaust ventilation (LEV)
- If venting is unavailable, workers should wear respiratory equipment (RPE)
- Workers should wear protective work clothing[13].

3.2 LEVEL OF PROTECTION ACHIEVED (OELS)

Typical OELs in EU are of the order of 0.002-0.005 mg/m^3, except in the Netherlands (0.0000005507 mg/m^3) and Latvia (0.0001 mg/m^3). Estimated exposure concentrations were of the order of 0.001 mg/m^3. Our estimate of current exposure concentration is likely to be higher than current exposure, as we applied a reduction factor, to the concentrations reported in the 1990s, based on the reduction in concentrations from 1980 to 2000 (Friesen *et al*, 2006). Progress in exposure controls over the last 10 years is likely to have resulted in more efficient reduction in exposure, which is not reflected in our reduction factor. According to our estimates all industries have exposure lower than current OELs and would currently comply with an OEL to 0.002 mg/m^3.

The higher exposure has been reported in the production of coke. The major steps in coke production are: (1) loading coal into the oven (the "charging" step), (2) heating the coal until it becomes coke ("coking"), and (3) "pushing" the coke out of the oven into cooling and transport cars. Approximately 60% of the total emissions occur during charging, 30% during pushing, and 10% during quenching (Kirk-Othmer, 1979). The total amount of emission depends largely on the type of oven.

There are several methods of controlling fugitive coke oven emissions. In old oven models leaks which occur when the coal is heating are controlled through proper maintenance and operating procedures. Several methods (e.g., coke oven sheds, fume hoods, maintenance and operating procedures) exist for controlling side door emissions, but the most common method is to assure the tight sealing of the doors

[13] Delaware Health and Social Services (HSS): Division of Public Health: Benzo[a]pyrene. Available here http://www.dhss.delaware.gov/dph/files/benzopyrenefaq.pdf

[14] Agency for Toxic Substances and Disease Registry (ADTSR) (1996) Toxicological profile: Polycyclic Aromatic Hydrocarbons (PAHs) (on-line version). Available here: http://www.atsdr.cdc.gov/tfacts69.pdf

through various techniques such as wet clay sealing (luting) and metal-to-metal sealing.

New model designs include negative pressure ovens which trap all gases inside the oven by keeping the oven pressure lower than the surrounding air pressure. Progress is also being made on cleaner methods of dry-coal charging (most procedures now mix the bunker coal with some water), and better methods for recycling the waste gases.

It should bear in mind that current coke production is dominated by China (60 % of the overall production in 2008). In the EU there are very few coke production plants mostly located in England, Germany, Belgium and France. Coke production in the EU was 52 million tonnes in 2002.

4 ANALYSIS OF IMPACTS

4.1 HEALTH IMPACTS FROM CHANGES TO THE EU DIRECTIVE

4.1.1 Health information

We have assessed the potential impact of introducing an OEL of 0.002 mg/m^3. However, because the estimated exposures are all low and it is not expect that anyone is currently exposed above the typical OEL there are no health benefits from introducing the limit.

4.1.2 Monetised health benefits

As indicated previously, it is assumed that there are currently no individuals exposed above the possible OEL of 0.002 mg/m^3. As such, it is assumed that there would be no health benefits of introducing an OEL at the most commonly adopted level amongst the EU Member States. (The terms of reference for the project require that the impact that the most commonly adopted value, or range of values, would have if adopted at EU level.)

4.2 ECONOMIC IMPACTS

4.2.1 Operating costs and conduct of business

Compliance Costs

In Section 2.2, it is estimated that there would be approximately 234,010 employees across the EU exposed to levels of benzo[a]pyrene in high exposure industries but that none would be exposed in excess of the possible OEL value of 0.002 mg/m^3.

Therefore there is not expected to be a need for additional direct control measures to comply with the OEL but there may be costs associated with the administrative and workplace requirements that arise from using a substance that is on the Directive. However, some of these measures may already be part of best practice in achieving compliance with other legislative requirements (e.g. as a result of classification and labelling and the Chemical Agents Directive). Specifically, it has not been identified that any additional control measures would be required to comply with an EU-wide OEL at that level as compared to control measures already in place.

Conduct of employers

Employees may need to change their working practices to ensure that RMM put in place as a result of benzo[a]pyrene being on the Directive are adhered to correctly (if they are not doing so already through any legislation). However, there is no indication that RMMs are not being adhered to.

Potential for closure of companies

There is not expected to be any significant additional potential for closure of companies as a result of introducing an EU-wide OEL of 0.002 mg/m^3 because compliance costs are likely to be minimal.

Potential impacts for specific types of companies

There are not expected to be any particular impacts for specific types of companies, since any additional costs of meeting an OEL of 0.002 mg/m^3 relative to the baseline scenario are likely to be minimal (or nil).

The main advantage of an EU-wide OEL would be to create consistency in regulation across the EU and remove any competitive disadvantage to those Member States that previously had more stringent national OELs in place (the Netherlands and Latvia). However, there is unlikely to be any practical difference.

Administrative costs to employers and public authorities

The following table (Table 4.1) describes the administrative burden to employers already subject to the Carcinogens Directive but will now incur costs of introducing an EU wide OEL on to Annex III.

Table 4.1 Administrative burdens to employers

Type of administrative cost	Relevant article(s)	Type of cost	Significance
1. Change in practice to use closed systems when using the substance.	5 – Prevention and reduction of exposure	These costs are already estimated in the cost of compliance section - This will only affect those firms that do not have or use closed systems	Estimated elsewhere
2. Develop/update health and safety and best practice guidance for: o Minimising use and exposure to workers to the substance o Redesign work processes and engineering controls to avoid/minimise release of carcinogens or mutagens o Hygiene measures, in particular regular cleaning of floors, walls and other surfaces o Information for workers o Warnings and safety signs o Drawing up plans to deal with emergencies likely to result in abnormally high exposure	5 – Prevention and reduction of exposure 7 – Unforeseen exposure 8 – Foreseeable exposure 9 – Access to risk areas 10 – Hygiene and individual protection	Firms will already have been required to develop/update health and safety and best practice guidance. The guidance and procedures may be required to be updated as control measures may change in light of a more stringent OEL. Some firms may need to redesign work practices to minimise exposure to workers and the number of workers exposed. The costs of implementing controls on exposure (such as LEV or PPE) are already estimated in the costs of compliance section.	Low
3. Additional costs of training new and existing staff in line with requirements of the Directive 4. Additional costs of making information available to employees 5. Consultation with employees on compliance with the Directive	11 – Information and training of workers 12 – Information for workers 13 – Consultation and participation with workers	Firms will already have been required to ensure training and adequate aware of risks and control measures to reduce/minimise exposure. Largely one-off cost if the revised OEL requires a change in control measures/working practice.	Low

Note: Readers should consult the Directive for the official wording around specific requirements. This table provides only a summary of what are perceived to be the most significant administrative requirements of the Directive. Grading of the significance of impacts is subjective and is based on professional judgement.

The following table (Table 4.2) describes the administrative burden to competent authorities already enforcing the Carcinogens Directive but will now incur costs of introducing an EU wide OEL on to Annex III.

Table 4.2 Administrative burdens to Competent Authorities

Type of administrative cost	Relevant article(s)	Type of cost	Significance
1. Communication with the Commission on provisions in national law to enforce the revised OEL. 2. Time and costs of implementing revised OEL into national law (consultation process)	19 – Notifying the commission 20 – Repeal	Largely one-off cost of transposing the revised OEL into national law	Low - Medium (one-off cost)

Note: Readers should consult the Directive for the official wording around specific requirements. This table provides only a summary of what are perceived to be the most significant administrative requirements of the Directive. Grading of the significance of impacts is subjective and is based on professional judgement.

Third countries

Since it is not expected that the introduction of an EU-wide OEL at 0.002 mg/m^3 will have significant impacts on affected industries, there is not expected to be any significant impact on third countries such as redistribution of investment, jobs or sales.

As shown in Table 1.1, some non-EU countries have a pre-existing OEL in place. A harmonised EU-wide OEL may encourage other countries outside the EU to implement an OEL into national legislation.

4.2.2 Impact on innovation and research

Impacts on innovation and research from introducing an EU-wide OEL of 0.002 mg/m^3 are expected to be minimal.

4.2.3 Macroeconomic impact

Since compliance with an OEL would not involve changing the current manufacturing process there is unlikely to be any significant change to macro-economic impacts.

4.3 SOCIAL IMPACTS

4.3.1 Employment and labour markets

There are not expected to be any noticeable changes to the numbers of workers required as a result of introducing an EU-wide OEL.

4.3.2 Changes in end products

There are not expected to be any noticeable changes to the end product since control measures do not change the characteristics of the product and no additional control measures are expected to be required. Since there is not expected to be any closure of companies, there should not be any change in supply of products relative to the baseline scenario.

4.4 ENVIRONMENTAL IMPACTS

Any effect on the environment of introducing an EU-wide OEL will probably be negligible because it is estimated that exposure is already controlled to levels below 0.002 mg/m^3.

5 COMPARISON OF OPTIONS

The main impacts discussed in more detail in section 4 are summarised in the tables below, which are broken down by the main types of impacts (health, economic, social, macroeconomic and environmental).

Table 5.1 Comparison of health impacts by scenario (Present Value – 2010 €m prices)

Baseline Scenario		**Intervention scenario (2) – Assumes full compliance for OEL = 0.002 mg/m^3**	
Health Costs	**Health Benefits**	**Health Costs**	**Health Benefits**
As set out in section 2.5, the health costs of cancer (bladder, lung and NMSC) over the period 2010-70 are estimated to be: - Females: €1.4bn to €3.1bn - Males: €4.8bn to €16bn - Total: €6.2bn to €194bn This range takes into consideration tangible costs (e.g. lost income, lost output from reduced productivity, medical costs, life years lost) and intangible costs (e.g. emotional and physical suffering from having cancer).	It is assumed that exposures fall by 6% per year in the future continuing the historical trend in reduced exposure. Therefore there is expected to be some reduction in health costs going forward in the absence of further regulatory intervention.	None.	None – exposure is already estimated to be below the possible OEL.

Note: Costs and benefits under the intervention options are relative to the baseline scenario (i.e. are not absolute impacts but differences)

Table 5.2 Comparison of economic impacts by scenario

Baseline Scenario		Intervention scenario (2) – Assumes full compliance for OEL = 0.002 mg/m^3	
Economic Costs	**Economic Benefits**	**Economic Costs**	**Economic Benefits**
It is assumed that exposures will fall by 6% per year in the future. Therefore, there are expected to be some costs to firms where b[a]p exposure occurs to put into place employee training, PPE and ventilation measures to reduce inhalation and dermal exposure. These would occur regardless of further intervention over the period 2010-2070.	-	It is estimated that, under the baseline scenario, firms are already achieving exposures less than 0.002 mg/m^3. Therefore there are not expected to be any significant additional costs of meeting an OEL of 0.002 mg/m^3 relative to the baseline scenario.	Having an EU-wide OEL should remove any EU competitive distortions between EU Member States with different OELs.

Note: Costs and benefits under the intervention options are relative to the baseline scenario (i.e. are not absolute impacts but differences)

Table 5.3 Comparison of social impacts by scenario

Baseline Scenario		Intervention scenario (2) – Assumes full compliance for OEL = 0.002 mg/m^3	
Social Costs	**Social Benefits**	**Social Costs**	**Social Benefits**
There are not expected to be any noticeable social impacts under the baseline scenario at an EU level.		There are not expected to be any noticeable changes to the numbers of workers required as a result of introducing an EU-wide OEL.	

Note: Costs and benefits under the intervention options are relative to the baseline scenario (i.e. are not absolute impacts but differences)

Table 5.4 Comparison of macro-economic impacts by scenario

Baseline Scenario		Intervention scenario (2) – Assumes full compliance for OEL = 0.002 mg/m^3	
Marco-economic Costs	**Marco-economic Benefits**	**Marco-economic Costs**	**Marco-economic Benefits**
There are not expected to be any noticeable macroeconomic impacts under the baseline scenario.		Since there are not expected to be any significant economic impacts, there are not expected to be any significant changes in macroeconomic impacts relative to the baseline scenario from introducing an EU-wide OEL.	

Note: Costs and benefits under the intervention options are relative to the baseline scenario (i.e. are not absolute impacts but differences)

Table 5.5 Comparison of environmental impacts by scenario

Baseline Scenario		Intervention scenario (2) – Assumes full compliance for OEL = 0.002 mg/m^3	
Environmental Costs	**Environmental Benefits**	**Environmental Costs**	**Environmental Benefits**
There are not expected to be any noticeable environmental impacts under the baseline scenario.		No workers exposed to b[a]p are estimated to be exposed above the possible EU-wide OEL value of 0.002 mg/m^3 and therefore most workplaces are unlikely to be affected/require further changes to their existing working practice. Therefore there are not estimated to be any significant changes in environmental impacts.	

Note: Costs and benefits under the intervention options are relative to the baseline scenario (i.e. are not absolute impacts but differences)

6 CONCLUSIONS

Benzo[a]pyrene (B[a]P) has been considered as a marker of exposure to polycyclic aromatic hydrocarbon (PAH) mixtures. This report considers the likely health, socioeconomic and environmental impacts associated with possible changes to the Carcinogens Directive, in particular the possible introduction of an occupational exposure limit (OEL) of 0.002 mg/m^3 for benzo[a]pyrene.

There is potential exposure to benzo[a]pyrene in aluminium, iron and steel production plants, foundries, waste incineration, mining or oil refining, coke and tar production plants, coal gasification sites, bitumen and asphalt production plants, road and roof tarring operations, and other facilities that burn carbonaceous materials. While benzo[a]pyrene may be found in diesel engine exhaust emissions we have excluded this source as we have considered these emissions in a separate report.

We estimated that in 2006 in the EU there were 234,000 workers who were potentially exposed to high levels of benzo[a]pyrene and about 7 million to low levels. The overall geometric mean exposure level was 0.000023 mg/m^3 with a geometric standard deviation of 6.29. According to these data exposure concentrations are currently below the suggested OEL in all EU countries and it is unlikely that many workers are exposed above the potential OEL of 0.002 mg/m^3. We assume exposure levels have been decreasing by about 6% per annum and that this reduction will continue for at least the next 20-years.

Exposure to PAH may cause lung and bladder cancer and skin contact with tar or pitch containing PAH may cause non-melanoma skin cancer (NMSC). The epidemiological literature has allowed for an assessment of a relative risk for each of these cancers.

We estimate that in 2010 in the EU there will be about 151 incident cases of bladder cancer and 466 cases of lung cancer that might be attributable to past exposure to PAH mixtures containing benzo[a]pyrene (corresponding to 0.114% of all bladder cancer cases and 0.153% of lung cancers amongst the exposed workers). There are estimated to be 47 bladder and 430 lung cancer deaths in the same year attributable to past PAH exposure. Future attributable incidence and mortality are expected to decreases from the identified decline in exposures so that by the decade starting 2060 it is judged there will be three bladder cancer registrations per year and five lung cancer registrations per year that are attributable to exposure to PAH containing benzo[a]pyrene. DALYs decrease from 6,978 to 64 per year and 703 to 17 each year for lung and bladder cancer, respectively.

For NMSC there are 254 incident cases in 2010 attributed to past exposure to PAH containing benzo[a]pyrene with two deaths and 24 DALYs. The number of NMSC each year form PAH exposure is estimated to rise slowly so that by the decade starting 2060 there are 299 incident cases, three deaths and 29 DALYs, per year. The main cause of the increase is the increase in survival amongst the population as a consequence of improving general health and our assumption of continued exposure to benzo[a]pyrene in remediation of roads and roofs containing tar or pitch. Total estimated health costs over the period up to 2069 that are associated with inaction range from €6,292m to €19,438m.

The impacts of NMSC are relatively limited compared to the total costs (€6-19bn), with total costs over the period 2010-69 being between €45m and €453m. The rest of the health costs relate to bladder and lung cancer.

Current exposures in the EU are judged to be well below 0.002 mg/m^3 and so there are no predicted health benefits and no important costs associated with compliance with the suggested OEL. There are also no social or macro-economic costs associated with introducing an OEL at either of these levels.

There are no significant environmental impacts foreseen.

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8 APPENDIX

8.1 ESTIMATED NUMBER OF EMPLOYEES IN EACH INDUSTRY GROUP – MEMBER STATE BREAKDOWN – MALES AND FEMALES

Table 8.1.1 Number of workers exposed to Benzo[a]pyrene by Member State and NACE code – males and females

	NACE Code																	
	13			14			15			20			21			22		
Country	**Total**	**Male**	**Female**	**Total**	**Male**	**Female**	**Total**	**Male**	**Female**	**Total**	**Male**	**Female**	**Total**	**Male**	**Female**	**Total**	**Male**	**Female**
Austria		Not Available		27	26	1	348	281	66	121	98	23	48	39	9	7	6	1
Belgium		Not Available			Not Available		441	357	84	43	35	8	38	31	7	9	8	2
Bulgaria	502	432	70	42	36	6	502	261	241	63	33	30	30	15	14	5	2	2
Cyprus	0	0	0	3	3	0	58	44	15	10	7	2	2	2	1	1	0	0
Czech Republic	2	2	0	37	34	3		Not Available		230	149	80	54	35	19	12	8	4
Denmark	0	0	0	7	6	2	390	285	105	47	34	13	20	15	5	10	7	3
Estonia	0	0	0	5	5	0	79	43	35	61	33	27	5	3	2	2	1	1
Finland	45	43	2	14	13	1	178	132	46	100	74	26	83	61	22	9	7	2
France	27	23	4	160	135	26		Not Available		273	210	63	212	163	49	52	40	12
Germany	0	0	0	200	182	18	3,763	2,897	865	448	345	103	388	299	89	100	77	23
Greece	56	54	2	35	34	1	393	298	94	45	35	11	20	15	5	8	6	2
Hungary	21	20	1	25	24	1	558	351	206	84	53	31	47	29	17	9	6	3
Ireland		Not Available		21	20	1	226	170	57	22	16	5	9	7	2	4	3	1
Italy	23	21	2	174	160	14	2,019	1,514	505	529	397	132	213	160	53	45	34	11
Latvia	0	0	0	5	4	1	161	93	68	101	58	42	4	3	2	3	2	1
Lithuania	0	0	0	9	8	1	235	122	113	104	54	50	6	3	3	3	2	2
Luxembourg	0	0	0	2	2	0		Not Available		2	2	0		Not Available			Not Available	
Malta		Not Available		2	2	0		Not Available			Not Available		1	1	0	1	0	0
Netherlands		Not Available		12	10	2	581	477	105	62	51	11	59	48	11	22	18	4
Poland		Not Available			Not Available		2,051	1,374	677	431	289	142	119	80	39	27	18	9
Portugal	82	79	2	79	76	2	490	289	201	146	86	60	32	19	13	10	6	4
Romania	676	595	81	63	55	8	943	509	434	253	136	116	44	24	20	10	6	5

	NACE Code																	
	13			14			15			20			21			22		
Country	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female
Slovakia	49	48	1	14	13	0	215	138	77	46	30	17	21	13	7	3	2	1
Slovenia	Not Available			Not Available			89	59	30	38	25	13	14	9	5	3	2	1
Spain	39	37	2	165	156	8	1,786	1,393	393	324	252	71	149	116	33	43	33	9
Sweden	409	364	45	15	13	2	Not Available			133	104	29	111	87	24	14	11	3
United Kingdom	0	0	0	171	151	21	2,018	1,634	383	267	217	51	199	161	38	91	73	17
Total	1,931	1,718	213	1,291	1,173	118	17,552	12,743	4,809	3,987	2,827	1,160	1,934	1,442	492	502	378	125

	NACE Code														
	23			24			26			27			28		
Country	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female
Austria	Not Available			230	186	44	135	109	26	5,535	4,483	1,052	541	438	103
Belgium	504	408	96	599	485	114	123	100	23	5,648	4,575	1,073	512	415	97
Bulgaria	407	212	195	222	116	107	112	58	54	3,753	1,952	1,802	315	164	151
Cyprus	11	8	3	16	12	4	13	10	3	61	46	15	29	22	7
Czech Republic	258	168	90	354	230	124	293	191	103	9,604	6,242	3,361	1,260	819	441
Denmark	Not Available			256	187	69	69	50	19	897	655	242	358	261	97
Estonia	92	51	42	26	14	11	22	12	10	69	38	31	98	54	44
Finland	230	170	60	160	118	42	73	54	19	2,450	1,813	637	369	273	96
France	2,347	1,807	540	2,353	1,812	541	528	407	121	16,694	12,854	3,840	3,238	2,493	745
Germany	1,781	1,389	392	3,917	3,016	901	923	720	203	43,022	33,557	9,465	5,949	4,640	1,309
Greece	351	267	84	155	118	37	98	74	23	2,297	1,745	551	304	231	73
Hungary	548	345	203	274	173	101	109	69	40	3,205	2,019	1,186	562	354	208
Ireland	Not Available			212	159	53	42	31	10	410	308	103	99	74	25
Italy	1,454	1,090	363	1,709	1,282	427	936	702	234	22,741	17,056	5,685	5,336	4,002	1,334
Latvia	4	2	2	37	22	16	24	14	10	601	349	252	73	43	31
Lithuania	304	158	146	52	27	25	46	24	22	154	80	74	139	72	67
Luxembourg	0	0	0	9	8	1	11	10	1	1,012	881	132	32	28	4

	NACE Code														
	23			24			26			27			28		
Country	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female
Malta	Not Available			8	5	2	Not Available			Not Available			Not Available		
Netherlands	568	471	96	545	447	98	112	93	19	3,499	2,904	595	743	616	126
Poland	1,280	857	422	924	619	305	539	361	178	12,026	8,057	3,968	2,095	1,404	691
Portugal	183	108	75	184	108	75	230	136	94	1,613	952	661	665	393	273
Romania	597	322	275	417	225	192	230	124	106	10,144	5,478	4,666	775	419	357
Slovakia	15	10	5	110	70	40	80	51	29	4,430	2,835	1,595	260	166	94
Slovenia	8	5	3	120	79	41	37	24	12	1,521	1,004	517	257	170	87
Spain	757	590	166	1,193	931	263	765	596	168	12,292	9,587	2,704	2,834	2,210	623
Sweden	280	219	62	372	290	82	78	60	17	7,825	6,104	1,722	642	501	141
United Kingdom	2,065	1,672	392	1,834	1,485	348	430	348	82	12,212	9,892	2,320	2,508	2,032	477
Total	14,051	10,337	3,714	16,301	12,234	4,066	6,080	4,446	1,635	183,787	135,517	48,270	30,092	22,363	7,729

	NACE Code														
	29			34			35			40			45		
Country	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female
Austria	461	373	88	1,125	911	214	385	312	73	847	737	110	545	518	27
Belgium	247	200	47	1,599	1,295	304	321	260	61	489	425	64	567	550	17
Bulgaria	397	206	190	95	49	45	384	200	184	1,131	984	147	400	380	20
Cyprus	6	4	1	8	6	2	5	4	1	Not Available			74	71	3
Czech Republic	923	600	323	3,822	2,484	1,338	739	480	259	1,090	927	164	849	789	59
Denmark	354	258	96	217	159	59	268	195	72	406	325	81	438	412	26
Estonia	31	17	14	76	42	34	97	53	44	196	176	20	108	98	10
Finland	378	280	98	222	164	58	552	408	144	390	335	55	375	356	19
France	1,728	1,331	398	9,096	7,004	2,092	5,044	3,884	1,160	4,705	3,623	1,082	3,564	3,422	143
Germany	5,970	4,597	1,373	28,558	21,990	6,568	4,738	3,648	1,090	6,904	6,006	898	3,235	3,073	162
Greece	129	98	31	97	74	23	475	361	114	Not Available			668	655	13

	NACE Code														
	29			34			35			40			45		
Country	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female
Hungary	388	244	144	1,741	1,097	644	275	173	102	967	812	155	518	502	16
Ireland	65	49	16	131	98	33	129	97	32	287	276	11	156	155	2
Italy	3,206	2,405	802	5,644	4,233	1,411	3,685	2,764	921	2,616	2,276	340	3,982	3,862	119
Latvia	41	24	17	42	24	17	185	107	78	384	311	73	158	147	11
Lithuania	62	32	30	40	21	19	244	127	117	569	438	131	269	253	16
Luxembourg	14	12	2		Not Available			Not Available		28	26	2	77	76	1
Malta	2	2	1	2	2	1	127	90	37		Not Available		28	27	1
Netherlands	506	415	91	765	627	138	855	701	154	565	452	113	1,038	997	42
Poland	1,172	785	387	4,086	2,738	1,348	2,416	1,619	797	4,617	3,924	693	1,511	1,451	60
Portugal	269	159	110	786	464	322		not available		310	269	40	1,066	1,055	11
Romania	584	315	269	2,124	1,147	977	2,052	1,108	944	2,824	2,344	480	922	849	74
Slovakia	256	164	92	988	632	356	249	159	90	761	647	114	156	149	6
Slovenia	153	101	52	302	199	103	90	60	31	227	191	36	155	147	8
Spain	1,094	854	241	5,377	4,194	1,183	1,971	1,538	434	1,153	992	161	6,037	5,856	181
Sweden	663	517	146	2,917	2,275	642	756	590	166	858	686	172	586	563	23
United Kingdom	1,572	1,273	299	6,064	4,912	1,152	5,002	4,052	950	3,254	2,766	488	3,007	2,917	90
Total	20,671	15,315	5,356	75,924	56,841	19,083	31,043	22,989	8,054	35,911	30,236	5,676	30,514	29,353	1,161

	NACE Code														
	50			51			60			63			73		
Country	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female
Austria	2,259	1,401	858	1,429	886	543	433	355	78	10,963	8,990	1,973	23	16	7
Belgium	2,071	1,553	518	1,634	1,226	409	341	300	41	9,843	8,661	1,181	26	18	9
Bulgaria		Not Available			Not Available		336	306	30	7,649	6,960	688	1	1	0
Cyprus	232	188	44	143	116	27	17	13	4	1,346	1,050	296	0	0	0
Czech Republic	2,351	1,646	705	1,721	1,204	516	756	627	128	8,086	6,711	1,375	26	16	11
Denmark	1,603	1,250	353	1,235	963	272	280	227	53	6,406	5,189	1,217	27	18	10

	NACE Code														
		50			51			60			63			73	
Country	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female
Estonia	321	202	119	292	184	108	83	64	19	2,152	1,657	495	2	1	1
Finland	1,309	838	471	700	448	252	269	218	51	6,600	5,346	1,254	106	63	43
France	11,620	8,134	3,486	7,730	5,411	2,319	2,620	2,070	550	52,696	41,630	11,066	180	113	67
Germany	18,555	11,504	7,051	9,148	5,671	3,476	2,411	2,073	337	97,923	84,214	13,709	403	230	173
Greece	2,762	2,182	580	2,413	1,906	507	456	419	36	7,918	7,285	633	38	23	16
Hungary	2,080	749	1,331	1,210	436	774	585	521	64	6,066	5,398	667	28	18	9
Ireland	1,064	841	224	625	494	131	109	99	10	3,873	3,524	349	10	7	3
Italy	12,228	9,171	3,057	7,944	5,958	1,986	1,975	1,679	296	64,210	54,578	9,631	114	72	42
Latvia	555	272	283	394	193	201	171	135	36	3,208	2,534	674	5	3	2
Lithuania	1,188	737	452	560	347	213	234	192	42	3,008	2,467	541	3	2	1
Luxembourg	213	160	53	104	78	26	47	41	6	517	455	62		Not Available	
Malta	96	66	30	70	48	22	8	7	1	912	775	137	0	0	0
Netherlands	3,879	2,754	1,125	3,415	2,424	990	703	597	105	17,348	14,746	2,602	145	96	49
Poland	6,848	4,725	2,123	5,182	3,576	1,607	1,759	1,548	211	14,907	13,118	1,789	18	11	6
Portugal	3,343	1,571	1,772	2,088	981	1,106	376	331	45	7,493	6,594	899	5	3	2
Romania	2,816	1,886	929	2,525	1,691	833	747	657	90	13,233	11,645	1,588	99	64	35
Slovakia	423	284	140	632	424	209	222	191	31	2,108	1,813	295	19	11	8
Slovenia	412	255	157	312	194	119	115	99	16	1,710	1,470	239	11	7	4
Spain	10,434	7,617	2,817	8,332	6,083	2,250	2,068	1,799	269	45,768	39,818	5,950	72	37	34
Sweden	2,215	1,772	443	1,649	1,320	330	488	410	78	11,444	9,613	1,831		Not Available	
United Kingdom	15,546	11,193	4,353	8,473	6,100	2,372	2,027	1,783	243	72,681	63,960	8,722	443	297	146
Total	106,484	72,992	33,491	70,020	48,404	21,616	19,672	16,794	2,878	480,522	410,589	69,933	1,806	1,126	681

	NACE Code											
		74			75			80			Grand Total	
Country	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female
Austria	24,656	16,766	7,890	58,690	36,975	21,715	18,989	5,507	13,482	**127,335**	**79,412**	**48,296**
Belgium	34,696	23,247	11,450	97,608	61,493	36,115	32,599	10,106	22,494	**189,713**	**115,748**	**74,165**
Bulgaria	10,488	7,027	3,461	52,123	37,528	14,594	18,735	5,995	12,740	**97,293**	**62,485**	**34,583**
Cyprus	1,161	685	476	6,939	4,649	2,290	1,948	604	1,344	**12,076**	**7,544**	**4,537**
Czech Republic	30,125	18,075	12,050	74,355	39,408	34,947	24,395	6,099	18,296	**160,419**	**86,944**	**74,073**
Denmark	21,301	13,846	7,455	38,570	21,213	17,356	18,419	7,736	10,683	**91,223**	**53,291**	**38,192**
Estonia	3,491	1,955	1,536	9,027	3,521	5,507	5,081	762	4,319	**21,383**	**8,985**	**12,414**
Finland	15,200	8,968	6,232	27,100	13,008	14,092	14,600	4,818	9,782	**71,134**	**37,966**	**33,405**
France	203,482	128,194	75,288	558,263	279,132	279,132	154,029	49,289	104,740	**1,038,914**	**553,158**	**487,066**
Germany	276,721	157,731	118,990	667,567	320,432	347,135	180,390	64,940	115,449	**1,357,044**	**733,233**	**628,407**
Greece	23,492	13,860	9,632	88,256	60,014	28,242	26,220	9,701	16,519	**156,556**	**99,401**	**57,199**
Hungary	27,232	17,973	9,259	66,209	32,442	33,767	27,598	6,899	20,698	**139,952**	**70,691**	**69,486**
Ireland	11,986	8,031	3,955	24,182	16,685	7,496	11,223	3,030	8,193	**54,822**	**34,174**	**20,697**
Italy	165,859	104,491	61,368	328,585	220,152	108,433	133,057	31,934	101,123	**765,078**	**469,972**	**297,491**
Latvia	3,678	1,950	1,729	20,260	10,130	10,130	7,626	1,373	6,253	**37,678**	**17,790**	**19,911**
Lithuania	4,727	2,505	2,222	17,568	9,311	8,257	11,495	2,069	9,426	**40,960**	**19,052**	**21,941**
Luxembourg	3,381	2,096	1,285	5,152	3,864	1,288	1,307	445	863	**11,893**	**8,181**	**3,724**
Malta	688	434	255	3,249	1,917	1,332	1,053	295	758	**6,245**	**3,671**	**2,576**
Netherlands	105,505	69,633	35,872	129,889	79,232	50,657	46,648	19,126	27,523	**316,957**	**196,936**	**120,435**
Poland	56,927	36,433	20,494	212,435	112,591	99,845	98,360	23,606	74,754	**428,558**	**219,185**	**210,159**
Portugal	39,541	23,329	16,212	81,502	52,977	28,526	27,045	7,302	19,743	**167,269**	**97,208**	**70,141**
Romania	24,655	16,026	8,629	112,646	68,714	43,932	35,908	9,695	26,213	**214,703**	**123,441**	**90,981**
Slovakia	5,915	3,490	2,425	37,595	18,422	19,173	14,426	2,885	11,541	**68,737**	**32,598**	**36,254**
Slovenia	4,552	2,777	1,775	13,135	7,224	5,911	6,529	1,436	5,092	**29,636**	**15,538**	**14,201**
Spain	160,828	83,630	77,197	283,495	158,757	124,738	92,454	34,208	58,246	**638,336**	**361,250**	**277,902**
Sweden	29,951	20,367	9,584	58,504	27,497	31,007	42,085	10,521	31,564	**161,331**	**83,518**	**77,968**
United Kingdom	274,188	183,706	90,482	467,548	257,151	210,397	219,939	79,178	140,761	**1,099,966**	**636,953**	**464,286**
Total	1,564,696	967,394	597,303	3,540,451	1,954,439	1,586,012	1,272,159	399,560	872,598	**7,505,213**	**4,228,324**	**3,290,486**

8.2 ESTIMATED DEATHS AND REGISTRATIONS IN THE EU FROM LUNG AND BLADDER CANCERS AND NMSC

Table 8.2.1 Forecast number of lung, bladder and NMSC cancers in ages 25+ (ages 15+ for lung and bladder cancer registrations), based on projected EU country populations

Lung cancer deaths	***MEN***						***WOMEN***					
FTY	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Austria	2,698	3,346	3,956	4,483	4,711	4,745	1,129	1,290	1,459	1,611	1,705	1,687
Belgium	0	0	0	0	0	0	0	0	0	0	0	0
Bulgaria	3,127	3,202	3,344	3,500	3,456	3,149	590	604	627	634	624	588
Cyprus	146	199	257	320	389	456	38	50	66	82	96	113
Czech Republic	4,741	5,771	6,660	7,492	8,086	8,078	1,582	1,790	2,024	2,204	2,278	2,323
Denmark	2,342	2,915	3,363	3,606	3,695	3,745	1,819	2,137	2,380	2,529	2,552	2,563
Estonia	610	666	751	847	937	982	154	166	172	182	189	183
Finland	1,686	2,167	2,617	2,783	2,822	2,923	592	693	786	824	818	817
France	24,854	29,288	33,628	36,549	38,217	39,689	6,697	7,502	8,353	9,042	9,293	9,389
Germany (including ex-GDR from 1991)	33,102	39,458	44,318	48,341	48,129	46,049	12,629	14,018	14,868	15,581	15,458	14,585
Greece	5,779	6,593	7,578	8,628	9,275	9,333	1,070	1,265	1,388	1,542	1,665	1,705
Hungary	6,068	6,634	7,398	8,125	8,599	8,624	2,437	2,557	2,746	2,803	2,814	2,785
Ireland	1,175	1,595	2,112	2,691	3,299	3,759	720	932	1,209	1,512	1,815	2,051
Italy	29,397	34,515	40,206	46,091	49,731	49,259	7,857	8,917	9,911	10,930	11,683	11,548
Latvia	1,025	1,091	1,220	1,355	1,483	1,502	220	231	239	256	265	264
Lithuania	1,384	1,538	1,764	1,982	2,138	2,164	267	286	313	344	352	350
Luxembourg	176	228	291	350	386	413	52	61	75	89	96	102
Malta	146	192	235	255	275	299	20	21	22	23	24	23
Netherlands	7,177	9,325	11,423	12,679	12,877	12,754	3,444	4,079	4,583	4,835	4,782	4,720
Poland	19,813	24,204	28,329	31,413	34,266	34,929	5,717	6,552	7,274	8,001	8,124	7,952
Portugal	3,111	3,600	4,173	4,708	5,070	5,188	677	778	878	977	1,046	1,073
Romania	8,342	9,179	10,368	11,480	11,726	11,057	1,935	2,100	2,335	2,521	2,626	2,589
Slovakia	1,963	2,488	3,057	3,508	3,884	3,932	438	508	608	709	742	773
Slovenia	944	1,168	1,406	1,545	1,581	1,552	282	317	353	379	379	370
Spain	20,051	24,629	30,491	36,512	40,400	40,734	2,942	3,503	4,051	4,536	4,903	5,021
Sweden	2,078	2,503	2,886	3,122	3,340	3,542	1,659	1,862	2,064	2,198	2,302	2,390

Lung cancer deaths	MEN						WOMEN					
FTY	2010	2020	2030	2040	2050	2060	2010	2020	2030	2040	2050	2060
United Kingdom	21,915	26,107	30,805	34,784	38,234	41,219	15,291	17,180	19,778	22,297	24,098	25,562
European Union (27 countries)	210,064	249,072	289,493	323,680	342,919	348,763	70,053	79,186	88,770	96,845	100,598	100,564

Lung cancer registrations	MEN						WOMEN					
FTY	2010	2020	2030	2040	2050	2060	2010	2020	2030	2040	2050	2060
Austria	3,195	3,838	4,514	4,960	5,120	5,164	1,214	1,357	1,526	1,653	1,691	1,679
Belgium	7,322	8,692	10,013	10,852	11,262	11,628	1,292	1,445	1,593	1,703	1,753	1,779
Bulgaria	2,684	2,717	2,857	2,967	2,899	2,741	513	529	545	553	541	514
Cyprus	0	0	0	0	0	0	0	0	0	0	0	0
Czech Republic	5,691	6,740	7,663	8,472	8,896	8,764	1,447	1,647	1,808	1,937	2,003	1,988
Denmark	2,325	2,806	3,129	3,278	3,289	3,392	1,648	1,877	2,063	2,137	2,166	2,201
Estonia	630	684	762	847	921	949	142	148	156	161	163	163
Finland	1,681	2,142	2,375	2,420	2,462	2,527	609	716	780	795	789	788
France	26,745	31,101	34,491	36,630	37,854	39,219	5,039	5,699	6,221	6,585	6,689	6,754
Germany (including ex-GDR from 1991)	38,324	44,013	49,121	51,188	50,140	48,059	11,541	12,457	13,257	13,586	13,278	12,593
Greece	6,094	6,934	7,896	8,787	9,161	8,965	1,059	1,189	1,307	1,413	1,454	1,415
Hungary	6,802	7,380	8,170	8,966	9,417	9,471	2,371	2,499	2,628	2,710	2,719	2,683
Ireland	1,252	1,689	2,180	2,721	3,274	3,530	716	932	1,193	1,470	1,747	1,894
Italy	34,941	40,490	46,453	51,486	52,717	51,737	7,555	8,466	9,366	10,142	10,308	9,994
Latvia	951	1,015	1,110	1,226	1,296	1,278	181	183	191	198	200	196
Lithuania	1,385	1,524	1,745	1,956	2,094	2,138	226	238	261	277	279	278
Luxembourg	252	326	405	467	507	544	60	73	86	97	107	114
Malta	146	186	213	228	246	256	25	30	34	35	37	38
Netherlands	8,745	11,124	12,938	13,657	13,484	13,607	2,635	3,038	3,312	3,421	3,423	3,370
Poland	22,877	27,302	31,024	34,644	36,831	36,566	5,119	5,745	6,372	6,806	6,831	6,624
Portugal	2,875	3,318	3,829	4,280	4,552	4,608	628	711	793	859	897	892
Romania	7,766	8,440	9,584	10,539	10,779	10,354	1,701	1,842	2,018	2,197	2,264	2,208
Slovakia	2,512	3,125	3,739	4,299	4,667	4,649	456	534	616	676	706	697
Slovenia	988	1,219	1,418	1,534	1,555	1,485	284	317	347	361	357	341

Lung cancer registrations	***MEN***						***WOMEN***					
FTY	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Spain	21,064	25,941	31,814	36,979	39,486	38,712	2,341	2,769	3,238	3,632	3,854	3,807
Sweden	1,965	2,314	2,570	2,754	2,899	3,067	1,342	1,479	1,609	1,701	1,772	1,816
United Kingdom	27,363	32,395	37,148	40,910	43,779	47,708	16,430	18,564	21,109	23,352	24,834	26,443
European Union (27 countries)	234,922	275,404	314,082	343,072	356,383	358,425	66,807	75,248	83,431	89,518	91,591	90,888

Bladder cancer deaths	***MEN***						***WOMEN***					
FTY	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Austria	372	488	623	791	957	951	172	189	230	280	334	331
Belgium	0	0	0	0	0	0	0	0	0	0	0	0
Bulgaria	387	404	445	490	531	548	119	125	136	142	147	149
Cyprus	32	44	59	77	96	115	3	5	7	9	12	15
Czech Republic	586	762	1,011	1,166	1,353	1,569	233	274	329	359	390	420
Denmark	408	536	672	754	810	811	175	210	252	279	295	294
Estonia	64	73	87	106	124	146	31	35	37	42	45	46
Finland	185	245	322	353	359	376	71	86	107	121	123	121
France	3,879	4,718	5,888	6,875	7,459	7,820	1,230	1,400	1,675	2,007	2,167	2,193
Germany (including ex-GDR from 1991)	4,075	5,444	6,257	7,520	8,350	7,819	2,005	2,360	2,572	2,989	3,319	3,069
Greece	921	1,098	1,264	1,532	1,792	1,942	200	256	283	334	385	410
Hungary	568	652	766	897	1,013	1,145	240	268	300	332	345	375
Ireland	138	192	267	354	458	569	67	84	113	149	188	234
Italy	4,620	5,650	6,689	7,945	9,277	9,511	1,257	1,474	1,668	1,918	2,236	2,314
Latvia	126	138	157	185	210	234	57	62	65	72	77	83
Lithuania	194	223	266	332	393	436	56	63	69	82	89	91
Luxembourg	22	30	40	54	64	70	8	9	10	14	17	19
Malta	34	47	68	81	86	101	8	11	15	17	18	20
Netherlands	900	1,196	1,600	1,869	2,025	1,974	367	441	555	646	690	673

Bladder cancer deaths	***MEN***						***WOMEN***					
FTY	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Poland	2,446	3,056	3,942	4,731	5,213	5,936	649	768	928	1,113	1,141	1,238
Portugal	560	674	808	981	1,149	1,279	207	253	295	351	406	445
Romania	1,011	1,131	1,330	1,577	1,810	1,931	307	340	397	451	510	551
Slovakia	199	253	350	446	523	614	75	90	116	139	153	172
Slovenia	101	136	175	215	235	246	45	53	62	73	77	78
Spain	4,148	5,075	6,370	8,147	9,959	10,917	870	1,033	1,238	1,545	1,886	2,106
Sweden	491	608	759	837	924	987	181	205	250	276	299	317
United Kingdom	3,481	4,249	5,260	6,126	7,001	7,473	1,691	1,873	2,260	2,638	3,019	3,190
European Union (27 countries)	30,722	37,976	46,330	55,274	62,497	65,778	10,637	12,330	14,440	16,995	18,957	19,638

Bladder cancer registrations	***MEN***						***WOMEN***					
FTY	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Austria	1,715	2,072	2,518	2,815	2,916	2,960	559	625	732	810	835	834
Belgium	2,030	2,449	2,895	3,176	3,304	3,430	548	627	724	793	823	842
Bulgaria	636	656	695	736	753	730	171	177	183	186	183	175
Cyprus	0	0	0	0	0	0	0	0	0	0	0	0
Czech Republic	1,759	2,186	2,488	2,787	3,040	3,050	636	736	809	873	918	915
Denmark	784	971	1,101	1,174	1,168	1,207	255	300	338	360	362	368
Estonia	156	170	191	213	236	248	55	59	62	64	66	67
Finland	686	882	983	1,001	1,019	1,048	220	266	293	299	297	298
France	10,183	12,430	14,253	15,519	16,066	16,701	2,158	2,575	2,959	3,250	3,310	3,336
Germany (including ex-GDR from 1991)	22,629	26,022	29,785	31,514	30,871	29,765	7,445	8,054	8,924	9,346	9,152	8,754
Greece	2,311	2,632	3,018	3,441	3,670	3,591	467	529	590	658	693	673
Hungary	1,456	1,630	1,809	2,016	2,201	2,256	540	582	613	640	662	661
Ireland	476	636	814	1,006	1,199	1,290	171	223	285	348	411	445

Bladder cancer registrations	MEN						WOMEN					
FTY	2010	2020	2030	2040	2050	2060	2010	2020	2030	2040	2050	2060
Italy	18,441	21,391	24,656	27,696	28,472	27,931	3,718	4,172	4,682	5,204	5,339	5,171
Latvia	205	217	243	270	293	304	72	73	78	81	83	84
Lithuania	351	382	450	510	552	583	105	111	124	133	136	136
Luxembourg	118	156	202	240	261	281	35	42	51	59	65	69
Malta	61	81	94	100	110	116	18	23	26	27	28	30
Netherlands	4,771	6,115	7,167	7,614	7,495	7,568	1,111	1,340	1,545	1,643	1,631	1,618
Poland	6,023	7,376	8,506	9,448	10,301	10,435	1,303	1,524	1,731	1,834	1,919	1,925
Portugal	1,695	1,958	2,269	2,570	2,754	2,790	467	532	601	666	699	695
Romania	2,508	2,757	3,134	3,579	3,840	3,818	678	738	809	890	929	916
Slovakia	522	675	833	961	1,088	1,120	165	201	240	265	287	294
Slovenia	182	233	281	309	324	313	50	57	65	70	72	69
Spain	12,477	15,309	18,883	22,192	23,633	23,079	1,710	2,022	2,425	2,846	3,090	3,035
Sweden	1,792	2,133	2,376	2,559	2,687	2,868	593	672	742	797	828	871
United Kingdom	9,713	11,527	13,260	14,634	15,638	17,095	3,654	4,144	4,754	5,296	5,627	6,031
European Union (27 countries)	102,412	121,289	140,370	155,410	162,871	164,733	26,842	30,599	34,652	37,902	39,265	39,223

NMSC deaths	MEN						WOMEN					
FTY	2010	2020	2030	2040	2050	2060	2010	2020	2030	2040	2050	2060
Austria	42	54	70	89	110	109	33	36	45	55	66	66
Belgium	59	71	89	112	128	134	43	49	57	70	79	81
Bulgaria	37	39	46	54	62	74	26	29	34	39	42	47
Cyprus	3	5	7	9	11	14	2	3	4	5	6	8
Czech Republic	43	55	79	93	108	135	34	40	53	61	66	80
Denmark	27	35	48	54	62	62	19	22	29	33	37	38
Estonia	5	6	7	8	10	12	5	6	7	8	8	9

NMSC deaths	*MEN*						*WOMEN*					
FTY	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Finland	27	36	50	58	60	62	21	25	33	37	38	38
France	347	423	550	674	750	792	260	299	360	444	486	493
Germany (including ex-GDR from 1991)	464	654	745	921	1,079	996	356	424	465	548	631	579
Greece	70	87	99	121	147	165	41	54	60	71	83	89
Hungary	42	49	62	76	88	112	37	43	50	59	61	72
Ireland	16	23	33	44	57	74	11	14	19	25	32	41
Italy	380	479	569	680	833	877	280	332	376	435	518	543
Latvia	8	10	11	14	17	20	9	10	11	12	14	14
Lithuania	12	14	17	22	27	30	12	14	16	19	22	22
Luxembourg.	2	3	4	5	7	7	2	2	2	3	4	4
Malta	2	2	4	4	5	5	1	2	2	3	3	3
Netherlands	76	102	144	175	197	190	54	64	86	105	118	114
Poland	140	177	241	327	350	429	118	145	181	238	243	276
Portugal	57	71	85	106	129	150	40	50	59	70	82	91
Romania	87	103	122	158	193	237	61	74	85	107	124	145
Slovakia	17	21	30	42	50	63	14	17	23	30	34	40
Slovenia	9	12	16	21	24	27	7	9	11	13	15	15
Spain	254	313	391	511	665	784	176	210	252	319	398	453
Sweden	56	67	90	100	113	121	37	41	52	58	64	69
United Kingdom	332	408	519	615	722	761	222	244	301	358	425	447
European Union (27 countries)	2,614	3,318	4,128	5,095	6,003	6,442	1921	2258	2670	3225	3696	3876

NMSC registrations	*MEN*						*WOMEN*					
FTY	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Austria	5378	6632	8027	9370	10205	10262	4822	5394	6226	7050	7617	7563
Belgium	7197	8492	10119	11576	12378	12848	6189	6885	7799	8775	9301	9486
Bulgaria	4880	5088	5598	6132	6653	6960	4360	4603	4936	5156	5279	5326
Cyprus	437	589	771	964	1160	1376	341	445	574	707	832	956
Czech Republic	6048	7522	9136	10267	11439	12324	5562	6399	7418	7985	8433	8950
Denmark	3587	4400	5179	5586	5841	5925	2890	3314	3841	4146	4333	4376
Estonia	676	747	848	973	1088	1196	828	888	935	992	1016	1031
Finland	3514	4436	5271	5585	5665	5847	3121	3607	4143	4383	4347	4340
France	40923	49117	58806	66292	70526	73575	36004	40981	47066	52777	55131	55647
Germany (including ex-GDR from 1991)	60375	73298	82922	92694	95729	90941	51897	57775	62331	67369	69161	65001
Greece	8337	9596	10964	12728	14122	14535	6532	7552	8282	9192	9845	9923
Hungary	5632	6401	7408	8424	9484	10429	5854	6419	7024	7487	7766	8156
Ireland	2227	2999	3937	4962	6051	6963	1776	2268	2898	3582	4256	4855
Italy	45165	53152	61403	70260	76854	76920	39101	44158	48945	54105	58168	57726
Latvia	1142	1252	1404	1617	1810	1963	1401	1467	1521	1614	1665	1674
Lithuania	1657	1851	2141	2530	2839	3037	1928	2096	2260	2478	2579	2536
Luxembourg (Grand-Duché)	285	369	471	577	655	702	239	284	344	417	474	508
Malta	249	323	399	442	472	516	207	254	300	328	339	359
Netherlands	10264	13054	15956	17694	18242	18022	8474	9929	11753	13034	13473	13167
Poland	19509	23982	29541	34284	37340	41016	19367	22584	26357	29625	30416	31792
Portugal	7066	8305	9774	11458	12904	13731	6182	7162	8092	9089	9855	10186
Romania	11878	13283	15405	18110	20686	22256	10646	11843	13214	14797	15987	16674
Slovakia	2505	3144	4022	4827	5476	6020	2507	2967	3566	4086	4378	4628
Slovenia	1219	1569	1921	2219	2352	2379	1152	1323	1482	1642	1693	1666
Spain	30287	36864	45495	56019	65008	67945	25602	30264	35625	41890	47007	48674

NMSC registrations	*MEN*						*WOMEN*					
FTY	2010	2020	2030	2040	2050	2060	2010	2020	2030	2040	2050	2060
Sweden	6694	7970	9324	10084	10854	11490	5302	5898	6759	7276	7718	8066
United Kingdom	40408	47829	56113	63240	69491	74687	32887	36440	41936	47172	51754	54557
European Union (27 countries)	327539	392263	462355	528914	575324	593864	285172	323199	365627	407153	432824	437825

8.3 SUPPLEMENTARY TABLES - COSTS UNDER THE BASELINE SCENARIO

Table 8.3.1 Health costs – baseline scenario – Member State breakdown - Based on a 4% discount rate

Low	Female	Male	Total	High	Female	Male	Total
Austria	€ 23.3	€ 98.8	€ 122.1	Austria	€ 57.5	€ 354.3	€ 411.8
Belgium	€ 1.9	€ 18.2	€ 20.2	Belgium	€ 62.1	€ 620.3	€ 682.4
Bulgaria	€ 15.7	€ 65.1	€ 80.8	Bulgaria	€ 34.2	€ 148.0	€ 182.2
Czech Republic	€ 58.3	€ 173.8	€ 232.1	Czech Republic	€ 146.5	€ 607.2	€ 753.8
Cyprus	€ 0.4	€ 2.1	€ 2.6	Cyprus	€ 0.0	€ 0.7	€ 0.7
Denmark	€ 29.5	€ 39.6	€ 69.1	Denmark	€ 56.8	€ 110.3	€ 167.1
Estonia	€ 2.9	€ 6.8	€ 9.7	Estonia	€ 6.9	€ 21.3	€ 28.3
Finland	€ 12.7	€ 40.3	€ 53.0	Finland	€ 32.0	€ 133.4	€ 165.4
France	€ 174.3	€ 704.9	€ 879.2	France	€ 249.3	€ 1,836.8	€ 2,086.1
Germany	€ 295.0	€ 967.0	€ 1,262.0	Germany	€ 655.5	€ 3,522.5	€ 4,178.0
Greece	€ 12.6	€ 99.8	€ 112.3	Greece	€ 31.6	€ 277.6	€ 309.2
Hungary	€ 54.2	€ 112.4	€ 166.6	Hungary	€ 111.4	€ 326.8	€ 438.3
Ireland	€ 7.6	€ 14.1	€ 21.8	Ireland	€ 16.1	€ 40.6	€ 56.7
Italy	€ 130.5	€ 669.9	€ 800.4	Italy	€ 312.3	€ 2,504.2	€ 2,816.5
Latvia	€ 4.0	€ 14.7	€ 18.7	Latvia	€ 9.0	€ 40.4	€ 49.4
Lithuania	€ 4.0	€ 14.2	€ 18.3	Lithuania	€ 10.4	€ 41.7	€ 52.1
Luxembourg	€ 1.9	€ 17.8	€ 19.7	Luxembourg	€ 5.7	€ 78.8	€ 84.5
Malta	€ 0.2	€ 1.2	€ 1.5	Malta	€ 0.5	€ 3.2	€ 3.7
Netherlands	€ 63.4	€ 164.1	€ 227.5	Netherlands	€ 96.4	€ 597.3	€ 693.7
Poland	€ 113.8	€ 361.4	€ 475.1	Poland	€ 216.3	€ 1,109.8	€ 1,326.2
Portugal	€ 12.6	€ 55.2	€ 67.8	Portugal	€ 29.1	€ 136.8	€ 165.8
Romania	€ 46.2	€ 161.1	€ 207.3	Romania	€ 109.0	€ 404.1	€ 513.0
Slovakia	€ 14.7	€ 57.8	€ 72.5	Slovakia	€ 39.0	€ 204.5	€ 243.4
Slovenia	€ 9.8	€ 30.5	€ 40.3	Slovenia	€ 19.5	€ 79.6	€ 99.2
Spain	€ 49.3	€ 325.7	€ 375.0	Spain	€ 75.1	€ 898.0	€ 973.1
Sweden	€ 49.1	€ 85.3	€ 134.5	Sweden	€ 98.1	€ 322.7	€ 420.8
United Kingdom	€ 266.7	€ 535.3	€ 802.0	United Kingdom	€ 646.2	€ 1,891.0	€ 2,537.2
TOTAL	€ 1,454.7	€ 4,837.2	€ 6,291.9	**TOTAL**	€ 3,126.3	€ 16,312.1	€ 19,438.4

Table 8.3.2 Health costs - baseline scenario - Industry group breakdown - Based on a 4% discount rate

Low	Female	Male	Total
Manufacture of coke, refined petroleum products and nuclear fuel	€ 48.4	€ 201.1	€ 249.5
Manufacture of fabricated metal products, except machinery and equipment	€ 72.0	€ 376.2	€ 448.2
Mining of metal ores	€ 0.1	€ 1.3	€ 1.4
Other mining and quarrying	€ 0.1	€ 0.9	€ 1.0
Manufacture of Food Products and Beverages	€ 2.1	€ 10.0	€ 12.1
Manufacture of wood and of products of wood and cork, except furniture	€ 0.5	€ 2.2	€ 2.7
Manufacture of pulp, paper and paper products	€ 0.2	€ 1.2	€ 1.4

Low	Female	Male	Total
Publishing, printing and reproduction of recorded media	€ 0.1	€ 0.3	€ 0.4
Manufacture of printing inks	€ 1.9	€ 10.1	€ 12.0
Manufacture of machinery and equipment	€ 2.5	€ 12.4	€ 14.9
Manufacture of motor vehicles, trailers and semi-trailers	€ 8.8	€ 46.1	€ 54.9
Manufacture of other transport equipment	€ 3.9	€ 19.8	€ 23.6
Electricity, gas, steam and hot water supply	€ 2.7	€ 24.8	€ 27.6
Construction	€ 3.8	€ 75.3	€ 79.1
Sale, maintenance and repair of motor vehicles and motorcycles; retail sale of automotive fuel	€ 8.9	€ 37.5	€ 46.4
Wholesale trade and commission trade, except of motor vehicles and motorcycles	€ 5.7	€ 24.9	€ 30.6
Land transport; transport via pipelines	€ 0.8	€ 8.7	€ 9.4
Supporting and auxiliary transport activities; activities of travel agencies	€ 18.5	€ 211.2	€ 229.7
Research and development	€ 0.2	€ 0.6	€ 0.8
Other business activities	€ 157.7	€ 495.9	€ 653.5
Public Administration and Defence	€ 419.8	€ 1,006.0	€ 1,425.8
Education	€ 231.1	€ 205.0	€ 436.0
TOTAL	**€ 1,459.4**	**€ 5,119.2**	**€ 6,575.3**

High	Female	Male	Total
Manufacture of coke, refined petroleum products and nuclear fuel	€ 141.4	€ 755.9	€ 897.3
Manufacture of other non-metallic mineral products	€ 38.1	€ 257.8	€ 295.9
Manufacture of basic metals	€ 1,163.8	€ 8,145.0	€ 9,308.8
Manufacture of fabricated metal products, except machinery and equipment	€ 184.2	€ 1,332.2	€ 1,516.5
Mining of metal ores	€ 0.2	€ 3.4	€ 3.5
Other mining and quarrying	€ 0.1	€ 2.3	€ 2.4
Manufacture of Food Products and Beverages	€ 3.9	€ 24.9	€ 28.9
Manufacture of wood and of products of wood and cork, except furniture	€ 1.0	€ 5.6	€ 6.5
Manufacture of pulp, paper and paper products	€ 0.4	€ 2.9	€ 3.3
Publishing, printing and reproduction of recorded media	€ 0.1	€ 0.8	€ 0.9
Manufacture of printing inks	€ 3.5	€ 25.3	€ 28.7
Manufacture of machinery and equipment	€ 4.5	€ 31.0	€ 35.5
Manufacture of motor vehicles, trailers and semi-trailers	€ 16.1	€ 115.3	€ 131.4
Manufacture of other transport equipment	€ 7.1	€ 49.4	€ 56.5
Electricity, gas, steam and hot water supply	€ 5.0	€ 62.1	€ 67.1
Construction	€ 14.0	€ 364.7	€ 378.7
Sale, maintenance and repair of motor vehicles and motorcycles; retail sale of automotive fuel	€ 16.2	€ 93.8	€ 109.9
Wholesale trade and commission trade, except of motor vehicles and motorcycles	€ 10.4	€ 62.2	€ 72.6
Land transport; transport via pipelines	€ 1.4	€ 21.6	€ 23.0
Supporting and auxiliary transport activities; activities of travel agencies	€ 33.8	€ 528.1	€ 561.9
Research and development	€ 0.3	€ 1.4	€ 1.8
Other business activities	€ 287.8	€ 1,239.8	€ 1,527.7
Public Administration and Defence	€ 766.4	€ 2,515.4	€ 3,281.8

High	Female	Male	Total
Education	€ 421.8	€ 512.6	€ 934.4
TOTAL	€ 3,121.4	€ 15,798.0	€ 18,869.8

Table 8.3.3 Health costs – baseline scenario – Member State breakdown - Based on a declining discount rate

Low	Female	Male	Total	High	Female	Male	Total
Austria	€ 24.3	€ 104.5	€ 128.9	Austria	€ 60.3	€ 377.4	€ 437.7
Belgium	€ 2.1	€ 19.5	€ 21.6	Belgium	€ 64.9	€ 654.4	€ 719.3
Bulgaria	€ 16.6	€ 68.2	€ 84.9	Bulgaria	€ 36.7	€ 156.6	€ 193.3
Czech Republic	€ 61.7	€ 185.5	€ 247.3	Czech Republic	€ 156.2	€ 651.9	€ 808.2
Cyprus	€ 0.4	€ 2.2	€ 2.6	Cyprus	€ 0.1	€ 0.8	€ 0.9
Denmark	€ 30.2	€ 41.0	€ 71.2	Denmark	€ 58.3	€ 114.8	€ 173.1
Estonia	€ 3.0	€ 7.0	€ 10.0	Estonia	€ 7.3	€ 22.3	€ 29.6
Finland	€ 13.2	€ 42.7	€ 55.9	Finland	€ 33.7	€ 142.3	€ 176.0
France	€ 179.3	€ 731.9	€ 911.2	France	€ 258.7	€ 1,919.3	€ 2,178.0
Germany	€ 305.9	€ 1,019.0	€ 1,325.0	Germany	€ 685.5	€ 3,736.2	€ 4,421.6
Greece	€ 13.0	€ 103.8	€ 116.8	Greece	€ 33.0	€ 290.9	€ 323.8
Hungary	€ 56.3	€ 117.7	€ 174.0	Hungary	€ 116.6	€ 344.2	€ 460.7
Ireland	€ 7.8	€ 14.6	€ 22.4	Ireland	€ 16.5	€ 42.2	€ 58.7
Italy	€ 136.4	€ 706.7	€ 843.1	Italy	€ 328.6	€ 2,655.9	€ 2,984.5
Latvia	€ 4.1	€ 15.3	€ 19.4	Latvia	€ 9.3	€ 42.2	€ 51.5
Lithuania	€ 4.2	€ 14.8	€ 19.1	Lithuania	€ 11.2	€ 44.0	€ 55.3
Luxembourg	€ 2.0	€ 19.1	€ 21.1	Luxembourg	€ 6.0	€ 85.0	€ 91.0
Malta	€ 0.2	€ 1.2	€ 1.5	Malta	€ 0.5	€ 3.3	€ 3.8
Netherlands	€ 64.9	€ 170.3	€ 235.2	Netherlands	€ 99.2	€ 624.4	€ 723.6
Poland	€ 118.7	€ 381.0	€ 499.7	Poland	€ 227.5	€ 1,177.1	€ 1,404.7
Portugal	€ 13.1	€ 57.3	€ 70.3	Portugal	€ 30.4	€ 144.1	€ 174.4
Romania	€ 48.9	€ 170.2	€ 219.1	Romania	€ 116.5	€ 430.4	€ 546.9
Slovakia	€ 15.6	€ 62.0	€ 77.5	Slovakia	€ 41.6	€ 220.4	€ 261.9
Slovenia	€ 10.3	€ 32.5	€ 42.8	Slovenia	€ 20.7	€ 85.4	€ 106.1
Spain	€ 51.2	€ 345.8	€ 397.0	Spain	€ 79.3	€ 968.9	€ 1,048.1
Sweden	€ 51.2	€ 90.6	€ 141.8	Sweden	€ 102.8	€ 344.4	€ 447.2
United Kingdom	€ 272.9	€ 553.4	€ 826.3	United Kingdom	€ 662.7	€ 1,962.0	€ 2,624.7
TOTAL	€ 1,507.7	€ 5,077.9	€ 6,585.6	**TOTAL**	€ 3,264.0	€ 17,240.8	€ 20,504.8

Table 8.3.4 Health costs – baseline scenario – Industry group breakdown - Based on a declining discount rate

Low	Female	Male	Total
Manufacture of coke, refined petroleum products and nuclear fuel	€ 53.9	€ 217.5	€ 271.3
Manufacture of other non-metallic mineral products	€ 15.9	€ 77.8	€ 93.7
Manufacture of basic metals	€ 485.1	€ 2,457.0	€ 2,942.1
Manufacture of fabricated metal products, except machinery and equipment	€ 76.8	€ 401.7	€ 478.4
Mining of metal ores	€ 0.1	€ 1.4	€ 1.5

Low	Female	Male	Total
Other mining and quarrying	€ 0.1	€ 0.9	€ 1.0
Manufacture of Food Products and Beverages	€ 2.2	€ 10.1	€ 12.3
Manufacture of wood and of products of wood and cork, except furniture	€ 0.5	€ 2.3	€ 2.8
Manufacture of pulp, paper and paper products	€ 0.2	€ 1.2	€ 1.4
Publishing, printing and reproduction of recorded media	€ 0.1	€ 0.3	€ 0.4
Manufacture of printing inks	€ 1.9	€ 10.3	€ 12.2
Manufacture of machinery and equipment	€ 2.5	€ 12.6	€ 15.1
Manufacture of motor vehicles, trailers and semi-trailers	€ 9.0	€ 46.9	€ 55.8
Manufacture of other transport equipment	€ 3.9	€ 20.1	€ 24.0
Electricity, gas, steam and hot water supply	€ 2.8	€ 25.2	€ 28.0
Construction	€ 4.6	€ 87.4	€ 92.0
Sale, maintenance and repair of motor vehicles and motorcycles; retail sale of automotive fuel	€ 9.0	€ 38.1	€ 47.1
Wholesale trade and commission trade, except of motor vehicles and motorcycles	€ 5.8	€ 25.3	€ 31.1
Land transport; transport via pipelines	€ 0.8	€ 8.8	€ 9.6
Supporting and auxiliary transport activities; activities of travel agencies	€ 18.8	€ 214.8	€ 233.6
Research and development	€ 0.2	€ 0.6	€ 0.8
Other business activities	€ 160.2	€ 504.2	€ 664.4
Public Administration and Defence	€ 426.7	€ 1,023.1	€ 1,449.8
Education	€ 234.9	€ 208.4	€ 443.3
TOTAL	**€ 1,515.9**	**€ 5,366.0**	**€ 6,877.7**

High	Female	Male	Total
Manufacture of coke, refined petroleum products and nuclear fuel	€ 160.3	€ 826.0	€ 986.3
Manufacture of other non-metallic mineral products	€ 40.7	€ 275.6	€ 316.3
Manufacture of basic metals	€ 1,243.1	€ 8,709.9	€ 9,952.9
Manufacture of fabricated metal products, except machinery and equipment	€ 196.5	€ 1,423.0	€ 1,619.5
Mining of metal ores	€ 0.2	€ 3.4	€ 3.6
Other mining and quarrying	€ 0.1	€ 2.4	€ 2.5
Manufacture of Food Products and Beverages	€ 4.0	€ 25.4	€ 29.3
Manufacture of wood and of products of wood and cork, except furniture	€ 1.0	€ 5.7	€ 6.6
Manufacture of pulp, paper and paper products	€ 0.4	€ 3.0	€ 3.4
Publishing, printing and reproduction of recorded media	€ 0.1	€ 0.8	€ 0.9
Manufacture of printing inks	€ 3.5	€ 25.7	€ 29.2
Manufacture of machinery and equipment	€ 4.6	€ 31.5	€ 36.1
Manufacture of motor vehicles, trailers and semi-trailers	€ 16.4	€ 117.2	€ 133.6
Manufacture of other transport equipment	€ 7.2	€ 50.2	€ 57.3
Electricity, gas, steam and hot water supply	€ 5.1	€ 63.1	€ 68.2
Construction	€ 17.0	€ 438.0	€ 455.0
Sale, maintenance and repair of motor vehicles and motorcycles; retail sale of automotive fuel	€ 16.4	€ 95.4	€ 111.9
Wholesale trade and commission trade, except of motor vehicles and motorcycles	€ 10.6	€ 63.3	€ 73.9
Land transport; transport via pipelines	€ 1.4	€ 22.0	€ 23.4
Supporting and auxiliary transport activities; activities of travel agencies	€ 34.3	€ 537.4	€ 571.8

High	Female	Male	Total
Research and development	€ 0.3	€ 1.5	€ 1.8
Other business activities	€ 292.7	€ 1,261.3	€ 1,554.0
Public Administration and Defence	€ 779.5	€ 2,559.7	€ 3,339.1
Education	€ 429.0	€ 521.5	€ 950.5
TOTAL	€ 3,264.4	€ 16,617.0	€ 19,818.9

Table 8.3.5 Summary

Costs by Gender (€m)	2010-2019	2020-2029	2030-2039	2040-2049	2050-2059	2060-2069
Female	839 to 1744	450 to 963	161 to 382	38 to 108	14 to 45	6 to 21
Male	2596 to 8469	1508 to 5073	658 to 2389	206 to 830	78 to 334	31 to 146
Total	3435 to 10213	1958 to 6037	819 to 2771	244 to 939	93 to 378	37 to 167

Table 8.3.6 Health costs – baseline scenario – Member State breakdown - Based on a no discounting

Low	Female	Male	Total	High	Female	Male	Total
Austria	€ 38.8	€ 174.8	€ 213.6	Austria	€ 97.9	€ 643.1	€ 741.1
Belgium	€ 3.7	€ 33.9	€ 37.6	Belgium	€ 104.3	€ 1,084.2	€ 1,188.5
Bulgaria	€ 27.9	€ 110.8	€ 138.7	Bulgaria	€ 64.9	€ 262.2	€ 327.1
Czech Republic	€ 103.2	€ 318.6	€ 421.8	Czech Republic	€ 267.5	€ 1,140.6	€ 1,408.1
Cyprus	€ 0.6	€ 3.5	€ 4.1	Cyprus	€ 0.2	€ 2.2	€ 2.4
Denmark	€ 45.4	€ 63.8	€ 109.3	Denmark	€ 88.4	€ 183.7	€ 272.1
Estonia	€ 4.7	€ 11.0	€ 15.7	Estonia	€ 12.0	€ 36.2	€ 48.2
Finland	€ 21.3	€ 71.8	€ 93.1	Finland	€ 55.7	€ 245.5	€ 301.2
France	€ 273.4	€ 1,152.5	€ 1,425.8	France	€ 408.7	€ 3,093.6	€ 3,502.3
Germany	€ 479.8	€ 1,681.9	€ 2,161.7	Germany	€ 1,103.6	€ 6,287.7	€ 7,391.4
Greece	€ 20.3	€ 164.6	€ 184.8	Greece	€ 53.0	€ 473.4	€ 526.4
Hungary	€ 88.6	€ 189.7	€ 278.3	Hungary	€ 188.1	€ 567.5	€ 755.7
Ireland	€ 11.7	€ 22.4	€ 34.1	Ireland	€ 24.8	€ 66.7	€ 91.5
Italy	€ 219.5	€ 1,170.7	€ 1,390.2	Italy	€ 541.0	€ 4,476.0	€ 5,017.0
Latvia	€ 6.4	€ 24.0	€ 30.4	Latvia	€ 14.6	€ 67.9	€ 82.5
Lithuania	€ 7.0	€ 23.6	€ 30.7	Lithuania	€ 20.5	€ 73.9	€ 94.4
Luxembourg	€ 3.3	€ 33.1	€ 36.5	Luxembourg	€ 10.1	€ 150.4	€ 160.5
Malta	€ 0.3	€ 1.8	€ 2.1	Malta	€ 0.7	€ 5.0	€ 5.7
Netherlands	€ 97.4	€ 268.8	€ 366.2	Netherlands	€ 152.5	€ 1,010.6	€ 1,163.1
Poland	€ 189.5	€ 630.4	€ 819.9	Poland	€ 374.3	€ 1,987.1	€ 2,361.4
Portugal	€ 20.5	€ 90.3	€ 110.7	Portugal	€ 49.1	€ 240.1	€ 289.2
Romania	€ 81.9	€ 282.5	€ 364.4	Romania	€ 201.8	€ 734.3	€ 936.1
Slovakia	€ 26.0	€ 107.6	€ 133.7	Slovakia	€ 71.1	€ 389.8	€ 460.9
Slovenia	€ 16.9	€ 55.5	€ 72.4	Slovenia	€ 34.4	€ 149.3	€ 183.8
Spain	€ 81.1	€ 588.4	€ 669.5	Spain	€ 133.5	€ 1,738.9	€ 1,872.4
Sweden	€ 81.4	€ 152.8	€ 234.2	Sweden	€ 166.8	€ 591.3	€ 758.1

Low	Female	Male	Total	High	Female	Male	Total
United Kingdom	€ 408.2	€ 857.0	€ 1,265.1	United Kingdom	€ 999.6	€ 3,080.6	€ 4,080.2
TOTAL	€ 2,358.8	€ 8,285.6	€ 10,644.5	**TOTAL**	€ 5,239.2	€ 28,781.9	€ 34,021.1

Table 8.3.7 Health costs – baseline scenario – Industry group breakdown - Based on a declining discount rate

Low	Female	Male	Total
Manufacture of coke, refined petroleum products and nuclear fuel	€ 106.4	€ 391.7	€ 498.1
Manufacture of other non-metallic mineral products	€ 27.1	€ 133.5	€ 160.6
Manufacture of basic metals	€ 827.6	€ 4,216.9	€ 5,044.5
Manufacture of fabricated metal products, except machinery and equipment	€ 130.4	€ 687.0	€ 817.5
Mining of metal ores	€ 0.1	€ 2.0	€ 2.2
Other mining and quarrying	€ 0.1	€ 1.4	€ 1.5
Manufacture of Food Products and Beverages	€ 3.2	€ 14.8	€ 18.0
Manufacture of wood and of products of wood and cork, except furniture	€ 0.8	€ 3.3	€ 4.1
Manufacture of pulp, paper and paper products	€ 0.3	€ 1.7	€ 2.1
Publishing, printing and reproduction of recorded media	€ 0.1	€ 0.5	€ 0.6
Manufacture of printing inks	€ 2.8	€ 15.0	€ 17.8
Manufacture of machinery and equipment	€ 3.7	€ 18.4	€ 22.1
Manufacture of motor vehicles, trailers and semi-trailers	€ 13.1	€ 68.6	€ 81.7
Manufacture of other transport equipment	€ 5.7	€ 29.3	€ 35.0
Electricity, gas, steam and hot water supply	€ 4.0	€ 37.0	€ 41.0
Construction	€ 10.9	€ 197.7	€ 208.6
Sale, maintenance and repair of motor vehicles and motorcycles; retail sale of automotive fuel	€ 13.2	€ 55.9	€ 69.1
Wholesale trade and commission trade, except of motor vehicles and motorcycles	€ 8.5	€ 37.1	€ 45.6
Land transport; transport via pipelines	€ 1.1	€ 12.9	€ 14.1
Supporting and auxiliary transport activities; activities of travel agencies	€ 27.5	€ 315.1	€ 342.6
Research and development	€ 0.3	€ 0.9	€ 1.1
Other business activities	€ 234.2	€ 738.7	€ 973.0
Public Administration and Defence	€ 624.2	€ 1,500.5	€ 2,124.7
Education	€ 343.6	€ 305.5	€ 649.0
TOTAL	€ 2,389.0	€ 8,705.5	€ 11,083.0

High	Female	Male	Total
Manufacture of coke, refined petroleum products and nuclear fuel	€ 336.9	€ 1,544.8	€ 1,881.7
Manufacture of other non-metallic mineral products	€ 69.7	€ 473.8	€ 543.5
Manufacture of basic metals	€ 2,129.5	€ 14,979.8	€ 17,109.3
Manufacture of fabricated metal products, except machinery and equipment	€ 335.2	€ 2,438.5	€ 2,773.8
Mining of metal ores	€ 0.3	€ 5.1	€ 5.3
Other mining and quarrying	€ 0.2	€ 3.5	€ 3.6
Manufacture of Food Products and Beverages	€ 5.8	€ 37.2	€ 43.0
Manufacture of wood and of products of wood and cork, except furniture	€ 1.4	€ 8.3	€ 9.7

High	Female	Male	Total
Manufacture of pulp, paper and paper products	€ 0.6	€ 4.4	€ 5.0
Publishing, printing and reproduction of recorded media	€ 0.2	€ 1.2	€ 1.3
Manufacture of printing inks	€ 5.2	€ 37.6	€ 42.8
Manufacture of machinery and equipment	€ 6.7	€ 46.3	€ 53.0
Manufacture of motor vehicles, trailers and semi-trailers	€ 24.0	€ 172.1	€ 196.1
Manufacture of other transport equipment	€ 10.5	€ 73.4	€ 83.9
Electricity, gas, steam and hot water supply	€ 7.4	€ 92.7	€ 100.1
Construction	€ 42.4	€ 1,069.4	€ 1,111.8
Sale, maintenance and repair of motor vehicles and motorcycles; retail sale of automotive fuel	€ 24.1	€ 140.3	€ 164.4
Wholesale trade and commission trade, except of motor vehicles and motorcycles	€ 15.6	€ 93.1	€ 108.6
Land transport; transport via pipelines	€ 2.1	€ 32.4	€ 34.5
Supporting and auxiliary transport activities; activities of travel agencies	€ 50.4	€ 790.3	€ 840.7
Research and development	€ 0.5	€ 2.2	€ 2.6
Other business activities	€ 429.0	€ 1,852.9	€ 2,281.9
Public Administration and Defence	€ 1,143.1	€ 3,763.9	€ 4,907.0
Education	€ 629.2	€ 766.2	€ 1,395.4
TOTAL	€ 5,269.8	€ 27,235.1	€ 32,333.7

Table 8.3.8 Summary

Costs by Gender (€m)	2010-2019	2020-2029	2030-2039	2040-2049	2050-2059	2060-2069
Female	1020 to 2122	810 to 1735	337 to 801	107 to 305	55 to 169	30 to 108
Male	3159 to 10304	2716 to 9137	1378 to 5001	580 to 2337	296 to 1261	156 to 742
Total	4179 to 12426	3526 to 10871	1715 to 5802	688 to 2642	351 to 1430	186 to 850