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Energy, sustainable development and health

Background document

TABLE OF CONTENTS

	<i>Page</i>
Abstract	2
Acknowledgement.....	3
Chapter 1: Introduction	1
Chapter 2: Energy availability, demand and trends in Europe	5
2.1. Introduction.....	5
2.2. Trends: Consumption of Energy	5
2.3. Trends: Energy Efficiency	13
2.4. Trends: Reducing Air Pollutants.....	17
2.5. Trends: Reducing Greenhouse Gas Emissions	19
2.6. Trends: Changes in the Climate System	21
2.7. Trends: Waste and Soil Contamination.....	23
2.8. Conclusions.....	25
Chapter 3: Access to electricity and heating	27
3.1. Introduction.....	27
3.2. Access to commercial energy in Europe.....	27
3.3. The consequences of poor access to commercial energy.....	31
3.4. Measures to improve access to commercial energy.....	36
3.5. Conclusions.....	39
Chapter 4: Exposure and Health Impacts of Electric Power Generation, Transmission and Distribution ..	40
4.1. Introduction.....	40
4.2. Non-renewable energy	41
4.3. Direct health impacts of fossil fuels.....	50
4.4. Indirect health impacts of fossil fuels	57
4.5. Nuclear Fuel Cycle.....	60
4.6. Renewable energy	64
4.7. Health impacts of electricity transmission and distribution	72
4.8. Conclusions.....	77
Chapter 5: A possible way forward.....	80
5.1. The consequences for health of an energy supply which is not secure.....	80
5.2. The effects on health of changes in weather and climate.....	83
5.3. The protection of health as a consequence of the generation, transformation and distribution of energy	84
5.4. Future Actions.....	85
Acronyms	88
The ExternE description.....	90
References	102

Abstract

Europe faces considerable challenges in restructuring its energy sector to reconcile environmental, social and economic objectives – the three pillars of sustainable development. This document reviews trends in energy availability and demand, access to electricity and heating, and the effects on health of electric power generation, transmission and distribution.

Some parts of Europe still have problems with the affordability of commercial energy and with improving the efficiency of energy use. Such unmet demand may lead to increased use of domestic solid fuel with associated health effects. The various forms of electric power generation are associated with different health effects on workers in industries involved in energy production and in the general population. These effects may arise during the different phases of fuel extraction (mining, drilling), power generation and waste disposal. While some occur after a very short time, others (such as those associated with chronic exposure to airborne pollutants) may occur after a period of some years. No form of power generation is entirely free of effects on health, but there are clear contrasts in the type and magnitude of health burdens associated with each.

Although many factors influence energy policies, health considerations would favour a substantial increase in the contribution from renewable sources, especially those based on non-combustion processes.

Overall, progress has been made over the past decade in reducing the health burdens of energy generation, transport and distribution. Nevertheless, energy consumption is still one of the key pressures on health within Europe, and further policies and actions are needed to reduce health risks in the future.

The views expressed in this document are the views of the authors

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The document was prepared by Bettina Menne from the WHO Regional Office for Europe and Anil Markandya, from the World Bank and Bath University. The development of the framework, the writing process and first review process was coordinated by the WHO Regional Office for Europe, Global Change and Health Programme. The document still needs further in depth development and expert review.

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Chapter 1: Introduction

Author: Anil Markandya

With the onset of industrialization, rapid technological change and the advance of economic development, the people of the industrialized world have seen a remarkable rise in their living standards and improvement of health status.

Carefully reconstructed data for Western Europe show, for example, that twelve Western European countries had a per capita income of \$1,230 in 1820; by 1992, this had risen to \$17,400 (Maddison, 1995) ¹, implying a sustained annual growth rate of 1.6 percent for 172 years, something that was unprecedented in the history of the world. In parallel to this we observe an increase of life expectancy in Europe from around 40 years at the beginning of the 19th Century in Europe to nearly 80 years for a child born today (Woods, 2000). The increase of life expectancy is not linear with economic growth. In general once the per capita income has exceeded 7,500 USD, life expectancy is expected to rise more slowly.

Needless to say, neither the improvement of health status nor the economic growth would have been possible without an increase in the supply of energy, both as an input in production as well as an end-use commodity in its own right. Energy data only go back on a consistent basis to 1850. Since then and up to 1990 (i.e. 140 years) energy use in Western Europe has gone up 4.7 times while GDP has gone up 21.5 times (Gruebler, 1997)². The implied increase in energy ‘efficiency’ – the amount of output one gets from a given input of energy – has been quite steady over the whole period. Each unit of energy now produces more than 4.5 times as much output as it did in 1850.

Both population growth as well as economic growth has led to increased well-being, but also increased energy consumption. What have been the health implications of this increase in energy consumption?

Overall, there is little doubt that the impact has been positive. This is particularly so because of the shift away from non-commercial fuels, such as wood, and towards commercial energy, particularly electricity, which we have seen as part of the development process. Our present concern with the health implications of burning fossil fuels should not blind us to the fact that, compared to the situation that existed in the 19th Century, the positive health impacts of ‘modern’ energy use (cleaner air in the home, adequate heating in winter, reduced risk of fires, less health hazards associated with animal waste, more efficient and cleaner medical services) might outweigh the negative impacts that are so much the focus of our attention today.

As we look to the future, we must recognize the important contribution increased access to commercial energy can make to improved health and to the reduction of poverty throughout the world. Indeed this recognition is among the key objectives of sustainable development, as

¹ The countries are: Austria, Belgium, Denmark, Finland, France, Germany, Italy, Netherlands, Sweden, Switzerland and the United Kingdom.

² Based on detailed data for France, Germany and the UK. Data are from A. Grübler et al and J-M Martin.

articulated at the World Summit on Sustainable Development in Johannesburg in September of 2000.

Box 1 The Millennium development Goals⁴

In September 2000, 147 heads of state and government and 189 nations in total committed themselves to making the right to development a reality for everyone. The objective of the declaration is to promote “a comprehensive approach and coordinated strategy, tackling many problems simultaneously across a broad front”. To help trace progress, a set of time-bound and measurable goals and targets for combating poverty, hunger, disease, illiteracy, environmental degradation and discrimination against women were defined.

At that conference the international community committed itself to eight Millennium Development Goals (MDGs)⁵. To a lesser or greater degree, development of, and access to, commercial energy is necessary for meeting all these goals. It is particularly relevant to the health and poverty-related goals. A recent World Bank study looked at demographic and health data from over 60 low-income countries and investigated the determinants of health outcomes using cross-country data between 1985 and 1999 (Wang, 2003). It found that in urban areas, linking households to electricity is the only key factor that reduces both the infant mortality rate (IMR) and the under five-mortality rate (U5MR), and that this effect is large, significant and independent of incomes. In rural areas, improving female secondary education is crucial for reducing IMR, while expanding vaccination coverage reduces U5MR.

The MDGs contain not only the goals listed above, but also a number of targets for these goals, and indicators that should be monitored as part of the program. Goal 7 is to ensure environmental sustainability, with the target to integrate the principles of sustainable development into country policies and programmes and reverse the loss of environmental resources. The energy indicators that will be monitored under the MDG implementation program are:

- Energy use (kg oil equivalent) per \$1 GDP (PPP) (IEA, World Bank);
- Carbon dioxide emissions per capita (UNFCCC, UNSD) and consumption of ozone-depleting CFCs (ODP tons) (UNEP-Ozone Secretariat); and
- Proportion of population using solid fuels (WHO).

A reduction in each of these indicators will have beneficial health impacts. That is a major reason for preparing this report, which takes stock of our knowledge of the links between energy sustainable development and health and addresses a number of high profile concerns.

The substantive part of the report begins (in Chapter 2) by providing important background information relevant to understanding energy and health linkages, such as the key trends in energy demand and use in different parts of Europe, the outlook for the future and the main problems that need to be addressed at the national and international level.

⁴ <http://www.who.int/indoorair/mdg/en/>; accessed 10 May, 2004

⁵ <http://www.un.org/millenniumgoals/>; accessed 10 May, 2004

The rest of the report addresses a number of major concerns. The first of these concerns is of social nature – the accessibility of commercial energy. Although we have no shortage of energy in most countries of Europe, there is concern about energy prices, energy efficiency in houses and frequency of energy-related local accidents. There are individuals, families and households who cannot afford enough for their basic needs and there is energy poverty in the midst of plenty. How serious a problem this is and what are the links with health⁶? What could be effective measures? Chapter three deals with access to electricity and heating. It also addresses the problems of indoor air pollution arising from the use of solid fuel in the home. In general these are less serious in Europe than they are in tropical countries, but there are some communities, especially in the Former Soviet Union, that are increasingly burning solid fuels to meet their energy needs. This has health implications, which need to be studied and the scale of the present problem evaluated.

The second major concern arises from emissions from commercial fuels used for heat, electricity and transport, especially small particles. To assist our understanding of the diversity and complexity of the health impacts of energy generation, transmission and distribution, we have, adopted the Life Cycle approach, where each stage of the activity (production, transportation, consumption, disposal of waste etc.) are analysed for their health impacts. We consider which stages of the cycle are the most relevant from this perspective for each of the energy-generating resources and hence identify the numerous pathways through which the health impacts occur. This is followed by a review of recent studies, such as ExternE, that assess the potentially damaging and spatially and temporally far-reaching effects of burning coal, oil, gas and other fossil fuels. The implied costs of their use have been estimated and the implications for energy policy, which are still being worked out, are discussed. One important fact is that, of all the impacts of using such fuels, the most important ones relate to health. All this is dealt with in chapter 4.

The health issues arising from the present pattern use of energy need to be seen in a longer-term perspective as well. We started by stressing the importance of increased commercial energy supplies for economic development and, *pari passu*, improved human health. Of course, as we note in Chapters 3-4, new problems are coming to the forefront from the massive expansion in the use of energy, especially fossil fuels and these need to be addressed. In the short to medium term we can address them by adopting cleaner versions of existing large-scale energy production technologies. But in the longer term we will need to switch much more to renewable sources that are much less damaging to health and increase energy security. The reason is that the planet will not be able to sustain energy use at the present levels of the industrialized countries once the developing countries have also reached similar levels of GDP *per capita*. This is most clearly brought out in the debate on climate change, where it is recognized that both developing and developed countries have to reduce emissions of carbon into the atmosphere. Presently developed countries emit around 4.3 tons of carbon per person, the countries of Eastern Europe and the Former Soviet Union emit 2.2 tons per person and the developing countries emit half of that -- 1.1 tons. If climate is eventually to be stabilized (and no one seriously doubts that it must) the target emissions *per capita* in 2100 must be around 0.3 tons per person, which is less than one-third of what developing countries are emitting today. The target can only be achieved with a 'renewable transition' – i.e. a whole-scale shift out of using fossil fuels and a shift to renewable sources of energy.

⁶ See, for example, The World Bank. *Coping with the Cold*, Technical Paper, No 529, Washington DC, 2002.

The report concludes (chapter 5), by bringing together the main findings and makes some recommendations for follow-up action, to fill the gaps in knowledge that have been revealed and to direct policy-makers on areas that the literature has identified as critical for the protection of human health.

Chapter 2: Energy availability, demand and trends in Europe

Authors: Peter Taylor, Paul Watkiss, Claire Handley, Daniel Waller and Aphrodite Mourelatou

2.1. Introduction

Energy-use can affect health in a range of positive and negative ways. It can have direct positive effects by providing heat in our homes, as well as improving personal comfort and amenity. It also provides the power for many of the activities or services that improve our health, for example, for cooking food, by providing the power for water supply and treatment and obviously for health care systems. Energy is also essential for most industrial and commercial activities, and underlies social and economic development with associated health improvements. Finally, energy provides greater personal mobility, allowing access to services, opportunities for work and social activities, all of which have the potential to improve our health. However, energy use also has the potential to lead to a large number of negative health impacts, and there are often inequalities in the pattern of the distribution of these effects. These negative impacts include the traditional burdens from air, water and waste pollution, but also the wider effects of regional and global climate change on our well-being.

This chapter summarises the key energy trends in Europe. It identifies the key challenges facing the energy sector in delivering positive health benefits, and reducing negative health impacts, from energy-use. It assesses progress, by region, against the key objectives of a) reducing energy-use/increasing energy efficiency, b) using cleaner technologies and c) achievements from policies reducing the burden from air, waste and soil pollution and makes recommendations on what policy options could be used to further reduce the health impacts of energy-use.

2.2. Trends: Consumption of Energy

Total Energy Consumption

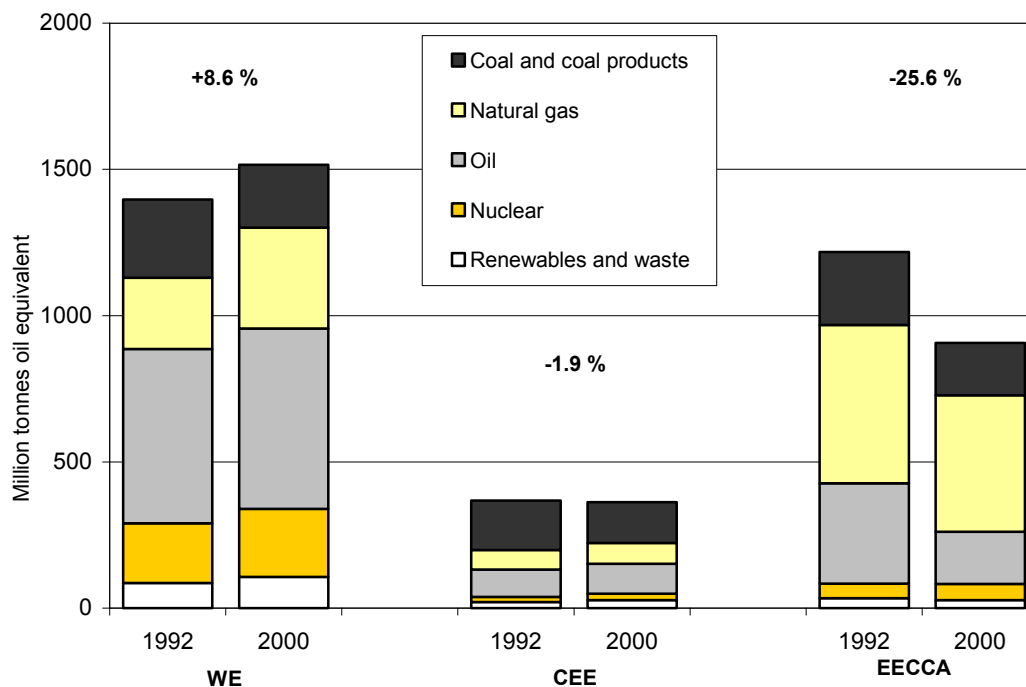
Total energy consumption fell by 6.6% in the European Region between 1992 and 2000 (see Figure 2.1). This fall was mainly the result of reduced energy consumption in Eastern Europe, the Caucasus and the Central Asian Republics (EECCA⁷), and is attributed to economic decline rather than increased energy efficiency. Energy consumption in central and eastern Europe (CEE⁸) also fell due to a combination of economic restructuring and the implementation of energy efficiency measures. Turkey, a major energy consumer within the CEE region, increased its energy consumption substantially over the period as a result of high economic growth and only limited measures to improve energy efficiency. In contrast, energy consumption in western Europe (WE⁹) increased, roughly in line with economic growth, a pattern that is expected to be followed by CEE and EECCA as the countries in these regions complete their transition to market-based economies. This means that on current trends total energy consumption in Europe is likely to increase by over 50% by 2030 (European Commission, 2003b).

⁷ EECCA countries: Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Moldova, Russian Federation, Turkmenistan, Tajikistan, Ukraine, Uzbekistan.

⁸ CEE countries: Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Macedonia, Poland, Romania, Serbia and Montenegro, Slovak Republic, Slovenia, Cyprus, Malta and Turkey.

⁹ WE countries: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden, United Kingdom (all EU15), Iceland, Liechtenstein, Norway, Switzerland (EFTA).

Figure 2.1 Total energy consumption in Europe, 1992 - 2000



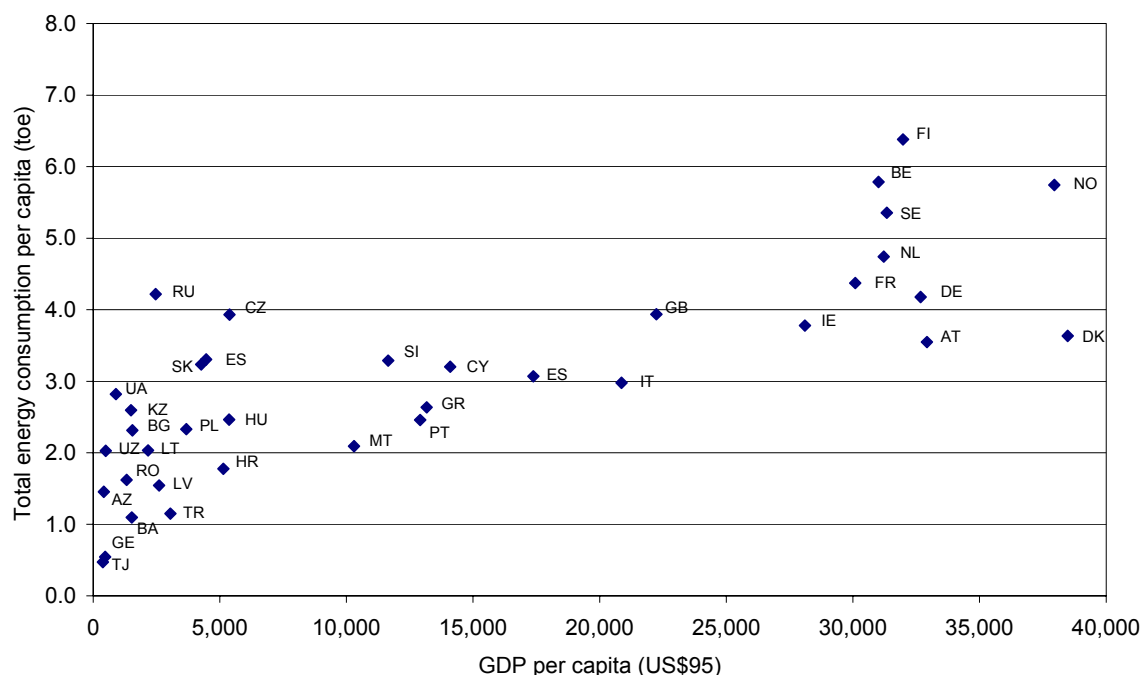
Notes: Total energy consumption is also known as total primary energy supply or gross inland energy consumption. It is a measure of the energy inputs to an economy and can be calculated by adding total indigenous energy production, energy imports minus exports and net withdrawals from existing stocks. Waste includes wood wastes, other biodegradable solid wastes, and industrial and municipal wastes which contain both biodegradable and non-biodegradable components. Only biodegradable waste is considered to be a renewable energy source.
Source: IEA, 2002

The link between economic development and energy consumption can be seen by looking at total energy consumption per capita versus GDP per capita for different nations (see Figure 2.2). Such an analysis reveals a trend line, with higher per capita energy consumption correlating with higher per capita incomes. The implication on this relationship is that, as countries develop, so energy consumption per capita is likely to increase. This, combined with rising populations in many countries, particularly in CEE and EECCA, explains the increases in energy consumption in Europe. However it shows also that in some countries energy consumption is very high although per capita income is low, this might be related to energy efficiencies in those countries.

In order to consume energy needs to be supplied. So, is for example the EU15 external dependency for energy constantly increasing. As of the green paper of the EU15, 50% of the energy requirements are imported and if no measures are taken within the next 20 to 30 years this figure will rise to 70%. This external dependence has economic, social, ecological and physical risks for the EU. Energy imports represent 6% of total imports, which means in geopolitical terms that, 45% of oil imports come from the Middle East and 40% of natural gas comes from the Russian Federation. The EU does not yet have all the means possible to change the international market. This weakness was clearly highlighted at the end of 2000 by the strong increase in oil prices¹⁰.

¹⁰ <http://europa.eu.int/scadplus/leg/en/lvb/l27037.htm>

Figure 2.2 Relationship between total energy consumption and economic growth



Note: Selected European countries only. Two letter ISO country codes have been used to label data points. Source: World Bank, 2003 and IEA, 2002

Energy sources and consumption

The impacts of increasing energy consumption on health will depend on the fuels and technologies being used but also on increased energy security. Trends over the last decade show that there has been reductions in coal and oil consumption and a growth in natural gas use.

Total coal energy consumption decreased across Europe during 1992 to 2000, the EECCA saw the largest decrease of 29% and Western Europe and CEE also had a significant decline of 19% and 17%, respectively. Table 2.1 shows the share of coal in total energy consumption for the European regions in 1992 and 2000. In Western Europe the reduction in coal use is mainly the result of one-off fuel switching in favour of natural gas. However, longer-term projections highlight the possibility of renewed growth in coal in WE after 2010 (European Commission, 2003b). The reduction in coal use in CEE and EECCA is linked to the reduction of government support and the closure of a number of uneconomic mines. However, there is a risk of renewed growth in coal consumption if the Russian Federation turns to coal for electricity production to free up more natural gas and oil for export (European Commission, 2002).

Table 2.1. Coal production in Europe 1992 – 2000
(for countries producing over 1000 ktoe coal in 2000)

Country >1000 ktoe coal in 2000	*Coal production (ktoe)	
	1992	2000
Central and Eastern Europe		
Bosnia and Herzegovina	3,186	2,660
Bulgaria	5,459	4,413
Czech Republic	31,522	25,001
Estonia	3,933	2,416
Hungary	3,610	2,892
Macedonia- the Former Yugoslav Republic of	1,482	1,209
Poland	89,231	71,302
Romania	8,535	5,593
Serbia and Montenegro	8,554	7,325
Slovenia	1,184	1,062
Slovakia	1,024	1,018
Turkey	12,115	13,290
Western Europe		
Germany	97,645	60,633
Spain	11,504	7,660
Finland	1,779	1,207
France	7,290	2,482
United Kingdom	48,694	17,454
Greece	6,997	8,222
Newly Independent States		
Kazakhstan	55,767	31,840
Russian federation	143,924	117,021
Ukraine	68,552	41,679

Coal extraction and use has historically had large health impacts and still continues to exert significant pressure. Coal mining has long been associated with occupational accidents and exposure to dust and radon. Coal extraction also has potential local health effects on local communities, from the dust from open cast mines, or from coalmines potentially contaminating local water supplies. Production of coal, summarised in the above table, has declined for all European countries, except for Turkey and Greece, over the period 1992 to 2000. The Russian Federation remains the largest coal producer in Europe.

Coal combustion has the highest emissions of 'regulated pollutants' (notably SO₂ and NO_x, which are acidifying pollutants, and particulates (PM)). Coal use also leads to the highest emissions of greenhouse gases (with methane from coal mining, and CO₂ from combustion). However, end-of-pipe clean-up or advanced technology can significantly reduce the level of air emissions and the associated health risk. Coal use also produces considerable solid and liquid pollution that requires waste disposal. Risks also arise when coalmines close down, as there can be potential health risks through contaminated land or the presence of chemical wastes (as well as physical hazards such as shafts, holes, tunnels).

In some European countries, some end users, particularly those disconnected from energy distribution grids, still use significant quantities of coal and wood as the domestic energy source, and these are associated with substantial indoor air pollution and health impacts.

Table 2.2 Oil production in Europe 1992 – 2000
(for countries producing over 1000 ktoe oil in 2000)

Country	*Oil Production (ktoe)	
	1992	2000
Central and Eastern Europe		
Croatia	2,171	1,347
Hungary	2,128	1,681
Poland	210	1,197
Romania	6,651	6,162
Turkey	4,075	2,729
Western Europe		
Austria	1,238	1,092
Germany	3,959	3,937
Denmark	7,966	18,260
France	3,464	1,811
United Kingdom	98,494	131,664
Italy	4,624	4,694
Netherlands	3,405	2,425
Norway	111,255	169,498
Newly Independent States		
Azerbaijan	11,620	14,086
Belarus	2,010	1,860
Kazakhstan	25,962	35,475
Russian federation	398,841	323,300
Turkmenistan	4,974	7,765
Ukraine	4,496	4,252
Uzbekistan	3,309	7,731

European oil energy consumption fell by 13% between 1992 and 2000, entirely as a result of reduced consumption in EECCA where oil energy consumption decreased by 48% during this period. Oil consumption increased in the countries of WE and CEE, mainly as a result of growth in transport demand, particularly road transport. This trend is expected to continue, as European states experience higher levels of car ownership and increases in both passenger and freight transport activity. The scope for future increases in oil consumption in transport is highlighted by the fact that despite rapid increases in recent years, transport energy consumption per capita in CEE countries is still three to four times lower than in the EU (EEA 2002). As shown in the table above, both Norway and the UK have increased oil production considerably during the period 1992 to 2000; in contrast, the Russian Federation has experienced the largest fall in production levels.

Oil (used for domestic or industrial power generation) has similar emissions to coal use, with high levels of air pollution and greenhouse gas emissions. As with the coal sector, a number of major accidents have occurred in the oil and gas industry (e.g. in the North Sea) over the past 20 years, although recently occupational accidents have been dramatically reduced as a result of health and safety legislation. Marine pollution can also occur as a result of accidental oil tanker spills and the activities of refineries and offshore installations.

Box 2.1. The Prestige oil tanker spill

The holing and subsequent sinking of the 'Prestige' oil tanker on 14th November 2002, created the longest (in terms of time) and lengthiest (in distance) oil slick in the history of the northeast Atlantic. 4000 tonnes of heavy fuel oil were released before the ship sank with a further 60 – 70 thousand tonnes on board in its compartments. It is hoped that the high pressures and low temperatures of the sea bottom will prevent further leakage of this oil. The major impact of the spill was on wildlife along a 100 km long stretch of coast and fisheries in this area were closed. The major risks to human health are represented by polycyclic aromatic hydrocarbons (PAH) that could be absorbed by the skin or via inhalation. Mineral oils can produce alterations in the neuropsychological status of individuals and might be teratogenic in animals (Medina S, 2003). The precautions necessary to safeguard against damage to human health from ingestion of contaminated fish are expected to lead to economic losses of up to 100 million euros. The toxicity of the leaked material means that oil residues can last for 20 years.

The use of oil for transport fuel production also gives rise to specific health issues: notably the additional release of lead. Whilst lead has almost entirely phased out in parts of the European Region (OECD countries), it still remains an issue in other areas. Transport is also particularly important with respect to particulate emissions (and also NO_x) because emissions are released at ground level, often in areas of exceptionally high population density (e.g. cities). The relative health risk from emissions is therefore much greater.

Nuclear power production increased in CEE by 20% and WE by 14%, and to a lesser extent in EECCA (9%). Further significant increases in nuclear power production are not expected in the near term as nuclear plants start to be decommissioned throughout Europe and few new plants are being planned. This is expected to result in a further growth in combustion-related emissions in the long term, including carbon dioxide, if the shortfall in capacity is replaced by fossil-fuelled plant. However, in the longer term (post 2020) the building of new nuclear power plants may be necessary to ensure secure energy supplies in Europe. Nuclear energy does not produce greenhouse gas emissions or the air pollution associated with fossil fuels. However, it does release small quantities of radioactive material, potentially across all media (air, water and land) with associated health risk, and produces highly radioactive waste. The disposal of nuclear waste remains controversial in many countries. Detailed description of the health effects is given in chapter 4.

Table 2.3 Nuclear production in Europe 1992 – 2000.
(for countries producing nuclear power in 2000)

Country	Nuclear Power Production (ktoe)	
	1992	2000
Central and Eastern Europe		
Bulgaria	3011	4748
Czech Republic	3192	3542
Hungary	3639	3710
Lithuania	3905	2217
Romania	0	1428
Slovenia	1035	1241
Slovakia	2880	4298
Western Europe		
Belgium	11325	12550
Switzerland	6130	6914
Germany	41401	44200
Spain	14537	16211
Finland	5019	5858
France	88201	108194
United Kingdom	20016	22168
Netherlands	990	1023
Sweden	16560	14937
Newly Independent States		
Armenia	0	523
Russian federation	31523	34419
Ukraine	19215	20156

The majority of countries producing nuclear power in 2000 have increased their ¹¹generation levels since 1992, with only Lithuania and Sweden reducing power generation.

The health impacts of the natural gas cycle are outlined in chapter 4. Natural gas energy consumption grew rapidly in WE with an increase of 42% from 1992 to 2000, though gas consumption for all of Europe only increased by 4% due to the decline in energy consumption in the EECCA. Natural gas has the lowest air emissions of the fossil fuels. The levels of the major air pollutants (especially SO₂ and PM₁₀) from combustion are much lower from natural gas than from other fossil fuels. Nonetheless, natural gas combustion is still a major source of carbon dioxide emissions, and there are important emissions of methane (a potent greenhouse gas) from gas extraction and transport. The extraction of natural gas (either from oil fields, or in separate reserves) and its transportation have occupational risks. In a domestic context, gas consumption also brings risk from carbon monoxide poisoning and explosions. Natural gas production has increased in the United Kingdom and Norway, however the Russian federation slightly decreased the production (Table 2.4.).

¹¹ Note: a map of distribution of Nuclear power plants in Europe is under development

Table 2.4. Gas production in Europe 1992 – 2000.
(for countries producing over 1000 ktoe gas in 2000)

Country	*Gas Production (ktoe)	
	1992	2000
Central and Eastern Europe		
Croatia	1,472	1,354
Hungary	3,613	2,474
Poland	2,559	3,312
Romania	17,607	10,965
Western Europe		
Austria	1,223	1,532
Germany	13,717	15,796
Denmark	3,624	7,409
France	2,782	1,504
United Kingdom	46,323	97,404
Italy	14,729	13,619
Netherlands	61,991	51,890
Norway	25,751	45,804
Newly Independent States		
Azerbaijan	6,378	4,731
Kazakhstan	6,573	10,066
Russian federation	517,166	470,600
Turkmenistan	43,848	38,202
Ukraine	16,918	14,996
Uzbekistan	34,954	45,924

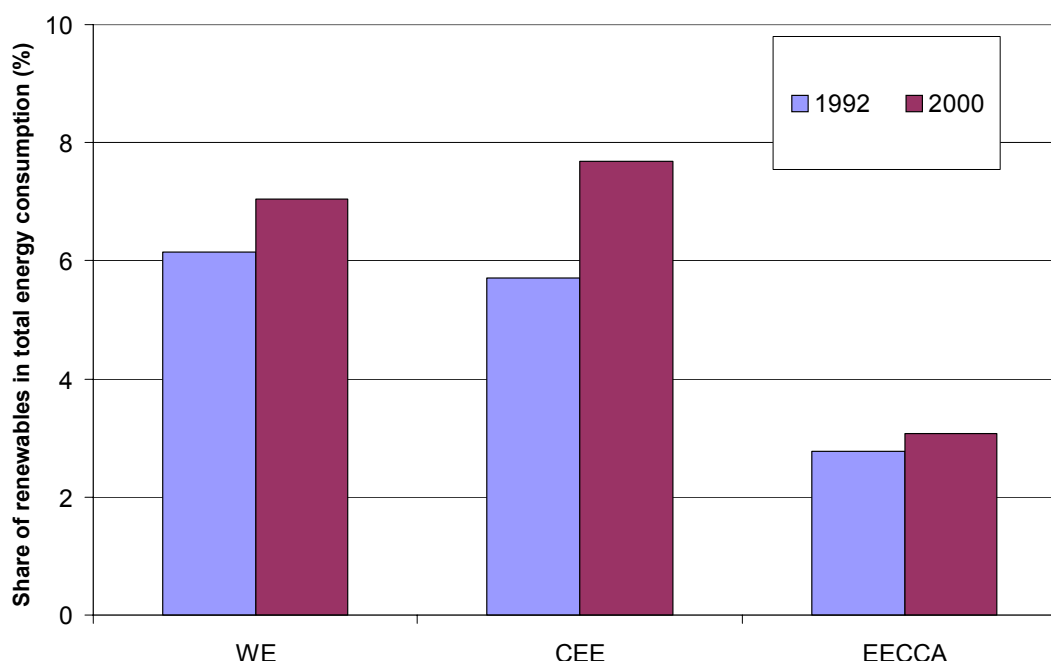
Overall, the proportion of renewable energy sources in total energy consumption, which have the lowest health consequences, increased slightly (see Figure 2.3). Total renewable energy consumption (both electricity and heat) increased by 15% between 1992 and 2000, increasing its share of total energy consumption from 4.7 to 5.8% (see below). Electricity production from renewable sources increased by 19%, thus bringing its share of total electricity production from 18 to 20%. In Western Europe this growth was supported by a range of policy interventions, mainly aimed at stimulating the growth of new renewable technologies for electricity production. In CEE most growth came from an expansion of biomass/waste combustion and hydropower, but this does not appear to be linked to any coordinated policy initiatives. Renewable energy production decreased in EECCA due to a decrease in production from combustible renewable sources and hydropower. However, due to falling overall energy consumption, the proportion of renewable energy sources in total energy consumption actually increased.

Renewable energy source exert the least pressure in terms of greenhouse gas emissions and air pollution. Some renewables (e.g. biomass) do produce similar combustion products to fossil fuels (e.g. particulates, NO_x), though they do not have significant greenhouse gas emissions (see discussion of wood above). Many renewable technologies (e.g. wind, hydro, solar) have negligible emissions, even when considered on a life-cycle basis (e.g. Thorpe *et al*, 1998). Wind energy can, however, have some potential burdens on amenity through visual intrusion or/and noise.

Total renewable energy consumption is expected to continue increasing in the future, but without further policy intervention, the rate of growth in WE is unlikely to be significantly higher than the growth in total energy consumption and so the share of renewables is not expected to

increase significantly. In the CEE and EECCA the higher growth in total energy consumption may mean that the share of renewables actually falls (EC 2003b). Electricity generation is expected to continue being the sector where most renewables are deployed. Projections by the European Commission for the whole European region (EC 2003b), expect that by 2030, electricity generation from renewables will increase by around 50% in WE and EECCA countries and will double in CEE. However, this significant growth needs to be seen in the context of increasing electricity generation, which is expected to increase by almost 80% over the same period. Thus even in the electricity sector, without additional policy stimulus the share of renewables is unlikely to increase substantially.

Figure 2.3 Contribution of renewable energy sources and waste to total energy consumption, Europe 1992 – 2000



2.3. Trends: Energy Efficiency

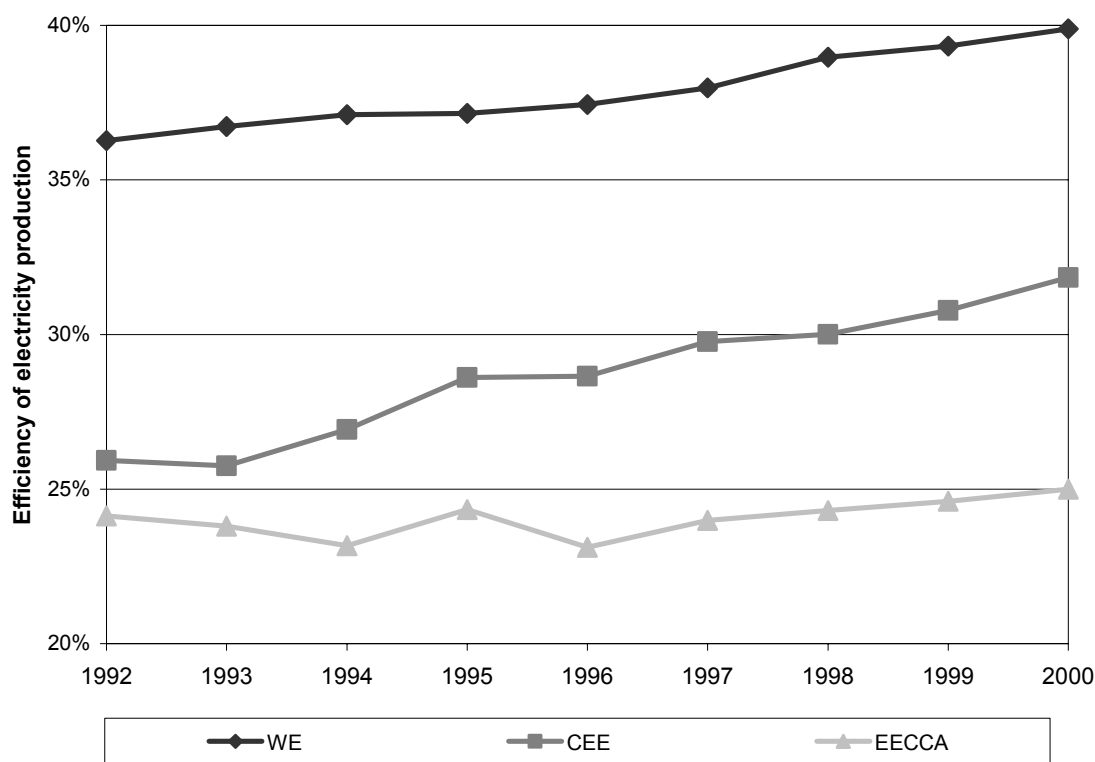
Energy efficiency reduces the demand for energy-consuming services or delivers these services with more efficient devices. It therefore reduces the potential health burdens of energy-use. The importance of using energy efficiently is recognised in a number of policy agreements and measures including the Energy Charter Treaty and Protocol on Energy Efficiency and Related Environmental Aspects (ECS, 2002). In addition, the EU has developed an action plan that aims to deliver a 1% per year reduction in energy intensity, over and above 'that which would have otherwise been attained' (Council of the European Union, 1998). In this case the energy intensity of a country is defined as its final energy consumption divided by its gross domestic product (GDP). The measures contained in this plan should encourage developments in countries that have applied for EU membership, as well as in current Member States. In addition, the recent Ministerial Conference on "Environment for Europe" held in Kiev, recognised that improved energy efficiency is fundamental to meeting many energy and environmental objectives and the final statement includes a commitment to supporting both energy efficiency and renewable energy.

Energy Efficiency: Electricity Generation Sector

The electricity production sector is of particular importance. Experience shows that the proportion of electricity in final energy consumption increases as economies develop. This is because greater automation in industrial production usually requires a greater use of electricity, while increased wealth results in more electricity use by households and services. Between 1992 and 2000 Europe's share of electricity in final energy consumption increased by more than 11%, reaching 19% in WE, 15.5% in CEE and 12.6% in EECCA. Since this trend is likely to continue, it is vital for the environment that electricity is produced with maximum efficiency, especially when produced from fossil fuels that release substantial quantities of greenhouse gases and other pollutants.

On average, the efficiency of fossil-fuelled electricity production in Europe increased from 29% to 33% between 1992 and 2000. This was due mostly to plant replacement in WE (especially switching to inherently more efficient systems such as gas turbines), and technical improvements and refurbishment in CEE (see Figure 2.4). However, production efficiency in both CEE and EECCA remains substantially below WE levels. In CEE countries this is due to high reliance on coal (the source of 74% of fossil-fuelled electricity production in 2000, compared with 49% in WE), which is intrinsically less efficient for electricity production than gas, and to the age and low technical standard of many of the plants. In EECCA, 60% of fossil-fuelled electricity production comes from natural gas, which is capable of higher production efficiencies, but the low efficiency observed in the region indicates the age and poor technical performance of such plant. Significant efficiency improvements in CEE and EECCA will only come from investment in new plant, but few national utilities can afford this. Consequently, many countries are implementing or are planning market liberalisation measures in order to attract private investment.

Figure 2.4 Efficiency of electricity production from fossil-fuelled power plant, Europe 1992 - 2000



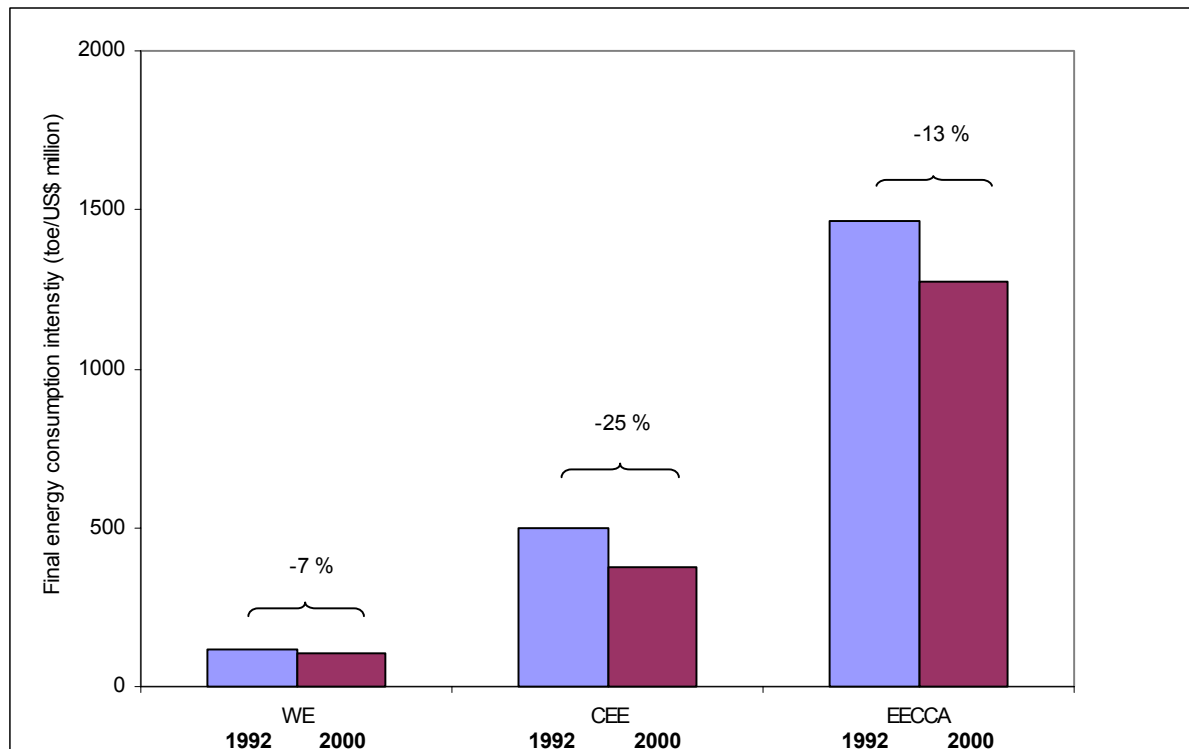
Source: IEA, 2002

Energy Use Efficiency

Improvements in the way end-use sectors use energy can be tracked by measuring final energy intensity (i.e. final energy consumption per unit of GDP). The lower the intensity the less energy is used per unit of wealth created.

Energy intensities in CEE and EECCA are substantially higher than in WE (see Figure 2.5). This reflects lower efficiency in all end-use sectors due to a combination of factors including older, less efficient industrial plant, inadequate maintenance, older, less efficient vehicle fleets, and the combined effect of poorly insulated building stock, a lack of heating controls in buildings and the comparatively longer and colder winters experienced in some parts of CEE and EECCA. Historically, this situation developed as a result of countries' access to relatively abundant, low-cost energy resources, which made them less exposed to the energy price shocks of the 1970s, and provided less incentive to invest in energy efficiency. The situation persisted due to a shortage of investment, especially in EECCA.

Figure 2.5 Final energy intensity, Europe 1992 - 2000



Note: Final energy consumption is the energy consumption of the transport, industry and other (household, services and agriculture) sectors. It includes the consumption of converted energy (i.e. electricity, publicly supplied heat, refined oil products, coke, etc.) and the direct use of primary fuels such as natural gas or renewables (e.g. solar heat, biomass). It excludes petrochemical feedstocks. Due to incomplete data, western Europe excludes Andorra, Liechtenstein, Monaco and San Marino, and central and eastern Europe excludes Bosnia and Herzegovina and Serbia and Montenegro.
Source: IEA, 2002, World Bank, 2003

Most EECCA and CEE countries developed policies to encourage and support rational energy saving. This, together with one-off economic restructuring, contributed to reduced energy intensities, particularly in CEE. However, in many countries, the implementation of energy efficiency measures has been weak because priority has been given to economic recovery and social issues, and the institutions needed to drive energy efficiency policies were poorly supported. Consequently in a number of countries, particularly in EECCA, the improvements have been due mainly to deprivation rather than rational energy saving, and may therefore be reversed as economies develop, unless stronger measures to support energy efficiency are implemented. The slow pace with which energy intensity decreased in WE is the result of low prioritisation of energy efficiency policies due to abundant energy supplies and low fossil fuel prices.

It is expected that final energy intensities in European countries will continue to fall, but that these reductions will not be sufficient to offset the effects of economic growth, so that final energy consumption will continue increasing. While the rate of improvement in CEE and EECCA is likely to be higher than that in WE these countries are still likely to have higher energy intensities for many years to come.

There is considerable potential for energy savings in all sectors throughout Europe and especially in CEE and EECCA. In CEE, improvements in industrial energy intensity resulted from a combination of the closure of some less-efficient plant and investment in new production facilities by international companies. Energy efficiency improvements in households and services resulted from a combination of measures including increased prices, reduced subsidies,

metering and billing by consumption, all of which provided a financial incentive to reduce energy consumption. In EECCA, industrial energy intensity actually increased between 1992 and 2000, indicating that, on average, the economic decline and restructuring in these countries has not yielded any improvement in efficiency. The improvements in energy intensity in households and services were mainly due to supply limitations and self-deprivation, rather than as a result of energy services being provided more efficiently. Price and market reforms in these countries have proved difficult to introduce in EECCA at a time of economic recession and high unemployment, when the political priority has been to ensure that energy prices are kept low.

2.4. Trends: Reducing Air Pollutants

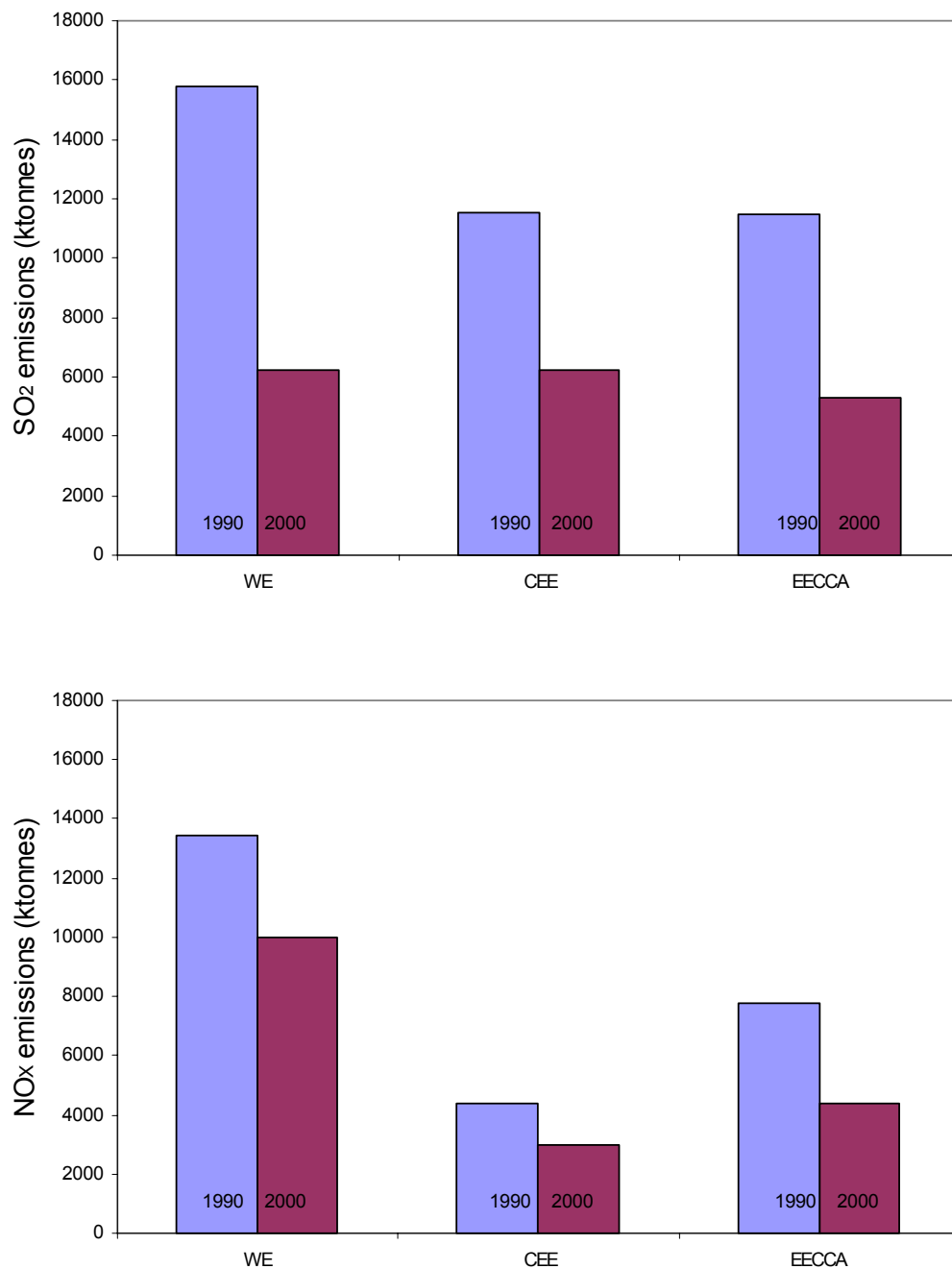
The trends above relate to generic energy use. It is also important to look at the specific trends in targeting specific health impacts. The most important of these are for air pollution and the potential risk of climate change.

Energy use is the major source of sulphur dioxide (SO₂) and nitrogen oxide (NO_x) emissions, accounting for over 90% of both emissions in Europe in 2000. Considerable progress has been made in reducing these energy-related acid gas emissions and this has greatly helped all three regions to be on track to achieve their aggregate targets under the UNECE Convention on Long-Range Transboundary Air Pollution (see Figure 2.6).

The reductions in acid gas emissions in WE, shown below were achieved mainly by direct actions including switching to lower sulphur fuels, installing flue gas clean-up systems, introducing catalytic converters in cars (in order to meet the 'Euro' standards) and modifying combustion processes. The reductions in CEE were also greatly helped by direct actions. However, the reduction in energy use in CEE, in particular of coal use, also played an important role. Data problems for some EECCA countries prevent precise conclusions being drawn, but judging from the energy consumption data, it is likely that the reduction in acid gas emissions was mostly the result of reduced energy use, with direct actions also contributing.

The fact that direct actions contributed significantly to the reductions in Europe, particularly in WE and CEE, is encouraging. Nevertheless, a number of regions in Europe, mostly in CEE and EECCA countries, face serious air pollution problems (including acidifying pollutants and urban pollution) that need to be addressed urgently and the potential for improvement through direct actions in CEE and EECCA remains large. In addition, the potential for further improvement through energy efficiency measures remains to be explored by all three regions.

Figure 2.6 Energy-related emissions of sulphur dioxide (a) and nitrogen oxides (b), Europe 1992 - 2000



Notes: Energy-related emissions include emissions from transport. SO₂ emissions for EECCA cover all emission sources (including non-energy sources), but exclude emissions from Kyrgyzstan, Tajikistan and Turkmenistan, due to incomplete data coverage. SO₂ emissions for CEE exclude emissions from Albania, Bosnia-Herzegovina, Malta and Romania, due to incomplete data coverage. NO_x emissions for CEE exclude emissions from Albania, Malta and Romania, due to incomplete data coverage.
Source: EEA/ETC on Air and Climate Change

2.5. Trends: Reducing Greenhouse Gas Emissions

For millennia, the greenhouse effect has facilitated a balance between incoming solar radiation and outgoing terrestrial radiation; a change in either incoming or outgoing radiation modifies the surface temperature of the Earth. Currently, carbon dioxide averages around 370 parts per million (ppmv) in the atmosphere; pre-industrial concentrations were about 280 ppmv. CO₂ concentrations have not been this high in the past 400,000 years.

As a result, there have been major policy initiatives, such as the Kyoto protocol (see box below), to reduce greenhouse gas emissions world-wide.

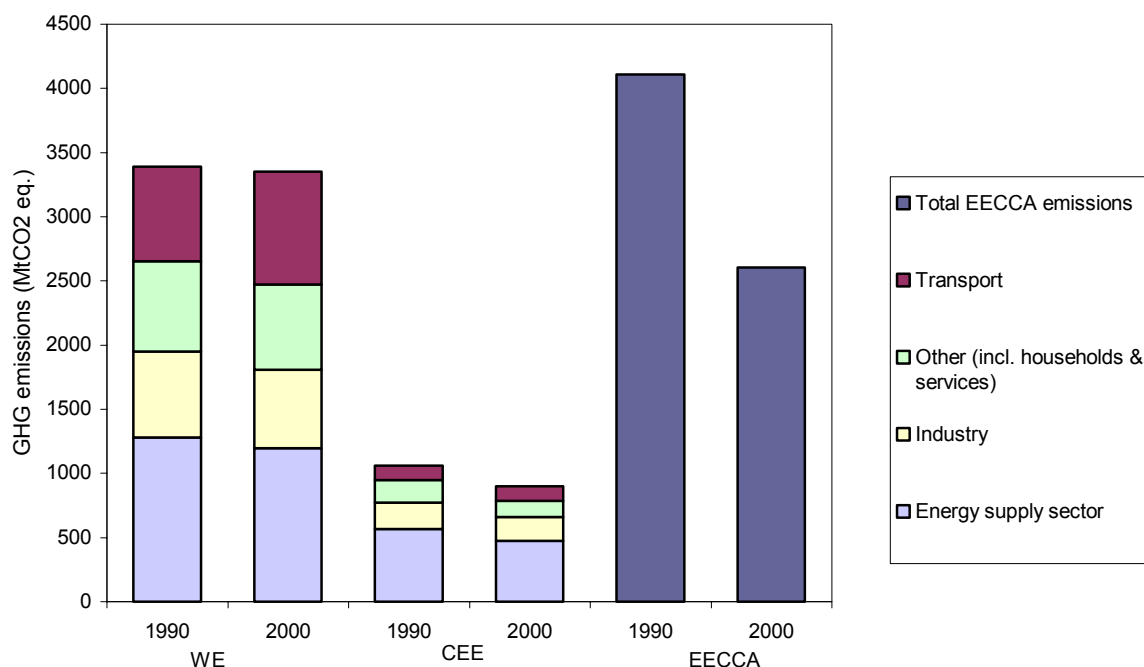
Box 2.2 The Kyoto Protocol

The reduction of global greenhouse gas emissions is a priority action area for industrialised countries, as agreed under the UN Kyoto protocol. The Kyoto protocol emissions target for EU Member States is a reduction to 8% below 1990 levels by 2008–12. Several CEE countries have Kyoto reduction targets of between 5 and 8%. The target for the Russian Federation and the Ukraine, the only EECCA countries that have Kyoto targets, and the two largest economies of EECCA, is to stabilise emissions to 1990 levels. As at 15 April 2004, 84 Parties have signed and 122 Parties have ratified or acceded to the Kyoto Protocol. It shall enter into force on the ninetieth day after the date on which not less than 55 Parties to the Convention, incorporating Annex I Parties which accounted in total for at least 55% of the total carbon dioxide emissions for 1990 from that group, have deposited their instruments of ratification, acceptance, approval or accession. Although 84 Parties have signed they account only to 44.2% of overall emissions. There is a clear need for action to reduce emissions arising from energy and transport. Moreover, while the attainment of these targets is important, they only represent a first step, since it is estimated that global emissions need to be reduced by about 70% in the long term to stabilise greenhouse gas concentrations at an acceptable level (IPCC, 2001). It is therefore important for emissions reductions to be based on lasting measures and actions.

Energy industries are the most important source of greenhouse gas emissions in Europe, contributing a 29% of total emissions in WE; 42% in accession countries and about 20% in EECCA countries.

Overall, energy-related greenhouse gas emissions in Europe fell considerably between 1990 and 1999. This was due mainly to the Russian Federation and Ukraine, two of the biggest energy consumers in Europe, which reduced their total emissions by 36% and 50% respectively over the period. These reductions were mostly the result of economic difficulties and restructuring, which resulted in a substantial reduction in the energy use of these two countries over this period. CEE countries achieved a reduction of 15% in their energy related greenhouse gas emissions due to large cuts in most countries, mainly as a result of economic restructuring, which were partly offset by increased emissions from Turkey (65%) and Croatia (12%). Energy-related emissions in WE fell by only 1.1%. Nevertheless, this was achieved against a background of a 22% increase in economic growth over the same period.

Figure 2.7 Energy-related greenhouse gas emissions, Europe 1990 - 2000



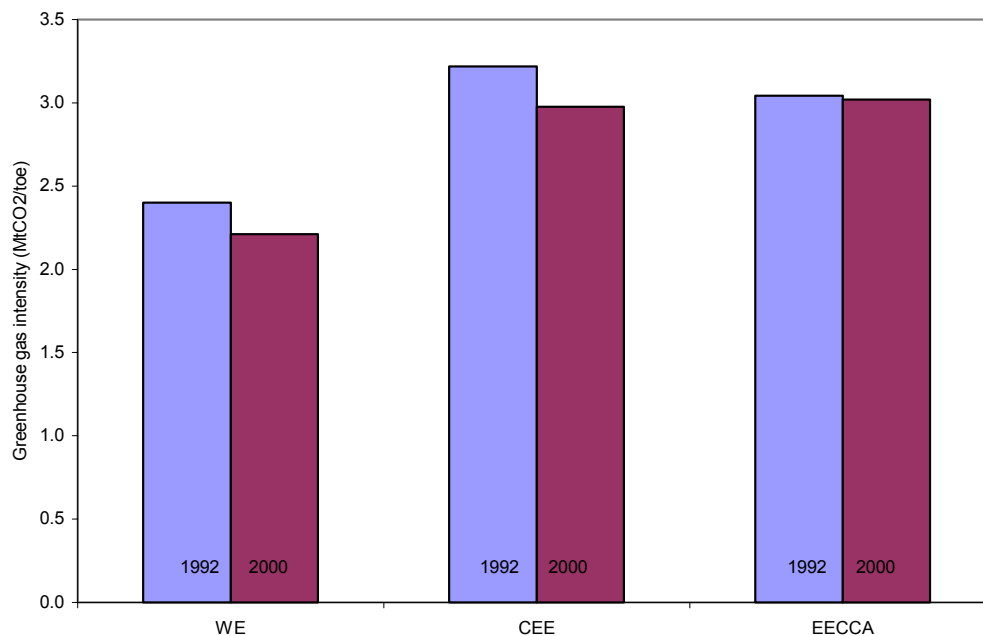
Notes: Due to an incomplete sectoral breakdown, data for EECCA cover all sources of carbon dioxide, methane and nitrous oxide, but estimates indicate that energy use accounts for over 80% of these emissions. CEE excludes Albania, Bosnia and Herzegovina, the former Yugoslav Republic of Macedonia, Romania and Serbia and Montenegro due to missing or incomplete data. EECCA excludes Kyrgyzstan, Tajikistan and Turkmenistan due to missing or incomplete data. The Russian Federation and Ukraine accounted for almost 80% of the reported greenhouse gas emissions from EECCA countries. Energy supply sector emissions include those from coal mining, oil and gas exploration and extraction, public electricity and heat production, oil refining and other industries engaged in converting primary energy into energy products. It also includes fugitive emissions from the exploration, production, storage and transport of fuels. The data are for emissions of carbon dioxide, methane and nitrous oxide, and exclude the fluorinated gases. Source: EEA/ETC on Air and Climate Change

Transport contributes a substantial proportion of greenhouse gas emissions in WE countries but much less in CEE countries. Over the period 1990 to 2000, transport greenhouse gas emissions from WE increased by 19%, whereas emissions from the CEE had a smaller increase of 4%. This gradual increase in emissions from CEE disguises the overall trend: for the first half of the decade transport emissions dropped rapidly, falling by 8% to 1995. However, the trend reversed in 1996 towards rapid growth, which is set to continue beyond 2000. In the EU, where the largest emission growth occurred, passenger transport activity followed economic growth, while freight transport increased above the economic growth rate. The low energy consumption of the transport sector in EECCA indicates that the contribution of transport emissions in this region much less than the other regions of Europe. Transport growth is strongly driven by economic growth and transport emissions are expected to grow substantially in CEE and EECCA as economies recover and the demand for transport increases.

One option for achieving a lasting reduction in energy-related greenhouse gas emissions is to reduce the greenhouse gas intensity of energy use by switching to energy sources that contain less carbon (e.g. from coal to natural gas or renewable energy sources), and/or by reducing the emissions associated with the production and use of these sources. The figure shows that all three regions achieved reductions in greenhouse gas intensity between 1992 and 2000. In fact, with total energy consumption growing in WE, the reduction in its energy-related greenhouse

gas emissions observed was largely due to switching from coal to oil and gas and a consequent cut in greenhouse gas intensity. However, greenhouse gas intensities in CEE and EECCA remain substantially higher than in WE, mainly as a result of a large use of coal in CEE and of substantial fugitive methane emissions in EECCA.

Figure 2.8 Greenhouse gas intensity of total energy consumption, Europe 1992 - 2000



Note: Greenhouse gas intensity is defined as the amount of greenhouse gas emissions, expressed in units of carbon dioxide equivalent, released per unit of total energy consumption. EECCA: based on total emissions because energy-related emissions data are not available for most countries in the region.

Sources: IEA, 2002; EEA/ETC on Air and Climate Change

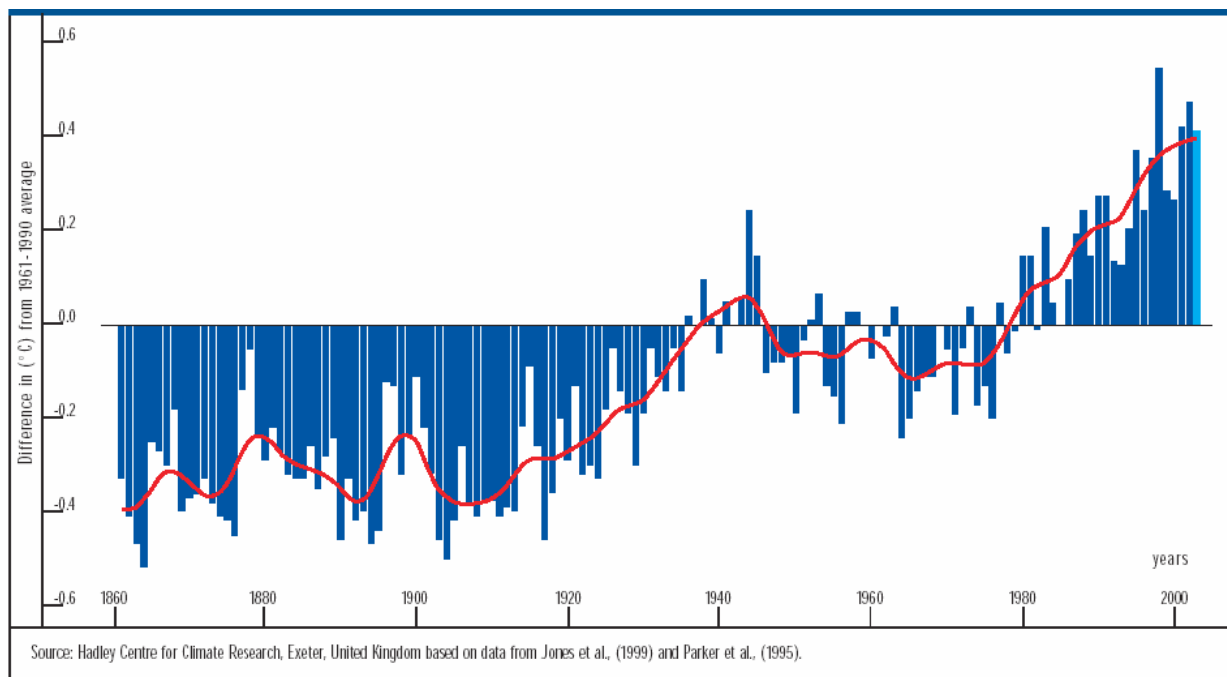
2.6. Trends: Changes in the Climate System

The reductions above are modest in relation to the emission cuts needed to avert climate change. If CO₂ concentrations globally continue to increase, average surface temperatures must increase for the “balance” of the earth to be maintained. Although there are many confounding factors, most of the alternative explanations for the changing climate have been ruled out, with the exception that increasing concentrations of CO₂ are leading to increasing temperatures and other changes in the climate system.

In fact, the global average surface temperature has increased since 1861. This unprecedented warming has taken place in a time span far shorter than the spans paleoclimatic studies have shown for geological periods with similar changes. The global average sea level has risen, the heat content of the oceans has increased and the extent of snow cover and ice has decreased (Figure 2.9).

The assessment of over 100 meteorological stations and the trends in indices of daily temperature and precipitation extremes in Europe, between 1946–99 (Klein Tank et al, 2002), showed that the warming observed in Europe can be split into two sub-periods: the 1946-1975 sub-period, with slight cooling and a decrease of annual numbers of warm extremes but no

Figure 2.9 Past and future changes in global mean temperature
Global average near-surface temperatures, 1860–July 2003 from 1961 to 1990 average



increase of the annual numbers of cold extremes; the 1976-1999 sub-period, being an episode of pronounced warming, the annual number of warm extremes increased two times faster than expected from the corresponding decrease in the number of cold extremes. Throughout the year, the frequency of days that are much colder than normal has decreased and the frequency of days that are much warmer than normal has increased. A decreasing number of frost days and to a lower extent an increasing number of summer days accompanied the observed warming trend.

In their most recent Third Assessment Report, the Intergovernmental Panel on Climate Change (IPCC) suggested that global temperatures will increase by a range of 1.4- 5.8°C by 2100 relative to 1990. The projected rise will be very much larger than observed changes over the last century, and is unprecedented in the last 10,000 years. Precipitation is projected to increase (though there are regional differences). Sea level is projected to rise by additional 0.09 to 0.88 m by 2100. There are likely to be more extreme events (e.g. cyclones) and possibly major events beyond 2100 (e.g. alteration of ocean currents). Projections at national, regional, and local levels are uncertain. Included in the range of projections for this century are thawing of the permafrost and an ice-free Arctic.

One of the questions recently addressed within a WHO/EEA meeting is whether the likelihood of extreme events will be increasing over Europe? Extreme weather events are events that are rare within its statistical reference distribution at a particular place. Definitions of “rare” vary, but an extreme weather event would normally be as rare or rarer than the 10th or 90th percentile. Extreme climate events are the average of a number of weather events over a certain period, which is itself extreme (e.g. rainfall over a season). A range of hypotheses exists concerning how extreme events might alter with climate change. These include the “no change”, “mean effect” (increase in mean but not variability), “variance effect” (increase in range) and “structural change” (increase in mean and skew of low probability events) hypotheses.

Two broad approaches are taken to assess these hypotheses: statistical modelling using extreme value theory and modelling using General Circulation Models (GCMs) or Regional Climate Models (RCMs). Both approaches have projected the following outcomes for Europe, which in terms of scientific confidence are rated as likely to very likely:

1. more frequent extreme high temperatures and less frequent extreme low temperatures, with an associated increase (decrease) in cooling (heating) degree days;
2. an increase in daily minimum temperatures in many regions that will exceed the increases for daytime maximum temperatures;
3. daily temperature variability will decrease in winter but increase in summer;
4. there will be a general drying of mid-continental areas during summer; and
5. there will be an increase in precipitation intensity in some regions.

Confidence in such projections exists because trends in observed weather and climate extremes for Europe in many ways match the expected outcomes of climate change; the heat-wave of August 2003 is a possible harbinger of the future.

Due to the slow rate of change in the energy sector and the residual time of greenhouse gases in the atmosphere, most experts conclude we are probably already committed to at least 2°C of warming. The emissions cuts required are much greater, for example, a 60% or greater reduction on 1990 emissions by 2050 to at least slow the climate change.

2.7. Trends: Waste and Soil Contamination

Energy use, particularly in the electricity generation sector, can also produce solid and liquid wastes that may be hazardous to human health. These wastes are largely products of the combustion process, and have the potential to enter the environment. Solid wastes are a common form of potential pollution from electricity generation. Combustion of all solid and liquid fossil fuels will result in some ash, the disposal of which must be carried out in order to avoid pollution that may have the potential to damage human health. There are large country to country variations in the management of such wastes and the risks to human health depend as much on the degree to which they are managed as to the toxicity of the wastes. Large volume solid residues from coal combustion (fly ash, bottom ash and slag, desulphurization residues) are utilized in some countries as construction materials (cement, bricks, road filling materials etc). Advances in waste management practices mean there are now careful controls over waste residue disposal, although practices have led to significant pollution and health risks through soil and/or groundwater contamination. Oil combustion residues may contain heavy metals including nickel and vanadium. These wastes are not generally recycled as usable materials and as such end up being deposited in landfills.

Soil contamination by heavy metals is a problem in all countries. In the European Region, the level of emissions of mercury and lead decreased during the 1990s, 'with emissions in 1999 being 40% of those in 1990' (EEA, 2003). This is partially confirmed by Herpin et al (2004) who compared the results of the 1990/91 and 1995/96 moss-monitoring programmes for 19 countries.

The comparison of the medians of the elements analyzed for 19 European countries indicates for most of the elements a general tendency to lower values in 1995, except for Lithuania, Netherlands, Portugal, Italy and United Kingdom. In general it shows a fall in the concentration of heavy metals, with the exception of cadmium, copper and zinc, over the relevant period. Especially in former East Germany, chromium (Cr), iron (Fe), titanium (Ti) and vanadium (V) decreased significantly. This is, firstly, a reflection of the closure of and/or technological improvements to large power plants; secondly it is due to the fact that lignite has given way to other fuels. Vanadium (V) and nickel (Ni), typical constituents of crude oil, also show a decrease in the western part and thus document changes in the type of fuel consumed. The significant fall in lead concentration in 1995/96 as compared to 1990/91 in what used to be East and West Germany probably results from the increasing use of lead-free petrol. Although there are decreasing trends in some countries soil contamination remains of particular concern in particular for some CEE and EECCA countries.

Low volume solid waste residues (sludge, coal pile run-off, coal mill rejects, heater, exchanger and precipitator cleaning wastewater) are typically managed in impoundments and landfills. Some of these wastes may be described as hazardous, however they do not generally pose a risk to human health and the environment. The following table identifies the pollution risks associated with different fossil fuels and shows that natural gas has significantly lower impacts than either coal or heavy fuel oil.

Table 2.5. Pollution risks associated with different fossil fuels

Fuel	Quantity of residue	Toxicity of residue	Disposal method	Risk to Human health ¹²
Coal	High	Medium	Landfill / Construction products	Medium
Heavy Fuel Oil	Low	High	Landfill / Construction products? ¹³	High
Natural gas	Very low	Low	N/A	Low

The success of measures to improve the safety of nuclear generation is indicated by the number of 'unusual events' reported to the incident reporting system operated jointly by the International Atomic Energy Agency (IAEA) and OECD. This shows the number of incidents reported in Europe varying between 177 and 76 during the period 1992-2001, but with no clear improvement trend. Nevertheless, 2000 and 2001 had the lowest number of incidents. The risk of health impacts from nuclear remains highest outside of WE regions. Data on the accumulation of radioactive wastes across all three regions is not available in consistent format. However, OECD (Organisation for Economic Co-operation and Development) data for WE show on average an annual removal of nearly 3000 tonnes of highly radioactive used nuclear fuel from reactors to stores during the 1985-2010 period (OECD, 1999).

¹² If released uncontrolled into the natural environment.

¹³ Ashes can be used by the construction industry where Flue Gas Desulphurisation is fitted.

2.8. Conclusions

This chapter has looked at a variety of trends in energy consumption, energy efficiency, air pollution, greenhouse gases, the changing climate and other effects of energy generation and transportation. The consumption of energy is a key part of any sustainable development strategy, and increases in energy will be needed to support any sustainable growth strategy that is designed for Europe.

There are a number of important aspects when dealing with energy demand and supply:

- 1 The external dependency of a number of European countries is constantly increasing. As of the green paper of the EU15, 50% of the energy requirements are imported and if no measures are taken within the next 20 to 30 years this figure will rise to 70%;
- 2 Energy use has increased in Western Europe, but in both the eastern and western parts of the Region, the trend has been towards increased energy efficiency (that is, energy use per unit of gross output, measured in monetary terms); and
- 3 At the same time, the gap between energy efficiency in the west and the east remains large, and energy efficiency has even declined in some eastern countries such as Belarus and Ukraine.

There are significant positive trends, developed through policy measures, market liberalization and technological improvement in particular in the Western countries of Europe. This includes a decrease of emissions of air pollutants and some improvement in waste management. The reductions of air pollution in Western Europe are primarily a consequence of clean air policy (e.g. the introduction of Euro standards in the transport sector, regulations on emission sources such as large combustion plants, international agreements like the UNECE protocols), but also market liberalization in the electricity generation sector have led to the introduction of cleaner fuels and technologies. Emission reductions in CEE have largely resulted from economic restructuring. Though the situation has improved, there is still a considerable health risk from exposure to air pollution in Europe. It also seems that reduction potentials are higher in the CEE and EECCA regions, since regulations are currently often less strict.

Other related improvements have also been made in western Europe in waste and water pollution, particularly as a result of increasing natural gas use at the expense of coal. The picture is somehow different in central and eastern Europe. In the early stages of economic transition, most cities benefited environmentally from the industrial decline, which meant fewer harmful pollutants being emitted. More recently, however, as industry has managed to recover, emissions have started to increase and the plants and equipment used do not meet adequate emission standards yet. Eastern Europe has hotspots that require urgent action. There have also been reductions in the occupational health risks of energy extraction and production. However, while progress has been made in these areas in WE and CEE, the levels and health risks remain much higher in EECCA countries.

One of the biggest long term problems still remain the globally increasing CO₂ emissions. Although, greenhouse gas emissions from energy-use have fallen over the past decade in Europe, these reductions are largely due to the reduction in energy consumption from economic restructuring, rather than due to successful implementation of abatement strategies. In Western Europe the emissions reduction were very low (though they were achieved against a background

of economic growth). Most of the emissions reductions were achieved from fuel switching from coal and oil to natural gas. However, the pressures for emissions increases, especially in the transport sector, and from coal use in CEE, are likely to grow. Overall, the progress towards reducing the health risks of climate change has been modest, and much greater emissions reductions are needed to achieve the necessary objectives to reduce the potential health risks.

The future effects largely depend on what happens to emissions worldwide, and the role of Europe, while not insignificant, is relatively small in this wider scenario. Many European countries are listed in Annex B of the Kyoto Protocol and therefore have a commitment to reduce greenhouse gases by a small amount by 2008–2012. Climate change-related policies have significantly driven the integration of environmental considerations into energy policies. Among the most significant is the recently adopted EU directive on emissions trading. This decision will essentially cap the emissions allowed by large industry (including the power-generating sector) within Europe, effectively placing an EU-wide price on carbon dioxide emissions for the first time. The direct benefit of these reductions will be a further decline in local primary and associated secondary air pollutants. However, these reductions are modest in relation to those needed to avert the negative effects of climate change. This requires much greater reductions over the longer term to 2050.

Chapter 3: Access to electricity and heating

Authors: Bettina Menne, Anil Markandya and Tom Kosatsky

3.1. Introduction

In the twenty-first century, residential access to commercial energy is fundamental to human health. It powers many of the daily functions that maintain and improve our health, such as cooking, refrigeration, provision of safe water, household heating, information and communication, even life support to severely ill outpatients. While worldwide, some 1.6 billion people do not have access to electricity and some 2.4 billion rely on burning biomass (World Energy Outlook, 2002), Europe as a region does not face this problem on a large scale. However, Europe is beset by a growing lack of affordable energy as well as by problems of efficient production and secure supply.

This chapter portrays the state of access to commercial energy in Europe, providing largely qualitative descriptions of difficulties in energy affordability, supply and efficiency. The three phenomena are closely connected, together presenting important threats to human health. The health impacts addressed in this chapter include acute exposure to heat and cold, chronic exposure to cold and the health effects consequent to the use of alternative fuels, in particular for heating. To a limited extent we address the many indirect health effects that may be caused by both short and long term deficiencies lack in energy supply, examples being food borne diseases related to lack of refrigeration and water borne diseases resulting from insufficient water treatment. A review of measures taken to mitigate the access problem is followed by conclusions as to the present state of knowledge in this area and what directions future research and policy should take.

3.2. Access to commercial energy in Europe

Data on access to commercial energy in Europe as related to socio-economic status is patchy and derives mainly from qualitative surveys. While the information available is revealing, it must be viewed with some caution.

World Bank surveys show that the use of non-network energy in Eastern Europe and Central Asia is significant, and is especially high among poor households. Table 3.1 shows that, while access to electricity overall is virtually universal (Moldova is an exception), access to district heating supplies or to central gas is much more limited. Moreover this access is notably lower among poor households.

Table 3.1. Urban network energy use in Eastern Europe and Central Asia (percent).

	District heating		Central gas		Electricity	
Country	Poor	Nonpoor	Poor	Nonpoor	Poor	Nonpoor
Armenia, 1999	11	14	4	16	97	99
Croatia, 1997	15	39	19	30	99	100
Kyrgyz Republic, 1999	17	55	13	33	100	99
Latvia, 1997	70	83	57	68	99	100
Lithuania, 1998	31	46	47	56	85	94
Moldova, 1999	17	57	37	70	65	89
Tajikistan, 1999	1	1	3	6	100	100

Source: World Bank, 2002

Possible reasons for not using ‘network energy’ are (a) it is not available and (b) not affordable. District heating systems were well developed in the countries of the former Soviet Union, especially in the large housing blocks surrounding industries. But the systems were inefficient in terms of energy losses, were largely unregulated, and there was no metering. In those countries where district heating is profitable, improved management, the gradual introduction of regulation, newer technology, and metering, has achieved significant improvements. In some of the low-income countries, district heating systems collapsed, owing either to the collapse of the industry that used to supply excess heat or to a lack of revenues. In many countries, the delivery systems deteriorated. As one would expect, the evidence points to affordability being a much more serious problem among poorer households, although in Eastern Europe it is not confined to such households. During the winter months, particularly in those countries with very low winter temperatures (-30° Celsius it is not uncommon in parts of Europe) the frequency of failure of central heating facilities has been increasing, affecting all households that depend on such systems, including both the poor and non-poor.

The energy affordability problem has been exacerbated as a result of increased prices of network energy, as countries move to a market based system and struggle with the problem of financing energy supply. Certainly affordability is an issue in Eastern and to a lesser extent in Western Europe, when one looks at the percentage of total spending that is accounted for by energy.

A concept linked to affordability is that of fuel poverty. The World Health Organization and the British government, for example, use the following definition of fuel poverty: A fuel poor household is one that cannot afford to keep adequately warm at reasonable cost. The most widely accepted definition of a fuel poor household is one which needs to spend more than 10 per cent of its income on all fuel use to heat its home to an adequate standard of warmth. This is generally defined as 21°C in the living room and 18°C in the other occupied rooms. (The Department of Trade and Energy¹⁴, 2004)

¹⁴ http://www.dti.gov.uk/energy/consumers/fuel_poverty/, accessed 5 June, 2004

A survey conducted by the World Health Organization on housing and health in seven European cities (Angers (France); Bonn (Germany); Budapest (Hungary); Forli (Italy); Vilnius (Lithuania); Ferreira do Alentejo (Portugal) Bratislava (Slovakia); and Geneva (Switzerland), showed the following key preliminary findings (WHO¹⁵, forthcoming):

- Households reporting temperature problems in winter ranged from 72 percent in Vilnius to 27 percent in Bonn, with a simple average of 53 percent;
- Households paying more than 10 percent of their household income for heating ranged widely: from 71 percent in Vilnius to only 2 percent in Geneva. Households sampled from the present EU member states, however, had between 6 and 10 percent of households paying more than 10 percent;
- On average, across the whole sample, about a quarter of all households paid more than 10 percent and about half of all households felt that heating was an expensive item; and
- Of the top three reasons for inadequate heating in the home all cities cited inadequate insulation, including 'not tight windows'.

Other surveys, for example in the United Kingdom, showed that some four million households spend, or need to spend, 10% of their income on fuel in order to heat their homes. Of these, some one million households spend up to 30% of income on fuel (DEFRA, 2001). There are no conclusive average numbers for Europe available, therefore it is difficult to estimate how big the percentage is among households that spent more than 10 percent of their household income.

When this essential commodity takes up such a large share of the household budget, inevitably people are forced to economize on other commodities (for example health and dental care or education) or to use less energy, to such an extent that it might affect their health. This might even more affect the poor strata of populations of European societies. Interconnected to this problem of poverty is the problem that inefficient technologies which while being more affordable for the poorer strata might increase the final energy consumption expenditures. Thus, typically the poor spend a few percent more than the non-poor, and the amounts can reach as much as 12-14 percent of total spending for the former (WB, 2002).

The latter is a very important finding as 'affordability' is not simply a problem of paying for the energy, but also a problem of investing in infrastructure that makes the most effective use of this energy. Household insulation, and installation of efficient central heating systems are both dimensions of this affordability problem. More generally, the wider issue of the quality of the housing stock will need to be seen in the light of this problem.

Where households do not have access to network energy, what do they use? Some have access to Liquefied Petroleum Gas (LPG) and kerosene, while others depend on wood and coal. Wood and coal are more used by the poor than the non-poor (Table 3.2).

¹⁵ http://www.euro.who.int/Housing/Publications/20020409_1, accessed 5 June, 2004

Table 3.2. Urban non-network energy use in Eastern Europe and Central Asia (percent)

	LPG		Kerosene		Coal		Wood	
Country	Poor	Non poor	Poor	Non poor	Poor	Non poor	Poor	Non poor
Armenia	17	27	14	11	n/a	n/a	47	50
Croatia	44	45	3	7	1	1	51	26
Kyrgyz Republic	24	39	31	17	60	31	46	22
Latvia	37	28	n/a	n/a	<1	<1	1	2
Lithuania	n/a	n/a	n/a	n/a	<1	<1	1	2
Moldova	6	7	n/a	n/a	9	5	12	9
Tajikistan	n/a	n/a	<1	1	11	18	47	32

Source: World Bank, 2002.

The percentage varies between countries and within countries of the World Bank survey. The use of these fuels contributes significantly to the deterioration of population health, as will be explained below. The use of wood also puts pressure on forest resources. (UNECE, 2003)

A World Resources Institute (WRI) study looked at the use of coal and biomass in households across 96 countries and constructed a measure of exposure to biomass use based on the kilograms of coal equivalent per household. Four countries from the European region were included in the study and these (Armenia, Georgia, Kazakhstan and Uzbekistan) ranked, respectively 94th 91st, 90th and 80th. Table 3.3 provides the details. Thus, although by world levels the problem in the region is relatively small, it is nevertheless a matter of concern, and better quality data need to be collected regularly.

Table 3.3. Use of Coal and Biomass in Selected Countries

	Residential Use of Coal and Biomass Fuel (tons of coal equivalent) (1994)	Average Size of Households (1994)	Total Population 1994 (000)	Number of Households (000)	Residential Use of Coal and Biomass Fuel per Household (kilograms of coal equivalent)	Rank of Potential Exposure to Biomass Use (1 is highest level in sample)
Armenia	6,120	5.3	3,622	683	9	94
Georgia	34,100	5.3	5,458	1,030	33	91
Kazakhstan	102,300	5.3	16,824	3,174	32	92
Uzbekistan	911,880	5.3	22,317	4,211	217	80

Source: Potential exposure to polluted indoor air in developing countries, WRI. <http://www.wri.org/ehi/indoorair.html>

Available data show that in Armenia, Georgia, Kazakhstan, Uzbekistan, and, to a large extent, the other countries of Central Asia, the problem of air quality in enclosed premises is aggravated by the use of stoves of local design in which various cheap, low-grade fuels are burned. During food preparation or heating, ambient air is contaminated by the chemical products of combustion (UN, 2002; Ministry of Health, Georgia, 2002). In recent years the price of all forms of energy has increased, leading to the use of a wide variety of sources to heat buildings and to reduction in ventilation in order to conserve heat, thereby markedly increasing ambient air pollution.

3.3. The consequences of poor access to commercial energy

There are a number of health effects that can be related to poor access to commercial energy. The first is that electricity cuts and disconnection to commercial systems may enhance short-term exposure to cold and heat waves. The second group of health effects are related to long-term exposure to cold. And the third type of health effects are related to alternative fuels used, in particular for heating, causing indoor air pollution.

Acute exposure to cold

During cold periods the availability of continuous electricity and heating is essential for human well-being. There are numerous examples of accidents in electricity supply and cut-offs in the Russian Federation and many eastern European countries. In the case of heat supply cut-offs, when outdoor temperatures are below 10°C (this period lasts 3 - 5 months a year in the Northern countries), indoor temperatures fall below 15°C. For example, during the winter of 2002 – 2003, 20 Russian cities had problems with residential heating systems. More than 1 million people experienced temperature discomfort, which lasted for longer than a month. (Revich, personal communication). Freezing to death and accidental hypothermia resulting in frostbites is extremely rare as a consequence of lack of heating in homes; the rare extreme cases have been observed during the very cold winters in places like Northern Russia and the Baltic States. Accidental cold exposure occurs mainly outdoors, in socially deprived people, workers, alcoholics, the homeless, the elderly in temperate cold climates (Ranhoff AH, 2000). The risk of suffering frostbite increases with age. (Juopperi et al, 2002) The onset of air-related frostbite appears at an environmental temperature of -11°C. Wind, high altitude and wet clothing lead to onset of injury at higher environmental temperatures. (Danielsson, 1996). The incidence of more serious frostbite requiring hospital treatment increases at temperatures of -15°C and below.

Theories about the mechanisms of cold-related cardiovascular mortality have tended to focus on changes in the circulation and haemostasis that may pre-dispose to thrombotic events (Woodhouse et al, 1993; Stout et al, 1996; Bokenes et al, 2000; Neild et al, 1994) as a result of body cooling (Smolander et al, 2002; Goodwin et al, 2000). Keatinge and colleagues place more emphasis on personal behaviours, and have argued that much of the excess winter mortality from arterial thrombosis is related to cold exposure from "brief excursions outdoors rather than to low indoor temperature". (The Eurowinter group, 1997; Keatinge et al. 1989)

Persons who have been affected by frostbites often are known to suffer from local hypersensitivity to cold and pain in the injured area, cold-induced sensations and disturbances of muscular function. These latent symptoms may have negative impacts on occupational activities in 13-43% cases. (Ervasti et al, 2000).

Acute exposure to heat

While the predominant problem of access to energy is one of exposure to cold, there is also an impact on health when people are unable to keep cool at very high temperatures. The European study Climate Change and Adaptation Strategies for Health (cCASHh) showed an increase in observed mortality once a threshold temperature has been exceeded, with individual risk factors for mortality being age (the elderly and children and infants are most vulnerable), pre-existing disease (cardiovascular, renal disorders, coagulation disorders and others), and physical activity (either over-exertion or inactivity) (Koppe et al, 2004) (see also the session on indirect health effects of fossil fuel). Social factors include living alone, type of housing (energy inefficient, lack of insulation, higher floors in buildings) and level of urbanization (heat island effect). There are some probabilities that impacts can be reduced through early heat warnings, and action taken in a timely manner to mitigate the effects of a heat wave. Heat-waves are expected to become more frequent and intense in the European Region (IPCC, 2001). This poses the question on how best mitigate the health effects. The literature, mainly from the United States, suggests that through energy-use, such as air conditioning, the risk of such impacts could be reduced. Estimations of air-conditioning availability in households in southern European Union countries varies between 5-10%. However it is expected that air conditioning use in the years to come will increase. Quantifying the role of air-conditioning in reducing mortality is difficult because of multiple confounding factors. Davis et al. (2003) pose interesting questions for the United States, such as whether air-conditioning is indeed the main cause of the observed declines in mortality. Once air-conditioning penetration approaches market saturation, will heat continue to significantly influence mortality in the United States? Will air conditioning be available to all socioeconomic classes? Will future changes in energy markets and pricing inadvertently force some people to put their health at risk during heat-waves? Can poorer people afford to buy and operate air-conditioning? What is the role of energy efficiency standards and changing policies?

Air-conditioning increases energy consumption, which increases greenhouse gas emissions if no carbon dioxide-neutral technology is used for energy production. Energy supply failed during the summer heat-wave of 2003 in some European countries, when the energy demand rose. Anthropogenic heat production might worsen the urban heat island effect: Wilby (2003) assumes that the increasing trend in the nocturnal urban heat island in London in spring, summer and autumn has been caused in part by the greater use of air-conditioning in recent decades. The need to use extra energy to counteract the urban heat island disproportionately affects resource-constrained people, who often live in urban areas and thus face the heat island phenomenon even more directly.

However more generally the problem should also be addressed through urban planning measures, such as reducing the density of buildings, planting trees in urban areas, and equipping houses with efficient cooling measures (Koppe et al, 2004).

Chronic exposure to cold

Mortality is subject to seasonality. In many temperate countries 'all-cause mortality' as well as cardiovascular and respiratory mortality are higher during winter months. Some epidemiologist's

use the notion of excess winter mortality to describe this seasonal phenomenon. Most European countries suffer from 5-30% excess winter mortality (Healy, 2003).

The Eurowinter group studied whether increases in mortality per 1 degree C fall in temperature differ across various European regions and related any differences to average winter climate and to measures to protect against cold. The findings were that the percentage increases in all-cause mortality per 1 degree C fall in temperature below 18 degrees C were greater in warmer regions than in colder regions, e.g. Athens 2.15% [95% CI 1.20-3.10] versus south Finland 0.27% [0.15-0.40]). At an outdoor temperature of 7 degrees C, the mean living-room temperature was 19.2 degrees C in Athens and 21.7 degrees C in South Finland; 13% and 72% of people in these regions, respectively, wore hats when outdoors at 7 degrees C.

Multiple regression analyses (with allowance for sex and age, in the six regions with full data) showed that high indices of cold-related mortality were associated with high mean winter temperatures, low living-room temperatures, limited bedroom heating, low proportions of people wearing hats, gloves, and anoraks, and inactivity and shivering when outdoors at 7 degrees C ($p < 0.01$ for all-cause mortality and respiratory mortality; $p > 0.05$ for mortality from ischaemic heart disease and cerebrovascular disease) (The Euro winter group, 1997).

A study published by Healy (2003) concluded that high seasonal mortality could be reduced through improved protection from the cold indoors, increased public spending on health care, and improved socio-economic circumstances resulting in a more equitable income distribution. Kunst et al, however, noted that in the Netherlands, there was a 50% reduction in winter excess mortality between the 1950s and 1970 followed by a much smaller reduction in later years. The authors argue that the role of the introduction of central heating has been minimal and that a fundamental role is played by factors closely related to socio-economic progress, with reduction of in winter temperatures through global warming perhaps also playing a role.

A recent study conducted by Wilkinson et al, (forthcoming) in the United Kingdom, assessed factors for winter excess mortality in the over 75 years old. A relationship between winter mortality and cold was found, however the findings suggest that the risk of excess winter death is more widely distributed within the elderly population than hitherto has been appreciated, and is less related to factors such as access to heating than had been thought. This may limit the potential health benefits of government energy efficiency initiatives that are specifically targeted at low-income households.

Morbidity also varies with latitude. Although epidemiological evidence is missing, some Russian authors noted that infarct of myocardium is registered two times more often in high latitudes, than in middle latitudes (Mitropolsky, 1988). The incidence of child respiratory diseases at high latitudes is 1.5 – 2 times higher than the average for the Russian Federation (Sorogin et al. 1993).

Epidemiological evidence on the links between indoor air temperature and morbidity is less easy to find and one is forced to draw on anecdotal information collected in the course of various household surveys. Recent World Bank surveys in Eastern Europe, for example, show households complaining about insufficient heat and increasing illnesses relating to being cold. For example, a survey in Sevastopol, Ukraine, showed that in 56 percent of households interviewed somebody had become sick because indoor temperatures were too low. In Moldova many households are subjected to indoor temperatures of only 5-10° Celsius in the winter

months. Similar problems have been encountered in many other countries, especially during the winter of 2003, which was exceptionally cold.

Alternative fuel burning and health

The use of alternative fuels to keep houses warm during winter times has impacts on human health. These are mainly mediated through indoor air pollutants emitted by solid fossil fuels. Based on estimates from Smith and Mehta (Smith and Mehta, 2000) there are about 2 million deaths a year world-wide attributable to solid fuel use.

A recent study carried out by the WHO assessed the Burden of Disease (BOD) for indoor sources of air pollution. People's exposure to indoor air pollution is determined by the concentrations of pollutants in the indoor environment (mainly determined by the type of fuel and stove used, and the kitchen location) and, most importantly, by the time that individuals spend in polluted environments. On a global basis, solid fuel use (SFU) represents the largest source of indoor air pollution. Household combustion of coal or biomass for cooking and heating determines the emission of smoke containing particles, carbon monoxide, nitrous oxides, sulfur oxides (mainly from coal), benzene and benzopyrene, formaldehyde, and polyaromatic compounds. (WHO, 1999).

Indoor sources of air pollution may be associated with a substantial burden of disease in childhood because they are likely to produce very high exposure levels (Ezzatti and Kammen, 2001). In fact, since children spend most of their time indoors, they are likely to reach high levels of exposure even to pollutants at relatively low air concentrations. Exposure levels can be even higher under conditions of poor ventilation.

Several diseases have been linked to the exposure to SFU. The evidence for the association between indoor air pollution and acute lower respiratory infections (ALRI) in small children is strong: several studies suggest that indoor air pollution increases the risk, although there is variability in the relative risk estimates (Bruce et al 2002). The evidence for the association between exposure to solid fuels and asthma is moderate, with a number of studies finding no effect, and others suggesting that indoor air pollution may increase the risk. Indoor air pollution is considered a risk factor for chronic bronchitis (CB) and chronic obstructive pulmonary disease (COPD - progressive and incompletely reversible airflow obstruction). The association between exposure to biomass smoke and CB/COPD has been particularly well established for women. Smoke from both coal and biomass contains substantial amounts of carcinogens (chemical substances known to increase the risk of cancer). It has also been hypothesized that women exposed to smoke from coal fires in the home have an elevated risk of lung cancer.

Smith, Mehta and Feuz (2003) estimated child exposure to solid fuel use. Exposure to solid fuels in the population was estimated as the product of the proportion of households using solid fuels and a ventilation factor reflecting both ventilation-related and stove characteristics. Child (0-14) exposure to indoor smoke from solid fuels in the 3 European sub regions according to Smith et al. (2003) is reported in the following table.

Table 3.4. Child (0-14) exposures to indoor smoke from solid fuels

Subregion	Household solid-fuel use	Ventilation factor	Point estimate	(95%CI)
EURO A	0.2%	0.73	0.0%	(0.0-0.4%)
EURO B	41.5%	0.51	20.5%	(16.2-24.5%)
EURO C	22.8%	0.24	6.4%	(4.3-10.4%)

Source: Smith K et al, 2003 ; 95%CI : 95% Confidence Interval

Valent et al estimated the attributable burden of disease of household fuel use in Europe. As European infants and young children in general spend up to 90% of their time indoors, indoor sources of air pollution are likely to produce very high exposure levels even at relatively low air concentrations. Over 50,000 children 0-4 years of age were estimated to have died (37.5% of all deaths) and over 1,75 million “healthy life years”(DALYs) were lost from Acute Lower Respiratory Infections (ALRI) due to indoor pollution in the 52 countries of the WHO European Region. Household SFU is accountable for about 10,000 deaths in this age group. More than 90% of these deaths are estimated to occur in the EURO B group of countries where approximately 2/5 of the households use these types of fuel. It is estimated that over 9,000 lives could be saved each year if households could climb the so-called “energy ladder”, shifting from solid fuels to cleaner liquid or gaseous fuels.

Table 3.4. Burden of acute lower respiratory infections (ALRI) attributable only to household solid fuel use in Europe, children 0-4 years of age, year 2001.

Subregion	Deaths		DALYs			
	Deaths	% of all cause deaths	Deaths per 10,000 children	DALYs	% of all cause DALYs	DALYs per 10,000 children
EURO A	0	0%	0	0	0%	0
EURO B	9,289	6.6%	5.2	321,483	5.0%	178.9
EURO C	556	1.1%	0.5	19,335	0.7%	17.0
Total EURO	9,845	4.6%	1.9	340,818	3.1%	66.1

The burden of disease estimates presented here are subject to some limitations. As was explained above, to date, there are few studies assessing household use of solid fuels, therefore a statistical model had to be used. In addition, burden of disease analyses consider exposure to solid fuels to be a binary variable (exposed or not exposed). This is consistent with the epidemiological literature, but in reality many different levels of exposure to indoor air pollution may occur, depending on the type and quality of the fuel and stove, cooking and heating methods, activity patterns, and the season. Further on other diseases believed to be associated with SFU are also not included in the burden of disease analysis because the evidence on causality is either indirect or insufficient. Perinatal conditions are probably the most important of such excluded effects.

The preparation of food at home and poor ventilation lead to exposure to elevated levels of carbon monoxide. From the United States and Canada we have findings about unintentional carbon monoxide (CO) poisoning, often during electric power outages caused by severe storms, with associated increased mortality.

3.4. Measures to improve access to commercial energy

Most European countries take some measures to improve access to commercial energy and to improve the effective use of that energy by citizens deemed to be vulnerable. The methods most commonly used are:

- a. Advice and support for improved energy efficiency measures in the home;
- b. Tariff and social support policies that reduce the cost of energy to the poor;

Advice and support for improved energy efficiency measures in the home

As was noted, the issue of energy access has to be seen in the wider context of energy efficiency. Households with inadequate insulation or inefficient equipment for converting fuels such as oil and gas to heat cannot be protected from the consequences of inadequate energy simply by making more energy available at an 'affordable' price. Apart from the cost of doing so, it will not achieve the desired results if the issue of infrastructure is not addressed.

There are programmes in some countries that promote energy efficiency in the home, by providing advice on how to improve insulation and undertake other simple energy efficiency measures, as well as subsidising the replacement of old heating equipment by more efficient modern household apparatus. One such scheme that has been ongoing for some time and that has been partly evaluated in terms of its success is the Warm Front programme in the United Kingdom. Box 3.1 provides some details of this. A full evaluation is still outstanding but the messages are clear: a well-targeted programme of assistance to improve energy efficiency can reduce fuel poverty and the health consequences of that poverty. The key issues to be addressed relate to making the most efficient use of scarce public funds, which means targeting the assistance carefully, and focusing on those measures that will work over a sustained period of time.

Box 3.1: The Warm Front Scheme in the United Kingdom

Much of the UK housing stock is old and of comparatively low energy efficiency. It is also known that the UK has a large burden of excess winter mortality, which in part appears to be related to low indoor temperatures. While changes to building regulations address thermal properties of new housing, there remains the issue of existing stock, only a small fraction of which is replaced each year.

In part motivated by health arguments, the UK Government launched a programme of Home Energy Efficiency in England known as *Warm Front*. This grant-funded programme for tackling domestic fuel poverty provides packages of insulation and heating measures depending upon the needs of the householder and the construction of the property. These include insulation (e.g. loft and/or cavity wall insulation and draught proofing) and heating improvements (e.g. gas wall heaters, dual element foam insulated immersion tank, electric storage heaters, and, for those who do not have an existing heating system, a central heating system for the main living areas). The scheme is targeted at households in receipt of a state benefit and containing one of the following vulnerable groups: children under the age of 16, pregnant women, disabled people, persons over 60 years of age.

The scheme was launched in June 2000 and has helped more than half a million households so far. On a scale of energy efficiency with an effective range of zero to 100, increases between 9 and 11 points per-household assisted have been estimated.

Health benefits of the scheme

A national evaluation of the health impact of the *Warm Front* scheme is currently in progress. Among other aims, this evaluation will quantify changes in:

- Indoor temperatures
- Fuel consumption and fuel expenditure
- Thermal comfort and health related quality of life
- Winter mortality and morbidity

Although firm evidence is not yet available, a pilot project suggests that favourable changes are likely to occur in these parameters. One of the key aims benefits is expected to be the alleviation of fuel poverty, which is defined to exist when a household needs to spend more than 10% of its total income on energy in order to maintain a satisfactory indoor temperature. The main cause of fuel poverty in the UK is a combination of poor energy efficiency in homes and low incomes.

A report, based on data to 2001, shows that the number of fuel poor households in the UK has dropped by over 40%, or about 2½ million mainly as a result of falling energy prices and higher social security benefits. In 1996, 5½ million UK households had to spend more than 10% of their income on heating their homes adequately. The continuing *Warm Front* programme will help to reduce this further and to meet the overall goal of ending the problem of fuel poverty. The government's initial target is to reach those most vulnerable to cold-related ill health by 2010. Questions still remain, however, about how to optimize the implementation and targeting of the scheme, but the results of the national health impact evaluation should provide valuable lessons for those involved in developing housing and energy policies.

Tariff and Social Support Policies

Access to commercial energy is inextricably intertwined with the amount people have to pay for energy and the financial assistance they are given in this regard. The World Bank recently carried out a review of different mechanisms for social protection of poor households in the context of liberalized markets. (World Bank, 2000). This has been developed further by Markandya and Streimikiene (2003) to evaluate the following tariff and social support schemes:

- I. No disconnection of households who do not pay their utility bills.
- II. Provide price subsidies to all households, funded by higher commercial and industrial tariffs. Set 'Lifeline' rates with fixed or 'floating blocks'. A lifeline rate means that a certain amount of energy is provided at a low cost, after which the rate rises
- III. to a normal level. A floating block means that the size of this block can vary with household circumstances¹⁶.
- IV. A Price discount for certain categories of customers, e.g. pensioners.
- V. A 'burden limit', so that households are only required to pay a certain percentage of their disposable income for the service. Payments above that amount are made by the state to the utility. The actual payment can be for the full amount consumed, or for a notional amount that the household is "entitled" to spend.
- VI. Other "earmarked cash transfers". These are cash advances for the payment of the utility bill, but based on some household income targets. For example, the state might decide that, after paying its utilities, each household must have a minimum income of \$X per person. The utility payments the household must make would then be determined based on that figure of \$X. Usually the scheme is limited to certain categories of consumers (e.g. households classified as poor, or living in small dwellings).
- VII. "Non earmarked cash transfers". These are payments to households to get them to a certain level of income. Once they have this minimum income, they can then spend the money on any item they see fit.

How should these alternatives be judged? A number of criteria have been identified. One is coverage – what percent of poor households benefit from the scheme? For example, a scheme that provided support to pensioners would not pick up other poor groups and would score poorly by these criteria. A second is targeting – what percent of the support actually goes to the poor? A block tariff that provides a minimum amount of cheap energy to everybody would not score so well on this criterion as much of the subsidy would go to the non-poor. A third is predictability. Can the poor be sure they will receive the subsidy? Some schemes, based on burden limits, can leave the poor in a state of uncertainty about how much they will actually get, making them inclined to consume less than they would otherwise. A fourth is administrative cost and complexity. Do the authorities have the capacity to implement the scheme? All these factors have to be borne in mind when selecting the appropriate scheme. The conclusions from the different reviews are that, while no one system is always the 'best', some options are generally preferable to others from a socio-economic point of view. For example a policy of price discounts does not result in high coverage or good targeting. Likewise a policy of not disconnecting non-payers provides perverse incentives not to pay and can result in the utility facing serious financial problems. Hence it has to be used with extreme care. The options of

¹⁶ There can be more than one block offered at below the full rate.

burden limits or cash transfers are expensive for the state, and may not be affordable in some of the poorer European countries. On the other hand the use of lifeline rates can get round the problem of state funding of the subsidy and, as long as the target group is not too large, can provide an affordable basis for social protection and access to energy for the poor.

3.5. Conclusions

This chapter has looked at the important problem of access to energy. In most of Europe access is a problem of ‘demand’: some people cannot afford to acquire enough energy and do not have energy efficient housing or heating equipment. There is strong physiological evidence on the negative health impacts of exposure to temperature extremes and some evidence supporting these findings with epidemiological studies. The latter are much more limited, however, and more work is needed in this area. Nevertheless what is available is compelling enough to point to a problem that needs to be addressed.

There is also, in some parts of the continent, a ‘supply’ problem: i.e. a failure of the system to provide enough commercial energy at an affordable price, with the result that households are switching to home use of biomass, with consequent impacts on health through increased air pollution. The latter is also recognized in the MDG’s in many ways. First most of the disease burden due to indoor air pollution falls on children under five years of age, interventions will help achieve a significant reduction in child mortality (Goal 4) and second the proportion of the population relying on solid fuels constitutes one of the indicators to monitor progress towards ensuring environmental sustainability (Goal 7).

Making commercial energy affordable enough, so that everyone has enough heat in the winter and does not suffer from too much heat in the summer, while restricting the use of solid fossil fuels should be a priority area for action across the whole continent. The measures needed are generally well known. One is to design tariffs for electricity, gas and district heating so that the poor do indeed have access to enough of the relevant type of energy. A number of schemes are possible and the policy problem is to select the one that takes account of budgetary and other constraints. In Western Europe social protection against fuel poverty through the welfare system is probably the most effective. In Eastern Europe it may be necessary to use the tariff structure to achieve the same results.

Another measure is to improve the stock of ‘complementary assets’ that determine the efficiency of the energy households use. This includes providing subsidies to insulation, replacement of old heating equipment with newer more efficient equipment etc. While programs like this are in place in several countries a detailed assessment of their effectiveness is still lacking. Work in this area will be well rewarded in terms of better-targeted future programs that are also cost-effective. There are also some actions to mitigate the problems of fuel poverty where there is a lack of agreement on from a technical and scientific perspective. This is especially the case for exposure to very high temperatures, where the phenomenon has become more noticeable in recent years and where the effectiveness of measures such as air conditioning is a matter of debate. More work is needed to resolve these differences of opinion.

Chapter 4: Exposure and Health Impacts of Electric Power Generation, Transmission and Distribution

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4.1. Introduction

There is a diverse range of energy-generating-resources, which can be harnessed for the generation of electrical power, and these resources are generally divided into three broad categories: non-renewable energy (coal, oil and gas), renewable energy (wave, wind), and nuclear energy. Most, if not all, of these resources have the potential to impact, both directly and indirectly, on the environment and human health. In general, the types and scales of these impacts will vary from one resource (raw material) to another, and will depend on a wide range of other variables, including the methods used to extract and convert this raw material into electricity; the means by which the raw material is transported to the power plant; the technology used; the health and safety standards at all stages; national and regional emissions regulations; methods for disposal of waste materials, and many other factors.

In this chapter we use a cyclical approach (based on that used for a recent global report on the mining and minerals sector (IIED, 1999)) to describe the different impacts that are likely to result from each of the different resources used for the production of electrical power. We will not provide a detailed account of all the potential impacts of each and every resource. Rather, the intention is to provide an overview of the kinds of impacts that need to be considered for each type of resource. The chapter relies on expert reviews, and attempts to critically review the health impacts of electricity generation, transmission and distribution. In addition, quantitative evidence of health impacts is provided, such as morbidity or attributable mortality, where available. The European Commission funded ExternE project provided a major source of quantitative information, and is further, described in Annex 2. There are a number of ongoing projects, which review and extend the ExternE methodology and will provide further insights. Since the results of these projects are not yet available we have not been able to include them in this chapter.

The key issues, which we attempt to address in this chapter, include:

- 1 The types of exposures produced by the various energy cycles
- 2 The sources of exposure (e.g. air pollutants, chemicals, climate change)
- 3 The geographical and temporal scales of exposure (e.g. domestic, national, regional and global; current and future)?
- 4 The populations exposed (e.g. children, workers, population living in the surroundings)?
- 5 The short- and long-term health impacts (e.g. cardiovascular, respiratory, gastrointestinal, psychological, etc)?
- 6 The quantification of the health impacts in Tera Watt Hours (TWH)

4.2. Non-renewable energy

Non-renewable resources, which are often known as ‘fossil fuels’ – coal, natural gas, and oil – are, considered as, finite in supply. Renewable energy resources¹⁷ – hydro, solar, wind – do not deplete the Earth’s finite mineral resources. Nuclear energy is a separate category due to its particular characteristics, and because of public concerns about the safety of nuclear power stations and the safe long-term disposal of nuclear waste materials.

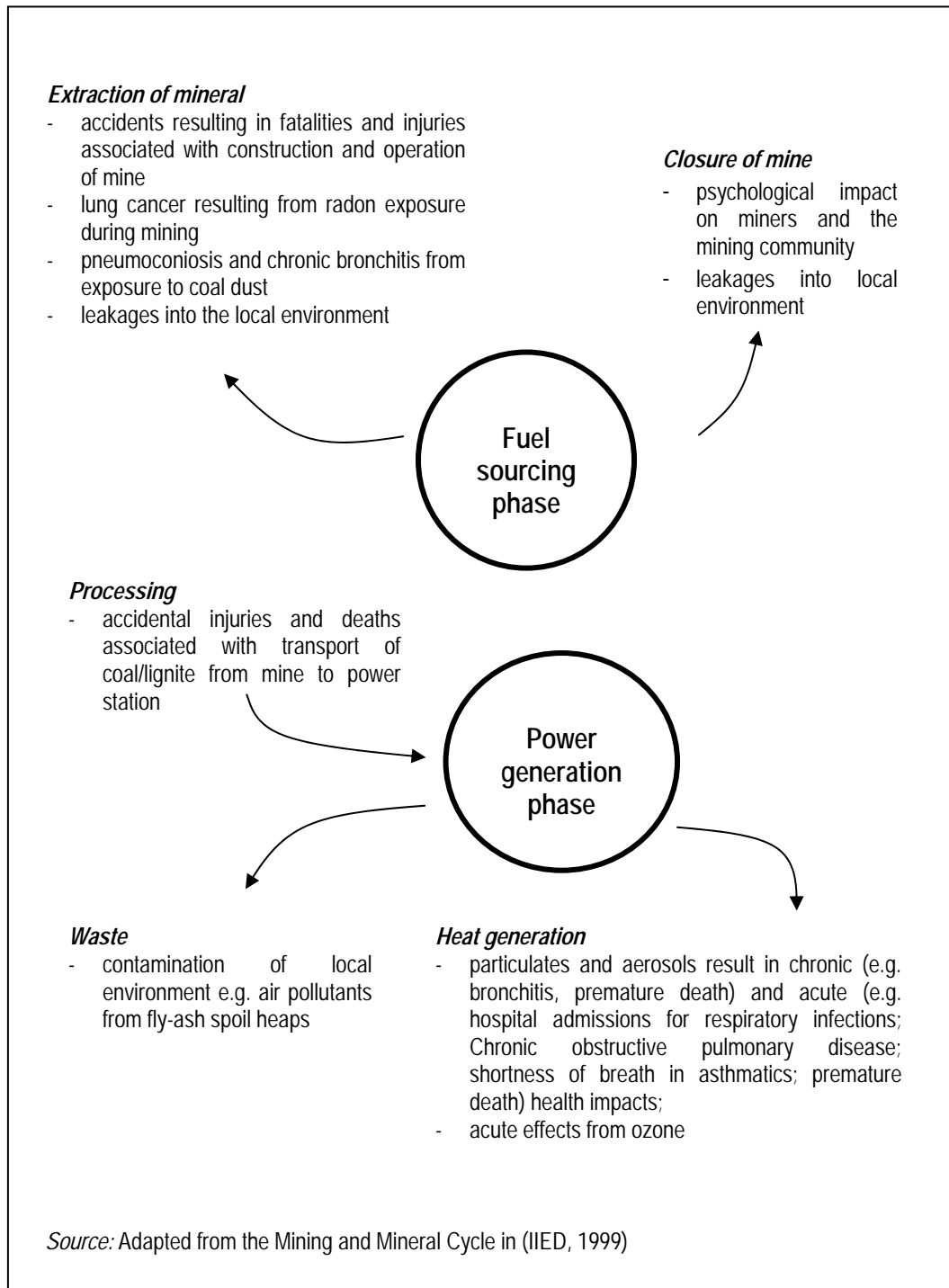
Fossil fuels comprise organic materials remaining after the decomposition of organisms, which lived many millennia ago, and as such their replenishment would take as many years again. Thus, the supply of these fuels is considered to be finite. In this section we provide an overview of each of the fossil fuels – coal, lignite, peat, natural gas and oil – and summarise some of the quantitative estimates of health impacts arising from different stages in each fuel cycle. These impacts are quantified in terms of measure (deaths, Year of Life lost, cases, etc.) per terawatt hour– a standard unit of comparison in the ExternE research as explained in Annex 2 below.

Coal

Coal is a carbon-rich mineral deposit formed from the remains of fossil wood and plants, which while deposited initially as peat, are transformed into coal with but burial and increase in temperatures at depth (Allaby and Allaby 1999). Globally coal use and production has been reduced, as well as European production (see chapter 2). The process of ‘coalification’ results in the production of coals of different ranks (‘coal series’), in order of increasing carbon content and decreasing moisture content: peat, lignite, sub-bituminous, bituminous and anthracite; the first three commonly referred to as ‘black coal’ and the latter two as ‘hard coal’ (MMSD 2002). Between 1900 and 1960, coal was the largest primary energy source until overtaken by oil (Holdren and Smith 2000). In 2000, coal provided about 24% of the world’s primary energy (Holdren and Smith 2000; MMSD 2002), and is used both for the generation of electricity and directly as a source of domestic heat. The coal fuel cycle is characterised in Figure 4.1 below.

¹⁷ These are also often referred to as sources of ‘alternative energy’

Figure 4.1 Indicative occupational and public health impacts from coal and lignite fuel cycles



The coal fuel cycle in Figure 4.1 illustrates some of the key impacts on human health. Health impacts can be classified into occupational and non-occupational. The occupational health includes mainly accidents and injuries and the short and long term consequences of dust particle inhalation; the non-occupational exposures associated with the coal fuel cycle can be seen as short- and long-term, and effects can be described as mediated via air, water and soil. The main concern is air pollution, discussed in more detail below in the section on direct and indirect health impacts of fossil fuels.

Coal is generally extracted from deep underground and there are a number of occupational exposures that are of primary concern. A recent review of the literature found over 200 studies that discuss coal mining and the risks posed to occupational health and safety (Stephens and Ahern 2001). In these studies, the main health outcomes that were of concern were injuries and dust particle inhalation. Injuries result from accidents such as mine collapse or explosions through the build-up of gases. In recent decades, efforts have been made to reduce these injuries through improved mining technology and implementation of health and safety legislation. Stephens and Ahern (2001) found that although fatalities and injuries have declined over time, they are still the subject of current research (Watson and White 1984; Asogwa 1988; Hunting and Weeks 1993; Lee, Anderson et al. 1993; Bell, Gardner et al. 2000). These studies show a variety of findings: Hunting and Weeks (1993) report on age-related injuries with younger men more likely to be injured; (Bell and Gardner et al. (2000) found that cold exacerbated risk of injury for coal miners; and Hunting and Weeks (1993) found that smaller coal mines showed higher risks, linked to the length of experience of the miners in these mines.

Coal typically contains variable but substantial amounts of mineral matter, of which quartz is an important component. The major exposures to coal dust occur during mining and processing of coal. In these operations the exposure includes dusts generated not only from the coal but also from adjacent rock strata and other sources. These may increase the quartz component of the airborne dust to about 10% of the total mixed dust, or to even greater levels if significant rock cutting is being undertaken. Exposure to coal dust also occurs during bulk loading and transfer, and at sites where coal is stored and used, such as power stations, steel and coke works, chemical plants, and during domestic use. (IARC, 1998)

The biological effects of coal mine dust in coal miners include simple coal workers' pneumoconiosis, progressive massive fibrosis, emphysema, chronic bronchitis and accelerated loss of lung function. (IARC, 1998) Stephens and Ahern (2001) found 40 studies and reviews, which looked at the major short and long-term respiratory impacts associated with coal mining. Coal mine dust exposure is associated with accelerated loss of lung function (Soutar and Hurley 1986; Henneberger and Attfield 1997; Love, Miller et al. 1997; Beeckman, Wang et al. 2001). Chronic bronchitis was the subject of several studies (Gilson 1970) and Love, Miller et al. 1997) but pneumoconiosis and silicosis are the most severe outcomes related to coal dust exposure by mine workers. Studies show that up to 12% of coal miners develop these potentially fatal diseases.

The evidence from occupational cohort studies for an association between coal mine dust and lung cancer has not been consistent; some studies revealed excess risks, whereas others indicated cohort-wide lung cancer deficits. There is no consistent evidence supporting an exposure-response relation for lung cancer with any of the customary dose surrogates, including duration of exposure, cumulative exposure or radiographic evidence of pneumoconiosis. In contrast to the lung cancer findings, there have been reasonably consistent indications of stomach cancer excess among coal miners, detected both in occupational cohort studies and in community-based case-control studies. However, there is no consistent evidence supporting an exposure-response gradient for coal mine dust and stomach cancer. (IARC, 1998)

In addition to these occupational exposures one should also consider the psychosocial impacts of mine closures. A 1994 study in the UK suggested that men who had been employed in collieries in 1992 were psychologically and physically disadvantaged compared with working non-miners (Avery et al 1998). However, the authors were unable to ascertain whether these findings were a result of the closure of the mine.

The community studies in coal mining regions have been predominantly concerned with respiratory illness caused by air pollution from mining activities. The emissions of atmospheric pollutants are determined by the coal composition and the combustion technology used. One study (Charpin, Kleisbauer et al. 1988) evaluated the long-term effects of exposure to air pollutants in school children. The study found the prevalence of pulmonary and ear, nose and throat symptoms to be higher in polluted communities. However, a statistically significant difference was only observed for the symptom “wheezing in the chest”. A second study (Pless-Mulloli, Howel et al. 2000) provided little evidence for associations between living near an open cast coal mine site and an increased prevalence of respiratory illnesses, or asthma severity. However, children in open cast coal mine communities had significantly more respiratory consultations compared to children in the control communities. In a European context these occupational exposures have been largely reduced through improved technology and enforcement of improved health and safety legislation. However, problems still remain, and these are especially concentrated in the countries in the Eastern Europe including Poland, Ukraine and the Russian Federation, where coal extraction, although declining, remains an important source of income and as fuel for many of the region’s power generation plants.

After extraction and transportation coal gasification is done. Town gas and industrial gases derived from the destructive distillation of coal are produced in thousands of plants throughout the world. The processes are based on several gasifier designs, which are nowadays substantially improved. However exposures to airborne polynuclear aromatic compounds, together with concomitant exposure to a variety of other contaminants, have been measured. (IARC, 1984)

After coal is extracted and transported to the power plant for conversion to electricity, there are further occupational exposures. These include injuries; sprains and strains to soft tissues of the body, with back strain injuries being the most common; industrial diseases associated with chronic exposure to noise and to asbestos are also found (McManus, 1998). During the coal handling stage, exposure to coal dust may lead to pneumoconiosis, which can be reduced by water spraying of the coal pile. The quantity of waste from energy transformation depends on the fuel used, but some indication of quantities can be derived from the amount of electricity generated. There is very little information on waste generation from power stations in Europe, and therefore for illustrative purposes, the relative use of various energy sources can be used as a surrogate indicator for waste types and quantities: coal and other fossil fuels produce the largest amount of waste residues, such as fly ash (EEA, 2003).

The ExternE Project (see Annex 2), established a methodology and accounting framework for the comparable assessment of the externalities from a wide range of different fuel cycles. In the ExternE Project, the major burdens of the coal, lignite, oil and gas fuel cycles were acute and chronic effects of air pollution from atmospheric emissions from the power generation stage and occupational exposure. The results show that the impacts range from occupational accidents to public health impacts, including respiratory and cardiovascular effects from combustion-related pollution. Perhaps the most significant are the mortality impacts of power generation that arise from the impacts of NO_x, SO₂ and particulates. These are significantly higher – about 250 times - than those arising from accidents. The delayed, or chronic, mortality impacts of over 218 years of life lost from every Terawatt¹⁸ hour of electricity generated from coal, are in fact the third largest in any of the fuel cycles considered in the ExternE work (see Figure 4.2).

¹⁸ Terre=10¹² Watt = 1 Billion kW; Energy = power * time = Watt * hour

Figure 4.2 Years of Life Lost from acute and chronic air pollution effects per TWH (CIEMAT, 1998)

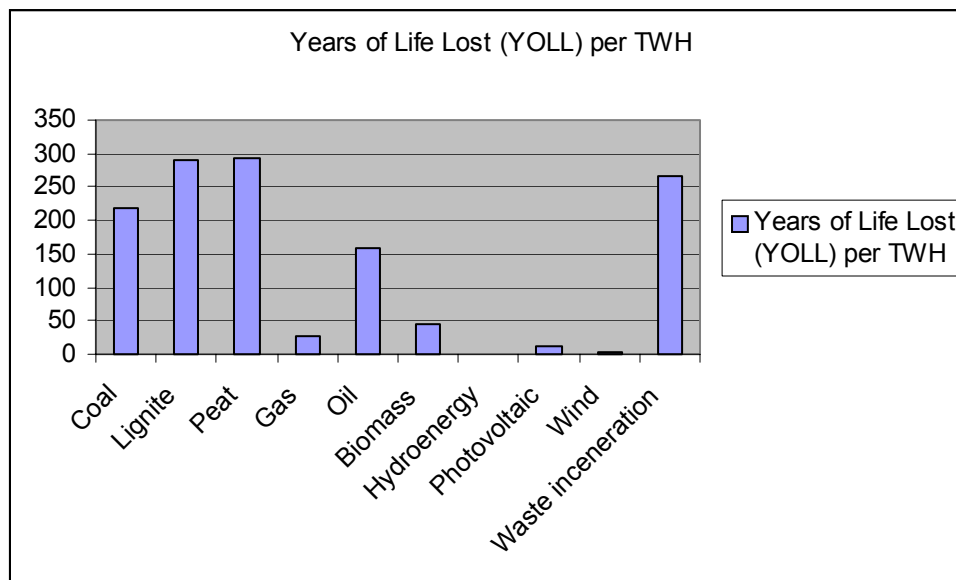
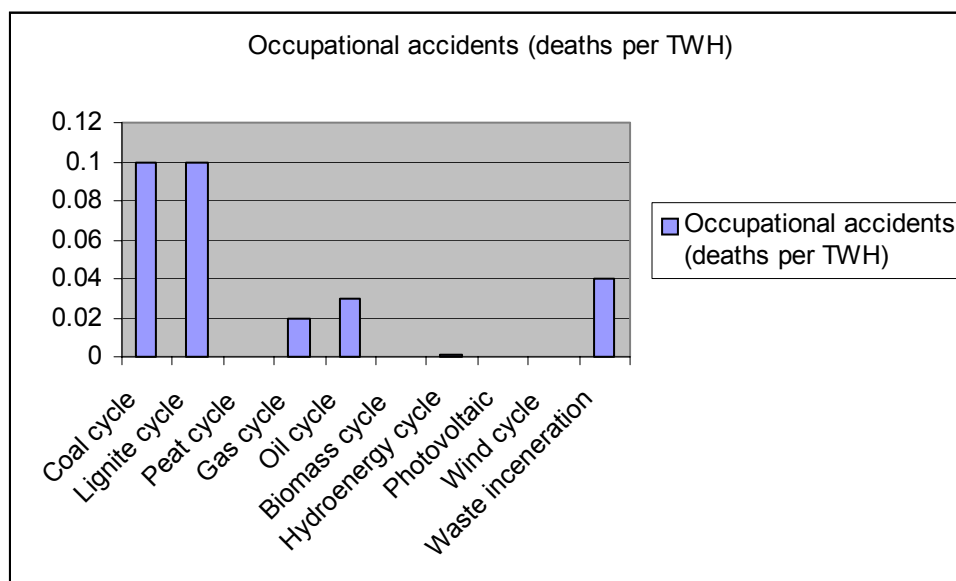


Figure 4.3 Occupational accidents (deaths per TWH) (CIEMAT, 1998)



Both for lignite and coal the occupational accidents (number of deaths per TWH) have been estimated of being equal of 0.1 per TWH. However in comparison to other fuel cycles they are the highest.

It should however be noted, that the single numbers elaborated (for all fuel cycles) do not reflect the uncertainty that should be attached to these estimates. In particular, uncertainty from both, the air pollution dispersion modelling and the epidemiological evidence that quantifies the exposure-impact relationship remain considerable and suggest that impacts could be 50% less or greater than those reported. This caveat is therefore relevant to the reporting of all fuel cycles (see Annex 2). Further the approach did not take into consideration other exposures or effects, such as the health effects of climate change. (CIEMAT 1998).

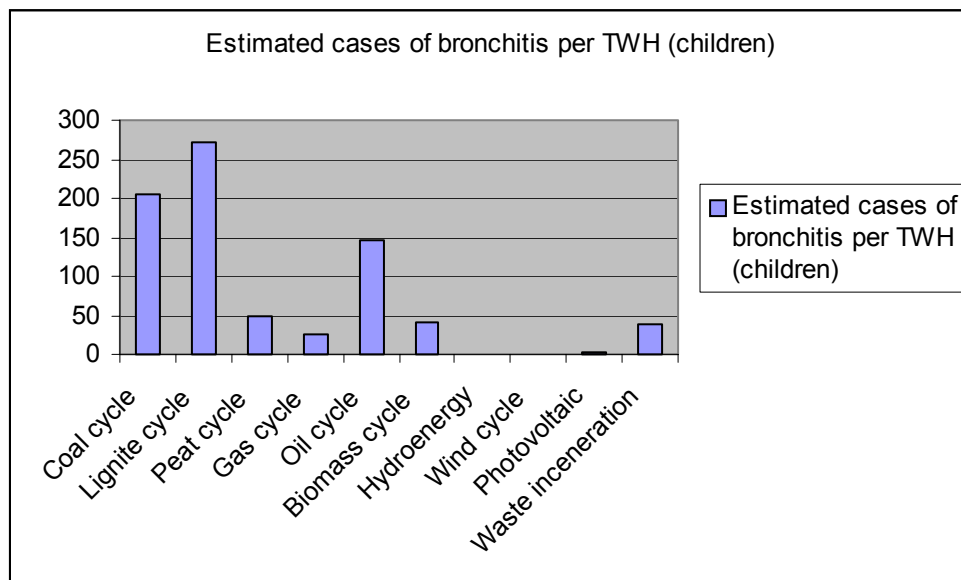
Lignite

Lignite is extracted in open-cast mines, and is a low rank, consolidated, brownish-black coal that produces less than 8,300 British thermal units (Btu) per pound on a moist, mineral-matter-free basis when burned. Lignite has a high content of volatile matter, which makes it more convertible into gas and liquid petroleum products than the higher ranking coals. However, its high moisture content and susceptibility to spontaneous combustion may cause problems in transportation and storage.

The mineral has a fuel cycle similar to the coal fuel cycle shown in Figure 4.1. Due to the material's low energy density, long-distance transport is not economical and the mineral is therefore only used in power plants sited close to where the mineral is mined (CIEMAT 1998). Compared with coal which is mined underground, open-cast mining of lignite tends to result in much lower rates of occupational accidents. However, compared with coal, lignite also tends to produce higher pollutant emissions per kWh produced, with atmospheric emissions of pollutants at the power generation stage being the major burden (CIEMAT 1998). The delayed, or chronic, mortality impacts of over 291 years of life lost from every Terawatt¹⁹ hour of electricity generated, are in fact the largest in any of the fuel cycles considered in the ExterneE work (see Figure 4.2). Estimations about the estimated number of cases of child bronchitis per TWH in children, are shown in Figure 4.4. They are highest for lignite, followed by coal and oil.

The amount of emissions varies depending on the composition of the lignite used and the type of combustion technology used. Other impacts include the global warming effects from CO₂ emissions, and this is especially so for lignite due to its low energy density.

Figure 4.4 Estimated number of cases of bronchitis per TWH in children

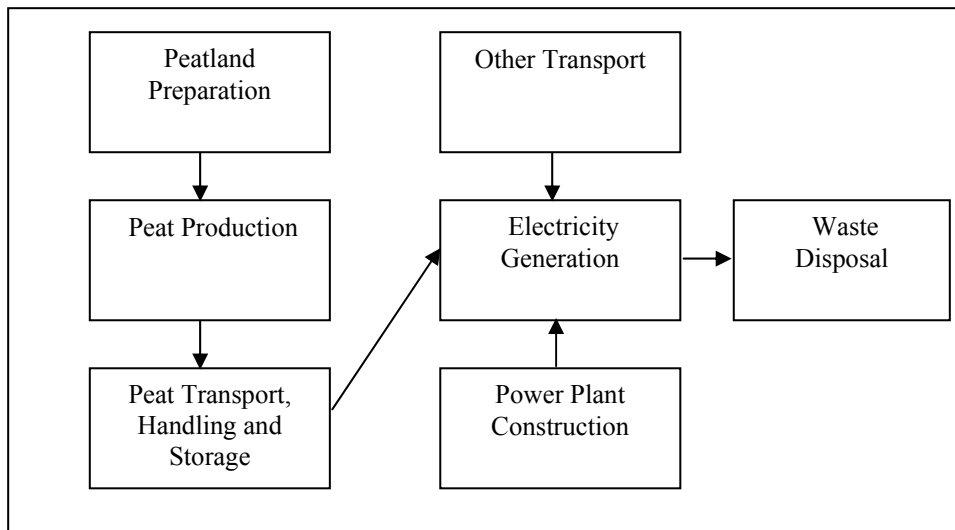


¹⁹ Terre=10¹² Watt = 1 Billion kW; Energy = power * time = Watt * hour

Peat

Peat is used as fuel only in some European countries. However, in these countries it represents a significant share of the electricity production (11% in Ireland, 9% in Finland). Although it is considered a fossil fuel, it has some distinctive characteristics. It has low heating values (around 8 MJ/kg), high moisture content, and low density. In addition, its extraction from peatlands is also specific. Peat bogs are first stripped of vegetation and then drained before peat is harvested. Several methods exist for this, the main ones being PECO (in Ireland) and HAKU (in Finland). The high moisture content requires advanced combustion technologies, such as fluidised bed combustion (FBC), which are used for efficient production of electricity. Peat is used only in some European countries, e.g. the Baltic States and Belarus, Ireland and Finland. The stages of the peat fuel cycle are illustrated in Figure 4.5.

Figure 4.5 Peat Fuel-Cycle



Carbon dioxide emissions from the power generation phase are high due to the low energy density and high water content of the fuel; the same aspects determine that atmospheric emissions during transport are also higher than for other fuel cycles (CIEMAT 1998). From a global warming perspective, the extraction of peat is significant, as the peatland is a carbon sink, and when developed is converted into a source of carbon dioxide and other greenhouse gases, although the treatment of this conversion is complex, and it is necessary to consider the alternative uses of the peatland after the peat has been extracted (CIEMAT 1998). The major burdens of the fuel cycle are the atmospheric emissions generated during power generation and transport activities.

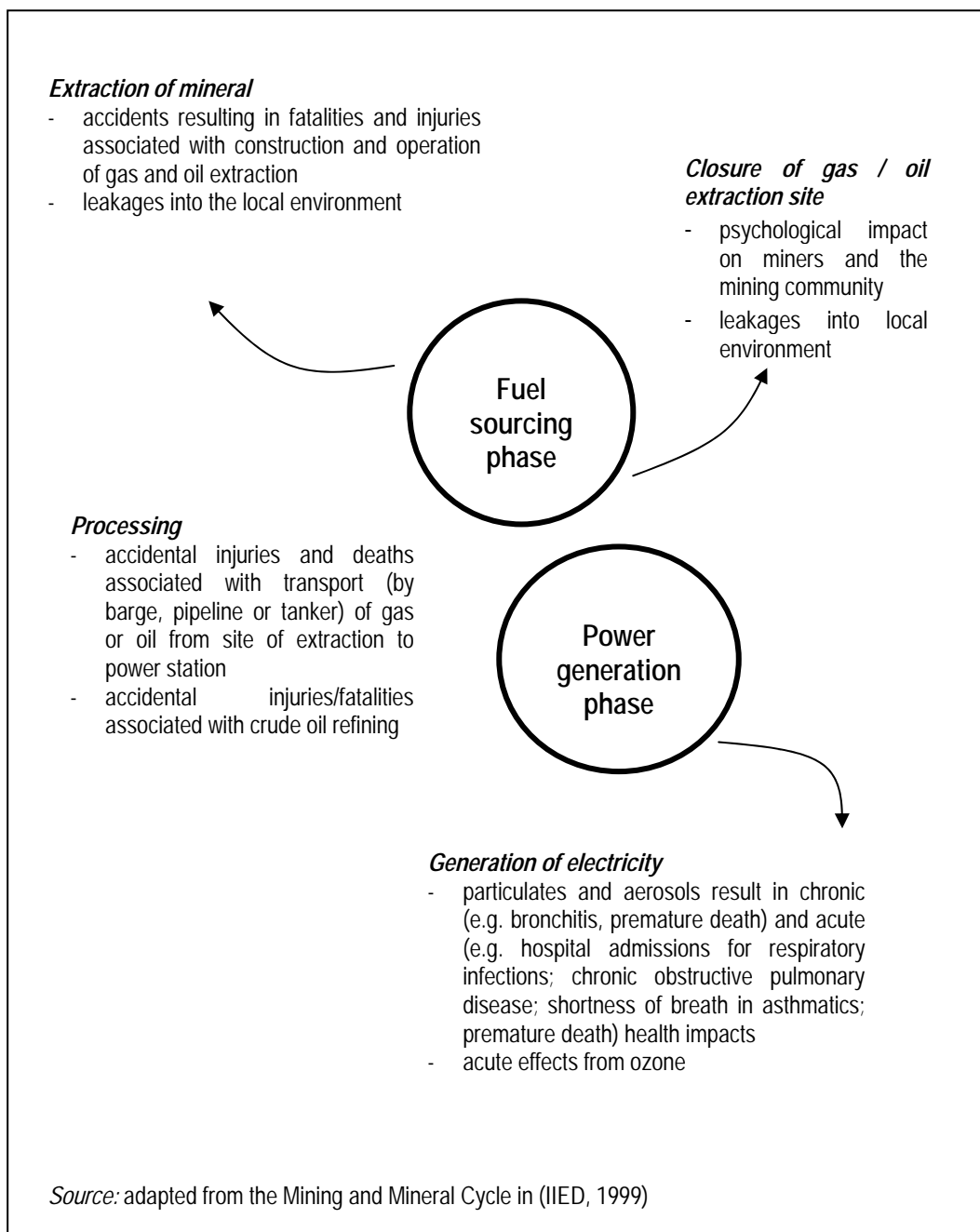
Natural Gas

Natural gas is the gaseous component of petroleum, and is generally extracted from oil wells. Before natural gas can be used as a fuel, the heavier hydrocarbons, butane and propane, are extracted; in liquid form, these hydrocarbons are forced into containers as bottled gas. The remaining 'dry gas', which is composed of methane and ethane, is piped to consumers for the use as fuel (OUP 2002). The gas fuel cycle, which is similar to the fuel cycle of oil, is illustrated

in Figure 4.6 and indicates some of the key health impacts associated with this fuel. The major burdens of the gas fuel cycle are the atmospheric emissions of pollutants, arising mostly from the power generation stage, although some emissions are also present in the extraction and transportation stages. The pollutants emitted are NO_x, CO, CH₄, and CO₂; emissions of SO₂ are negligible given the very small content of SO₂ in the natural gas. Gas-fired power stations do not generate solid waste (European Environment Agency 2003), and although the effects of liquid effluents and solid wastes are not yet quantifiable, in a European context, they are expected not to be highly significant compared to other pollutants (CIEMAT 1998). Exploration, drilling, and gas production activities may have important impacts on the marine environment, and the risk of accidents to pipelines is also of concern.

The ExternE comparison with the results for the coal fuel cycle shows the impacts from the gas fuel cycle are considerably smaller (see Figure 4.2, 4.3, 4.4)– around one-tenth for the case of chronic mortality. This is primarily due to the lower atmospheric emissions - most importantly articulates - and higher efficiency of the modern gas powered station that is used as the reference technology, (CCGT), in this case. In the ExternE project the main difference in the fuel cycle is the origins of the fuel, which in the main is supplied from Algeria, Norway, Italy or Russia (CIEMAT 1998). In ExternE most projects considered combined cycles with gas turbines (CCGT) power plants; a technology which has high conversion efficiency and low pollutant emissions. Some projects considered cogeneration plants, others assessed electricity-only plants; the former having a higher efficiency and thus the impacts allocated to them tend to be much smaller than in electricity-only plants.

Figure 4.6 Indicative occupational and public health impacts from gas and oil fuel cycles



Oil

Here, we are concerned with mineral oils, most notably crude oil or petroleum oil. Petroleum is composed mainly of hydrocarbons and some other elements, such as sulphur, oxygen, and nitrogen (OUP 2000; OUP 2002). The unrefined form of petroleum is crude oil, which when refined produces the following products:

- Refinery gas – a mixture of methane, ethane, butane, and propane used as a fuel and for other organic chemical;
- Petrol (or gasoline) – a mixture of hydrocarbons, and used for motor fuels and making other chemicals;
- Kerosene (or paraffin oil) – a mixture of hydrocarbons, and used as a fuel for jet aircraft and oil-fired domestic heating;
- Diesel oil (or gas oil) – a mixture of hydrocarbons, used as a fuel for diesel engines; and
- The residue is a mixture of other hydrocarbons; the liquid components are used in lubricating oil, and the solid components as paraffin wax; the final residue is a black tar used as asphalt or bitumen.

The oil fuel cycle is similar to the gas fuel cycle illustrated in 4.6. The potential occupational health impacts of this fuel cycle are numerous and include: ergonomic hazards (risks of back pain and joint pain); injuries from burns and explosions; skin damage from exposure to oil and chemicals; the stress and fatigue caused by long-distance commuting to off-shore installations (Holdren and Smith, 2000). In the ExterneE Project, the oil used for power generation came from a variety of sources, including North Sea oil fields, the Arabian Gulf region and Libya, and in most cases was transported by tanker or pipeline (CIEMAT 1998). The refining process may lead to high pollutant emissions, of which sulphur is often a major component depending on crude oil characteristics. The major health burden (see Annex 2) was from atmospheric pollutant emissions, which result from the power generation phase (see also Figure 4.6.). The results also show estimates of accidents associated with all stages of the fuel cycle are estimated to be 50% higher than those for gas, although only 20% of those associated with coal and lignite, which derive substantially from mining accidents.

There are also emissions to water, related to routine and accidental oil spills during exploration and drilling, oil extraction and transport. Such emissions are likely to impact the local environment and may also impact human health, as was described in chapter 2.

4.3. Direct health impacts of fossil fuels

Energy generation leads to a number of key insults on the environment, and the proportions of various pollutants released into the environment are listed in

Table 4.1 shows the human disruption index, which is the ratio of the amount released by human activities to natural releases. It further indicates the share human disruption caused by several productive sectors. This indicates that together with other human activities ‘energy systems significantly affect the cycling of important chemical species at the global scale’.(Holdren and Smith, 2000).

This subchapter provides a very brief summary of the health impacts of those pollutants that are of major concern to the public health community, produced by the energy cycles. These health impacts are divided into direct and indirect. Direct impacts are those caused by those pollutants that are released to the air, water or soil during the energy cycles. The indirect effects instead refer to the global effects of climate change.

Table 4.2 details the major pollutants associated with power generation. These have been classified according to the type of energy-generating resource, and the various media (air, water and soil) through which pollutants are transferred.

Air pollutants are emitted at a number of different stages in the generation of energy. There are, for example, the occupational exposures associated with the mining of fossil fuels, and the non-occupational exposures associated with emissions from power stations. The air pollutants with which we are primarily concerned can be sub-divided into primary pollutants – those which are emitted directly into the atmosphere – and secondary pollutants – those which are formed in the atmosphere following a reaction among the primary pollutants or involving one primary pollutant and one or more minor constituents of air (Gupta and Asher 1998; Holman 1999). Seven important primary pollutants are described below, and a summary of their sources, effects and controlling techniques are shown in Table 4.3.

Air pollution has been the focus of public and scientific debate in recent years. Evidence has accumulated from a large number of studies that health effects arise at the modest concentrations of pollutants seen currently in European cities. However, questions remain about the mechanisms of toxicity, levels of exposure, susceptible populations and most effective abatement strategies. Carbon dioxide is on a mass basis the most important gas emitted by fossil fuel burning, but it has no significant effects on health except by contributing to global warming, the health impacts of which are discussed in more detail below. Particles of a diameter so small that they can enter the respiratory tract have attracted much focus recently. Evidence of adverse health effects is strong for particles with a diameter of less than 10 microns (so-called PM₁₀) and for those less than 2.5 microns (PM_{2.5}), as these are small enough to penetrate deep into the lung. In most countries, the principle source of pollutants is road traffic and other transport-related sources. However, there are also other important sources such as power stations, industrial sources and domestic heating. The relationship between emissions, ambient air concentrations and exposure is complex and influenced by many factors, such as emission height, atmospheric dispersion conditions, air chemistry etc.

Table 4.1. Environmental Insults due to human activities by sector, Mid-1990s

Insult ²⁰	Natural baseline (tonnes a year)	Human disruption index	Share of human disruption caused by			
			Commercial energy supply	Traditional energy supply	Agriculture	Manufacturing, other
Lead emissions to atmosphere ^b	12,000	18	41% (fossil fuel burning, including additives)	Negligible	Negligible	59% (metal processing, manufacturing, refuse burning)
Oil added to oceans	200,000	10	44% (petroleum harvesting, processing, and transport)	Negligible	Negligible	56% (disposal of oil wastes, including motor oil changes)
Cadmium emissions to atmosphere	1,400	5.4	13% (fossil fuel burning)	5% (traditional fuel burning)	12% (agricultural burning)	70% (metals processing, manufacturing, refuse burning)
Sulphur emissions to atmosphere	31 million (sulphur)	2.7	85% (fossil fuel burning)	0.5% (traditional fuel burning)	1% (agricultural burning)	13% (smelting, refuse burning)
Methane flow to atmosphere	160 million	2.3	18% (fossil fuel burning)	5% (traditional fuel burning)	65% (agricultural burning)	12% (landfills)
Nitrogen fixation (as nitrogen oxide and ammonium) ^c	140 million (nitrogen)	1.5	30% (fossil fuel burning)	2% (traditional fuel burning)	67% (fertiliser, agricultural burning)	1% (refuse burning)
Mercury emissions to atmosphere	2,500	1.4	20% (fossil fuel burning)	1% (traditional fuel burning)	2% (agricultural burning)	77% (metals processing, manufacturing, refuse burning)
Nitrous oxide flows to atmosphere	33 million	0.5	12% (fossil fuel burning)	8% (traditional fuel burning)	80% (fertiliser, land clearing, aquifer disruption)	Negligible
Non-methane hydrocarbon emissions to atmosphere	1,000 million	0.12	35% (fossil fuel processing and burning)	5% (traditional fuel burning)	40% (agricultural burning)	20% (non-agricultural land clearing, refuse)
Particulate emissions to atmosphere	3,100 million ^d	0.12	35% (fossil fuel burning)	10% (traditional fuel burning)	40% (agricultural burning)	15% (smelting, non-agricultural land clearing, refuse)
Carbon dioxide flows to atmosphere	150 billion (carbon)	0.05 ^e	75% (fossil fuel burning)	3% (net deforestation for fuel wood)	15% (net deforestation for land clearing)	7% (net deforestation for lumber, cement manufacturing)

Note: The magnitude of the insult is only one factor determining the size of the actual environmental impact. a) The human disruption index is the ratio of human-generated flow to the natural (baseline) flow. b) The automotive portion of anthropogenic lead emissions in the mid-1990s is assumed to be 50% of global automotive emissions in the early 1990s. c) Calculated from total nitrogen fixation minus that from nitrous oxide. d) Dry mass. e) Although seemingly small, because of the long atmospheric lifetime and other characteristics of carbon dioxide, this slight imbalance in natural flows is causing a 0.4% annual increase in the global atmospheric concentration of carbon dioxide

Source : Adapted from Table 3.1 (Holdren and Smith 2000) Chapter 3 of the World Energy Assessment Report, 2000.

²⁰ Insult is defined here as the physical stressor (such as air pollution) produced by an energy system.

Table 4.2. Major pollutants of power generation

Type of plant	Air	Water*	Soil
Fossil fuels	CO	Acids / bases	Acids / bases
	CO ₂	Hydrocarbons	Ash
	NO ₂	Metals	Hydrocarbons
	Particulates	Oil	Metals
	SO ₂	PCBs	Oil
	Volatile organic compounds	Solvents	PCBs
Nuclear	Radioactive emissions		Solvents
Hydro	Chiefly leachates from soils to water behind dams		

* There are also increases in the temperature of water courses which receive plant.

Source: Adapted from Table 76.4 in (Pittman 1998)

Table 4.3. Major pollutants of air – summary of observations

Type	Source	Effect	Control
Carbon monoxide	Incomplete combustion of carbon in car exhausts, fossil fuels and biomass burning; industrial activities	Inhalation may lead to loss of oxygen in blood, leading to nerve and brain dysfunction and cardiac problems	Control of vehicle emissions (catalytic converter); use of public transport
Hydrocarbons and aldehydes	Organic solvent evaporation vehicle emissions; industrial processes, especially petroleum refining;;	Benzene: leukaemia; eye, nose and throat irritation;	Control of vehicle emissions (catalytic converter); replacement of organic solvents; fuel efficiency
photochemical oxidants, e.g. ozone, and Peroxyacyl nitrates (PANs) ¹	Ozone is formed in the atmosphere from sunlight in the presence of NO _x and VOC	Effects on the respiratory system; acute effects include mortality; plant damage;	Reduction of NO _x and VOC emissions
Lead	Car emissions	Behavioural changes and brain damage	Use of unleaded petrol
Nitrogen oxides (NO _x) including nitrogen dioxide (NO ₂)	Transportation; stationary source of fuel combustion	contribution to photochemical smog and sec. PM formation; effects on respiratory systems ; eutrophication of ecosystems to plants,	Transport: three-way catalytic converters; SCR (Selective catalytic reduction)
Particles (often referred to as particulate matter –PM) ¹	Vehicle emissions, industry; stationary source of fuel combustion; biomass burning; waste incineration;	Effects on the respiratory and cardiovascular system including increased mortality	Particle traps; tissue filter for industrial sources; reduction of emission of PM precursors (SO ₂ ; NO _x ; NH ₃ , VOC)
Sulphur oxides, including sulphur dioxide (SO ₂)	Fossil fuel combustion, especially of sulphur-rich coal and oil for power generation, in industry and from domestic sources	Acid rain damage to vegetation and buildings; corrosion of material; precursor of PM (see above); respiratory effects	Fuel switch; flue gas desulphurisation; use of low-S fuels

Source: Adapted from (Gupta and Asher 1998)

Notes:

¹ Particulate matter refers to airborne solid or liquid particles suspended in air in a size range from a few nm to several µm. They are also referred to as suspended particulate matter (SPM) or total suspended particles (TSP). Particles may be classified according to their size. PM₁₀ refers to particles with an aerodynamic diameter less than 10 µm.

² Peroxyacyl nitrates (PANs) are an important component of summer smog. They can cause eye irritation. They are also a temporary reservoir for reactive intermediates in summer smog formation.

Sulphur dioxide (SO₂) is not the only sulphur component in air, but is of particular public health concern. The combustion of fossil fuels containing sulphur – especially in electric power generating stations that use coal and heavy fuel oil, but also industrial and domestic sources – are the main source of SO₂ (Gupta and Asher 1998; Holman 1999). In the European region energy generation accounted for over 90% of SO₂ emissions in 1999 (EEA, 2003:31).

Sulphur dioxide is a respiratory irritant, particularly among people with asthma, and emissions of SO₂ can lead to cardio-respiratory problems. Detailed assessment of the health impact of SO₂ has been difficult because it usually occurs with other particles of combustion and its own secondary products (sulphate aerosols). However, there is good evidence of the contribution of short-term increases in SO₂ exposure to mortality, as for example in the European APHEA study (Touloumi, Samoli et al. 1996). The APHEA study also demonstrated a link with respiratory hospital admissions (Ponce de Leon, Anderson et al. 1996). The results from the APHEA study are used in the Externe research. Similar findings have been reported in American cities (Schwartz and Morris 1995), with asthma admissions in Birmingham, England (Walters, Phupinyokul et al. 1995), and in Oulu, Finland (Rossi, Kinnula et al. 1993). Other short-term effects from SO₂ have been identified including increased wheeze and bronchodilator usage among children with chronic respiratory symptoms (Roemer, Hoek et al. 1993; Higgins, Francis et al. 1995). There is also some evidence of adverse health effects from long-term exposure to SO₂ although again it is difficult to separate the effects of SO₂ from those of other pollutants (Imai, Yoshida et al. 1986; Bobak and Leon 1992).

Sulphur dioxide emissions can effectively be lowered by switching fuel from S-rich to S-free fuels (e.g., coal to gas), flue gas desulphurisation, reduction of the S-content of liquid fuels, etc. Such measures have reduced emissions and concentrations in many European countries considerably since the 1980s (EEA, 2003).

Oxides of nitrogen (NO_x) include both nitric oxide (NO) and nitrogen dioxide (NO₂). In the atmosphere, both compounds interconvert rapidly. Nitric oxide reacts with ozone to form NO₂, while NO₂ may be photolysed by sunlight (Harrison 1999). Nitrogen oxides (NO_x) are predominantly emitted in the form of nitric oxide (NO), while NO₂ predominates in all but the most polluted environments. NO₂ is the subject of air quality standards (Harrison, 1999). Nitrogen dioxide is both a primary (usually from traffic-related emissions and other combustion sources) and secondary pollutant, and the majority of NO₂ results from the oxidation of nitric oxide (NO) by ozone in the air (Holman 1999). Exposure to periodic high levels of pollution in particular from traffic emissions in urban areas has been shown to have an adverse effect on health, but epidemiological studies have had difficulties in disentangling the role of different pollutants such as PM and NO₂. Control of NO_x emissions is not only important due to its effects per se, but it is also an important precursor for both ozone and secondary PM. There is evidence of increases in mortality related to short-term increases in NO₂ concentrations (Touloumi, Katsouyanni et al. 1997), but it is difficult to assess if these effects are caused by NO₂ per se or if NO₂ serves as a marker of traffic-generated air pollution. Studies of long-term exposure suggest that NO₂ may have effects on lung function in children (Gaudermann et al, 2002; McConnell et al, 2003).

Particulate matter (PM) is not a single pollutant, but a mixture of particles from different sources with different chemical and physical properties such as composition and size. Particulate matter refers to airborne solid or liquid particles suspended in air in a size range from a few nanometres to several micrometres.

WHO has recently reviewed the health effects of exposure to PM (WHO 2003, WHO 2004). The review concluded that long-term exposure to current ambient PM concentrations may lead to a marked reduction in life expectancy due primarily to increased cardio-pulmonary and lung cancer mortality. Increases in lower respiratory symptoms have been shown in children as well as reduced lung function, and increased incidence of chronic obstructive pulmonary disease and reduced lung function have been shown in adults. Epidemiological studies on large populations

have not identified a threshold concentration below which ambient PM has no effect on health. It is likely that within any large human population, there is such a wide range in susceptibility that some subjects are at risk even at the lowest end of the current concentration range.

Estimates from the recent WHO Global Burden of Disease study, suggest that between 23,000 and 46,000 deaths in the European Region are due to outdoor air pollution (Ezzati et al, 2002). However, it is unclear how many of these deaths are directly attributable to the energy sector.

The WHO review also assessed the question of susceptible population groups. In short-term studies, elderly subjects, and subjects with pre-existing heart and lung disease were found to be more susceptible to effects of ambient PM on mortality and morbidity. In panel studies, asthmatics have also been shown to respond to ambient PM with more symptoms, greater lung function changes and with increased medication use than non-asthmatics. In long-term studies, it has been suggested that socially disadvantaged and poorly educated populations respond more strongly in terms of mortality. PM also is related to reduced lung growth in children.

Given the absence of clearly documented thresholds in the exposure-response relationships for long-term as well as short-term effects and given the fact that these exposure response relationships have been established in studies at currently observed exposure ranges, adverse effects on health occur with certainty in Europe. Such effects are a reduction of life expectancy by up to a few years, with possibly some contribution from increased infant mortality in the more highly exposed areas, as increased chronic bronchitis and chronic obstructive pulmonary disease (COPD) rates, reduced lung function and perhaps other chronic effects. Recently it has been shown that the acute effects of air pollution on life expectancy can be calculated using time series studies. For almost all types of health effects, data are available not only from studies conducted in the United States of America and Canada, but also from Europe, which adds strength to the conclusions (WHO, 2003).

Ozone (O₃) Ozone is the most important photochemical oxidant in the troposphere. It is formed by the photochemical reaction of O₂ molecules in the presence of precursor pollutants such as NO_x and volatile organic compounds. In the vicinity of strong NO_x emission sources, where there is an abundance of NO, O₃ is “scavenged” and as a result its concentrations are often low in busy urban centres and higher in suburban and adjacent rural areas. On the other hand, O₃ is also subject to long-range atmospheric transport and is therefore considered as a trans-boundary problem. As a result of its photochemical origin, O₃ displays strong seasonal and diurnal patterns, with higher concentrations in summer and in the afternoon. The correlation of O₃ with other pollutants varies by season and location.

Recent epidemiological studies have strengthened the evidence that there are short-term O₃ effects on mortality and respiratory morbidity and there is new epidemiological evidence on long-term O₃ effects and experimental evidence on lung damage and inflammatory responses (WHO, 2003; WHO, 2004). There are indications that certain individuals are in particular susceptible to ozone effects. Among this subpopulation are those with already depressed lung function, such as asthmatics (Whittemore and Korn 1980; Ostro and Rothschild 1989).

Carbon monoxide (CO) – a colourless and odourless gas – results from the incomplete combustion of carbon-containing fuels. Carbon monoxide is dangerous for human health as it gives no warning before the symptoms of drowsiness, dizziness, headache, and unconsciousness occur. Its toxicity results from its binding to haemoglobin in the blood, blocking oxygen transport and creating chemical asphyxiation (Holdren and Smith 2000). Coal miners are at risk

to such exposure (Holdren and Smith 2000), and the main source of non-occupational exposure in developed countries is from petrol powered vehicles – emissions from diesel engines and stationary combustion plants (such as power plants) are comparably small (Harrison 1999). There is evidence that short-term increases in CO concentrations effect mortality (Touloumi, Samoli et al. 1996; Shumway, Azari et al. 1998), and exposure has also been linked with hospital admissions (Schwartz and Morris 1995; Burnett, Dales et al. 1997; Poloniecki, Atkinson et al. 1997) for both congestive heart failure and cardiovascular disease. It is not clear if these associations are caused by CO or if CO acts as a marker of traffic related air pollution.

Trace heavy metal emissions are persistent in the environment and can have serious toxic effects. Some heavy metals may be carcinogens. There is evidence for the adverse health effects of several heavy metals including lead, cadmium, mercury, arsenic, chromium and nickel (WHO, 2000). Contamination of the soil by heavy metals (lead, zinc, cadmium, mercury, copper and arsenic) presents the greatest danger. Sewage sludge and solid domestic and industrial waste are the primary sources from which these substances enter the soil. These metals are highly toxic, are harmful to health at low concentrations, and have the ability to bioaccumulate (e.g. in fish stocks and thus affect human health through the food chain). There are inherent methodological problems in quantifying source apportionment for metals such as cadmium, mercury and lead.

Cadmium is primarily released to air and cadmium deposits contribute to soil pollution and consequently to uptake in crops. Food is normally the main source of cadmium exposure for the general population. Much of the chronic effects knowledge comes from occupational studies. There is evidence that long-term occupational exposure to cadmium might contribute to the development of cancer of the lung. Cadmium and cadmium compounds are *carcinogenic to humans (Group 1)*. (WHO, 1995; IARC, 1993)

Different forms of mercury have different toxic properties. Workers are exposed to mercury by inhalation, principally to metallic mercury but also to inorganic and organic mercury compounds. Occupations in which the highest exposures occur include mercury mining, work in chloralkali and alkaline battery plants and production of devices for measuring temperature and pressure. Non occupational sources of exposure to mercury include food (methylmercury compounds, mainly in aquatic organisms) and dental amalgam fillings (metallic mercury). These exposure levels are usually lower than those typically detected in occupational settings. The main target of long-term effects of metallic mercury is the nervous system. Methylmercury compounds are possibly carcinogenic to humans (Group 2B), but metallic mercury and inorganic mercury compounds are not classifiable as to their carcinogenicity to humans (Group 3).

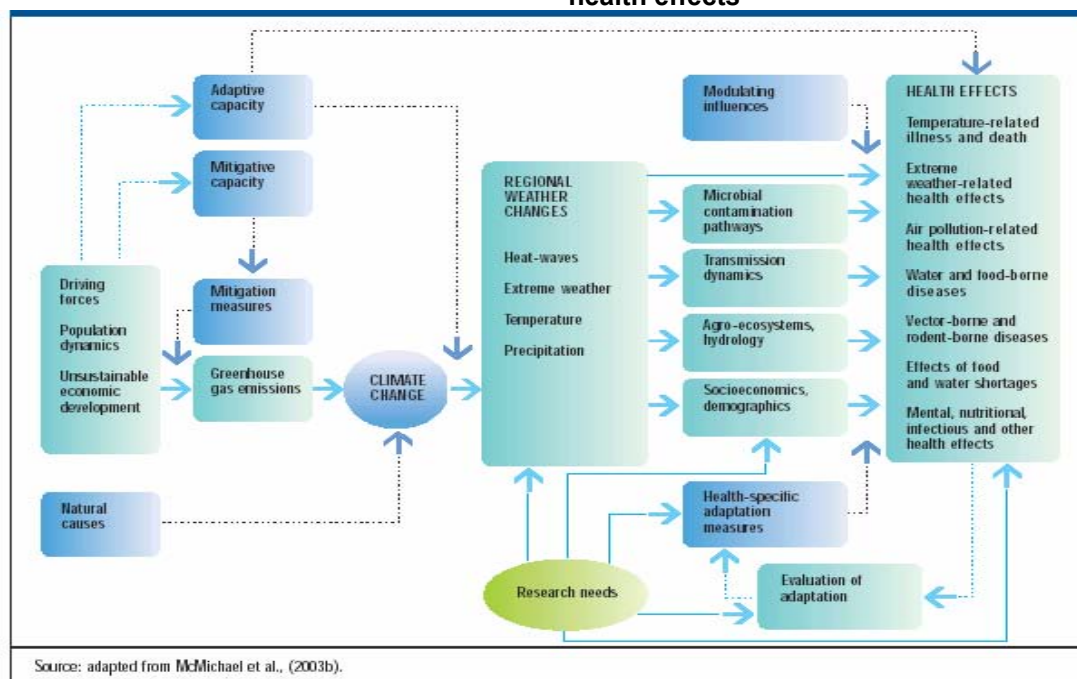
Lead exposure mainly results from the combustion of lead containing petrol or industrial activities. Lead and inorganic lead compounds are possibly *carcinogenic to humans (Group 2B)*. Lead affects practically all systems of the human organism. Most toxic exposures occur at chronic low levels and can result in reductions in Intelligence Quotient (IQ) in children, increased blood pressure, and a range of behavioural and development effects. The range and extent of adverse health effects has been appreciated only relatively recently. Lead is now understood to be toxic, especially to children, at levels previously thought to be safe. According to WHO estimates exposure to lead results in about 68,000 deaths and the loss of 1,246 million DALYs (0.82%) annually in the European Region. As results of the control measures in particular though the phasing out of leaded petrol, levels have been steadily declining in industrialised countries. However, it has been estimated that at least 5% of children, particularly in poor households still have elevated blood lead levels.

Energy combustion also releases other toxic compounds, though generally at much lower levels, including benzene, 1,3-butadiene, poly-aromatic hydrocarbons (PAHs). The health effects of these many compounds are not further described here. However significant literature on the health effects of these compounds can be found at the International Agency on Research on Cancer (IARC)²¹.

4.4. Indirect health impacts of fossil fuels

Climate change is projected to have impacts on all sectors in society, although the degree to which one country will be affected will be different to others. The health impacts from climate change would arise via complex processes and the scale of these effects can be detected primarily at population or community levels. The health impacts of climate change have a unique feature, (a) they are global, (b) they might affect future generations even more than the current one, (c) they are unevenly distributed. An important further consideration is that climate change would not affect human health in isolation, but would do so with other ecological and demographical changes. These coexistent environmental changes will often influence one another and will also interact in making their impact. The effects will undoubtedly have a greater impact on societies or individuals with scarce resources, where technologies are lacking, and where infrastructure and institutions are least able to adapt. (WHO, 2002)

Figure 4.7 Climate change and health: pathway from driving forces through exposure to potential health effects



Some impacts of global climate change can be estimated from reasonable extrapolation of relatively simple cause-effect models. For example, an increase in ambient temperature can be expected to change the number of temperature-related deaths. Infectious diseases are the most obvious example of a category of health problem with complex, climate-related, ecologically based dynamics (see Figure 4.7). The Burden of Disease assessment of the WHO estimated, that,

²¹ <http://www.iarc.fr>

in 2000 160,000 deaths were due to climate change in the World. The African and Asian continents facing the biggest risk. Major health impacts, which may arise from climatic changes in Europe, are described below. However, it should be noted that effects on other regions surrounding Europe (Africa and Asia) may be of considerable importance for the European regions as well.

Heat-waves and impacts

It is predicted that the current increasing instability of the climate system may lead to increased climate variability and, with it, a change in the frequency and intensity of extreme temperatures. Heat-related deaths have caused much public and political concerns after the excess death of more than 25,000 people in Europe in summer of 2003, one of the worst heat waves on record for the northern hemisphere. (Kovats et al, 2004) France was worst affected in the 2003 summer episode, with 14,802 excess recorded deaths, over a two-week period, as temperatures soared to 40°C. The observed excess mortality particularly affected the elderly (70% for those aged 75 years and over), but was also severe for those aged between 45 and 74 years (30%). In all age groups, female mortality was 15% to 20% higher than male mortality. Almost the whole country was affected by the excess mortality, although its intensity varied significantly from one region to another: 20% in Languedoc-Roussillon (South), but 130% in Île-de-France (Paris and suburbs). The excess mortality clearly increased with the duration of extreme temperatures. The mortality rate was highest in nursing homes where the number of deaths observed was twice that expected.²²

High excess mortality rates were also observed in other European countries, such as Italy, where general mortality for all ages in the 21 capitals of the Italian regions was 15% higher than during the same period in 2002; in particular, the figure for those aged 75 years and over was 21%. It may be noted that deaths of elderly people represent more than 90% of the overall excess mortality. Portugal recorded a 26% increase in mortality in August 2003 compared to the average of the previous five years. Temperature increases in London have claimed an estimated 900 lives, with fatalities across the UK reaching 2,045 excess deaths, a 6% increase in mortality over a 10 day heat wave.

Heat waves generally go unnoticed despite claiming more lives each year than floods, tornadoes and hurricanes combined. Elderly, very young and ill people are most vulnerable to heat stress. Death rates rise significantly if the heat stays for more than two consecutive days. Research shows that there are a number of risk factors, such as people living in cities are more susceptible to heat-related death because of the urban heat island effect with lesser night time temperatures dropping down. During heat waves, cities can record temperatures of up to 3.7°C higher than in surrounding rural areas. By varying blood flows and perspiring, the human body can normally maintain its optimum temperature of 37°C. But if the body temperature rises to any higher than 40°C, vital organs are at risk and death will follow unless the body can be cooled. High humidity poses a particular threat as evaporation levels drop, making perspiration less efficient.

Flooding and impacts

Flood hazards and associated health risks have increased in many areas because of a number of climatic and non-climatic factors. The latter include the impact of changes in terrestrial systems

²² Impact sanitaire de la vague de chaleur d'août 2003. *Bulletin épidémiologique hebdomadaire*, 2003, 45–46.

(hydrological systems and ecosystems) and economic and social systems. Land use changes, which induce land cover changes, affect the rainfall–runoff relationship. Deforestation, urbanization and reduction of wetlands decrease the available water storage capacity and increase the runoff coefficient, leading to growth in flood amplitude and reduction of the time-to-peak. Urbanization has adversely influenced flood hazards by increasing the extent of impervious areas. In addition, more industrial and human activities are carried out in flood-prone areas. Flood losses in 2002 were higher than in any single year in the past. The floods in central Europe in August 2002 (on the rivers Danube and Elbe and their tributaries) caused damage exceeding €15 billion. Damage was also caused to water and electricity installations and health care institutions. Health impacts of floods can occur during or after flooding events. Relatively low numbers of flood-related deaths are recorded in Europe in comparison with other regions. Between 1980 and 2002, 260 flooding events resulted in 2500 victims.²³ The number of deaths associated with flooding is closely related to the life-threatening characteristics of floods (rapid rising of water, deep flood water and objects carried by the rapid flow of water) and the behaviour of victims. Injuries (such as sprains, strains, lacerations and contusions) may occur during flooding, but are more frequent in the aftermath of a flood disaster as residents return to their homes to clean up damage and debris. Infectious diseases are not common and are normally confined to illnesses endemic to the flooded region. Most of these illnesses are attributable to reduced sanitation or to overcrowding among displaced people. Some studies have shown an increased incidence of common mental health disorders for long periods after a flooding event. Anxiety and depression may last for months and possibly even years after the flood event and so the true health burden is rarely appreciated. During the 2002 floods in Dresden, two public health issues needed immediate attention: (1) the maintenance of public hygiene; and (2) the problems involved in evacuating complete hospitals.

Other health impacts of climate change

The vector organisms like the mosquitoes are typically sensitive to climatic conditions (especially temperature and humidity), as are the life-cycle stages of the infecting parasite within the vector. The distribution and seasonality of diseases that are transmitted by insects or ticks are likely to be affected by climate change. Thus, the geographic range of potential transmission of some vector-borne diseases (VBDs) is expected to change under climate change. The five main VBDs in Europe can be classified in the following categories: (1) formerly widespread, e.g., Malaria which is re-emerging in some European countries; (2) locally endemic, e.g., leishmaniasis, tickborne encephalitis; and (3) emerging diseases, such as the Lyme disease prevalent over much of Europe.

However, it must be noted that incidence of all VBDs is greatly influenced by human interventions, deliberate and inadvertent. Environmental controls, the use of vaccines, population surveillance with effective treatment of cases, and changes in physical and behavioural lifestyles, all radically affect the incidences of VBD transmission.

Waterborne diseases include bacterial and viral diarrhoeal diseases, protozoal diseases like giardiasis, other viral diseases and amoebiasis. There is a likelihood of increase in food borne infections (e.g., *Salmonella*, *Cyanobacteria*) with climate change, by enhancing the survival and proliferation of bacteria. For example, the analyzes of the time series of climate patterns and

²³ EM-DAT: The OFDA/CRED International Disaster Database. Brussels, Université Catholique de Louvain (<http://www.cred.be/emdat>, accessed 27 February 2004).

laboratory confirmed cases of indigenous salmonella infections from the Czech Republic, Denmark, England & Wales, Estonia, Netherlands, Scotland, Slovak Republic, Poland, Switzerland, and Spain, found on average a linear association between environmental temperature and the number of reported cases of salmonellosis above a threshold of 6°C. Temperature contributed to an estimated 30% of cases of salmonellosis in the majority of countries investigated.

Warmer, more humid weather conditions will extend the breeding period of the flies which in turn will lead to higher infestation rates. Temperature is also an important factor in the growth and toxin production of *Clostridium botulinum*, which causes botulism. Optimum temperatures for bacterial growth and toxin production are around 30°C.

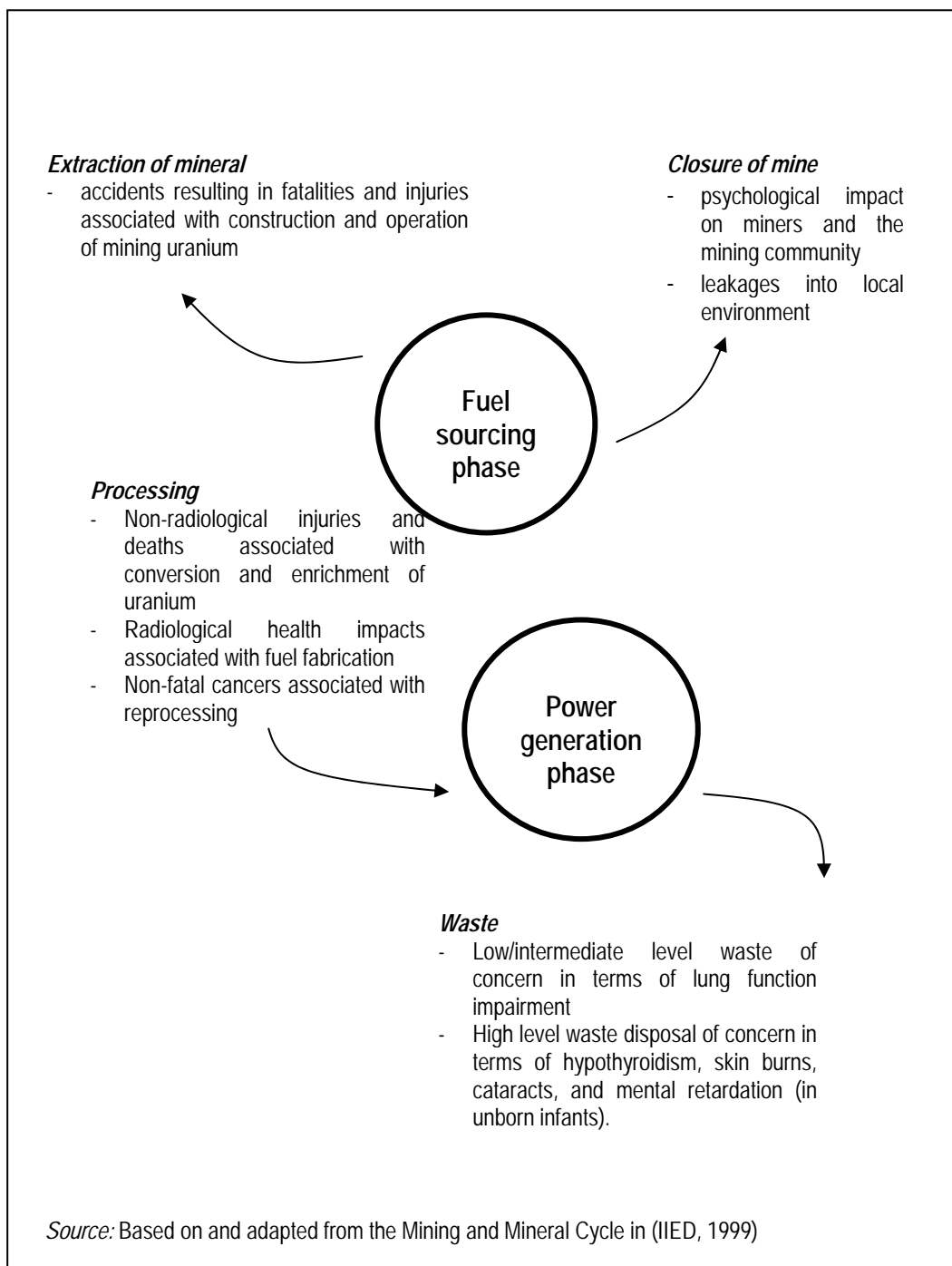
What is clear is that there will be large inequalities from climate change. Impacts will depend on the location of the events and the adaptive responses. Poorer countries are likely to be net losers, whereas rich countries, especially mid – Northern latitudes, may actually gain from moderate warming (i.e. in the short-term). Developing countries are more vulnerable to climate change than developed countries because their economies rely more heavily on climate-sensitive activities, they are close to environmental tolerances, and are poorly prepared to adapt to climate change.

The results for health impacts alone have not been disaggregated to be expressed in terms of a “per ton of carbon” rate in the literature. It is therefore not possible to make a direct comparison between the results for climate change impacts on health and the other impacts such as those from local and regional air pollution expressed in units per Terawatt hour.

4.5. Nuclear Fuel Cycle

The generation of electricity in nuclear power stations is reliant upon materials that will sustain a fission chain reaction. These fissionable materials include uranium-235 (^{235}U), uranium-233 (^{233}U), plutonium-241 (^{241}Pu), and plutonium-239 (^{239}Pu). The only naturally occurring fissionable material is uranium, but is not capable of sustaining a chain reaction because its major isotope, ^{238}U , tends to absorb neutrons before they can split another atom. Currently, there are two main methods of creating a sustained chain reaction in uranium fuel. In the first, the neutrons released by fission of ^{235}U are slowed down by a moderator composed of light atoms, such as deuterium, which does not absorb neutrons; most nuclear reactors use this method. Alternatively, the uranium may be enriched (increasing the amount of fissionable material); fast-breeder reactors employ this process. ^{235}U occurs in nature as 1 part in 140 of natural uranium; the other fissionable materials have to be made artificially, and the fission of 1 kg of ^{235}U is equivalent to 20,000 megawatt-hours – the amount of energy produced by the combustion of 3×10^6 tonnes of coal. Mass for mass, uranium yields about 2,500,000 times more energy by fission than carbon does by combustion (Isaacs 2000). The main stages of the nuclear fuel cycle, extraction of the raw material, processing and waste disposal are illustrated in figure 4.8.

Figure 4.8 Indicative occupational and public health impacts from the nuclear fuel cycle



Unlike fossil fuels, the generation of electricity with nuclear fuels does not result in emissions of nitrogen oxides, particulates, sulphur dioxide, carbon dioxide or other greenhouse gases, and for this reason is often generally accepted as being less environmental polluting than other fuel cycles (World health Organisation 1992). Nevertheless, there are concerns about other stages of the nuclear cycle, and indeed among the general public there are major concerns about the safety of nuclear power plants, particularly with regard to the potential for accidental releases of radioactive material, or over the safe long-term disposal of nuclear waste.

Health impacts of the nuclear fuel cycle

The primary health concern is the release of radioactive materials, and the resulting exposure to radionuclides, which have a half-life of thousands of years (Isaacs 2000). These radioactive materials may affect health through several pathways: inhalation and external exposure to radionuclides in the air, external exposure from ground deposition, and ingestion of contaminated foods resulting from ground deposition (CIEMAT 1998). Exposure to radionuclides can lead to cancer, and there is also the potential for severe hereditary effects.

Mining of uranium creates risks in two ways, through dusts and released radon, and although uranium was discovered in 1789, it is only in the last 30 years that occupational exposures to uranium mining have been investigated (Isaacs 2000; Stephens and Ahern 2001). Many of the studies focus on lung cancer, the risks of which are only now being evaluated more fully. In the review by Stephens and Ahern (2001) uranium mining merits over 50 international studies, many from Eastern Europe and the former Soviet Union (Nedvidek, Cermak et al. 1982; Fatkova 1989; Schuttmann 1993; Enderle and Friedrich 1995), and from the United States (Newcombe, Smith et al. 1983; Hornung and Meinhardt 1987; Roscoe 1997; Hornung, Deddens et al. 1998; Langholz, Thomas et al. 1999).

Uranium mining presents a complex worker health and safety problem: studies in the 1990s and to date, are only now finding out the nature of risks that men experienced in mines in the 1940s. Several studies look at rates of lung cancer in men who were working in uranium mines more than 20 years before the onset of their disease (Roscoe, Steenland et al. 1989; Woodward, Roder et al. 1991; Enderle and Friedrich 1995; Roscoe 1997; Kreuzer, Grosche et al. 1999; Langholz, Thomas et al. 1999). Several authors highlight the fact that the health impacts they evaluate today reflect exposures during times of lower standards. Several papers stress that standards for uranium mining have changed incrementally as more evidence has been brought to bear on the dangerous nature of uranium mining for workers (Pearson 1980; Lambert 1991; Enderle and Friedrich 1995). Only one study cited by Stephens and Ahern (2001) reported non-conclusive findings of uranium mining on the risk of lung cancer (Polednak and Frome 1981) and even this paper calls for more long-term studies.

A recent review (Hornung 2001) of the health risks of uranium mining reports that “lung cancer caused by exposure to radon decay products is the primary hazard to underground uranium miners”. The Hornung review summarises studies of eight cohorts of radium miners, and several pooled analyses. As with many of the cohort studies, the author finds that the relative risk of lung cancer is linearly related to cumulative exposure to radon decay products. The review finds that excess risk decreases with attained age and time since exposure. In addition, prolonged exposure at low levels of radon appears to be more hazardous than shorter exposures to higher levels (Hornung 2001). This review is only one of several large cohort studies, of up to 60,000 miners in each study from Australia and Germany (Woodward, Roder et al. 1991; Kreuzer, Grosche et al. 1999).

Many of the studies in Stephens and Ahern (2001) report the extreme complexity of assessing historical exposures, and differ in their assessment of the extent of excess risk experienced by uranium miners in comparison to the general population or to other industries. Most find relative risks of lung cancer between 2 and 5 times higher in uranium workers who have been exposed to higher levels of radon, or to longer periods of low exposure (Woodward, Roder et al. 1991;

Tomasek, Darby et al. 1994). Some studies put these risks at much higher levels (Gilliland, Hunt et al. 2000).

The effects of uranium mining on human health are not immediate and it may take several years before any adverse consequences are recognised. Only a few studies have started to unpack this complex issue for the health of communities living near uranium mines. In two studies (Au, Lane et al. 1995; Au, McConnell et al. 1998) uranium concentrations in soil samples were found to be significantly higher in the target area than those in the control areas. Local residents were exposed to low levels of radioactive contamination from the mining/milling activities on a daily basis for many years and they had increased health risks. The authors concluded that the health risk among the exposed residents was similar to those among nuclear workers. A third study in New Mexico, U.S.A. (Shields, Wiese et al. 1992), considered the role of environmental radiation in the aetiology of birth defects, stillbirths, and other adverse outcomes of pregnancy. The only statistically significant association between uranium operations and unfavourable birth outcome was identified with the mother living near tailings or mine dumps. Overall, the associations between adverse pregnancy outcome and exposure to radiation were weak and must be interpreted with caution with respect to implying a biogenetic basis.

Radionuclides may also be released through waste materials, which are produced in the mining and processing of the ore, and through power generation. Waste materials are categorised as high-level (spent nuclear fuel), intermediate-level (processing plant sludge and reactor components), and low-level (solids or liquids lightly contaminated by radioactive substances) (Isaacs 2000). While the quantities of radioactive waste generated in the Europe Union annually are very small – compared with the quantities of hazardous and other non-radioactive waste – there is still public concern about the health impacts of disposal of this material. Therefore, the management of nuclear waste is normally considered separately from other wastes (EEA, 2003:159). Very little nuclear waste materials has been moved to final waste repositories, and thus the volume of waste continues to grow (UNSCEAR 2000). For those European countries which use nuclear power, the most favoured long-term solution for wastes with the longest-lived radioactivity is deep geological disposal, but again because of public concerns, progress in this area has been slow (European Environment Agency 2003).

A study carried out on more than 90,000 nuclear power employees in the United States and Europe, found that there is a relative risk of 0.99 for all cancers excluding leukemia and 1.22 for leukemia excluding CLL for a cumulative protracted dose of 100 mSv compared to 0 mSv in workers. These estimates, which did not differ significantly across cohorts or between men and women, are the most comprehensive and precise direct estimates of cancer risk associated with low-dose protracted exposures obtained to date. Although they are lower than the linear estimates obtained from studies of atomic bomb survivors, they are compatible with a range of possibilities, from a reduction of risk at low doses, to risks twice those on which current radiation protection recommendations are based.

In addition, to all above mentioned health impacts there are also concerns with regard to accidental release of radioactive materials. In the European context such concerns have been heightened following the nuclear accident at Chernobyl and are further driven by fears of 1) the detonation of a nuclear weapon; 2) other nuclear power plant events, and 3) the dispersal of radionuclides by conventional explosive or the crash of a transport vehicle. (American Academy of Pediatrics Committee on Environmental Health, 2003).

Box 4.1. 1986 Chernobyl, Ukraine, reactor accident

The direct health impacts of the Chernobyl nuclear power plant accident and subsequent release of radionuclides include the effects of exposure to ionizing radiation, and those resulting from the stress and relocation. They occurred largely in three groups of people: workers at the plant and clean-up workers, especially those active in the first two years of decontamination; resident populations living in areas of high deposition of radionuclides; populations who was moved quickly to avoid radiation exposure. Two persons died during the explosion; 134 people had radiation sickness, 28 of whom died of it in the first three months (UN, 1999). Numerous research activities have been carried out since 1986, to measure whether cancer rates increased, to estimate the health effects of the immediate residents, as well as that of the population relocated. Marked increases in the incidence of thyroid cancer have occurred over a relatively limited period of observation in all areas of the Republic of Belarus and Ukraine among all age categories. The greatest increases have occurred among children, suggesting that a high prevalence of pre-existing iodine deficiency in combination with unique susceptibility among younger people might have contributed to potential carcinogenic exposures to the thyroid. (Mahoney et al, 2004) Children born after the accident have a much lower prevalence and this cohort effect will wear out. No excess in leukaemia or in other cancers could be found, contrary to what was expected from the experience with exposures to atomic bombs.

The ExternE Project considered both occupational and non-occupational exposures, and included fatal and non-fatal cancers and hereditary effects from routine releases and occupational accidents. ExternE also considered the non-radioactive pollutants emitted during the nuclear fuel cycle. In general ExternE indicates that the damages are quite low, especially for the power generation stage. For other stages in the fuel cycle, damages were larger, and these were mostly due to radioactive emissions from abandoned mill tailings, and due to the global warming effects associated with the energy used for reprocessing and enrichment. It should be noted, for example, that occupational health impacts from the milling stage are higher than those for public health impacts from generation. In terms of the impact of radioactive emissions from mill tailings, the quantification of impacts is uncertain, because of the difficulties in transferring dose-response functions to low doses, since average individual doses are very small. Estimated impacts from nuclear accidents are negligible and not included in the table below. While waste is included in the reprocessing estimates, the possible impacts resulting from trade in waste have not been addressed systematically in the ExternE analysis. (see Annex 2)

4.6. Renewable energy

Renewable resources are much less polluting (and in most cases cause virtually no pollution) unlike fossil fuels and nuclear energy. In the context of sustainable development, renewable sources are considered to be the better option for supplying energy to the current global population, and indeed to the populations of the future. Renewable energy sources supplied about 14% of world primary energy consumption in 1998; this comprised major contributions from *traditional biomass* (68%), *hydropower* (16%), *modern biomass* (12.5%); contribution of all other renewables – *small hydropower, geothermal, wind, solar and marine energy* (3.5%) (Turkenburg 2000). Renewable energy sources generally depend on energy flows through the Earth's ecosystem from the capture of solar energy and the geothermal energy of the Earth (Turkenburg 2000). In this section we focus on:

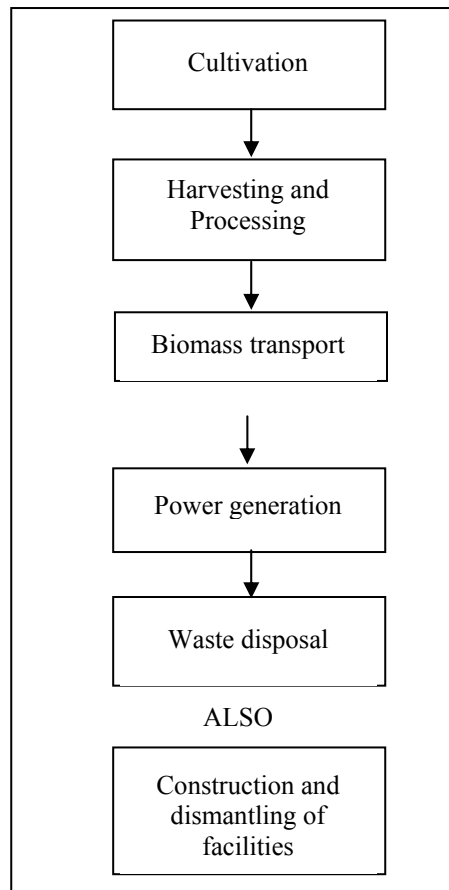
- Biomass energy (plant growth driven by solar radiation);
- Direct use of solar energy (as for heating and electricity production);
- Geothermal energy (from heat stored in rock by the natural heat flow of Earth);
- Hydropower;
- Marine energy (such as wave energy, marine current energy, and energy from tidal barrages); and
- Wind energy (moving air masses driven by solar energy).

In general terms the fuels included in this category are not as environmentally polluting as the fossil fuels described previously. Nevertheless, it is important to recognise that there are health impacts associated with these renewable sources, which by and large are concentrated at the production and installation stages.

Biomass

Biomass includes all organic material derived from plants, trees, and crops. Sources are diverse, including organic waste streams; agricultural and forestry residues; as well as crops grown to produce heat, fuels, and electricity (energy plantations) (Turkenburg, 2000:222). In developing countries, biomass constitutes between 20-30% of energy consumption, and is traditionally used in open fires for cooking and heating. The combustion of biomass materials on these open fires is inefficient and combined with poor ventilation is considered to be associated with the large burden of mortality and morbidity due to indoor air pollution (Bruce, Perez-Padilla et al. 2000). In industrialised economies, biomass provides about 3% of the energy supply (Turkenburg 2000). The fuel cycle is outlined in Figure 4.9.

Figure 4.9 Biomass fuel cycle



The ExternE project considered a number of different biomass fuels. For example, some national projects focused on forest residues, while others assessed energy crops (both short-rotation woody crops and herbaceous energy crops), or wood residues (CIEMAT 1998).

Although biomass combustion produces CO₂ emissions, these emissions tend to be cancelled out because of the previous fixation of CO₂ by the growing of plants. This contribution to global warming was considered to be relatively small (CIEMAT 1998). Emissions of SO₂ were also much lower than for the other fuel cycles, because of the negligible sulphur content of biomass. As an indication, the resulting chronic mortality impacts were less than 20% of those from the lignite reference technology reported above. The most important emissions were for ozone precursors – such as NO_x and VOCs, and the magnitude of these emissions depended on the fuel and technology used. Emissions of NO_x were reduced when using advanced technologies such as gasification, or fluidised bed combustion (CIEMAT 1998).

Geothermal

Geothermal energy has been used for thousands of years, but has been used for electrical power generation only since the early twentieth century (Turkenburg 2000). For every 100 metres in depth, the Earth's temperature increases by some 3°C, and the heat, which is generated, originates in the Earth's molten interior and radioactive material decay (Rogner 2000). Four types of geothermal energy are usually distinguished

- Geopressed – hot-water aquifers containing dissolved methane under high pressure at depths of 3-6 kilometres;
- Hot dry rock – abnormally hot geological formations with little or no water;
- Hydrothermal – hot water or steam at moderate depths (100-4,500 metres); and
- Magma – molten rock at temperatures of 700-1,200°C.

The fuel cycle can be simplified into three key elements: construction and development, operation, and dismantling.

A variety of gases are contained in geothermal fluids, and include nitrogen and carbon dioxide, with some hydrogen sulphide and smaller proportions of ammonia, mercury, radon, and boron. While the amount of these gases varies with the geology of the particular site, most are concentrated in the disposal water, which is re-injected into drill holes, and therefore not released into the environment, where it might affect human health (Turkenburg 2000). In addition to these, there is the potential for accidental injuries and fatalities associated with the development, construction, operation and dismantling of geothermal installations.

The ExternE Project found that the most important feature of the geo-thermal fuel cycle is its site specificity, as damages are mostly produced on the local environment, its conditions determines the results; results are therefore very difficult to extrapolate to other sites, and large differences may be produced depending on the sites and technologies chosen (CIEMAT, 1998). The health impacts of hydrogen sulphide account for most of the totals presented.

Hydroelectric

Hydroelectric energy is usually generated by damming rivers, and generally considered to be ‘the renewable energy source par excellence [because it is] non-exhaustible, non-polluting, and more economically attractive than other options’ (Turkenburg, 2000). Large-scale hydroelectric projects can bring many benefits to society, but in recent decades controversy has surrounded this form of energy-generating-resource because of concerns about the adverse effects on human health and the environment (World Commission on Dams 2000). For instance, to create the reservoir of water for the operation of the power station necessitates flooding the surrounding area. When earth and rock are flooded by acidic waters this can lead to the leaching of metals from these materials, and bioaccumulation of mercury has subsequently been found in fish caught in these flooded areas (McManus 1998).

There is a range of occupational health hazards associated with the generation of hydroelectric power, and these are summarised in the following table. Unlike other electricity generating sources hydroelectric power stations do not generate solid wastes (European Environment Agency 2003).

Table 4.4. Exposures to selected chemicals and biological hazards in hydroelectric power generation

Exposure	Where it can be found	Affected workers
Abrasive dusts (blasting)	Dust can contain blast material and paint dust. Paint applied prior to 1971 may contain PCBs	Mechanical maintenance workers
Asbestos	Asbestos may be present in generator brakes, pipe and electrical insulation, spray-on coatings, asbestos cement and other products; exposure depends on friability and proximity to source	Electrical maintenance workers, mechanical maintenance workers
Battery explosion products	Short circuit across terminals in banks of batteries could cause explosion and fire and exposure to liquid and aerosols of the electrolyte	Electrical maintenance workers
Coating decomposition products	Emissions can include: carbon monoxide, inorganic pigments, containing lead and other chromates and decomposition products from paint resins. PCBs may have been used as plasticizers prior to 1971. PCBs can form furans and dioxins, when heated	Mechanical maintenance workers
Chlorine	Chlorine exposure can occur during connection/disconnection of chlorine cylinders in water and wastewater treatment systems	Operators
Degreasing solvents	Degreasing of electrical equipment requires solvents with specific properties of inflammability, salivation and rapid evaporation without leaving a residue; solvents meeting these characteristics are volatile and can pose inhalation hazards	Electrical maintenance workers
Diesel exhaust emissions	Emissions primarily include nitrogen dioxide, nitric oxide, carbon monoxide, carbon dioxide, sulphur dioxide and particulates containing polycyclic aromatic hydrocarbons (PAHs) from vehicles or engines operated in the powerhouse	All workers
Insect remains	Some insects breed in the fast waters around the station; following mating, the adults die and the carcasses decay and dry; some individuals develop allergic respiratory sensitisation to substances in the dust	All workers
Oils and lubricants	Oils and hydraulic fluids coat windings of the rotor and stator; decomposition of hydrocarbons in contact with hot surfaces can produce PAHs. Exposure can occur by inhalation and skin contact. Skin contact can cause dermatitis	Electrical maintenance workers, mechanical maintenance workers
Ozone	Ozone generated by arcing in the rotor and other electrical equipment could pose an exposure problem, depending on proximity to the source	All workers
Paint fumes	Paint aerosols contain sprayed paint and diluent; solvent in droplets and vapour can form flammable mixture; resin system can include isocyanates, epoxies, amines, peroxides and other reactive intermediaries. Solvent vapours can be present in paint storage and mixing areas, and paint booth; flammable mixtures can develop inside confined spaces during spraying.	Bystanders, painters
Polychlorinated biphenyls (PCBs)	PCBs were used in electrical insulating fluids until the early 1970s; original fluids or residuals may still be present in cables, capacitors, transformers or other equipment; exposure can occur by inhalation or skin contact. Fire or extreme heating during service can convert PCBs into furans and dioxins	Electrical maintenance workers
Sulphur hexafluoride and breakdown products	Electrical arc breakdown of sulphur hexafluoride produces gaseous and solid substances of considerably greater toxicity. Release of large quantities of sulphur hexafluoride into subgrade spaces can create oxygen deficiency by displacing the atmosphere	Electrical maintenance workers
Welding and brazing fumes	Cadmium, lead, silver in solder	Electrical maintenance workers

Source: Adapted from Table 76.1 in (McManus 1998)

The ExternE Project found that most of the damages tend to be the ecological effects due to plant operation; construction of the plant, may for example result in pollutant emissions (CIEMAT 1998), including greenhouse gases, caused by the decay of vegetation in flooded areas and through the use of cement in the construction phase (Turkenburg 2000). It is important to note also that hydropower is particularly sensitive to the amount, timing, and geographical pattern of precipitation as well as temperature, and is therefore likely to be impacted by climate change (Scott and Gupta 2001).

The ExternE Project found that the most important feature of the hydro fuel cycle is its site specificity, as damages are mostly produced on the local environment, its conditions determines the results; results are therefore very difficult to extrapolate to other sites, and large differences may be produced depending on the sites and technologies chosen (CIEMAT 1998). However,

some indicative results are presented for occupational accidents. These results are for the Sauda Hydroelectric Development Project in Norway.

Marine energy

The marine environment has the potential to provide a substantial amount of energy for the production of electrical power. Many of the technologies, which enable this form of energy to be harnessed are in their infancy. The key marine energy-generating-resources are:

- Tidal barrage energy
- Wave energy
- Tidal/marine currents
- Ocean thermal energy conversion (OTEC)
- Salinity gradient/osmotic energy
- Marine biomass fuels

Tidal barrage energy is based on the rise and fall of tides, which create a low-head hydropower system (Turkenburg 2000). However, there are major costs and environmental impacts associated with this technology, and together with poor load factors makes this energy-generating-resource unattractive (Turkenburg 2000). With wave energy the availability of energy is sensitive to the distance from the shoreline, and currently this technology remains at an experimental stage, although it is estimated that this technology could provide as much as 100 terawatt-hours a year for Europe, and perhaps 300 terawatt-hours a year for the world (Turkenburg 2000). The third category – tidal and marine currents – is the most recent of the marine energy sources to be considered with most of the development work occurring in the 1990s. Ocean thermal energy conversion exploits natural temperature differences in the sea by using some form of heat engine, and as OTEC requires a temperature difference of 20°C the application of the technology is restricted to a few tropical regions (Turkenburg 2000). The practical application of the last two categories has yet to be developed (Turkenburg 2000). These marine energy sources have minimal impacts on the environment and human health, with few producing pollution while in operation, although OTEC may lead to the release of CO₂ from seawater to the atmosphere (Turkenburg 2000).

Photovoltaic

Using a solar module, normally consisting of a number of solar cells connected in series, photovoltaic solar energy conversion results from the direct conversion of sunlight into electricity (Turkenburg 2000). The main stages in the photovoltaic fuel cycle are: building and manufacturing, normal operation, decommissioning. During the production and installation phase there are emissions of air pollutants – CO₂, NO_x, particulate matter, SO₂, and other substances – silicon and copper – into the environment (CIEMAT 1998; Turkenburg 2000). Although these emissions are larger than for the wind fuel cycle, they have been considered to be negligible when compared with other fuel cycles (CIEMAT 1998). Quantified results of a level typical in Europe have been estimated within the ExternE project, using the same health outcomes than for other cycles. However results show that they are almost negligible. (Annex 2)

Wind power

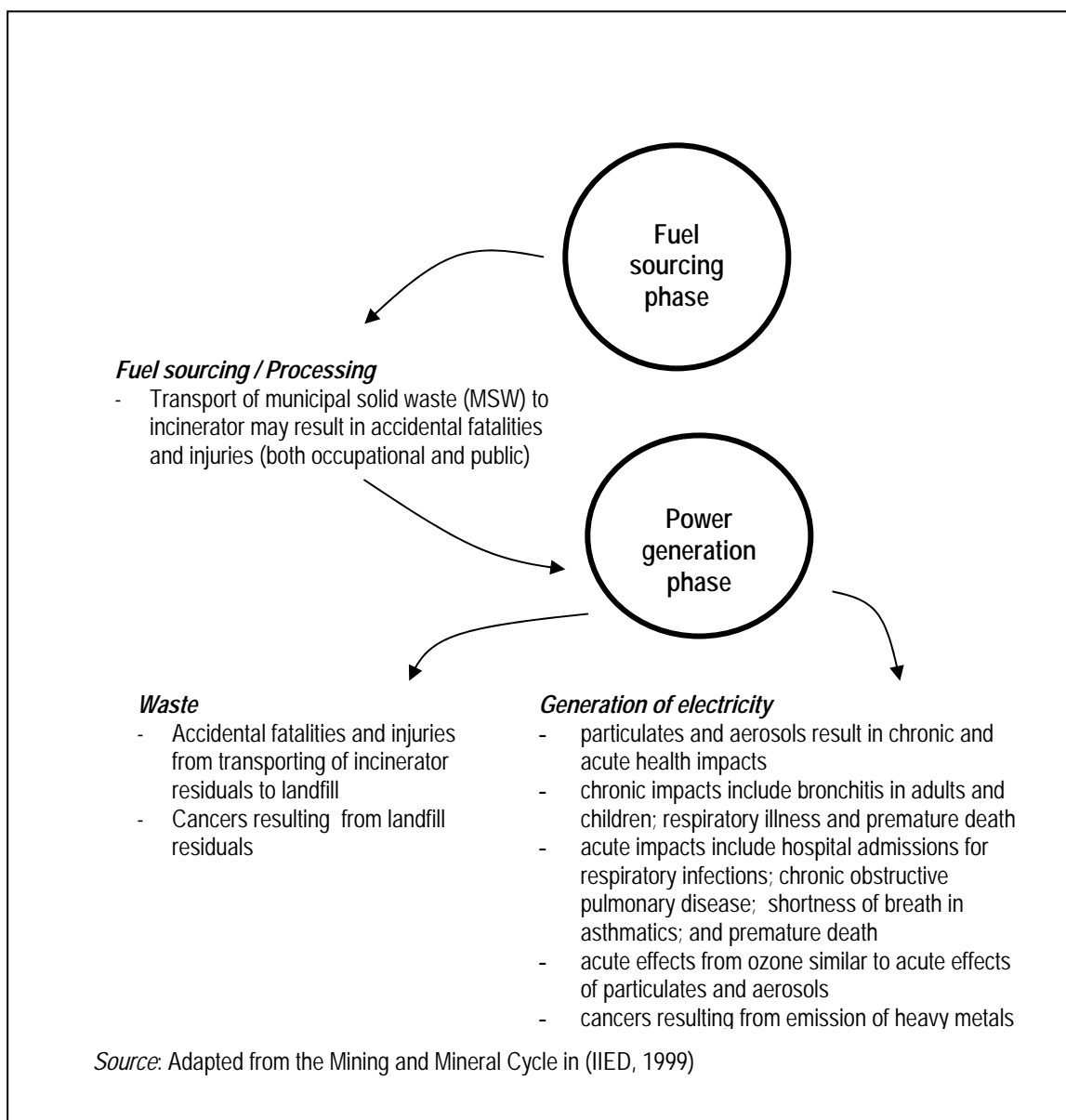
Wind energy was widely used prior to the industrial revolution, but was then displaced by fossil fuels because of differences in costs and reliability (Turkenburg 2000). We have not included a figure of the wind fuel cycle here, but the main stages are: building and manufacturing, normal operation during the turbine's lifetime, decommissioning. In the turbine construction phase there are some pollutant emissions, but these have been considered to be negligible when compared with other fuel cycles (CIEMAT 1998). Most wind farms are considered to have very low impacts, and these are caused mostly at the local scale – noise pollution may be a problem if turbines are situated close to centres of population. A wind turbine produces no emissions, so in the context of global climate change the potential to reduce CO₂ emissions depends on the fuel mix of the fossil-fuelled plants the wind turbine is working with (Turkenburg 2000). One study (BTM Consult 1999), cited in (Turkenburg 2000), suggested that by the year 2025 wind energy could prevent the emission of 1.4 – 2.5 gigatonnes of CO₂ per annum. The ExternE Project considered wind energy to have the lowest level of impacts (health and environmental), of all the fuel cycles considered (CIEMAT 1998). For example, in Germany, the health impacts are 10% of those from coal per terawatt hour of electricity production. Clearly, these up-stream processes are dominant since no pollutants are emitted during power generation. Within the ExternE comparison, health effects from wind energy are negligible, however issues such as sleep disturbance, school absenteeism, eventually resulting from noise in vicinity, could not be evaluated.

Waste incineration

While it could be argued that waste incineration differs from the other fuel cycles described here, the fuel – waste materials – is readily available, and does not require extraction, as in the case of the fossil fuels. The waste incineration cycle, illustrated in Figure 4.10, consists of waste collection, and transport to the municipal solid waste (MSW) plant, where it is usually separated into recycling, composting, and incineration flows, and the most important burdens associated with this fuel cycle are the atmospheric emissions generated in the power generation stage (CIEMAT 1998). The key health impacts from the waste fuel cycle inevitably arise in the combustion process itself. As well as generating many of the classic air pollutants of combustion (PM, NO_x, SO_x, CO), waste incineration plants also emit dioxins and furans, metals such as lead, mercury, cadmium, arsenic, chromium, nickel, volatile organic compounds and polycyclic aromatic compounds. Exposure to incineration emissions is a complex process as it combines direct exposure to air pollutants with long-term exposure to dioxins and furans through ingestion. It is the latter, which are of most concern, given their very high toxicity.

Although there is clearly potential for waste incinerators to cause significant adverse health effects, the literature on the actual impacts of incinerators appears equivocal. The UK Royal Commission on Environmental Pollution concluded that although the pollutants produced by incinerators can cause acute and chronic toxicity in humans, the concentrations produced by incinerators are below levels likely to cause significant harm. However, the report also highlights that some concern still remains over emissions of heavy metals from solid waste incineration and highlights site-specific risk assessments that could be carried out to assess the risks of adverse health.

Figure 4.10 Indicative occupational and public health impacts from the waste incineration fuel cycle



Dioxins are of especial concern, although the precise impacts that these have on human health is still a matter of debate. The impacts of these pollutants are exacerbated by the fact that MSW plants are usually placed very near, or within, large population centres, so the number of individuals at risk is very large. Unfortunately the ExternE quantified analysis is limited only to the classical pollutants. It is therefore possible that the health effects per TWH are probably higher. There were two case studies in the ExternE Project – France and Spain (CIEMAT 1998). As there are major public concerns about the potential adverse effects that these plants may have on the environment and human health there is strict legislation on atmospheric emissions from this type of plant, and emission levels have to be very low. Especially for dioxins and furans, whose allowed emission level is so low that it is even difficult to measure. The ExternE project also identified damage caused to roads, and road accidents, produced by the amount of transport

involved in operating a MSW plant. In ExternE the effects of dioxins and furans were negligible when compared to those caused by NO_x and particulate emissions (CIEMAT 1998)

4.7. Health impacts of electricity transmission and distribution

The three key stages in the supply of electricity are generation, transmission and distribution (Fox 1998). The occupational and non-occupational health impacts of the first stage were described in the previous sections of this chapter. Here we focus on the health impacts associated with the second and third stages.

After generation at the power station, electricity is transmitted via high-voltage power cables that are supported overhead, or run underground, and these transmission lines run between substations. In this second stage, the major occupational hazards are electrical in nature, for example electrocutions (Fox 1998). The third stage – distribution – connects the transmission system to the customer's equipment, and as in the second stage the main occupational hazards are again electrical (Fox 1998). Compared with the health impacts of the generation stage, there are few non-occupational exposures associated with the transmission and distribution stages of the supply chain. One area which has received particular focus in recent years is the concern over exposure to electromagnetic fields (EMF). An increasing number of epidemiological studies have focused on these concerns, and a critical review of these is provided below.

Electromagnetic Fields

Physical Characteristics

Electromagnetic radiation is the transportation of energy through space. The electromagnetic spectrum covers more than 15 orders of magnitude, from below power-frequency fields to ionising radiation. This spectrum can be divided into three broad bands based on their frequency or wavelength: electromagnetic fields and radiation (0 hertz (Hz) to 300 gigahertz (GHz), where 1000 Hz = 1 kilohertz (kHz), 1000 kHz = 1 megahertz (MHz) and 1000 MHz = 1 GHz); infrared and optical radiation; and ionising radiation. Electromagnetic fields and radiation are further categorized into: extremely-low-frequency (ELF) EMF (3 to 3000 Hz); radio frequencies, which range from the very low frequencies of television sets and visual display units (about 30 kHz) to the high frequencies of FM radio (about 300 MHz); and microwaves, which are at the high end of this spectrum (up to 300 GHz). Power-frequency EMF falls into the ELF range of the spectrum, with the frequency depending on the power source. Electricity systems operate at frequencies of either 50 or 60 cycles per second (50 or 60 Hz).

Extremely-Low-Frequency Electromagnetic Fields (ELF-EMF)

An electromagnetic field is composed of an electric and a magnetic field. The electric field is created by the presence of an electric charge and is determined by the voltage. Magnetic fields are created from the presence and motion of electric charges whenever electricity is generated, transmitted or used; the current determines the magnitude of a magnetic field. Magnetic fields are three-dimensional and time-varying vector quantities that can be described by a number of parameters, including their frequency, phase, direction and magnitude.

Electric and magnetic fields have different properties that are of importance when considering possible biological effects. Essentially all materials, including clothing, easily shield power-frequency electric fields. In contrast, magnetic fields pass through nearly all materials, including

living tissues, building structures and the earth. The primary determinants of magnetic field exposure are source geometry and distance from the source to the measurement location. The magnitude of a magnetic field decreases fairly rapidly with distance from an isolated source. In general, magnetic fields from transmission and distribution lines decrease with the inverse square of the distance, while the fields from appliances decrease with the inverse square to the inverse cube of the distance. The strength of a magnetic field is usually designated by its magnetic flux density measured in Tesla (T). Occupational and residential magnetic field exposures from power frequency fields are in the range of μT ($1 \times 10^{-6} \text{ T}$).

Sources and magnitude of exposure

Major sources of EMF exposure include electrical power generation, transmission and use in residential and occupational settings, and telecommunications and broadcasting. Most devices that have electrical wires are potential sources of power-frequency EMF. Although the predominant exposure is to alternating current waveforms, humans are also exposed to a mixture of frequencies, including switching events that generate abrupt spikes of high-frequency transients that can extend into radio frequencies. Residential exposures include power-frequency exposures, radio frequencies and microwave sources. Exposures to magnetic fields vary over several orders of magnitude.

Magnetic field exposures from power lines are dependent on the current carried on the line, the geometry of the system, the number of consumers, the distance to the nearest electrical equipment (often substation or transformer), the grounding practices, and the season (Johnsson and Mild 2000). Typical magnetic field exposures directly under transmission lines are: 40 μT under a 400-kilovolt (kV) line, 22 μT under a 275-kV line and 7 μT under a 132-kV line (NRPB 2001). Exposures 25 meters away from these same lines typically are 8, 4 and 0.5 μT , respectively.

Table 4.5 summarizes time-weighted average exposures (measured by personal dosimeters) by occupational job title (Portier and Wolfe 1998). Large standard deviations indicate that workers in these categories are exposed to stronger fields than the means listed. (Foliart, Iriye et al. 2001) measured personal exposures for 1015 subjects working in 169 different job categories. The most common measurement was 0.05 μT and measurements above 1 μT were rare. Occupations considered to higher exposures include: the electric power industry; arc and spot welding; induction furnaces; electrified transport; use of video display terminals; and use of sewing machines (IARC Working Group on the Evaluation of Carcinogenic Risks to Humans 2002). The average magnetic fields to which workers are exposed for various jobs in the electric power industry have been reported as: 0.18-1.72 μT for workers in power stations; 0.8-1.4 μT for workers in substations; 0.03-4.57 μT for line and cable workers; and 0.2-18.48 μT for electricians (Portier and Wolfe 1998; NRPB 2001).

Table 4.5. Time-weighted average exposure to magnetic fields by job title

Occupational Title	Average Exposure (μT)	Standard Deviation
Train (railroad) driver	4.0	Not reported
Lineman	3.6	11
Sewing machine user	3.0	0.3
Logging worker	2.5	7.7
Welder	2.0	4.0
Electrician	1.6	1.6
Power station operator	1.4	2.2
Sheet metal worker	1.3	4.2
Cinema projectionist	0.8	0.7
Source: Adapted from (Portier and Wolfe 1998)		

Table 4.6 summarizes children's personal magnetic field exposures in six studies (Foliart, Iriye et al. 2001). Some of these studies were of childhood leukaemia and others were surveys. The 24-hour mean time-weighted average measurements ranged from 0.10 to 0.14 μT , with 10–14 % of children having exposures above 0.2 μT . Typically, high-voltage transmission lines account for a minority of high exposures. For example, in Germany, only 29% of all higher magnetic field exposures were attributable to high-voltage transmission lines (Schüz, Grigat et al. 2000).

Table 4.6. Children's personal magnetic field exposures by study

Study (age range)	N	24-hour time-weighted average mean (μT)	24-hour time-weighted average $\geq 0.2 \mu\text{T}$	Geometric mean (μT)	Geometric standard deviation	Median (μT)
Childhood leukaemia survival (case study: 0–15 years)	356	0.115 (0.104) ²	10.1%	0.075	2.30	0.073 μT
EMF-RAPID 1 000 person (0–18 years) (Zaffanella and Kalton 1998) ³	138	0.106	12.3	0.077	2.19	0.069
NCI – Washington, DC pilot (0–8 years) (Kaune, Darby et al. 1994)	29	0.13	14.3 ⁴	0.105	1.89	n/a
EPRI – Enertech study (0–18 years) (Kaune and Zaffanella 1994)	31	0.14	13	0.097 ⁵	2.46	n/a
NCI – cases (<15 years) (Linnet, Hatch et al. 1997)	615	0.104	11.4	0.077	2.09	0.072
BCCA study – controls (0–14 years) (McBride, Gallagher et al. 1999)	329		12.8 ⁶			

¹Includes studies reporting exposures among children.

²Excludes outlier associated with night-time use of portable fan.

³Includes 138 children up to the age of 17: the 24-hour time-weighted average exposures were 0.11 μT for children less than 5 years and 0.10 μT for children 5–17 years of age.

⁴Per cent $\geq 0.25 \mu\text{T}$.

⁵At-home average for combination of two days.

⁶Lifetime predicted exposure; contemporaneous measurements yield 15.3%.

Source: (Foliart, Iriye et al. 2001)

Potential Health Impacts

There is a large body of epidemiologic evidence concerning the association between occupational and residential exposure to power frequency magnetic fields and cancer. This literature has been reviewed by the US National Institute of Environmental Health Sciences (NIEHS), the National Radiological Protection Board (NRPB), the International Agency for Research on Cancer (IARC) and others (Portier and Wolfe 1998; Tenforde 2000; NRPB 2001; IARC Working Group on the Evaluation of Carcinogenic Risks to Humans 2002). All reviews noted that more than 20 years of research have not resolved scientific questions about the possible adverse health effects of power frequency EMF exposure and that evaluations of exposure assessment and epidemiologic studies were made more difficult because of (1) the lack of knowledge of what, if any, is the biologically relevant exposure and (2) the lack of a biological mechanism.

Childhood Cancers

The two cancers of concern are childhood leukaemia, which is primarily acute lymphocytic leukaemia (ALL), and brain cancer. There is a considerable body of epidemiological research on the association between power-frequency EMF and childhood leukaemia dating from 1979 (Wertheimer and Leeper 1979). IARC and US NIEHS concluded that the scientific evidence, in particular the evidence as it relates to childhood leukaemia, suggests that power-frequency EMF is possibly carcinogenic to humans (category 2B). The conclusions were based on the evaluations that there is limited evidence of carcinogenicity in humans and less than sufficient evidence of carcinogenicity in experimental animals.

Two recent studies conducted pooled analyses of magnetic fields and childhood leukaemia (Ahlbom, Day et al. 2000; Greenland, Sheppard et al. 2001). The highest exposure category was $\geq 0.4 \mu\text{T}$ in the Ahlbom et al. study and $\geq 0.3 \mu\text{T}$ in the Greenland et al. study. Both concluded that residential exposure in the highest exposure category increased the risk of childhood leukaemia by about a factor of two. Controlling for various potentially confounding variables made little difference in the risk estimates. Reviews of the epidemiologic evidence of an association between exposure to ELF-EMF and childhood brain tumours concluded that there is no support for an overall association (Portier and Wolfe 1998; Kheifets, Sussman et al. 1999).

Adult Cancers

IARC concluded that there is inadequate evidence in humans for the carcinogenicity of ELF-EMF in relation to cancers other than childhood leukaemia (IARC Working Group on the Evaluation of Carcinogenic Risks to Humans 2002). Occupational studies conducted in the 1980s and early 1990s suggested a possible association between above average magnetic field exposure and leukaemia and brain tumours (IARC Working Group on the Evaluation of Carcinogenic Risks to Humans 2002). However, study limitations and lack of appropriate exposure measurements made interpretation difficult. Several large studies conducted in the 1990s used improved methods for exposure assessment (NRPB 2001; IARC Working Group on the Evaluation of Carcinogenic Risks to Humans 2002). Some of these studies reported increased risk of cancer for intermediate or high magnetic field exposure categories. However, there were no consistent findings across studies of an exposure-response relationship and no consistency in the association with specific sub-types of leukaemia or brain tumour.

Neurodegenerative Disorders

There are several recent reviews of studies investigating the potential association between occupational magnetic field exposure and neurodegenerative disease (Portier and Wolfe 1998; Ahlbom, Cardis et al. 2001; NRPB 2001). Although early studies suggested a strong association between high occupational EMF exposure and Alzheimer's disease, most of the later studies found little to no increased risk. Reviews by both the International Commission on Non-Ionizing Radiation Protection (ICNIRP) and NRPB concluded that support for the hypothesis is weak (Ahlbom, Cardis et al. 2001; NRPB 2001). However, two new studies from Sweden suggest an association in highly exposed occupations (Feychting, Jonsson et al. 2003; Hakansson, Gustavsson et al. 2003).

There is more evidence supporting an association with amyotrophic lateral sclerosis (ALS). The epidemiologic evidence, although not totally consistent, suggests that employment in electrical occupations may increase the risk of ALS (Ahlbom, Cardis et al. 2001; NRPB 2001; Feychting, Jonsson et al. 2003; Hakansson, Gustavsson et al. 2003; Li and Sung 2003). The role of electric shock in the development of ALS needs to be further investigated.

Miscarriage

The US NIEHS concluded that the limited data on maternal exposure to ELF-EMF during pregnancy or paternal exposure before conception do not suggest an exposure-related increased risk of spontaneous abortion or adverse outcomes of pregnancy (Shaw 2001). However, two recent studies suggest an association (Lee, Neutra et al. 2002; Li, Odouli et al. 2002). In a commentary published with the papers, Savitz suggested that the results could be due to an artefact from the authors' attempts to integrate behaviour with environment (Savitz 2002). Further research is needed on this question.

Other

A range of other possible adverse health outcomes have either been proposed or studied (female breast cancer, prostate cancer, certain cardiovascular diseases, depression, etc.). To date, the suggestions of an association with occupational and/or residential EMF exposure have not been confirmed in well-conducted studies.

Contact Currents

It has recently been suggested that contact currents could be an explanatory factor for the observed associations between magnetic field exposures and childhood leukaemia (Kavet, Zaffanella et al. 2000; Brain, Kavet et al. 2003). A contact current occurs at home or in the workplace when a person touches two conductive surfaces that are at different electrical voltages. Typically, these currents may flow from hand to hand or from a hand through the feet, depending on how the contact is made. Contact currents meet three plausibility conditions: 1) there is an association between contact current exposure and measured magnetic fields; 2) residential contact current exposures are sufficient to deliver an adequate dose to the bone marrow; and 3) there are opportunities for exposure. Research is being conducted to further investigate this hypothesis.

The ExternE research project quantifies, as far as is currently possible, the health impacts associated with all stages of the fuel cycle. As the evidence presented in Section 2, above, suggests, in most fuel cycles it is the power generation stage that accounts for the majority of the health impacts. Nevertheless, some health impacts associated with the transmission and

distribution of electricity were discussed. In the following paragraphs we summarise the conclusions of these discussions.

In analysing the coal fuel cycle and other fuel cycles, the impacts caused by electro-magnetic fields of the kind noted above were considered. The conclusion here was that although the concern was noted, the researchers felt that since there was no definitive evidence that exposure to electro-magnetic fields associated with the transmission of electricity was capable of causing harm, the impacts could not be quantified.

In the gas reference fuel cycle, methane emissions from pipelines were studied for their climate change impacts, though the results were not disaggregated to identify a quantified health impact. Accident rates, associated with the transport of gas were, however, quantified. In the UK these amounted to 6.90E-05 deaths, 0.0025 serious injuries, and 0.026 minor injuries per Terawatt hour. These are of a very similar magnitude to those accident impacts associated with the distribution of fuels in the coal and lignite fuel cycles. Other impacts of distributing electricity itself were not quantified.

4.8. Conclusions

The different forms of electrical power production are associated with varying health effects on industry workers and the general population. These effects may arise during the phases of fuel extraction (mining or drilling), power generation, distribution and waste product disposal. Some health effects occur with very short time lags, whereas others (such as those associated with chronic exposure to airborne pollutants) may occur after a time lag of some years. In the case of climate change, the effects are predicted to build over a period of decades. Transboundary transport of pollutants and the processes of climate change mean that populations distant from the original site of power generation may be adversely affected by it.

There is uncertainty in quantifying the specific effects of each form of power generation because their magnitude depends on a range of variables including, for example, the technology used in generation, occupational health and safety practices, measures of control of pollutant emissions, the location of human settlements in relation to pollution dispersal and population vulnerability. Such factors are likely to significantly influence the associated health effects. The European Commission ExternE found that the effects are greatest from the coal cycle, followed by the oil and gas cycles. Renewable sources, such as photovoltaic and wind energy, are associated with fewer health effects. All the findings were expressed in monetary terms: the welfare effects of all externalities from electricity generation in the 15 EU countries in 1998 were equivalent to 1% of the total gross domestic product in the EU. Of this total, about 90% of the welfare effects are health-related. Uncertainty about the nature and magnitude of the health effects remains in several areas. There has been a shift in the types of fuels used, away from coal and towards relatively cleaner ones, such as gas, in several central and eastern European countries, both in district heating systems and in individual houses. The increased use of renewable energy, especially wind, solar and photovoltaic energy, will have positive health benefits, some of which have been estimated. Studies show that the health and the environmental benefits easily make up for the higher costs associated with renewable energy use.

The production of electricity from nuclear sources has also increased somewhat. Further increases in nuclear power are not expected, however, until after 2020, when some increase may be necessary to meet the targets for reducing greenhouse gases. Protecting human health from

nuclear power accidents and nuclear waste disposal is one of the greatest concerns. Many regulations have been developed or are under development.

The delayed health impacts arising from the contribution of electrical power generation to greenhouse gas emissions and hence to climate change are particularly difficult to estimate. Current evidence suggests that phenomenon of climate change in general is likely to be associated with significant public health burdens from a variety of mechanisms: the direct effects of exposure to high temperatures, more frequent severe weather events (floods, storms), increased burden of food and water-borne illness, altered distributions of vector-borne diseases, changes in water availability and crop yields, potential social dislocation. Populations in low income countries appear particularly vulnerable to many of these impacts. However, it is not possible to say with any precision what separate contribution any particular form of power generation will make to future health burdens, especially given the time lags and changes over time in important non-climate factors that may affect vulnerability. However, climate change has the potential to cause substantial adverse health effects in different regions of the world, and the tendency will be for these to increase over time as climate changes increases. From a health perspective, it is therefore very desirable that greenhouse gas emissions from all sources, including power generation, are reduced, so that the rate of climate change is slowed.

There is a need for systematic and rigorous assessment of the health implications of energy generation and distribution to underpin future energy policy. We would recommend that there needs to be more formal assessment of the short-, medium-, and long-term health impacts of each of the types of fuel referred to in this chapter.

Table 4.7. Summary of the of the health impacts of the different forms of electrical power generation

ENERGY-GENERATING-RESOURCE	DIRECT HEALTH IMPACTS	INDIRECT HEALTH IMPACTS (CONTRIBUTION TO CLIMATE CHANGE)	POTENTIAL FOR ACCIDENTAL INJURIES AND/OR FATALITIES
Biomass	Mainly from acute and chronic effects of outdoor air pollution, but magnitude of health impact depends on combustion process and technology	Little net contribution to greenhouse gases over the medium term provided renewable sources used.	Usually small and containable risks
Coal	As for biomass; additional burdens from occupational exposures	Forms greenhouse gases, but separate contribution to climate change and resultant health impacts difficult to quantify; impacts delayed	Appreciable occupational risks associated with extraction
Geothermal	No significant harmful emissions	Negligible	Minimal
Hydroelectric	No significant harmful emissions, but can lead to risks through altered ecology	Significant during construction phase; negligible during operation	Generally small, except to workers during construction
Lignite	As for coal; higher pollutant emissions and hence probably greater health impacts	As for coal	As for coal
Marine	Negligible	Small/negligible	Small (mainly occupational)
Natural gas	Cleaner burning than other fossil fuels, but health effects primarily from air pollution	Forms greenhouse gases but generally lower than for other fossil fuels	Some risks mainly during extraction
Oil	As for biomass; additional burdens from occupational exposures	Forms greenhouse gases, but separate contribution to climate change and resultant health impacts difficult to quantify and delayed	Appreciable occupational risks associated with extraction
Peat	Similar to lignite	Comparatively high greenhouse emissions versus coal	Usually small and containable risks
Photovoltaic	Small	Negligible	Negligible
Nuclear	Small risks from release of radioactive material, but containable by effective control systems. Debate about long term effects from exposure during mining.	Minimal (some during reprocessing).	Risk from uncontrolled releases of radiation usually small, but finite potential for catastrophic accident or terrorist threat
Waste incineration	Mainly from acute and chronic effects of outdoor air pollution, but magnitude of health impact depends on combustion process and technology	Contributes to greenhouse gases	Usually small
Wind power	No significant harmful emissions	Negligible	Negligible

Chapter 5: A possible way forward

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Europe faces considerable challenges in restructuring its energy sector to reconcile environmental, social and economic objectives – the three pillars of sustainable development. Fortunately, new opportunities arising through technological developments in the production and use of energy, particularly new technologies which favour energy efficiency, are consistent with the goals of sustainable development.

The consumption of energy is a key part of any sustainable development strategy, and increases in energy will be needed to support economic and social growth in Europe. Clearly, any shift in energy policy should be assessed in terms of its impacts on human health. In order that increased supply be consistent with sustainable development, the negative health and environmental impacts of the production and use of fossil fuel energy must be diminished. This focus on harm reduction should not detract from the fact that the increase in energy availability in the last 100 years, especially commercial energy, has brought significant benefits in terms of better living standards, or prevent future energy increases continuing to support improvements in living standards.

We offer this brief chapter in order to stimulate debate on how to better integrate health aspects into future energy developments. Based on the analysis in chapter 2 to 4, we identified three key areas of concern:

- (i) The consequences for health of dependence on energy supply that is not secure at the national or at the household level;
- (ii) The effects on health of changing weather and climate;
- (iii) The protection of health as a consequence of the generation, transformation and distribution of energy.

Figure 5.1 summarises the discussions from chapters 2-4 within the DPSEEA (Driving forces-Pressures-State-Exposure-Effect-Action) framework linking energy to health.

5.1. The consequences for health of an energy supply which is not secure

For both the EU25 as well as some other European countries, dependency for energy on external sources is constantly increasing. 50% of the energy requirements are imported and if no measures are taken within the next 20 to 30 years this figure could rise to 70%. This external dependence has economic, social, ecological and physical risks for European citizens. Energy imports represent 6% of total imports in the EU; in geopolitical terms, 45% of oil imports come from the Middle East and 40% of natural gas comes from the Russian Federation. In 2004 the enlarged Union will be consuming more than 20% of world oil production. Geopolitical uncertainties and oil price volatility heighten the importance of improving the organization of strategic oil stocks and coordinating their use.²⁴

²⁴ <http://europa.eu.int/scadplus/leg/en/lvb/l27037.htm>

Figure 5.1 Inter-connections between Health and Energy

Driving forces	→	Population growth and economic development	←	Actions
Pressures	→	Energy supply and demand	←	Global and regional energy strategies
State	→	Energy affordability, efficiency and fuel poverty Energy generation, transmission and distribution;	←	National strategies: Financial and legal measures (energy price reform, subsidies on renewable sources, market penetration measures..)
Exposure	→	<u>Short term:</u> Chemicals, heavy metals, ionizing and non-ionizing radiation through air, water and soil; cold and heat; lack of access to services and communication facilities; <u>Long term:</u> climate change and trans-boundary air and water pollution	←	Technological improvements Exposure reduction measures Regulations to reduce environmental pollution
Health effects	→	<u>Causes of morbidity and mortality</u> Respiratory diseases, Cardiovascular diseases, Intoxications, Injuries, Neurological and mental disorders, Allergic disorders, Genetic disorders, Cancer	←	Health impact assessment Public information

The European Commission's Green Paper, "Towards a European strategy for the security of energy supply"²⁵ addresses this problem. The strategy is based on improving energy security and managing energy demand. The Green Paper proposal for strategic oil reserves aims to promote greater solidarity between the Member States in time of crisis. Further, a Europe-wide security of supply concept should be developed to enable Europe to control its energy future. Also, the dialogue between the EU and the Russian federation aims to create/enforce new energy partnerships²⁶.

The issue of national energy security is important for health because volatility in the price of key fuels such as oil and gas has impacts on household expenditures, with periods of sudden high prices hurting the poorer strata of European societies. If they are unable to heat themselves adequately, without having to resort to 'dirty' fuels, or if they can only do so at a cost that makes them unable to acquire other essential commodities, their health is likely to suffer.

²⁵ http://europa.eu.int/comm/energy_transport/livrevert/final/report_en.pdf

²⁶ http://europa.eu.int/comm/energy/russia/overview/index_en.htm

In order to reduce energy dependencies, one of the key arguments is to manage demand. The demand management strategy of the EU is based on increased use of renewable sources for electricity production and energy consumption and on the application of energy efficiencies. Notable was the White Paper on renewable energy in 1997, and a 2001 directive on the promotion of electricity from renewable energy sources. The EU documents set, as an overall target, 12% of the EU's total energy consumption and 22.1% of the EU's electricity to come from renewable sources by 2010. Some small progress in meeting these targets can be seen from the fact that the share of renewable energy increased from 4.7% to 5.8% in the EU between 1992 and 2000.

In July 2000 the Group of Eight industrialized countries set up the G8 Renewable Energy Task Force with a mandate to identify actions that can be taken to promote a significant change in the supply, distribution and use of renewable energy in developing countries. The importance of renewable energy sources was further recognized at the World Summit on Sustainable Development²⁷ and in a number of EU policy documents. Some countries in central and eastern Europe, the Caucasus and central Asia have also developed energy and environment policies that include developing renewable sources, but in most countries this has had a low priority, since the necessary investment resources are lacking and the strong institutional structures needed to drive the process have not yet been established.

There is also, particularly in the former soviet union states of Eastern Europe, a 'supply' problem of different nature: an ageing technology with a failure of the system to provide enough commercial energy at an affordable price. As a consequence, households are switching to home use of fossil solid fuels, with resulting impacts on health through increased air pollution exposure. The latter is also recognized in the MDG in many ways. First, as most of the disease burden due to indoor air pollution falls on children under five years of age, interventions will help achieve a significant reduction in child mortality (Goal 4) and second, the proportion of the population relying on solid fuels constitutes one of the indicators to monitor progress towards ensuring environmental sustainability (Goal 7).

In these countries there is the need to invest in infrastructure and the need to make commercial energy affordable, so that everyone has enough heat in the winter and does not suffer from too much heat in the summer. In parallel, restricting the use of solid fossil fuels should be a priority area for action across the continent. Furthermore, in terms of affordability, one of the goals should be that households should not spend more than one tenth of their income to meet energy needs. The measures needed to achieve this are generally well known. One is to design tariffs for electricity, gas and district heating so that the poor do indeed have access to enough of the relevant type of energy. Another measure is to improve the stock of 'complementary assets' that set the efficiency of the household's energy use. This includes providing subsidies for insulation, replacement of old heating equipment with newer more efficient equipment etc. While programs like this are in place in several countries, a detailed assessment of their effectiveness is still lacking. Work in this area will be well rewarded in terms of better-targeted and more cost-effective programs. While action is also needed to mitigate the problems of fuel poverty, there is a lack of agreement from a technical and scientific perspective. In addition better information on the populations that face these problems is essential. There are some measures that can be done at household level to reduce indoor air pollution exposure in particular for children.

²⁷ <http://www.un.org/esa/sustdev/media/Brochure.PDF>

Better planning on energy efficiency is also part of the EU green paper, reducing energy consumption and thereby the need for increased supply. Buildings represent approximately 40% of energy consumption and the potential energy saving is more than 20%. The benefits of improving energy efficiency are not only by contributing to better management of demand but also through ensuring growth of GDP and household income. Improving household income will allow better spending on other goods and services. Further, energy efficient infrastructure would ensure human warmth during winter.

Energy efficiency improvement is also a problem connected with energy 'affordability', as investing in energy efficient infrastructure might be more difficult for the poorer strata of European populations. Household insulation and installation of efficient central heating systems are both dimensions of this affordability problem. More generally, the wider issue of the quality of the housing stock will need to be seen in the light of this problem.

The EU action plan proposes amending one of the key directives in this area, i.e. Directive 93/76/EEC on the energy certification of buildings, which seeks to limit carbon-dioxide emissions and includes insulation measures and heating requirements. In May 2001, the Commission therefore made a proposal for a directive on the energy performance of buildings. The Council adopted an amended version in 2002. The Directives on boilers (92/42/EEC) and on construction products (89/106/EEC) also figure among the main actions in the sector and, in September 2000, a Directive on energy efficiency for lighting was adopted. The dissemination of good practices, the extension of labelling and the training and qualification of fitters are also planned. Moreover, among the many initiatives in this sector, the EU also finances a "Green Light Programme" concerning lighting in commercial buildings. Last not least, biofuels should be promoted through a variety of measures.

Finally one of the key debates in the energy sector is whether or not to phase out or to place a moratorium on the nuclear industry. Overall nuclear power production has increased between 1990 and 1999 throughout Europe, and with this the generation of nuclear waste. The reasoning adopted by the European Commission is that in the medium to long term, and given the current state of the art, the total abandonment of nuclear power would imply 35% of electricity production coming from renewable and conventional energy sources, to which must be added the fact that energy demand is forecast to rise. Therefore, the nuclear option has been left open to EU Member States. In health terms, the generation of nuclear power does not appear to have significant health impacts from its day-to-day operations. One cannot, however, ignore the concern associated with the consequences of nuclear accidents, including releases from stored nuclear waste. In the future, therefore, a clear and unequivocal answer to the question of the processing and transportation of radioactive waste must be found.

5.2. The effects on health of changes in weather and climate

Another great source of concern for environment and health is the effects of climate change, driven through increased greenhouse gas emissions, primarily in the transport and energy sectors. The assessment activities undertaken by the Intergovernmental Panel on Climate Change have found increasing evidence in support of global warming and other changes in the climate system. The global average surface temperature has increased since 1861, and new analyses of proxy data from the northern hemisphere indicate that the increase in temperature in the 20th century is likely to have been the largest of any century during the last 1000 years. The future

effects largely depend on what happens to emissions worldwide, and the role of Europe as a promoter might be very important.

Climate change-related policies have significantly driven the integration of environmental considerations into energy policies. Among the most significant is the recently adopted EU directive on emissions trading. This decision will essentially cap the emissions allowed by large industry (including the power-generating sector) within Europe, effectively placing an EU-wide price on carbon dioxide emissions for the first time. The direct benefit of these reductions will be a further decline in local primary and associated secondary air pollutants, which will have important health benefits. However, the proposed reductions in CO₂ are modest in relation to those needed to avert the negative effects of climate change, which require much greater reductions over the longer term to 2050.

In the meantime signals of a changing climate are apparent. The most critical issue of the changing climate is that the effects are not localized to the place where the biggest emissions occur, but (a) they are global, (b) they will affect future generations even more than the current ones, (c) and they are unevenly distributed (developing countries are more affected than developed ones). An important further consideration is that climate change would not affect human health in isolation, but would affect other of our Earth maintaining ecosystems. These coexistent environmental changes will often influence one another and will also interact in making their impact. The effects will undoubtedly have a greater impact on societies or individuals with scarce resources, where technologies are lacking, and where infrastructure and institutions are least able to adapt.

These important long-term considerations need to be taken into consideration when planning energy strategies for the future.

5.3. The protection of health as a consequence of the generation, transformation and distribution of energy.

As explained in chapter 4, the different forms of electrical power production are associated with varying health effects on industry workers and the general population. These effects may arise during the phases of fuel extraction (mining or drilling), power generation, distribution and waste product disposal. Some health effects occur with very short time lags, whereas others (such as those associated with chronic exposure to airborne pollutants) may occur after a time lag of some years.

Many health outcomes in occupational health depend on the technology used in generation, occupational health and safety practices, measures of control of pollutant emissions, workers protection legislation and practices and enforcement mechanisms. Many of these activities are under the responsibility of the enterprise.

The exposure of the local population is very much dependent on the location of human settlements in relation to pollution dispersal and population vulnerability. Such factors are likely to significantly influence the associated health effects. It needs to make sure that the highest measures of protection are adopted by the enterprises and energy companies, in order to avoid any type of air, soil or water pollutants to affect the environment and therewith human health.

Renewable sources, such as photovoltaic and wind energy, are associated with fewer health effects in general. There has been a shift in the types of fuels used, away from coal and towards relatively cleaner ones, such as gas, in several central and eastern European countries, both in district heating systems and in individual houses. The increased use of renewable energy, especially wind, solar and photovoltaic energy, will have positive health benefits, some of which have been estimated. Studies show that the health and the environmental benefits easily make up for the higher costs associated with renewable energy use.

The production of electricity from nuclear sources has increased. Further increases in nuclear power are not expected, however, until after 2020, when some increase may be necessary to meet the targets for reducing greenhouse gases. As noted above, addressing public concerns about the human health consequences of nuclear power accidents and nuclear waste disposal is a “must” for policy makers.

5.4. Future Actions

The topic of energy, sustainable development and health is very broad and embraces many policy areas at several levels, from measures to reduce energy poverty, to win-win strategies to reduce both environmental and health burdens from energy production and the emissions of greenhouse gas emissions. As shown above, many initiatives and policies address, directly and indirectly, energy and the environment, but some measures and policies have still not been fully thought through in terms of their environmental implications. Furthermore most of the initiatives, measures and policies do not include health as a critical indicator of sustainable energy development. The energy policies and energy-related social and environment policies that have the greatest potential for improving health and the best overall trade-offs need to be identified and analyzed in greater depth. In addition, it is necessary to clarify how the environment and health community can collaborate effectively.

In order to mainstream health through the range of measures, initiatives and policies, it is important to promote the development and application of health impact assessment (HIA) in the energy field; identify appropriate health indicators and evaluate the effectiveness of policies and strategies with respect to health indicators.

Health impact assessment

Health is important to everyone. Until recently, this was not reflected in policy decisions in economic sectors such as energy, as "health" was commonly equated with "healthcare services", rather than as a social commodity of measurable worth. There has, however, been growing recognition that population health issues are of concern to everyone, and that there is an important role for government (including local government). This is reflected in the rapid growth of interest in Health Impact Assessment (HIA), and more generally an increasingly widespread view that health should be mainstreamed in policy decisions across a range of government activities, in the same way that environmental concerns are becoming part of universal policy development.

How to achieve this is less clear. From a statutory point of view, while Environmental Impact Assessments (EIAs) are legally required for a wide range of projects, the same is not true of Health Impact Assessments. While most EIA legislation requires that human health impacts be evaluated, in practice this has seldom been included, and when it has been done it does not usually give adequate emphasis to the most important health issues. In any case, projects and

policies can have important health impacts that are not mediated through "environmental" factors as has been made is clear in the case of health effects related to fuel poverty as mentioned earlier.

There is also considerable difference in the way that the two procedures have developed. Whereas EIA is a highly technical procedure, and is typically carried out by the proponents of the project, HIAs are usually carried out by independent bodies, and have so far tended to be much more limited in scope and resources, and to be less technical. The HIA process emphasises the participation of all stakeholders, including those communities which will be most affected by the intervention, and sets out to raise the awareness of health among decision makers. It also involves technical evaluation, but this is less central than with EIA, and is typically less precise.

As environmental assessment has evolved towards Strategic Environmental Assessment (SEA), there have been efforts to ensure that SEA better integrates health than has historically been the case with EIA. This process of convergence has been encouraged by WHO and other agencies, and promises to provide better involvement of health in policy development than has hitherto been the case. SEA is now required in many countries, including those within the EU.

Nevertheless, it remains an open question whether health will be adequately addressed if it continues to be made a part of environmental assessment, rather than considered in its own right. There is need for a procedure that centres on health, and that helps move policy development and implementation in a direction that would improve health and reduce social inequalities in health. This raises the question of multiple assessments, as policy makers are typically required also to assess other types of impacts, for example on small businesses or on gender issues. For this reason, there is increasing interest in embedding HIA and other impact assessments in a more general Integrated Impact Assessment (IIA).

Monitoring progress and information development and dissemination

There is urgency to address the lack of access to electricity and heating through social and tariff policies and other measures. As this report has shown, there is still considerable scientific uncertainty relating to the state of access to adequate energy in some countries and to the effectiveness of measures that have been taken to improve access. Although a substantial body of information and knowledge is already available, the information is fragmented and often spread among different disciplines, sectors and communities. A number of systems have been developed, or are being developed, to improve the collection of environment and health information, but they do not necessarily include energy and social information. Generating, collecting and disseminating this knowledge and information and focussing on the most sensitive health issues would be one important step. This can be also improved through international collaboration and identification of hot spot areas that need to be addressed urgently.

In terms of the health effects of energy use, a lot has been done regarding the health consequences of using fossil fuels for power generation and transport, but there are still gaps in our knowledge in these areas. Most important is the state of knowledge on the chronic health effects of small particles generated by burning fossil fuels and through the chemical reactions of different compounds in the atmosphere. But there are a number of other areas where further research is needed as well. All of these have been noted in Chapter 3 and 4 of this report.

In addition to collecting information for policy-makers, there is also a need to disseminate what is already known to the general public. The general population is not well informed about the

adverse health impacts of indoor solid fossil fuel use, especially on children. This can and should be corrected.

Annex 1

Acronyms

ALRI	Acute Low Respiratory Infections
ALS	Amyotrophic Lateral Sclerosis
APHEA	Air Pollution and Health: A European Approach
BOD	Burden of Disease
C	Celsius
CB	Chronic Bronchitis
cCASHh	climate Change and Adaptation Strategies for Human health
CCGT	Combined Cycles with Gas Turbine
CEE	Central and Eastern Europe
CH ₄	Methane
CI	Confidence Interval
CO	Carbon monoxide
CO ₂	Carbon dioxide
COPD	Chronic Obstructive Pulmonary Disease
COPD	Chronic obstructive pulmonary disease
EEA	European Environment Agency
EECCA	Caucasus and Central Asian Republics
EECCA	Eastern Europe, the Caucasus and Central Asia
ELF	Extremely-low-frequency
EMF	Electromagnetic fields
EU	European Union
FBC	Fluidised bed combustion
FSU	Former Soviet Union
GDP	Gross Domestic Product
GHz	gigahertz
Hz	hertz
IARC	International Agency for Research on Cancer
ICNIRP	International Commission on Non-Ionizing Radiation Protection
IEA	International Energy Agency
IMR	Infant Mortality Rates
IPCC	Intergovernmental Panel on Climate Change
Kg	kilogram
kV	kilovolt
kWh	kilowatt-hour
LPG	Liquefied Petroleum Gas
m	metre
MDG	Millenium Development Goals
MHz	megahertz
MSW	Municipal solid waste
n/a	Not applicable
NIEHS	United States National Institute of Environmental Health Sciences
NO	Nitrogen oxide
NO ₂	Nitrogen dioxide

NO _x	Nitrogen oxides
NRPB	National Radiological Protection Board
O ₃	Ozone
OECD	Organization for Economic Co-operation and Development
OTEC	Ocean thermal energy conversion
PAHs	Polycyclic aromatic hydrocarbons
PANs	Peroxyacyl nitrates
PCBs	Polychlorinated biphenyls
PM	Particulate matter
PM ₁₀	Particulate matter less than 10 microns in diameter
PM _{2.5}	Particulate matter less than 2.5 microns in diameter
ppm	Parts per million
SFU	Solid Fossil Fuels
SO ₂	Sulphur dioxide
SPM	Suspended particulate matter
SRC	Short Rotation Coppice
T	Tesla
TSP	Total suspended particles
TWh	Terawatt-hour
U5MR	Under five mortality rates
UK	United Kingdom
UN	United Nations
UNECE	United Nations Economic Council for Europe
UNEP	United Nations Environment Programme
UNFCCC	United Framework Convention on Climate Change
UNSD	United Nations Statistics Division
VOCs	Volatile organic compounds
WE	Western Europe
WHO	World Health Organization
WRI	World Resource Institute
YOLL	Years Of Life Lost
µg	microgrammes (one millionth of a gramme)
µg/m ³	microgrammes per cubic metre
°C	Degrees Celsius
²³³ U	Uranium-233
²³⁵ U	Uranium-235
²³⁹ Pu	Plutonium-239
²⁴¹ Pu	Plutonium-241

Annex 2

The ExternE description

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What is the ExternE Project?

The ExternE Project is the first comprehensive European attempt to use a consistent 'bottom-up' methodology to evaluate the external costs associated with a range of different fuel cycles, and is a major step forward in the assessment of environmental and social damages associated with energy use. It has established a methodology and accounting framework for the comparable assessment of the externalities from a wide range of different fuel cycles.

Fuel cycle externalities are the costs imposed on society and the environment that are not accounted for by the producers and consumers of energy, i.e. that are not included in the market price. The ExternE work reflects a growing interest in adopting a more sophisticated approach involving the quantification of these environmental and health impacts of energy use and their related external costs.

The bottom-up methodology – known as impact pathway analysis - adopted in ExternE takes as its starting point the specific, site-dependent activity that gives rise to the health and environmental effects. In the case of air pollution, this might be fuel combustion in a (technology-specific) power station that results in atmospheric emissions of pollutants. The spatial dispersion of such emissions is then modelled using atmospheric transport modelling techniques. The emissions are then mapped on to human (and other) receptors whose locations are given by the EUROSTAT REGIO database, up-dated using information from national statistics. The mapping was undertaken using exposure-response functions given by the epidemiological health literature.

This air pollution modelling – and the subsequent monetisation of the identified impacts – is incorporated within an integrated model called ECOSENSE which generated estimates of the physical impacts associated with the energy-related activity and converts these to monetary totals by multiplying the physical impacts by unit values that are estimated for each impact. Other health impacts not arising from air pollution are estimated on the basis of impact-pathway analysis as far as the science will allow. Health impacts resulting from accidents are estimated using probabilistic analysis, based on historic data. In each stage of the impact-pathway analysis there exist uncertainties in the estimation process reflecting the scientific uncertainties that remain in this new area of inter-disciplinary research, and ranges are presented for the measured external costs. The analysis attempts to be as comprehensive and robust as possible with its coverage of pollutants and impacts.

Nonetheless, the ExternE work have led to a parameterisation of the uncertainties equivalent to an outer limit of an order of magnitude difference from the central values presented in this report.

Key sources of uncertainty include:

- Uncertainty of data and parameters of models (e.g. slope of an exposure-response function; the functions used in the original ExternE do not necessarily represent the current knowledge and were not based on a formal meta-analysis);
- Uncertainty about choice of model (e.g. assumptions about causal links between a hazard and an assigned health effect);
- Uncertainty about policy and ethical choices (e.g., discount rates; value of statistical life);
- Uncertainties about future developments (e.g., progress in treatment of disease); and
- Idiosyncrasies of the analyst (e.g. interpretation of ambiguous or incomplete information).

These uncertainties have to be recognized and communicated when using the results. The results of ExternE have been widely discussed and used. At the same time, the need to critically review and update the methodology and the different assumptions is recognized. There are a number of ongoing projects, which review and extend the ExternE methodology and will provide further insights (since the results of these projects are not available yet, they could not be reflected in this report):

New Elements for the Assessment of External Costs from Energy Technologies
(New Ext, <http://www.ier.uni-stuttgart.de/public/de/organisation/abt/tfu/projekte/newext/nexabout.html>)

There are also areas for which a need for further research was identified in previous ExternE phases. Major uncertainties in the existing external cost data result from uncertainties in the monetary valuation of mortality effects, and from the omission of impacts on ecosystems due to acidification, eutrophication and global warming. The existing accounting framework has also been criticised for not taking into account the contamination of water and soil. Due to accumulation processes of persistent substances there is a significant potential for long-term effects that were not addressed in previous work. Another source for criticism is the unbalanced treatment of severe accidents, since the current framework is very much focused on accidents in the nuclear fuel chain, whilst neglecting severe accidents from other energy sources. The project therefore focus on the improvement of the existing framework in these key areas that are considered to be most relevant for the assessment of external costs, and which are expected to be principally affected by new scientific findings.

ExternE-Pol – (Externalities of Energy: Extension of accounting framework and policy applications) a 2 year project that started in November 2002. It aims to improve and extend the ExternE methodology by updating epidemiology and monetary valuation, undertaking new sensitivity studies, extending the scope to analyse energy supply security externalities and developing a new approach, based on multi-criteria analysis, for impact categories such as ecosystem damage that have defied quantification so far. It will also provide an assessment of new technologies for power production, residential heating, and transport and implement the ExternE methodology in the Czech Republic, Hungary and Poland.

RED (Review of externalities data) evaluates the state of science on externalities research and the present level of knowledge on external costs, based on an extensive review of literature and documentation in Europe and in other parts of the world. These studies highlight the way that external costs analysis has been used, the way that uncertainties have been dealt with, and differing views on valuation. A major outcome of the project is a database containing externalities data drawn from all relevant sources identified and analysed.

The coal cycle externalities:

Table A.1. summarises the health impacts that have been quantified in the ExternE European Commission research project. These results are taken for technologies located in the UK and derived from the National Implementation report. This table – along with the equivalent tables presented for each other fuel cycle considered below – shows the health impacts that have been estimated to result from activity during the various phases of the fuel cycle. The types of health impacts are disaggregated, (e.g. premature death, asthma attacks etc.), and the units in which they are expressed defined (e.g. number of cases). In order to make alternative energy technologies comparable, the health impacts are expressed in terms of the physical unit per Terrawatt-hour of electricity generated by the energy technology. Comparability is essential in order for the research exercise to be able to inform policy decisions relating to the internalisation of these external impacts. The results expressed in this way also allow different stages of the fuel cycle to be compared in terms of their health impacts.

The ExternE Project found differences both in the origin of coal (in some cases the coal is imported from non-EU countries, including FSU countries, China and Australia); characteristics of the coal used; and in the combustion technologies. The results shown below are for the UK context, which has impact rates for this fuel cycle that are close to the average for the EU, and which are based on the use of a conventional pulverised fuel generating technology with flue gas desulphurisation abatement technology. Where the energy-generating-resources is sourced is important when measuring externalities, as both the environmental and public health impacts of extraction and transport, may occur outside the country/region in which the resource is used. Thus, when coal is extracted in country A, but used for power generation in country B, the occupational exposures associated with extraction will occur in the former, whilst those associated with the operation of the power station will occur in the latter. This is an important concept, and potentially applies to all the energy-generating resources considered in this document. In most of the ExternE country studies the coal used had a low sulphur content, and environmental devices used for the removal of sulphur and nitrogen, resulted in low emission factors – although these devices are not used in some countries (Belgium and Ireland), which have high sulphur emission levels.

Table A.1. Main health impacts from generation of electricity by coal in Europe

Fuel cycle stage & source of impact	Media (e.g. air, water, soil)	Health Outcome	Unit of measurement	Magnitude of impact – units per TWh	Comments
All stages	Occupational accidents	Death	Cases	0.1008	Accident cases are the sum of those estimated for the mining, transport, extraction, generation and dismantling stages.
		Severe injuries	Cases	2.517	
		Minor injuries	Cases	21.773	
All stages	Public accidents	Death	Cases	0.0155	
		Severe injuries	Cases	0.1532	
		Minor injuries	Cases	0.6949	
Power Generation	Public health - acute effects: air pollution	'acute' mortality	[deaths] per TWh	2.786	The health impacts are the sum of those from individual pollutants SO ₂ , Particulates and Nitrogen Oxide.
		'acute' Years Of Life Lost (YOLL)	[years] per TWh	2.089	
		respiratory. hosp. admissions	[case] per TWh	1.8929	
		Cerebro-vascular hosp. admissions	[case] per TWh	2.664	
		congestive heart failure	[case] per TWh	1.2714	
		Restricted. activity days	[days] per TWh	7511.8	
		Bronchodilator usage (in asthmatic adults & children)	[case] per TWh	2060.92	
		Cough (in asthmatic adults & children)	[day] per TWh	2358.45	
		Lower resp. symptoms (in asthmatic adults & children)	[days] per TWh	1095.31	
	Public health - chronic effects: air pollution	'chronic' mortality	[deaths] per TWh	21.69	Sum, as for acute impacts.
		'chronic' YOLL	[years] per TWh	216.86	
		Chronic bronchitis (adults)	[cases] per TWh	14.546	
		Chronic bronchitis (children)	[cases] per TWh	204.3	
		chronic cough	[episodes] per TWh	261.58	

The lignite cycle externalities:

The results in Table A.2 are based on those for Germany and are derived from the German National Implementation report. The same comments regarding the importance of the technologies specified and the location of the operations in relation to the human receptors apply to the lignite fuel cycle as apply to that for coal, above. The air pollution impacts again dominate those from accidents and are approximately 30% higher than those for coal. Note that the results for occupational accidents and public accidents are the same as for coal because no differentiation is made between coal and lignite in the reporting of accidents.

Table A.2. Main health impacts from generation of electricity by lignite

Fuel cycle stage & source of impact	Category of impact/Media	Health Outcome	Unit of measurement	Magnitude of impact – units per TWh	Comments
All stages	Occupational accidents	Death	Cases	0.1008	Accident cases are the sum of those estimated for the mining, transport, extraction, generation and dismantling stages.
		Severe injuries	Cases	2.517	
		Minor injuries	Cases	21.773	
All stages	Public accidents	Death	Cases	0.0155	
		Severe injuries	Cases	0.1532	
		Minor injuries	Cases	0.6949	The health impacts are the sum of those from individual pollutants SO ₂ , Particulates and Nitrogen Oxide.
Power Generation	Public health - acute effects: air pollution	acute' mortality	[deaths] per TWh	3.71	
		'acute' Years Of Life Lost (YOLL)	[years] per TWh	2.78	
		respiratory. hosp. admissions	[cases] per TWh	2.52	
		Cerebrovascular hosp. Admissions	[cases] per TWh	3.54	
		congestive heart failure	[cases] per TWh	1.69	
		Restricted Activity days	[days] per TWh	9991	
		Bronchodilator usage (in asthmatic adults & children)	[cases] per TWh	2741	
		Cough (in asthmatic adults & children)	[days] per TWh	3137	
		Lower resp. symptoms (in asthmatic adults & children)	[days] per TWh	1457	
	Public health - chronic effects: air pollution	'chronic' mortality	[deaths] per TWh	28.87	Sum, as for acute impacts.
		'chronic' YOLL	[years] per TWh	288.42	
		chronic bronchitis (adults)	[cases] per TWh	19.34	
		chronic bronchitis (children)	[cases] per TWh	271.72	
		chronic cough	[episodes] per TWh	350	

The peat cycle externalities:

Table A.3. shows the main impacts form generation of electricity by peat in Europe

Table A.3. Main health impacts from generation of electricity by peat in Europe

Fuel cycle stage & source of impact	Category of impact/Media	Health Outcome	Unit of measurement	Magnitude of impact – units per TWh	Comments
All stages	Occupational & Public accidents	Death	Cases	Negligible	Accident cases are the sum of those estimated for the mining, transport, extraction, generation and dismantling stages.
		Severe injuries	Cases	Negligible	
		Minor injuries	Cases	Negligible	
Power Generation	Public health - acute effects: air pollution	'acute' and 'chronic' mortality	[years] per TWh	292.4	The health impacts are the sum of those from individual pollutants SO ₂ , Particulates and Nitrogen Oxide.
		morbidity	Cases (of chronic bronchitis – equivalent) per TWh	48.6	

The gas cycle externalities

Table A.4. summarises the health impacts that have been quantified in the ExternE project. Results are for the UK case study and are derived from the National Implementation report.

Table A.4. Main health impacts from generation of electricity by gas

Fuel cycle stage & source of impact	Category of impact/Media	Health Outcome	Unit of measurement	Magnitude of impact – units per TWh	Comments
All stages	Occupational accidents	Death	Cases	0.02	Accident cases are the sum of those estimated for the mining, transport, extraction, generation and dismantling stages.
		Severe injuries	Cases	0.2452	
		Minor injuries	Cases	1.472	
All stages	Public accidents	Death	Cases	0.001	
		Severe injuries	Cases	0.018	
		Minor injuries	Cases	0.083	
Power Generation	Public health - acute effects: air pollution	'acute' mortality	[deaths] per TWh	0.03893	The health impacts are the sum of those from individual pollutants SO ₂ and Nitrogen Oxide.
		'acute' Years Of Life Lost (YOLL)	[years] per TWh	0.02919	
		respiratory. hosp. admission	[cases] per TWh	1.417	
		cerebrovascular hosp. admissions	[cases] per TWh	0.34	
		congestive heart failure	[cases] per TWh	0.1645	
		Restr. activity days	[days] per TWh	959	
		Bronchodilator usage (in asthmatic adults & children)	[cases] per TWh	219	
		Cough (in asthmatic adults & children)	[days] per TWh	301.24	
		Lower resp. symptoms (in asthmatic adults & children)	[days] per TWh	140	
	Public health - chronic effects: air pollution	'chronic' mortality	[deaths] per TWh	2.77	Sum, as for acute impacts.
		'chronic' YOLL	[years] per TWh	27.7	
		chronic bronchitis (adults)	[cases] per TWh	1.89	
		chronic bronchitis (children)	[cases] per TWh	26.09	
		chronic cough	[episodes] per TWh	33.5	

The oil cycle externalities

Table A.5. shows the quantification of health impacts associated with the oil fuel cycle. The results are derived from the UK National Implementation Plan.

Table A.5. Main health impacts from generation of electricity by oil

Fuel cycle stage & source of impact	Category of impact/Media	Health Outcome	Unit of measurement	Magnitude of impact – units per TWh	Comments
All stages	Occupational accidents	Death	Cases	0.03327	Accident cases are the sum of those estimated for the mining, transport, extraction, generation and dismantling stages.
		Severe injuries	Cases	0.234	
		Minor injuries	Cases	2.471	
Power Generation	Public health - acute effects: air pollution	'acute' mortality	[deaths] per TWh	2.658	The health impacts are the sum of those from individual pollutants SO ₂ , Particulates and Nitrogen Oxide.
		'acute' Years Of Life Lost (YOLL)	[years] per TWh	1.994	
		respiratory. hosp. admission	[cases] per TWh	1.176	
		cerebrovascular hosp. adm	[cases] per TWh	1.9	
		congestive heart failure	[cases] per TWh	0.913	
		Restr.icted activity days	[days] per TWh	5402	
		Bronchodilator usage (in asthmatic adults & children)	[cases] per TWh	1480	
		Cough (in asthmatic adults & children)	[days] per TWh	1694	
		Lower resp. symptoms (in asthmatic adults & children)	[days] per TWh	786	
	Public health - chronic effects: air pollution	'chronic' mortality	[deaths] per TWh	15.57	Sum, as for acute impacts.
		'chronic' YOLL	[years] per TWh	155.7	
		chronic bronchitis (adults)	[cases] per TWh	10.377	
		chronic bronchitis (children)	[cases] per TWh	147	
		Chronic cough	[episodes] per TWh	189	

The radiation cycle externalities

Table A.6. presents the health impacts of use of nuclear fuel in electricity generation. For each stage of the fuel cycle considered we show the total radiation dose, measured in man-sieverts - together with the cancer impacts that result from this dose. Note that the cancer health impact (in terms of number of cases) is not dominant in the quantification of health impacts associated with other fuel cycles, making comparison of physical health impacts problematic.

Table A.6. Main health impacts from generation of electricity by nuclear fuel

Fuel cycle stage & source of impact	Category of impact/Media	Health Outcome	Unit of measurement	Magnitude of impact – units per TWh
Mining and milling	Public health: radiation	Collective dose	Man sievert	16.7
Mining and milling	Occupational health: radiation	Collective dose	Man sievert	0.7
		Fatal cancers	Deaths	0.028
		Non-fatal cancers	Cases	0.084
		Hereditary effects	Cases	0.0042
Conversion & fabrication	Public health: radiation	Collective dose	Man sievert	0.047
		Fatal cancers	Deaths	0.0024
		Non-fatal cancers	Cases	0.0057
		Hereditary effects	Cases	0.00047
Enrichment	Public health: radiation	Collective dose	Man sievert	5.60E-06
		Fatal cancers	Deaths	2.80E-07
		Non-fatal cancers	Cases	6.70E-07
		Hereditary effects	Cases	5.60E-08
Power generation	Public health: radiation	Collective dose	Man sievert	0.407
		Fatal cancers	Deaths	0.02
		Non-fatal cancers	Cases	0.049
		Hereditary effects	Cases	0.075
		Collective dose	Man sievert	0.028
		Fatal cancers	Deaths	0.011
		Non-fatal cancers	Cases	0.0034
		Hereditary effects	Cases	0.00017
	Accidents	Deaths	Cases	0.0032
		Severe injury	Cases	0.115
		Minor injury	Cases	1.181
Reprocessing	Public health: radiation	Collective dose	Man sievert	0.448
		Fatal cancers	Deaths	0.022
		Non-fatal cancers	Cases	0.054
		Hereditary effects	Cases	0.0045

The biomass cycle externalities

Table A.7. Main health impacts from generation of electricity by biomass

Fuel cycle stage & source of impact	Category of impact/Media	Health Outcome	Unit of measurement	Magnitude of impact – units per TWh	Comments
All stages	Occupational & Public accidents	Death	Cases	negligible	Accident cases are the sum of those estimated for the mining, transport, extraction, generation and dismantling stages.
		Severe injuries	Cases	negligible	
		Minor injuries	Cases	negligible	
Power Generation	Public health - acute effects: air pollution	'acute' mortality	[deaths] per TWh	0.13	The health impacts are the sum of those from individual pollutants SO ₂ , Particulates and Nitrogen Oxide.
		'acute' Years Of Life Lost (YOLL)	[years] per TWh	0.1	
		respiratory. hosp. admission	[cases] per TWh	0.258	
		Cerebrovascular hosp. Adm	[cases] per TWh	0.56	
		congestive heart failure	[cases] per TWh	0.25	
		Restricted. Activity days	[days] per TWh	1134	
		Bronchodilator usage (in asthmatic adults & children)	[cases] per TWh	430	
		Cough (in asthmatic adults & children)	[days] per TWh	492	
		Lower resp. symptoms (in asthmatic adults & children)	[days] per TWh	165.3	
	Public health - chronic effects: air pollution	'chronic' mortality	[deaths] per TWh	4.5	Sum, as for acute impacts.
		'chronic' YOLL	[years] per TWh	45.3	
		chronic bronchitis (adults)	[cases] per TWh	3.08	
		chronic bronchitis (children)	[cases] per TWh	42	
		chronic cough	[episodes] per TWh	54.78	

The hydro-energy externalities

Table A.8. Main health impacts from generation of electricity by hydro-energy

Fuel cycle stage & source of impact	Category of impact/Media	Health Outcome	Unit of measurement	Magnitude of impact – units per TWh	Comments
Construction	Occupational accidents	Death	Cases	0.000846	
		Severe injuries	Cases	0.0857	
		Minor injuries	Cases	1.117975	
Operation-generation	Occupational accidents	Death	Cases	0.000792	
		Severe injuries	Cases	0.080171	
		Minor injuries	Cases	1.045848	
Operation-transmission	Occupational accidents	Death	Cases	9.1E-06	
		Severe injuries	Cases	0.000922	
		Minor injuries	Cases	0.012021	

The Photovoltaic externalities

Table A.9. Main health impacts from generation of electricity from photo-voltaics

Fuel cycle stage & source of impact	Category of impact/Media	Health Outcome	Unit of measurement	Magnitude of impact – units per TWh	Comments
All stages	Occupational & Public accidents	Death	Cases	Negligible	Accident cases are the sum of those estimated for the mining, transport, extraction, generation and dismantling stages.
		Severe injuries	Cases	Negligible	
		Minor injuries	Cases	Negligible	
All stages	Public health - acute effects: air pollution	'acute' and 'chronic' mortality	[years] per TWh	13.04	The health impacts are the sum of those from individual pollutants SO ₂ , Particulates and Nitrogen Oxide.
		morbidity	Cases (of chronic bronchitis – equivalent) per TWh	1.3	

The wind cycle externalities

The ExternE Project considered wind energy to have the lowest level of impacts (health and environmental), of all the fuel cycles considered (CIEMAT 1998). For example, in Germany, the health impacts are 10% of those from coal per terawatt hour of electricity production. Clearly, these up-stream processes are dominant since no pollutants are emitted during power generation.

Table A.10. Main health impacts from generation of electricity from wind

Fuel cycle stage & source of impact	Category of impact/Media	Health Outcome	Unit of measurement	Magnitude of impact – units per TWh	Comments
All stages	Occupational & Public accidents	Death	Cases	Negligible	Accident cases are the sum of those estimated for the mining, transport, extraction, generation and dismantling stages.
		Severe injuries	Cases	Negligible	
		Minor injuries	Cases	Negligible	
All stages	Public health - acute effects: air pollution	'acute' and 'chronic' mortality	[years] per TWh	2.1	The health impacts are the sum of those from individual pollutants SO ₂ , Particulates and Nitrogen Oxide.
		morbidity	Cases (of chronic bronchitis – equivalent) per TWh	0.2	

The waste incineration fuel cycle externalities

The ExternE project also identified damage caused to roads, and road accidents, produced by the amount of transport involved in operating a MSW plant. In ExternE the effects of dioxins and furans were negligible when compared to those caused by NO_x and particulate emissions (CIEMAT 1998).

Table A.11. Main health impacts from generation of electricity from waste incineration

Fuel cycle stage & source of impact	Category of impact/Media	Health Outcome	Unit of measurement	Magnitude of impact – units per TWh	Comments
Transportation stages	Occupational accidents	Death	Cases	0.04	
		Severe injuries	Cases	4.33	
		Minor injuries	Cases	56.50	
	Public accidents	Death	Cases	0.01	
		Severe injuries	Cases	1.15	
		Minor injuries	Cases	15.03	
Power Generation	Public health: air pollution - TSP	'acute' and 'chronic' mortality	[years] per TWh	10.67	
	Public health: air pollution – SO ₂	'acute' and 'chronic' mortality	[years] per TWh	40.31	
	Public health: air pollution - NO _x	'acute' and 'chronic' mortality	[years] per TWh	216	
	Public health: all air pollution	Morbidity	Cases (of chronic bronchitis – equivalent) per TWh	38.76	

Annex 3

References

Chapter 1 – 3:

BOKENES, L. ET AL. Physiological and haematological responses to cold exposure in the elderly. *Int J Circumpolar Health*, **59**: 3-4:216-21 (2000).

BRUCE, N. ET AL. *The health effects of indoor air pollution exposure in developing countries*. World Health Organization, Protection of the Human Environment. Geneva 2002.

BRUCE, N. ET AL. Indoor air pollution in developing countries: a major environmental and public health challenge. *Bull WHO*, **78**: 1078-1092 (2000).

COMEAP (1998). *Quantification of the Effects of Air Pollution on Health in the UK*. Department of Health. The Stationery Office, London, United Kingdom.

COUNCIL OF THE EUROPEAN UNION. 1 June 1995. *Council resolution on the Green Paper 'For a European Union energy policy'*. (1995)

COUNCIL OF THE EUROPEAN UNION. *Council Resolution 98/C394/01 on energy efficiency in the European Community*, Brussels, Belgium (1998).

COUNCIL OF THE EUROPEAN UNION. *Proposal for a Directive relating to the Assessment and Management of Environmental Noise*. Brussels, 21 December (2000)

DANIELSSON, U. Windchill and the risk of tissue freezing. *J Appl Physiol*, **81**(6): 2666-2673 (1996).

DAVIS, RE. ET AL. Changing heat-related mortality in the United States. *Environmental Health Perspectives*, **111**(14): 1712–1718 (2003).

DEPARTMENT OF TRADE AND INDUSTRY'S ENERGY GROUP (DTI). *Energy its impact on the environment and society*. UK Department of Trade and Industry, 2002.

DEPARTMENT OF TRADE AND ENERGY, United Kingdom, (http://www.dti.gov.uk/energy/consumers/fuel_poverty/) accessed 3 June, 2004

ENERGY CHARTER SECRETARIAT (ECS). *The Energy Charter Treaty – a reader's guide*. ECS, Brussels, 2002.

EUROPEAN ENVIRONMENT AGENCY (EEA) *Renewable energies: success stories*. Environmental Issues Report No 27. EEA, Copenhagen, Denmark, 2001.

EUROPEAN ENVIRONMENT AGENCY (EEA). *Energy and environment in the European Union*. Environmental Issues Report No 31. EEA, Copenhagen, Denmark, 2002.

ERVASTI, O. ET AL. Sequelae of moderate finger frostbite as assessed by subjective sensations, clinical signs, and thermophysiological responses. *Int J Circumpolar Health* **59**(2): 137-145 (2000).

EUROPEAN COMMISSION. *Energy for the future: Renewable sources of energy*. White Paper for a Community strategy and action plan. COM(97) 30 final. Commission of the European Communities. Brussels, Belgium, 1997.

EUROPEAN COMMISSION. *Strengthening environmental integration within Community energy policy*. Communication from the Commission. COM(1998) 571 final. Commission of the European Communities. Brussels, Belgium, 1998.

EUROPEAN COMMISSION. *2001 annual energy review*. European Commission, Luxembourg, 2002.

EUROPEAN COMMISSION, *Final report on the Green Paper "Towards a European strategy for the security of energy supply"* COM(2002) 321 final.

EUROPEAN COMMISSION. *Proposal for a Council (Euratom) directive setting out basic obligations and general principles on the safety of nuclear installations. Proposal for a Council directive (Euratom) on the management of spent nuclear fuel and radioactive waste*. COM (2003) 32 final. Commission of the European Communities, Brussels, 2003.

EUROPEAN COMMISSION. *World energy, technology and climate policy outlook 2030*, WETO, Directorate General for Research, Commission of the European Communities, Brussels, 2003.

EUROPEAN COMMISSION. Information note: *Airborne particles and their health effects in Europe*. DG Environment, 2003.

EUROPEAN PARLIAMENT AND COUNCIL. *Directive 2001/77/EC on the promotion of electricity produced from renewable energy sources in the electricity market*. September, (2001).

EUROPEAN PARLIAMENT AND COUNCIL. *Decision 1600/2002/EC laying down the sixth Community environment action programme*, 2002.

EZZATI, M. ET AL. Indoor air pollution from biomass combustion and acute respiratory infections in Kenya: an exposure-response study. *Lancet* **358**: 619-624 (2001).

GOODWIN, J. ET AL. Seasonal cold, excursionsal behaviour, clothing protection and physical activity in young and old subjects. *Int J Circumpolar Health* 2000, **59**: (3-4), 195-203 (2000).

GRÜBLER, ET AL. Global Energy Perspectives: A Summary of the Joint Study by the International Institute for Applied Systems Analysis and World Energy Council. *Technological Forecasting and Social Change*. **51**: 237-264 (1996).

HEALY D. Excess winter mortality in Europe: a cross-country analysis identifying risk factors. *JECH*, **57**: 784-789 (2003).

HERPIN, U. ET AL. Second German heavy-metal survey by means of mosses, and comparison of the first and second approach in Germany and other European countries. *Environ Sci Pollut Res Int*, **11**(1): 57-66 (2004).

HOUGHTON, J.T. ET AL. eds. Climate change 2001: the scientific basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change. *Cambridge, Cambridge University Press*, (2001).

INTERNATIONAL ENERGY AGENCY (IEA). *Energy balances of OECD countries and energy balances of non-OECD countries*. IEA, Paris, 2002.

INTERNATIONAL ENERGY AGENCY. *World Energy Outlook*. Paris, France, 2003.

INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE (IPCC). *Third assessment report, summary for policy makers*. IPCC Working Group I, 2001.

MARTIN, J.M. L'Intensité Énergétique de L'Activité Économique dans Les Pays Industrialisé: Les Evolutions de Très Longue Periode Liverent-Elles des Enseignements Utiles? *Economies et Societé*, **4**: 9-27 (1988).

JUOPPERI, K. ET AL. Incidence of frostbite and ambient temperature in Finland, 1986-1995. A national study based on hospital admissions. *Int J Circumpolar Health* **61**(4): 352-362 (2002).

KEATINGE, W.R. ET AL. Changes in seasonal mortalities with improvement in home heating in England and Wales from 1964 to 1984. *Int J Biometeorol*, **33**(2): 71-6 (1989).

KLEIN, T. ET AL. *Climate of Europe: assessment of observed daily temperature and precipitation extremes*. De Bilt, the Netherlands, Royal Dutch Meteorological, 2002.

KOPPE, C. ET AL. *Heat-waves: risks and responses*. WHO Regional Office for Europe, Series No 2, Health and Global environment change. Kopenhagen, Denmark, 2004.

KUNST, A.E. ET AL. *The decline in winter excess mortality in the Netherlands*. Department of Public Health and Social Medicine, Erasmus University Medical School, Rotterdam, The Netherlands, (2002).

MADDISON, A. *Monitoring the World Economy*. OECD, Paris, 1995.

MANELIUS, J. Sequelae of moderate finger frostbite as assessed by subjective sensations, clinical signs, and thermophysiological responses. *Int J Circumpolar Health* **59**(2): 137-145 (2000).

MARKANDYA, A. Efficiency and Affordability Considerations In The Pricing Of Energy For Households, *Economic Journal of Development Issues*, 3, 2, 1-14 (2003).

MARKANDYA, A. & STREIMIKIENE, D. Efficiency and Affordability Considerations In The Pricing Of Energy For Households. *Economic Journal of Development Issues*, 3, 2, 1-14 (2003).
MEDINA, S. & CASAL, L. A. Oil spills and public health. *Gac Sanit.* **17**: 93 – 95 2003 (2003).

Ministry of Health, Armenia. *National environmental health profile of Armenia*. Yerevan, Ministry of health, 2003, pp. 30.

NEILD, P.J. ET AL. Cold-induced increases in erythrocyte count, plasma cholesterol and plasma fibrinogen of elderly people without a comparable rise in protein C or factor X. *Clin Sci (Lond)*. **86**(1): 43-8 (1994).

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT (OECD). *Environmental data compendium 1999*. OECD, Paris, 1999.

RANHOFF, A.H. Accidental hypothermia in the elderly. *Int J Circumpolar Health* **59**: (3-4), 255-259 (2000).

SMITH, K. & MEHTA, S. Burden of disease from indoor air pollution in developing countries: comparison of estimates. *International Journal of Hygiene and Environmental Health*, 206:279-289 (2003).

PRUSS, A & CORVALAN, C. *Methodology for Assessment of Environmental Burden of Disease*. WHO/SED/WSH/00.7: *Report on the ISEE session on environmental burden of disease*. Buffalo, 22 August 2000.

SMITH, K. ET AL. Indoor Smoke from Solid Fuels. In: Ezzati, M. et al.. *Comparative Quantification of Health Risks: Global and Regional Burden of Disease due to Selected Major Risk Factors*., World Health Organization, Vol.2. Geneva, Switzerland, 2003.

SMOLANDER, J. Effect of cold exposure on older humans. *Int J Sports Med*, **23**(2): 86-92 (2002).

STOUT, R.W. ET AL. Seasonal changes in haemostatic factors in young and elderly subjects. *Age Ageing*, **25**(3): 256-8 (1996).

THE EUROWINTER GROUP. Cold exposure and winter mortality from ischaemic heart disease, cerebrovascular disease, respiratory disease, and all causes in warm and cold regions of Europe. *Lancet*. **10**;349(9062):1341-6 (1997).

THORPE, T. ET AL. Benign Energy? The Environmental Implications of Renewables. *OECD/IEA Publications* 1998.

KYZANOVSKI, M. *Human health and the environment*. In: Environmental performance review of Kyrgyzstan. UN, New York, United States of America. (2000).

MENNE, B. & RACIOPPI, F. *Human health and the environment*. In: Environmental performance review of Uzbekistan. UN New York, United States of America. (2001).

UN (United Nations). *World Summit on Sustainable Development — Plan of implementation*. UN, Johannesburg. (2002)

VALENT ET AL (2004) Burden of disease attributable to selected environmental factors and injuries among Europe's children and adolescents. *BMJ*, forthcoming

WANG, L. ET AL *Lives Saved from Environmental Conditions: A Projection*. World Bank Environment Department Paper. World Bank: Washington DC, 2003.

WILBY, R.L. Past and projected trends in London's urban heat island. *Weather*, 58:251–260. (2003).

WOODHOUSE, P.R. ET AL. Seasonal variation of blood pressure and its relationship to ambient temperature in an elderly population. *J Hypertens*, 11(11): 1267-74 (1993).

WOODS, R. The Demography of Victorian England and Wales. *Cambridge: CUP, 2000 and http://www.efpia.org/1_efpia/Pharmainnovation.htm*. (2000).

WORLD BANK ENVIRONMENT DEPARTMENT PAPER. World Bank: Washington DC. (2003).

WORLD BANK, 2003. *World development indicators 2003*. The World Bank.

WORLD BANK. *Coping With the Cold*. World Bank. Technical Paper No 529, 2002.

WORLD HEALTH ORGANIZATION. REGIONAL OFFICE FOR EUROPE. *Concern for Europe tomorrow*. Health and the environment in the WHO European Region. Wissenschaftliche Verlagsgesellschaft, Stuttgart. Germany. P. 282 (1995).

WORLD HEALTH ORGANIZATION. *Protection of the Human Environment. Air Quality Guidelines*. (http://www.who.int/environmental_information/Air/Guidelines/Chapter4.htm#_Toc480011108). Last accessed August 14, 2003. Geneva, 1999.

WORLD HEALTH ORGANIZATION. *The World Health Report 2002*. Geneva, WHO, 2002.

WORLD HEALTH ORGANIZATION. REGIONAL OFFICE FOR EUROPE. *Data from the Pan-European Housing and Health survey*. WHO ECEH Bonn Office, Noise and Housing Unit. (<http://www.euro.who.int/Housing/>) (2004).

WU, X. ET AL. Coping with the Cold: Space Heating and the Urban Poor in Developing Countries, forthcoming. *Energy Economics*. (2004).

Chapter 4 and 5:

ABBEY, D. E. ET AL. Long-term ambient concentrations of total suspended particulates, ozone and sulphur dioxide and respiratory symptoms in a non-smoking population. *Archives of Environmental Health* 48(1): 33-46 (1993).

AHLBOM, A. ET AL. Review of the epidemiologic literature on EMF and Health. *Environmental Health Perspectives* 109(Suppl 6): 911-33 (2001).

AHLBOM, A. ET AL. A pooled analysis of magnetic fields and childhood leukaemia. *British Journal of Cancer* 83(5): 692-8 (2000).

ALLABY, A. & ALLABY, M. EDS. A Dictionary of Earth Sciences. Oxford Reference Online. Oxford, Oxford University Press, 1999.

ASOGWA, S. E. The health benefits of mechanization at the Nigerian Coal Corporation. *Accident Analysis and Prevention*, **20**(2): 103-8 (1988).

AU, W. W. ET AL. Biomarker monitoring of a population residing near uranium mining activities. *Environmental Health Perspectives* **103**(5): 466-70 (1995).

AU, W. W. ET AL. Population monitoring: experience with residents exposed to uranium mining/milling waste. *Mutation Research* **405**(2): 237-45 (1998).

BATES, D. V. *Introduction*. In: Air pollution and health. Holgate, S. T. et al. eds., San Diego, Academic Press. (1999).

EVERY, A. J ET AL. The mental and physical health of miners following the 1992 national pit closure programme: a cross-sectional survey using General Health Questionnaire GHQ-12 and Short Form SF-36. *Public Health* **112**(3): 169-73 (1998).

BEECKMAN, L. A. ET AL. Rapid declines in FEV1 and subsequent respiratory symptoms, illnesses, and mortality in coal miners in the United States. *American Journal of Respiratory and Critical Care Medicine* **163**(3): 633-9 (2001).

BELL, J. L. ET AL. Slip and fall-related injuries in relation to environmental cold and work location in above-ground coal mining operations. *American Journal of Industrial Medicine* **38**(1): 40-8 (2000).

BOBAK, M. ET AL. Air pollution and infant mortality in the Czech Republic 1986-88. *The Lancet* **340**(8826): 1010-4 (1992).

BRAIN, J. D. ET AL. Childhood leukaemia: electric and magnetic fields as possible risk factors. *Environmental Health Perspectives*, **111**(7): 962-70 (2003).

BRAUN-FAHRLÄNDER, C. ET AL. Respiratory health and long-term exposure to air pollutants in Swiss schoolchildren. SCARPOL Team. Swiss Study on Childhood Allergy and Respiratory Symptoms with Respect to Air Pollution, Climate and Pollen. *American Journal of Respiratory and Critical Care Medicine* **155**(3): 1042-9 (1997).

BRUCE, N. ET AL. Indoor air pollution in developing countries: a major environmental and public health challenge. *Bulletin of the World Health Organization*, **78**(9): 1078-1092 (2000).

BTM CONSULT. *International Wind Energy Development: World Market Update 1998*. Denmark, 1999.

BURNETT, R. T. ET AL. Association between ambient carbon monoxide levels and hospitalisations for congestive heart failure in the elderly in 10 Canadian cities. *Epidemiology* **8**(2): 162-7 (1997).

BURNETT, R. T. ET AL. Associations between ambient particulate sulfate and admissions to Ontario hospitals for cardiac and respiratory diseases. *American Journal Of Epidemiology*, **142**(1): 15-22 (1995).

CHARPIN, D. ET AL. Repercussions cliniques et spirometriques d'une exposition chronique aux polluants atmospheriques chez des enfants de la region du bassin de Gardanne [Clinical and spirometric repercussions of chronic exposure to air pollutants in children in the region of the Gardanne coal-basin]. *Revue de pneumologie clinique*, **44**(2): 64-7 (1988).

CIEMAT. ExternE Externalities of Energy - National Implementation. A research project of the European Commission. *European Commission*. (<http://externe.jrc.es/All-EU+Summary.htm>) (1998).

DAB, W. ET AL. Short-term respiratory health effects of ambient air pollution: results of the APHEA project in Paris. *Journal of Epidemiology and Community Health* **50**(Suppl 1): S42-S46 (1996).

DOCKERY, D. W. ET AL. Health effects of acid aerosols on North American children: respiratory symptoms. *Environmental Health Perspectives* **104**(5): 500-5 (1996).

DOCKERY, D. W. & POPE, C. A. Acute respiratory effects of particulate air pollution. *Annual Review of Public Health*. **15**: 107-32 (1994).

DOCKERY, D. W. ET AL. An association between air pollution and mortality in six US cities. *New England Journal of Medicine*, **329**(24): 1753-59 (1993).

DOCKERY, D. W. ET AL. Effects of inhalable particles on respiratory health of children. *American Review of Respiratory Disease*, **139**(3): 587-94 (1989).

DUSSELDORP, A. ET AL. Associations of PM₁₀ and airborne iron with respiratory health of adults living near a steel factory. *American Journal of Respiratory and Critical Care Medicine*, **152**(6): 1932-9 (1995).

ENDERLE, G. J. & FRIEDRICH, K. East German uranium miners (Wismut)--exposure conditions and health consequences. *Stem Cells* **13**(Suppl 1): 78-89 (1995).

EUROPEAN ENVIRONMENT AGENCY. *Environmental assessment report, No. 10. Europe's environment: the third assessment*. Copenhagen, European Environment Agency: 341 (2003).

EZZATI, M. ET AL. Selected major risk factors and global and regional burden of disease. *Lancet*, **360**: 1347-60 (2002).

FATKOVA, R. Carcinoma of the pancreas in patients at the National Health Institute of the Pribram Uranium Industry 1975-1987. *Casopis lekaru ceskych* **128**(30): 945-8 (1989).

FEYCHTING, M. ET AL. Occupational magnetic field exposure and neurodegenerative disease. *Epidemiology* **14**(4): 413-9 (2003).

FOLIART, D. E. ET AL. Alternative magnetic field exposure metrics: relationship to TWA, appliance use, and demographic characteristics of children in a leukaemia survival study. *Bioelectromagnetics* **22**(8): 574-80 (2001).

FOX, J. Power generation and Distribution. Chapter 76 - Electric power generation, transmission and distribution safety: a U.S. example. *Encyclopaedia of Occupational Health and Safety*. J. M. Stellman. Geneva, International Labour Office. **3**: 76.14-76.15 (1998).

GIELEN, M. H. ET AL. Acute effects of summer air pollution on respiratory health of asthmatic children. *American Journal of Respiratory and Critical Care Medicine* **155**(6): 2105-8 (1997).

GILLILAND, F. D. ET AL. "Radon progeny exposure and lung cancer risk among non-smoking uranium miners." *Health Physics* **79**(4): 365-72. (2000).

GILSON, J. C. Occupational bronchitis? *Proceedings of the Royal Society of Medicine* **63**(9): 857-64 (1970).

GOLDEMBERG, J. ET AL. World Energy Assessment: Energy and the challenge of sustainability. New York, United Nations Development Programme. (<http://www.undp.org/seed/eap/activities/wea/>) 2000.

GREENLAND, S. ET AL. A pooled analysis of magnetic fields, wire codes, and childhood leukaemia. Childhood Leukaemia-EMF Study Group. *Epidemiology* **11**(6): 624-34 (2001).

GUPTA, A. & ASHER, M.. Environment and the developing world. New York, John Wiley & Sons. (1998)

HAKANSSON, N. ET AL. Neurodegenerative diseases in welders and other workers exposed to high levels of magnetic fields. *Epidemiology* **14**(4): 420-6 (2003).

HARRISON, R. M. *Measurements of concentrations of air pollutants*. In: Air pollution and health. Holgate, S. T. et al. San Diego, Academic Press (1999).

HENNEBERGER, P. K. & ATTFIELD, M. D. Respiratory symptoms and spirometry in experienced coal miners: effects of both distant and recent coal mine dust exposures. *American Journal of Industrial Medicine* **32**(3): 268-74 (1997).

HIGGINS, B. G. ET AL. Effects of air pollution on symptoms and peak expiratory flow measurements in subjects with obstructive airways disease. *Thorax* **50**(2): 149-55 (1995).

HILTERMANN, T. J. ET AL. Asthma severity and susceptibility to air pollution. *European Respiratory Journal* **11**(3): 686-93 (1998).

HOLDREN, J. P. & SMITH, K. R. Energy, the environment and health. Chapter 3 in World Energy Assessment: Energy and the challenge of sustainability. J. Goldemberg. New York, UNDP: 61-110 (2000).

HOLMAN, C. *Sources of air pollution*. In: Air pollution and health. Holgate, S. T. et al. San Diego, Academic Press (1999).

HORNUNG, R. W. Health effects in underground uranium miners. *Occupational Medicine* **16**(2): 331-44 (2001).

HORNUNG, R. W. ET AL. Modifiers of lung cancer risk in uranium miners from the Colorado Plateau. *Health Physics* **74**(1): 12-21 (1998).

HORNUNG, R. W. & MEINHARDT, T. J. Quantitative risk assessment of lung cancer in U.S. uranium miners. *Health Physics* **52**(4): 417-30 (1987).

HUNTING, K. L. & WEEKS, J. L. Transport injuries in small coal mines: an exploratory analysis. *American Journal of Industrial Medicine* **23**(3): 391-406 (1993).

IARC Working Group on the Evaluation of Carcinogenic Risks to Humans. Non-ionizing radiation, Part 1: Static and extremely low-frequency (ELF) electric and magnetic fields. Lyon, France, IARC (2002).

IARC. Cadmium And Cadmium Compounds. VOL.: 58 (1993) (p. 119) (1993).

IARC. Mercury and its compounds. VOL.: 58 (1993) (p. 239) (1993).

IARC. Coal Gasification VOL.: 34 (p. 65) (1984)

IIED. *Final Report - Mining, Minerals and Sustainable Development. The results of a scoping project for the World Business Council for Sustainable Development.* London, International Institute for Environment and Development: 20 (1999).

IMAI, M. ET AL. Mortality from asthma and chronic bronchitis associated with changes in sulphur oxides air pollution. *Archives of Environmental Health* **41**(1): 29-35 (1986).

IPCC, I. P. o. C. C. *Climate change 2001: Impacts, Adaptation and Vulnerability. Contributions of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge, Cambridge University Press (2001).

ISAACS, A., ED. *A Dictionary of Physics. Oxford Reference Online.* Oxford, Oxford University Press (2000).

JOHNSSON, A. & MILD, K. H. *Electromagnetic fields - a threat to children's health?* Children and radiation. Selected topics raised at an international conference. T. Christensen and S. Stephens, Norwegian Centre for Child Research, Trondheim, Norway. (2000).

KATSOUYANNI, K. ET AL. Short term effects of ambient sulphur dioxide and particulate matter on mortality in 12 European cities: results from time series data from the APHEA project. *BMJ* **314**(7095): 1658 (1997).

KAUNE, W. T. ET AL. Development of a protocol for assessing time-weighted-average exposures of young children to power-frequency magnetic fields. *Bioelectromagnetics* **15**(1): 33-51 (1994).

KAUNE, W. T. & ZAFFANELLA, L. E. Assessing historical exposures of children to power-frequency magnetic fields. *Journal of exposure analysis and environmental epidemiology* **4**(2): 149-70 (1994).

KAVET, R. ET AL. The possible role of contact current in cancer risk associated with residential magnetic fields. *Bioelectromagnetics* **21**(7): 538-53 (2000).

KHEIFETS, L. I. ET AL. Childhood brain tumours and residential electromagnetic fields (EMF). *Reviews of Environmental Contamination and Toxicology* **159**: 111-29 (1999).

KOVATS, R.S. ET AL. Heatwave of August 2003 in Europe: provisional estimates of the impact on mortality. *Eurosurveillance Weekly* (2004).

KOVATS, R.S. ET AL. Climate change and human health in Europe. *BMJ*. **318**: 1682-1685 (1999).

KREUZER, M. ET AL. The German uranium miners cohort study: feasibility and first results. *Radiation Research*. **152**(Suppl 6): S56-8 (1999).

KÜNZLI, N. ET AL. Public health impact of outdoor and traffic-related air pollution: a European assessment. *The Lancet* **356**: 795-801 (2000).

LAMBERT, B. E. The adequacy of current occupational standards for protecting the health of nuclear workers. *Occupational Medicine*. **6**(4): 725-39 (1991).

LANGHOLZ, B. ET AL. Latency analysis in epidemiologic studies of occupational exposures: application to the Colorado Plateau uranium miners cohort. *American Journal of Industrial Medicine* **35**(3): 246-56 (1999).

LEE, G. M. ET AL. A nested case-control study of residential and personal magnetic field measures and miscarriages. *Epidemiology*. **13**(1): 21-31 (2002).

LEE, T. ET AL. Acute traumatic injuries in underground bituminous coal miners. *American Journal of Industrial Medicine*. **23**(3): 407-15 (1993).

LI, C. Y. & SUNG, F. C. Association between occupational exposure to power frequency electromagnetic fields and amyotrophic lateral sclerosis: a review. *American Journal of Industrial Medicine*. **43**(2): 212-20 (2003).

LI, D. K. ET AL. A population-based prospective cohort study of personal exposure to magnetic fields during pregnancy and the risk of miscarriage. *Epidemiology* **13**(1): 9-20 (2002).

LINET, M. S. ET AL. Residential exposure to magnetic fields and acute lymphoblastic leukaemia in children. *New England Journal of Medicine*. **337**(1): 1-7 (1997).

LOVE, R. G. ET AL. Respiratory health effects of opencast coalmining: a cross sectional study of current workers. *Occupational and Environmental Medicine*. **54**(6): 416-23 (1997).

MCBRIDE, M. L. ET AL. Power-frequency electric and magnetic fields and risk of childhood leukaemia in Canada. *American Journal of Epidemiology*. **149**(9): 831-42 (1999).

MCMANUS, N. Power generation and distribution. Chapter 76 - Hydroelectric power generation. *Encyclopaedia of Occupational Health and Safety*. J. M. Stellman. Geneva, International Labour Organisation. **3**: 76.2-76.6 (1998).

MCMICHAEL A.J. ET AL. *Human Population Health*, in R.T. Watson, M.C. Zinwera and R.H. Moss, eds., *Climate Change 1995: Impacts, Adaptations and Mitigation of Climate Change –*

Scientific Analyses – Contribution of Working Group II to the Second Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press, pp 561-584. (1996)

MCMICHAEL, A. J. & HAINES, A. Global climate change: the potential effects on health. *BMJ* **315**(7111): 805-9 (1997).

MCMICHAEL, ET AL. Climate change and health: risks and responses. World Health Organization, 2003.

MARTENS W.J.M. Climate Change, Thermal Stress and Mortality Changes, *Social Science and Medicine* **46**(3), 331-344 (1998).

MEDINA, S. ET AL. *Evaluation des Risques de la Pollution Urbaine sur la Santé (ERPURS). Analyse des liens à court terme entre pollution atmosphérique et santé: resultats*. 1991-95. Paris, Conseil Regional d'Ile de France. (1997).

MMSD. *Breaking Ground: Mining, Minerals and Sustainable Development*. The Report of the MMSD Project. London, International Institute for Environment and Development, and World Business Council for Sustainable Development. (2002).

NEDVIDEK, A. ET AL. Sociological study of the Czechoslovak uranium industry. *Ceskoslovenske zdravotnictvi*. **30**(3): 102-6 (1982).

NEUKIRCH, F. ET AL. Short-term effects of low-level winter pollution on respiratory health of asthmatic adults. *Archives of Environmental Health*. **53**(5): 320-8 (1998).

NEWCOMBE, H. B. ET AL. Reliability of computerized versus manual death searches in a study of the health of Eldorado uranium workers. *Computers in biology and medicine*. **13**(3): 157-69 (1983).

NRPB. *ELF electromagnetic fields and neurodegenerative disease*. Report of an Advisory Group on Non-Ionising Radiation. Chilton, UK, National Radiological Protection Board. (2001)

NRPB. *ELF electromagnetic fields and the risks of cancer*, Report of an Advisory Group on Non-Ionising Radiation. Chilton, UK, National Radiological Protection Board. (2001).

OSTRO, B. D. Associations between morbidity and alternative measures of particulate matter. *Risk Analysis* **10**(3): 421-27 (1990).

OSTRO, B. D. & ROTHCHILD, S. Air pollution and acute respiratory morbidity: an observational study of multiple pollutants. *Environmental Research*. **50**(2): 238-47 (1989).

OUP. *A Dictionary of Chemistry*. Oxford Reference Online. Oxford, Oxford University Press. Online. (2000).

OUP. *World Encyclopaedia*. Oxford Reference Online. Oxford, Oxford University Press. (2002).

PEARSON, J. Hazard visibility and occupational health problem solving the case of the uranium industry. *Journal of Community Health*. **6**(2): 136-47 (1980).

PITTMAN, A. C. Power generation and distribution. *Chapter 76 - Environmental and public health issues. Encyclopaedia of Occupational Health and Safety. J. M. Stellman. Geneva, International Labour Office*. **3**: 76.16-76.17 (1998).

PLESS-MULLOLI, T. ET AL. Living near opencast coal mining sites and children's respiratory health. *Occupational and Environmental Medicine* **57**(3): 145-51 (2000).

POLEDNAK, A. P. & FROME, E. L. Mortality among men employed between 1943 and 1947 at a uranium- processing plant. *Journal of Occupational Medicine*. **23**(3): 169-78 (1981).

POLONIECKI, J. D. ET AL. Daily time series for cardiovascular hospital admissions and previous day's air pollution in London, U.K. *Occupational and Environmental Medicine*. **54**(8): 535-40 (1997).

PONCE DE LEON, A. ET AL. Effects of air pollution on daily hospital admissions for respiratory disease in London between 1987-88 and 1991-92. *Journal of Epidemiology and Community Health*. **50**(Suppl 1): S63-S70 (1996).

POPE, C. A. ET AL. Particulate air pollution as a predictor of mortality in a prospective study of U.S. adults. *American Journal of Respiratory and Critical Care Medicine*. **151**(3): 669-74 (1995).

PORTIER, C. J. & WOLFE, M. S. Assessment of health effects of exposure to powerline frequency electric and magnetic fields. *National Institutes of Health Working Group Report*. (1998).

PRESCOTT, G. J. ET AL. Urban air pollution and cardiopulmonary ill health: a 14.5 year time series study. *Occupational and Environmental Medicine*. **55**(10): 697-704 (1998).

ROEMER, W. ET AL. Effect of ambient winter air pollution on respiratory health of children with chronic respiratory symptoms. *American Review of Respiratory Disease*. **147**(1): 118-24 (1993).

ROGNER, H. H. *Energy resources. Chapter 5 in World Energy Assessment: Energy and the challenge of sustainability. J. Goldemberg. New York, UNDP*: 135-171. (2000).

ROSCOE, R. J. An update of mortality from all causes among white uranium miners from the Colorado Plateau Study Group. *American Journal of Industrial Medicine*. **31**(2): 211-22 (1997).

ROSCOE, R. J. ET AL. Lung cancer mortality among non-smoking uranium miners exposed to radon daughters. *Journal of the American Medical Association*. **262**(5): 629-33 (1989).

ROSSI, O. V. ET AL. Association of severe asthma attacks with weather, pollen, and air pollutants. *Thorax*. **48**(3): 244-8 (1993).

SAVITZ, D. A. Commentary: Magnetic fields and miscarriage. *Epidemiology*. **13**(1): 9-20 (2002).

SCHLESINGER, R. B. *Toxicology of Sulphur Oxides*. In: Air pollution and health Holgate, S. T. et al. San Diego, Academic Press (1999).

SCHOUTEN, J. P. ET AL. Short-term effects of air pollution on emergency hospital admissions for respiratory disease: results of the APHEA project in two major cities in The Netherlands, 1977-89. *Journal of Epidemiology and Community Health*. **50**(Suppl 1): S22-S29 (1996).

SCHUTTMANN, W. Schneeberg lung disease and uranium mining in the Saxon Ore Mountains (Erzgebirge). *American Journal of Industrial Medicine*. **23**(2): 355-68 (1993).

SCHÜZ, J. ET AL. Extremely low frequency magnetic fields in residences in Germany. Distribution of measurements, comparison of two methods for assessing exposure, and predictors for the occurrence of magnetic fields above background level. *Radiation and Environmental Biophysics*. **39**(4): 233-40 (2000).

SCHWARTZ, J. & MORRIS, R. Air pollution and chronic respiratory disease. *Environmental Research* **62**: 7-13 (1995).

SCOTT, M. & GUPTA, S. Human Settlements, Energy, and Industry. Chapter 7 in Climate Change 2001: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change. J. J. McCarthy, O. F. Canziani, N. A. Leary, D. J. Dokken and K. S. White. *Cambridge, Cambridge University Press*. **2**: 381-416 (2001).

SEGALA, C. ET AL. Short-term effect of winter air pollution on respiratory health of asthmatic children in Paris. *European Respiratory Journal*. **11**(3): 677-85 (1998).

SHIELDS, L. M. ET AL. Navajo birth outcomes in the Shiprock uranium mining area. *Health Physics*. **63**(5): 542-51 (1992).

SHUMWAY, R. H. ET AL. Modelling mortality fluctuations in Los Angeles as functions of pollution and weather effects. *Environmental Research*. **45**: 224-242 (1998).

SOUTAR, C. A. & HURLEY, J. F. Relation between dust exposure and lung function in miners and ex- miners. *British Journal of Industrial Medicine*. **43**(5): 307-20 (1986).

SPIX, C. ET AL. Short-term effects of air pollution on hospital admissions of respiratory diseases in Europe: a quantitative summary of APHEA study results. Air Pollution and Health: a European Approach. *Archives of Environmental Health*. **53**(1): 54-64 (1998).

STEPHENS, C. & AHERN, M. J. Worker and Community Health Impacts Related to Mining Operations Internationally. A Rapid Review of the Literature. *London, Mining and Minerals for Sustainable Development Project*.
(http://www.iiied.org/mmsd/mmsd_pdfs/worker_community_health_impacts_literature_review.pdf) 59 (2001).

SUNYER, J. ET AL. Air pollution and mortality in Barcelona. *Journal of Epidemiology and Community Health*. **50**(Suppl 1): S76-S80 (1996).

TENFORDE, T. S. *Biological interactions and potential health effects of static and ELF fields*. ICNIRP. Non-Ionizing Radiation. Executive summary of the 4th International Non-Ionizing Radiation Workshop, Kyoto, Japan, ICNIRP. (2000).

TOL R.S.J. *Estimates of the Damage costs of Climate Change Part 1: Benchmark Estimates. Environmental and Resource Economics*. 21: 47-73 (2002)

TOMASEK, L. ET AL. Patterns of lung cancer mortality among uranium miners in West Bohemia with varying rates of exposure to radon and its progeny. *Radiation Research*. **137**(2): 251-61 (1994).

TOULOUMI, G. ET AL. Short-term effects of ambient oxidant exposure on mortality: a combined analysis within the APHEA project. Air Pollution and Health: a European Approach. *American Journal Of Epidemiology*. **146**(2): 177-85 (1997).

TOULOUMI, G. ET AL. Daily mortality and 'winter type' air pollution in Athens, Greece- a time series analysis within the APHEA project. *Journal of Epidemiology and Community Health* **50**(suppl 1): S47-S51 (1996).

TURKENBURG, W. C. Renewable energy technologies. Chapter 7 in World Energy Assessment: Energy and the challenge of sustainability. J. Goldemberg. New York, United Nations Development Programme: 219-272 (2000).

UK Department of Health. *Health Effects of Climate Change in the UK*. London. (2001).

UNSCEAR. *Sources and Effects of Ionizing Radiation*. UNSCEAR 2000 Report to the General Assembly, with scientific annexes: Volume I and II. Geneva, UNSCEAR (United Nations Scientific Committee on the Effects of Atomic Radiation). (2000).

VIGOTTI, M. A. ET AL. Short-term effects of urban air pollution on respiratory health in Milan, Italy, 1980-89. *Journal of Epidemiology and Community Health*. **50**(Suppl 1): S71-S75 (1996).

WALTERS, S. ET AL. Hospital admission rates for asthma and respiratory disease in the West Midlands: their relationship to air pollution levels. *Thorax*. **50**(9): 948-54 (1995).

WATSON, A. P. & WHITE, C. L. Workplace injury experience of female coal miners in the United States. *Archives of Environmental Health*. **39**(4): 284-93 (1984).

WBGU. *World in Transition. Towards sustainable energy systems*. Summary for Policy Makers. Berlin. Germany. 2003. <http://www.wbgu.de>

WERTHEIMER, N. & LEEPER, E. Electrical wiring configurations and childhood cancer. *American Journal of Epidemiology*. **109**(3): 273-84 (1979).

WHITTEMORE, A. S. & KORN, E. L. Asthma and air pollution in the Los Angeles area. *American Journal of Public Health*. **70**(7): 687-96 (1980).

WOODWARD, A., D. ET AL. Radon daughter exposures at the Radium Hill uranium mine and lung cancer rates among former workers, 1952-87. *Cancer Causes Control* **2**(4): 213-20 (1991).

WORDLEY, J., S. ET AL. Short term variations in hospital admissions and mortality and particulate air pollution. *Occupational and Environmental Medicine*. **54**(2): 108-116 (1997).

WORLD COMMISSION ON DAMS. *Dams and Development: A new framework for decision-making*. The Report of the World Commission on Dams. London, Earthscan Publications Ltd. 2000).

WORLD HEALTH ORGANISATION. *WHO Commission on Health and Environment*. Report of the Panel on Energy. WHO/EHE/92.3. Geneva, World Health Organisation (1992).

WORLD HEALTH ORGANIZATION. *Early human health effects of climate change*. Report on WHO workshop. Copenhagen, 1998. (1999).

WORLD HEALTH ORGANISATION. *Air Quality Guidelines for Europe*. Copenhagen, World Health Organisation, Regional Office for Europe. (2000)

WORLD HEALTH ORGANIZATION. The World Health Report 2002. Geneva, WHO, 2002.

ZAFFANELLA, L. E. & KALTON, G. W. Survey of personal magnetic field exposure: 1000-person survey, *EMF RAPID Engineering Project No 6. Final report, Eneritech Consultants*. (1998).