WIND ENERGY - THE FACTS

VOLUME 4

ENVIRONMENT

Acknowledgments

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1 INTRODUCTION TO VOLUME 4 - ENVIRONMENT

Sustainable development is an issue of prime importance both now and in the future. As defined by the Brundtland Commission in 1987, sustainable development is *"development that meets the needs of the present without compromising the ability of future generations to meet their own needs"* (World Commission for Environment and Development, 1987).

Environmental pollution and emissions of CO_2 caused by the use of fossil fuels constitute a significant threat to sustainable development. A major contributor to these emissions is electricity generation based on fossil fuels. The Intergovernmental Panel on Climate Change (IPCC) predicted in its last report (IPCC, 2001) that human-induced greenhouse gas (GHG) emissions will lead to a substantial increase in GHG concentrations in the atmosphere causing increased radiative forcing, with CO_2 contributing about 50% to this anthropogenic greenhouse effect. Without drastic emission reductions of CO_2 and other GHGs a significant change in the world's climate is inevitable unless energy systems and sources are changed as soon as possible. In addition to the problem of climate change, emissions of SO_2, NO_x and other pollutants from energy conversion processes in conventional electricity generation cause substantial regional damage to human health and the environment.

As most renewable energy sources, such as wind power, emit neither GHGs nor other pollutants such as SO_2 or NO_x, they will be the basis of any long-term sustainable energy supply system (Fischedick *et al.*, 2000). The large-scale use of renewable energy sources is essential if the necessary reductions in CO_2 and other emissions from electricity generation are to be met and if sustainable development is to be achieved.

The following chapters provide a summary of our current understanding of the direct and indirect environmental impacts associated with wind energy, as well as its economic (external) costs and those associated with avoiding the environmental and health impacts of conventional electricity generation by substitution with wind energy. Public acceptance of wind energy is crucial for its successful introduction. Thus, a public acceptance analysis is included in this volume, showing the main elements affecting public acceptance along with the results of some recent surveys from a selected number of EU countries.

In the first part of this volume, the concept of the external cost of energy is introduced. As environmental and health costs caused by energy conversion processes are not taken into account in the calculations of the producer or consumer of energy, economists call these costs "externalities". Analysis of these externalities enables the environmental and health benefits of wind energy compared to fossil fuels to be expressed in economic terms.

Subsequently, the benefits of wind energy are discussed. In contrast to fossil fuel fired power plants, wind energy converters cause virtually no operational emissions. There may be minor losses of lubricants from the turbine gearbox but these do not normally find their way into the environment. Being a clean energy source is the main advantage of wind energy when compared to conventional electricity generation. Indirect emissions, which result from manufacturing, installation, maintenance and removal, do play a very small part in this equation. Nevertheless, these have been taken into account in our analysis.

By means of external cost analysis, it is possible to quantify the environmental and health costs of the different electricity generation technologies. To compare the external costs of wind energy and of the substituted conventional electricity generation, we need to analyse and calculate them. The net avoided external costs of wind power are the external monetary benefits of wind energy. Only if we combine these with a comparison of the internal costs of wind energy and conventional electricity generation substituted do we get a fair picture of the competitive situation of wind energy.

In chapter 1, a review of the external cost concept is given. In chapter 2.1 a short description of the background for the calculations of avoided emissions and avoided external costs from the use of wind energy in the EU and in new member states is presented. In chapter 2.2, a short overview of electricity generation structure in each country, as well as a very brief description of the national environmental policy frameworks is given. In this chapter the total and specific emissions of CO_2, NO_x and SO_2 are given for each country.

Calculations of external costs of standard air pollutants are performed by the EcoSense model, which has been developed as part of a major European Commission research effort on the analysis of external energy costs. This model is briefly introduced in chapter 2.3, but a short description of the input data and modelling assumptions used are given here. Chapter 2.4 reports on the emissions and external costs which can be avoided by extending the use of wind energy in the EU and in the new member countries (Turkey, Romania and Bulgaria are also included). These are reported as total as well as specific values.

To facilitate a comparison of future and present calculations of emission and external cost reductions due to the use of wind energy, a standard methodology for calculating emission reductions has been designed. This is reported in chapter 3.

Based on the future diffusion of wind energy on the one hand and on improvements in conventional electricity-generating technologies on the other, mid- and long-term emission reductions are forecast in chapter 4.

Chapters 5 and 6 report the public debate on wind energy, as far as this has been subject to scientific research and as far as the results of this research are available. The debate considers such issues as visual intrusion, noise, and interference with birds, and their influence on public acceptance.

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1 EXTERNALITIES

1.1 Introduction to Externalities

The economics of wind energy show that the capital costs, O&M costs, taxes, insurance and other costs, along with the expected profit, comprise the price of a kWh of electricity. Depending on the market situation and, perhaps, additional promotional measures, wind energy may or may not be competitive. It is generally appreciated that although wind energy and other renewable energy sources have environmental benefits compared to conventional electricity generation, these benefits may not be fully reflected in electricity market prices. The question therefore is: "Do market prices for electricity give an appropriate representation of the full costs to society of producing electricity?"

The externalities of energy generation deal with these questions in order to estimate the hidden benefits/damages of electricity production not accounted for in the existing pricing system. The costs are "external" because they are paid for by third parties and by future generations. In order to establish a fair comparison of the different electricity production activities, all costs to society, both internal and external, need to be taken into account.

The following sections explain the basic concepts and describe present knowledge about the external costs of electricity generation. Chapter 2 will report on specific external costs, which can be avoided in the EU by the use of wind energy.

1.2 Definition and Classification

Looking at the foundations of externalities, the different definitions and interpretations are based upon the principles of welfare economics, which state that economic activities by any party or individual making use of scarce resources cannot be beneficial if they adversely affect the well-being of a third party or individual (Energy Information Administration, 1995).

From this, a generic definition of externalities is *"benefits and costs which arise when the social or economic activities of one group of people have an impact on another, and when the first group fails to fully account for their impacts"* (European Commission, 1994). Externalities are not included in the market pricing calculations and it can be concluded that private calculations of benefits or costs may differ substantially from society's valuation if substantial external costs occur.

Externalities can be classified according to their benefits or costs in two main categories: non-environmental and environmental externalities. Table 1.1 lists examples of these externalities of energy conversion (European Commission 1994; Centre for Energy, Policy and Technology, 2001):

Table 1.1: Classification of Externalities

Environmental and Human Health	Non–Environmental
• Human health (accidents, disease)	• Subsidies
• Occupational health (accidents, noise, physical stress)	• Research and development costs
• Amenity impacts (noise, visual impacts, odor)	• Employment
• Security and reliability of supply	• Effects on GDP
• Ecological impacts (acidification, eutrophication, soil quality)	
• Climate change (temperature rise, sea level rise, precipitation changes, storms)	

The environmental and human health externalities can additionally be classified as local, regional, or global, with the latter. referring to climate change caused by emissions of CO_2 or destruction of the ozone layer by emissions of CFCs or SF_6. Non-environmental externalities refer to hidden costs, such as those borne by tax-payers in the form of subsidies, research and development costs or benefits like employment opportunities, although for the latter it is debatable whether this constitutes an external benefit in the welfare economics sense.

1.3 Importance of Externalities

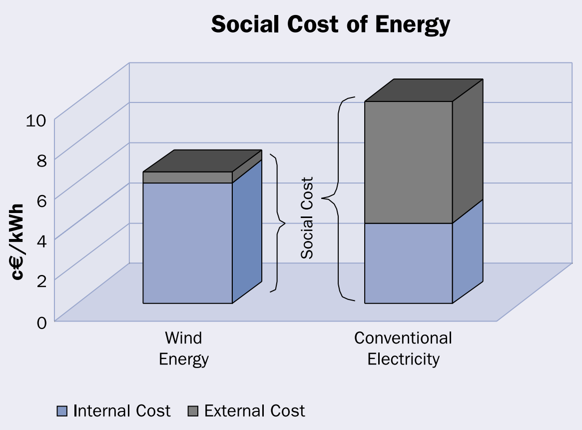
As markets neither include external effects nor their costs, it is important to identify external effects and to monetise the external costs of different energy systems if these are of a similar order of magnitude as the internal costs of energy, and if these external costs vary substantially between competing energy systems, like conventional electricity generation and wind energy.

As markets do not internalise external costs, internalisation has to be achieved by adequate policy measures like taxes or adjusted electricity rates. Before such measures can be taken, policy-makers need to be informed about the existence and the extent of external costs of different energy systems.

Analysing external costs is not an easy task. Science (to understand the nature of the impacts) and economics (to value the impacts) must work together to create analytical approaches and methodologies, producing results upon which policy-makers can base their decisions on appropriate measures and policies.

As much of the costing of non-market goods includes valuation procedures, for example by putting a value on a person becoming ill as a result of a nuclear accident or the cost of visual intrusion caused by a wind turbine (WT), or the cost of future damage caused by a tonne of CO_2, the externalities may pose uncertainties; include assumptions, risks and moral dilemmas. This sometimes makes it difficult to fully implement externalities by policy measures. Nevertheless, they offer a base for politicians to improve the allocation processes of the energy markets. Koomey and Krause (1997) in their introduction to environmental externality costs state that: *"... to not incorporate externalities in prices is to implicitly assign a value of zero, a number that is demonstrably wrong"*.

Figure 1.1: An Illustrative Example of the Social Cost of Energy



The question arises whether the internalisation of externalities in the pricing mechanism could impact on the competitive situation of different electricity-generating technologies, fuels or energy sources. As Figure 1.1 illustrates, a substantial difference in the external costs of two competing electricity generating technologies may result in a situation where the least-cost technology (where only internal costs are considered) may turn out to be the highest-cost solution to society, if all costs (internal and external) are taken into account.

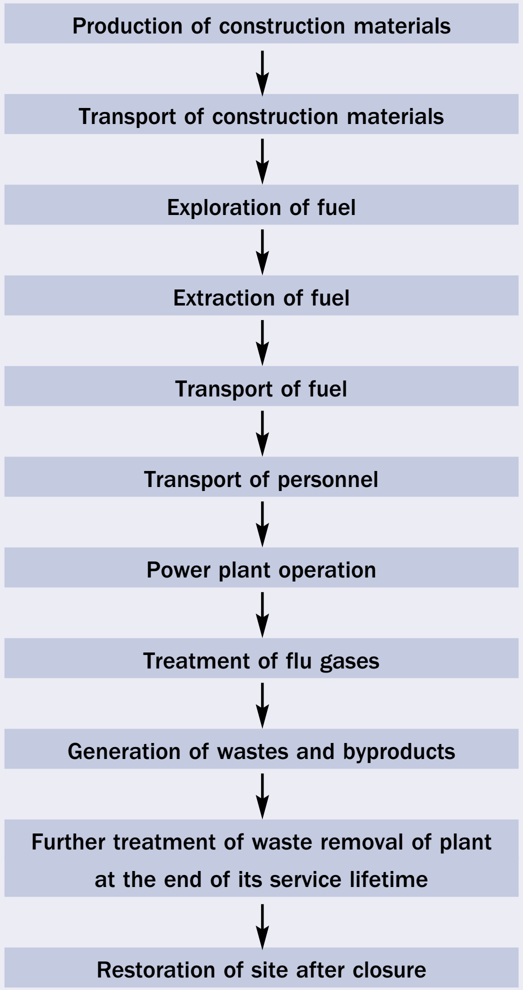
1.4 Externalities and Electricity Production

For the particular case of electricity production, the use of energy sources may *"cause damage to a wide range of receptors, including human health, natural ecosystems and the built environment, and they are referred to as external cost of energy"* (European Commission, 1994).

The externalities in the energy sector started to be quantified by pioneer studies in the late 1980s and beginning of the 1990s (Hohmeyer, 1988, Friedrich *et al.*, 1989, Ottinger *et al.*, 1990), which started the interest and gave a first insight into the importance of externalities for energy policy as a decision-making tool. The most outstanding project on determining the external cost of energy is the ExternE project, which developed a consistent methodology to assess the externalities of power generation in the EU. For that reason, a brief introduction of its methodology and an analysis of its results is provided in this chapter.

An important aspect in any analysis of the environmental externalities of electricity production is defining the activities that can have an impact. In that sense, the impacts of power production are not exclusively generated during the operation of the power plant, but also in the entire chain of activities needed for electricity production and distribution, such as fuel extraction, processing and transformation, construction and installation of the equipment, as well as waste disposal. These stages, which constitute the chain of electricity production and distribution, are known as the fuel cycle. Every technology (wind, hydro, coal, gas, etc) has its own very distinct fuel cycle. A generic fuel cycle can be seen in Figure 1.2.

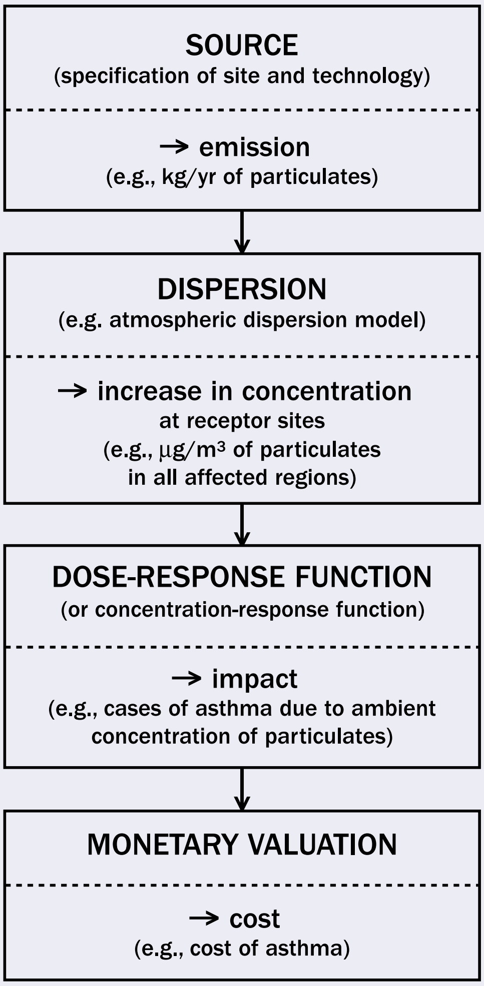
Figure 1.2: Generic Fuel Cycle



The impacts from any of the stages in the fuel cycle depend on the particular location of an activity. Impacts may vary greatly as a function of the sensitivity of the surrounding ecosystem, the population density, and economic and social aspects. In the case of renewable fuel cycles like wind, the major impacts of the fuel cycle arise from the activities required to produce and install a wind turbine and ancillary systems, while only minor externalities arise from wind turbine operation.

The ExternE methodology is a bottom-up approach, which first characterises the stages of the fuel cycle of the system in question (e.g. coal), defining the activities associated with the power technology. Subsequently, the fuel chain burdens are identified. Burdens refer to anything that is, or could be, capable of causing an impact of whatever type. After having identified the burdens, an identification of the potential impacts is achieved independent of their number, type or size. Every impact is then reported. This process just described for the fuel cycle is known as the Accounting Framework. For the final analysis, the most important impacts are selected and only their effects are calculated.

Figure 1.3: Impact Pathway Approach



Source: European Commission (1994).

Afterwards, the Impact Pathway approach developed by ExternE proceeds to establish the effects and spatial distribution of the burdens to see their final impact on health and the environment. Then, the economic valuation assigns the respective costs of the damages induced by a given activity.

The most important results of this study are found in its final phase in which the ExternE methodology was implemented in the EU in 1998 to take into account site-specific conditions, technologies, preferences, problems and policy issues. The aim was to create an EU-wide data set to assess the external cost. The results are shown in Table 1.2.

Table 1.2: External Cost Figures for Electricity Production in the EU for Existing Technologies (c€/kWh*)

Country	Coal&Lignite	Peat	Oil	Gas	Nuclear	Biomass	Hydro	PV	Wind
AT				1-3		2-3	0.1		
BE	4-15			1-2	0.5				
DE	3-6		5-8	1-2	0.2	3		0.6	0.05
DK	4-7			2-3		1			0.1
ES	5-8			1-2		3-5**			0.2
FI	2-4	2-5				1			
FR	7-10		8-11	2-4	0.3	1	1		
GR	5-8		3-5	1		0-0.8	1		0.25
IE	6-8	3-4							
IT			3-6	2-3			0.3		
NL	3-4			1-2	0.7	0.5			
NO				1-2		0.2	0.2		0-0.25
PT	4-7			1-2		1-2	0.03		
SE	2-4					0.3	0-0.7		
UK	4-7		3-5	1-2	0.25	1			0.15

* Subtotal of quantifiable externalities (such as global warming, public health, occupational health, material damage)
** biomass co-fired with lignites
Source: European Commission (1999), data updated in 2003.

Table 1.2 is a summary of the national reports with the final results. The values vary between countries since specific peculiarities from every country have an influence on the results due to a different range of technologies, fuels and pollution abatement options as well as locations. The fossil fuel cycles demonstrate the highest values (coal and lignite, peat, oil and gas), of which gas is the least damaging. Renewable energy and nuclear show the lowest externalities or damages.

In these results, the externalities for the nuclear cycle assume that waste and other hazardous impacts are well managed. As the results on nuclear power plants are based on calculations done for the ExternE project, and as the calculation of the underlying accident probabilities and source terms have never been made available for third party analysis, these figures are not as credible as the other estimates of external costs given in Table 1.2, where all assumptions underlying the calculations are revealed. What is more, the numbers seem to contradict the results of the German reactor safety study phase B which give rather more significant source terms and accident probabilities for severe core melt-down accidents with containment rupture (Gesellschaft für Reaktorsicherheit, 1989).

The ExternE results show that the damages vary substantially between countries. At present these external costs are hardly ever internalised, although the EU ordinance on subsidies for environmental measures (Official Journal of the European Communities, 2001) states that proven externalities may be compensated by public payments of up to 0.05 €/kWh without being considered as subsidies.

1.5 Impacts of Wind Energy and Other Technologies

The assessment of externalities is the result of the economic valuation of impacts on the environment and human health from all the activities required to produce a kWh of electricity. In order to provide an idea of the relevant impacts of wind energy and other technologies to assess the external cost, a broad description of the impacts of wind energy and other technologies is given.

Wind energy, a clean technology mainly due to the avoidance of air pollutant emissions, is not totally free of impacts on the environment and human health.

Wind energy has very few environmental impacts in its operation stage, although it may cause some impact in its direct vicinity in the form of aerodynamic noise. Furthermore, the visual impact of large WTs on the landscape may adversely affect some people. Visual intrusion of the turbines along with ancillary systems in the landscape and noise are considered as amenity impacts of the technology. Other impacts deal with indirect pollution from the production of components and construction of the turbine. A brief description of wind energy impacts follows:

- **Noise:** coming from WT operation, installation of the turbines at the wind farm site, turbine manufacturing processes, and transportation systems used in turbine delivery and maintenance. The dominant issue is aerodynamic noise from the turbines. However, modern WTs are seldomly heard at distances further than 300 m as background noise from wind in trees, for example, will be higher.

- **Visual intrusion of the turbines and associated equipment in the landscape:** the most difficult to quantify. Nevertheless, the total costs are generally overestimated, as the number of persons adversely affected is rather limited. In addition, since the beginning of the 1980s planners have become much more sophisticated. Today's wind power plants are erected in designated areas, thus further limiting the number of affected areas.

- **Indirect atmospheric emissions:** impacts of global warming and acid deposition due to emissions from materials processing and component manufacturing. Experience shows that these effects are in the range of less than 2% of the emissions avoided if fossil fuels are substituted. What is more, they decline as the share of clean renewable energy in the system increases.

- **Accidents:** affecting workers in manufacturing, construction and operation as well as accidents affecting the general public due to turbine operation and road travel by workers. So far, most accidents have affected workers installing and maintaining WTs.

- **Impact on birds:** collision in flight with turbines and behavioural disturbance from blade avoidance. Although numerous studies show that birds rarely collide with rotor blades this is an issue sometimes raised.

- **Impacts of construction on terrestrial ecosystems:** long-term loss of land where turbines are placed and impacts of erection activities together with electrical connections, buildings and access tracks. It has to be noted, however, that only the access roads and a very small area around the tower of a WT are lost for other uses. The Danish and German examples show that agriculture goes on in wind parks, which are often used for grazing cattle.

- **Electromagnetic interference:** the moving blades can affect radio waves and microwaves used for communication purposes although this has proven to be less of an issue.

These issues are explained in greater detail in the following chapters.

In order to also give an idea of the sources of externalities for other fuel cycles, Table 1.3 lists the priority impacts taken into account in the most important study available, the ExternE project. This list only includes those impacts which have been identified as having substantial importance. Other impacts such as land use by the installations, visual intrusion and interference of transmission lines on birds have not been included.

Table 1.3: Priority Impacts assessed in the ExternE Project

Fossil Fuel Technologies:

- Effects of atmospheric pollution on human health
- Accidents affecting workers and/or the public
- Effects of atmospheric pollution on:
    - materials
    - crops
    - forests
    - freshwater fisheries
    - unmanaged ecosystems
- Impacts of global warming
- Impacts of noise

Specific for some Activities in Fossil Fuel Technologies:

- Impacts of coal and lignite mining on ground and surface waters
- Impacts of coal mining on building and construction
- Resettlement necessary through lignite extraction
- Effects of accidental oil spills on marine life
- Effects of routine emissions from exploration, development and extraction from oil and gas wells

Nuclear Technologies:

- Radiological and non-radiological health impacts (routine and accidental releases to the environment)
- Occupational health Impacts (radiological and non-radiological exposures due to work accidents and radiation exposure)
- Impacts on the environment of increased levels of natural background radiation (major accident releases)

Renewable Technologies:

Wind

- Accidents affecting workers and/or the public
- Effects on visual amenity
- Effects of noise emissions on amenity
- Effects of atmospheric emissions (turbines' manufacturing, on site construction and servicing)

Hydro

- Occupational health effects
- Employment benefits and local economic effects
- Impacts of transmission lines on bird populations
- Damage to private goods (forestry, agriculture, water supply, ferry traffic)
- Damages to environmental goods and cultural objects

Source: European Commission (1999).

The nuclear fuel cycle in the ExternE project has eight stages covering electricity production from the mining of uranium oxide. The impacts deriving from this fuel cycle are caused by inhalation, external exposure and ingestion of agricultural products due to atmospheric emissions, liquid discharges and solid residues.

The hydro power fuel cycle differs greatly from the fossil fuel cycles. The particular impacts of this cycle are the intrusion of the infrastructure into the environment and the flooding of large areas in the case of large hydro dams.

1.6 Externalities of Wind Energy

Different studies and methodologies show that the externalities of wind energy are far smaller than the external costs of fossil fuel based electricity generation. The externality values shown in the final results of the national implementation of the ExternE project (see Table 1.2) range from 0.05 to 0.25 c€/kWh.

Looking at a conventional power production technology such as coal, the values observed are of the same order or double the magnitude of the internal electricity cost of these technologies. In general the lower and upper levels are between 2 and 15 c€/kWh.

With this information, it is possible to estimate the social cost of coal and wind power. Assuming that the cost of producing a kWh with coal is around 3 c€/kWh on average, internalisation of the coal externalities increase costs by between 5 and 18 c€/kWh resulting in rather high costs of electricity. Table 1.4 shows the social cost of coal and gas power systems for Spain, Denmark and Germany in which the external cost range given for coal is higher than the internal cost. For the case of gas the external cost is below the internal cost.

Based on the figures given in Volume 2, the cost of producing electricity with wind energy in coastal and inland sites can be derived. These costs were based on constant 2001 prices for Denmark. Taking the inland wind energy cost for machines of 600 and 1,000 kW along with the externality figures of Denmark from Table 1.2 the results are:

Table 1.5: Social Cost of Wind Energy

Costs	600 kW WT	1,000 kW WT
Cost of Wind c€/kWh	4.4	4.1
External Cost* c€/kWh	0.09 – 0.16	0.09 – 0.16
Social Cost	*4.49 – 4.56*	*4.19 – 4.26*

Note: *The external cost was not converted to € 2001 prices.

Table 1.4: Social Cost of Coal and Gas Powered Systems (Internal + External[a])

	Coal			Gas		
Costs	**Spain**	**Denmark**	**Germany[b]**	**Spain**	**Denmark**	**Germany[b]**
Internal cost[c] c€/kWh	3.93	3.41	3.14	5.2	5.23	2.85
External Cost c€/kWh	4.8 - 7.7	3.5 - 6.5	3.0 - 5.5	1.1 - 2.2	1.5 - 3.0	1.2 - 2.3
Total Cost	8.73 - 11.63	6.91 - 9.91	6.14 - 8.64	6.3 - 7.4	6.73 - 8.23	4.05 - 5.15

[a] The external cost was not converted to € 2001 prices.

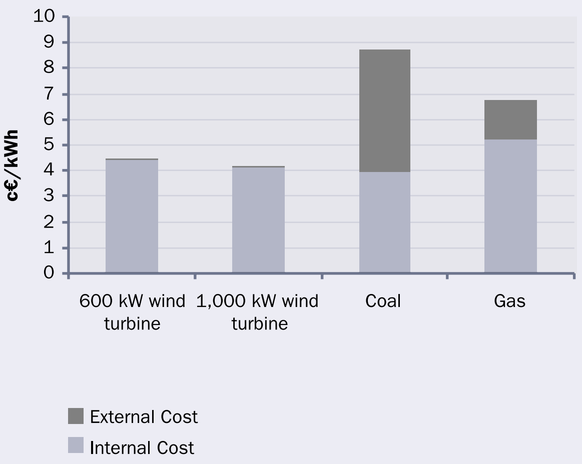
[b] Germany coal and gas (combined cycle) cost is own calculation. Source: Hohmeyer *et al.* (2000).

[c] Projected avoided cost of conventional power assuming 25% capacity credit for wind power (see Volume 2).

Source: Coal prices from IEA/OECD updated to € 2001 prices.

The social costs are practically unchanged by the inclusion of the external cost of wind energy. Based on this total cost comparison, the cost of wind energy is very competitive to the cost of conventional power plants as shown in figure 1.1. The social cost of coal for Denmark as shown in Table 1.4 ranges from 6.9 to 9.9 c€/kWh. Figure 1.4 illustates the social cost estimated in the tables for coal, gas and wind in Denmark.

Figure 1.4: Social Cost of Coal, Gas and Wind in Denmark



As was mentioned before, a precise estimation of damages is not an easy task. In addition, the results of the national implementation phase of the ExternE project have to be used with care since social and environmental impacts are difficult to quantify and damages of the fuel cycles are not fully quantified. For the case of wind energy the external costs are strongly influenced by local factors. Thus, translating values to other locations is not recommended. However, the results do show the order of magnitude of the differences between clean energy technologies and conventional ways of producing electricity.

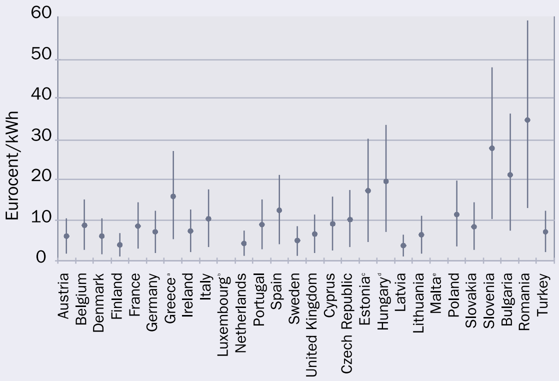
1.7 Benefits of Wind Energy

The benefits of wind energy are the avoided emissions and their impacts from fossil fuel electricity generation. The external costs avoidable through wind energy can be calculated as shown in chapter 2.

The evaluation includes damages from air pollutant emissions like SO_2 and NO_x as well as costs of the anthropogenic greenhouse effect resulting from CO_2 emissions. The analysis has been carried out based on a calculation with the EcoSense model (air pollutants) on the one hand and on the estimates of Azar and Sterner (1996) concerning the adverse effects of climate change on the other.

The calculations carried out for the EU-25, Turkey, Romania and Bulgaria take into account the replaceable energy mix of each country as well as the technological standards. The possible ranges of reductions in external costs due to the increased use of wind energy are shown in Figure 1.5.

Figure 1.5: Avoidable External Costs by the Use of Wind Energy in 2000 in c€/kWh, EU-25 and other European Countries



[a] source of CO_2 emission data: Ministry of Environment and Physical Planning: "National Programme for the Reduction of Greenhouse Gas Emissions", Athens 2002.

[b] no emission data available.

[c] all data are from 2002, source: EWEA (2003b).

[d] source of emission data: MVM, Hungary.

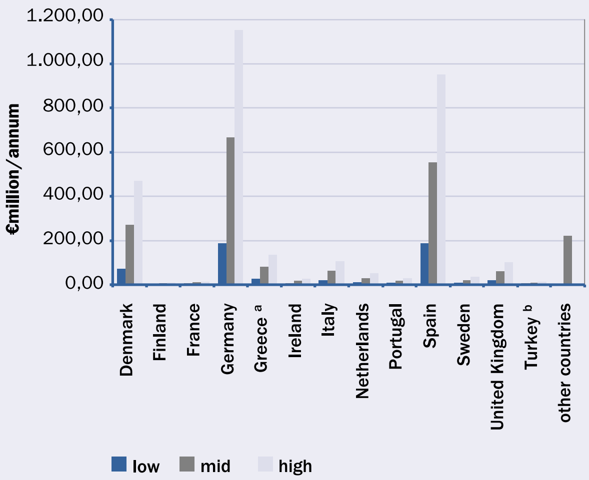
[e] no data available.

Source: Eurelectric (2002), own calculations.

Figure 1.5 gives an overview of the avoidable external costs by wind energy per kWh. It is observed that there is a noticeable difference between the countries covered by this study. Some new member states and accession countries, in particular, have very high emissions resulting in high external costs of electricity generation.

By combining the avoidable external costs with the amount of electricity produced by wind energy, the total amount of avoided external costs can be calculated. This is shown for the year 2000 in € millions for each country in Figure 1.6. Only three countries (Denmark, Germany and Spain) use substantial parts of their wind energy resource to reduce external costs. This reduction is more than €1 billion per year in the case of Germany.

Figure 1.6: Total Avoided External Costs by the Use of Wind Energy in 2000



[a] source of CO_2 emission data: Ministry of Environment and Physical Planning: "National Programme for the Reduction of Greenhouse Gas Emissions", Athens 2002.

[b] source of emission data: TEAS, Turkey.

Source: Eurelectric (2002), own calculations.

The ranges low, mid and high relate to the lower and upper bound and the central value of the specific externalities per kWh shown in the Figure above. The precise description of the calculations is given in chapter 2.

1.8 Present State of Knowledge

The current state of knowledge of external costs can be described as a process that was mainly initiated in the late 1980s, when the first studies were published attempting to quantify and compare the external costs of electricity generation. The studies released at that time started a public interest in externalities, as they showed for the first time that the differences in external costs are of the same order of magnitude as the direct internal costs of generating electricity. Since that time more research and different approaches, better scientific information and a constant improvement of the analytical methodologies used have driven an evolution of externalities research in Europe and the USA.

This development has resulted in a convergence of methodologies, at least for calculating the external costs of fossil fuel based electricity generation and wind energy. This has induced policy-makers to adopt some measures to attempt a first internalisation, as under the German Renewable Energy Law.

Despite the uncertainties and debates about externalities, it can be stated that with the exemption of nuclear power and long term impacts of GHGs on climate change, the results of the different research groups converge and can be used as a basis for developing policy measures aimed at a further internalisation of the different external costs of electricity generation.

Finally, it is worth drawing attention to issues that have not been mentioned in this chapter which may enhance the concept of external costs such as, for example, sustainability and security and reliability of supply.

With respect to sustainability, the neoclassical definition of externalities assumes that monetary valuation by manufactured and natural capital can be a substitute for environmental deterioration. This valuation is considered to be an indicator of weak sustainability (Rennings, 1996). In contrast, strong sustainability principles demand an economic system that does not exceed the capacity of the global ecological system and development that meets the needs of the present without compromising the ability of future generations to meet their own needs (WCED, 1987). The neoclassical definition of externalities and sustainability principles should be linked to sustainable development issues (Weinreich, 2002).

The security and reliability of supply and its consequences for market risk is an aspect that can also enhance the concept of externalities of electricity generation. The inclusion or accounting of market risk due to supply disruption and, especially, fuel price volatility represents a security issue. This has an effect on the economics of fossil fuel which is not recognised in traditional analysis. Furthermore, renewable energies (e.g. wind and solar) are not subject to volatile fuel prices. The inclusion of volatility in the private costs equation could change the perception that renewables are high cost (Awerbuch, 2003). This topic needs further research.

2 ENVIRONMENTAL BENEFITS OF WIND ENERGY

2.1 Background

Emissions

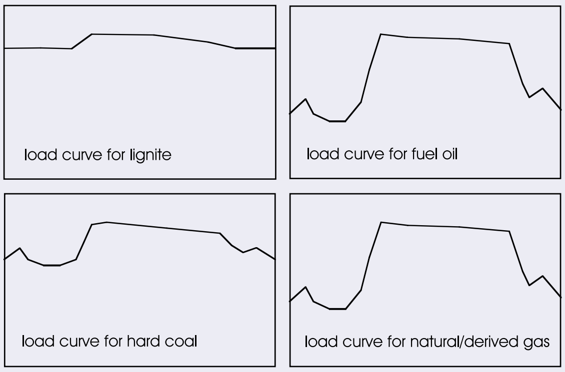
The most important emissions concerning electricity generation are CO_2, SO_2, NO_x and PM_{10} (particulate matter up to 10 micrometers in size). Emissions generally depend on the type of fuel used. CO_2 emissions are related to carbon content. There is no realistic opportunity of reducing carbon emissions by using filters or scrubbers, although techniques such as burning fossil fuel with pure oxygen and capturing and storing the exhaust gas may reduce the carbon content of emissions (IPCC, 2002). For SO_2, the quantity of emissions per kWh electricity generated depends on the sulphur content of the input fuel. Furthermore, SO_2 emissions can be reduced by filtering the exhaust gases and converting SO_2 to gypsum or elementary sulphur. In general, the sulphur content of lignite is rather high, fuel oil and hard coal have roughly a medium sulphur content and natural gas is nearly sulphur free. In contrast, NO_x emissions are practically unrelated to input fuel. As NO_x are formed from the nitrogen in air during combustion, their formation depends mainly upon the combustion temperature. Thus, NO_x emissions can be reduced by choosing a favourable (low) combustion temperature or by denitrifying the exhaust gases (by wet scrubbing).

Technology

Due to its intermittent nature, wind power can at present only replace specific segments of conventional electricity generation. And as it varies with available wind speed it cannot replace conventional base load power plants. As wind energy is a capital intensive technology, and because the fuel is free, it needs to be used as much as possible. Thus, it should be used to replace conventional power plants in the intermediate rather than peak load segment.

Keeping these facts in mind, we can define a reference system whereby wind farms may replace conventional power plants. Firstly, neither nuclear nor standard hydro power plants are replaceable by wind, as both almost exclusively operate in the base load segment. As pump storage (hydro) power plants are used to cover very short load peaks, they cannot be replaced by wind energy either, due to the latter's intermittent nature. This leaves electricity generation from the fossil fuels (assuming average generation structure): hard coal, lignite, fuel oil and gas. However, this assumption can lead to an overestimation of the share of the replaced electricity supplied by lignite, as this is predominantly used in the base load segment as well, and to an underestimation of substituted electricity from gas, which, due to the dynamic characteristics of gas fired power plants, lends itself perfectly to balance fluctuations in the supply of wind energy. As we know the current mode of operation of conventional power plants, the rules of their dispatch based on the so-called "merit order" and the dynamic behaviour of the different types of conventional power plants, we can safely assume a replacement of intermediate load by wind energy.

Figure 2.1: Load Curves for Lignite, Hard Coal, Fuel Oil and Gas



Source: based on VDEW (1998).

Apart from nuclear energy, all conventional fuel types are more or less used to generate intermediate load electricity. These are: hard coal, lignite, fuel oil, natural gas and derived gas. For our analysis, the contributions of the different energy sources to intermediate load electricity need to be specified. They probably differ substantially in different countries and there are virtually no national statistics available on their contributions. Therefore, data for the German situation supplied by Vereinigung Deutscher Elektrizitätswerke (VDEW, 2000) are used as the basis of our analysis. The load curves for one typical load day (Figure 2.1) have been derived for each relevant type of fuel and will be taken as the basis for the calculation of shares of intermediate load.

The graphs show that the highest load variations during one day are displayed by fuel oil and gas. Hard coal shows some variation, while electricity production based on lignite is almost constant. Although, these load curves are based on the German electricity generation structure, power plants have common fuel-specific technical and economic characteristics. Therefore, load curves are assumed to have similar day-to-day variations in other countries.

Based on these considerations, Table 2.1 sets out assumptions for the intermediate load shares, with the percentage figures being based on the total volume of electricity produced for each fuel.

Table 2.1: Share of Intermediate Load

Fuel Type	Share of Intermediate Load
lignite	10 %
hard coal	30 %
mixed firing	50 %
fuel oil	100 %
natural/derived gas	100 %

2.2 Electricity Generation and Emissions in EU-25 and other European Countries

This section provides a short overview of the 28 countries covered by this study. The countries are divided into groups according to their geographical location.

The EU-15 countries can be sub-divided into three groups, shown in Table 2.2.

Table 2.2: EU-15 Countries

North	Central	South
Denmark	Austria	Greece
Finland	Belgium	Italy
Sweden	France	Portugal
	Germany	Spain
	Ireland	
	Luxembourg*	
	Netherlands	
	UK	

*data are not available for emissions in Luxembourg.

The 10 new member states, along with Turkey, Bulgaria and Romania can be divided into three similar groups (see Table 2.3).

Table 2.3: New EU Member States, Bulgaria, Romania and Turkey

North-east	East	South-east
Estonia	Czech Republic	Bulgaria
Latvia	Hungary	Malta*
Lithuania	Poland	Romania
	Slovakia	Slovenia
		Turkey
		Cyprus

*data are not available for electricity generation and emissions in Malta.

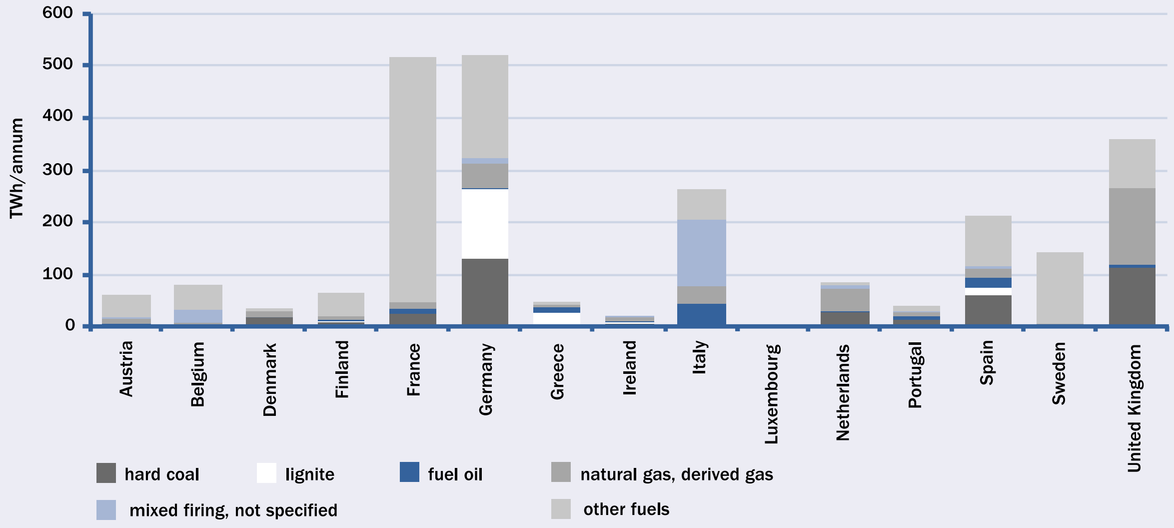
2.2.1 ELECTRICITY GENERATION SECTOR AND ENVIRONMENTAL POLICY FRAMEWORK

The countries covered by this study differ substantially in the volume and structure of their electricity generation. All data used have been taken from Eurelectric (2002). Therefore, the shares of input fuels for electricity generation vary strongly between different countries. The share of hydropower used is determined by the very different resources of the 28 countries, while the share of nuclear is a function of the nuclear energy policy of each country, varying from a very strong reliance on nuclear energy in the case of France to a policy of no nuclear energy in countries like Denmark and Austria. As has been explained above, intermittent renewable energy cannot at present replace nuclear or hydro power. Thus only fossil fuels are replaced by wind energy in this study. The structure of electricity generation by fossil fuel fired conventional thermal power plants is shown in Figures 2.2 and 2.3. Unfortunately, the only available comprehensive source of statistical data for the 28 countries studied (Eurelectric, 2002) does not allow a full disaggregation with respect to power plants suitable for more than one fuel (“mixed firing”). To permit a good comparison between electricity generation in all the countries, the same scale is used in the two figures.

As figure 2.2 shows, there are a few countries which use mainly hard coal and lignite for the fossil part of their electricity production. These are Germany, Greece, Spain, Denmark, Finland and Portugal. Other countries favour gas, for example the UK and the Netherlands.

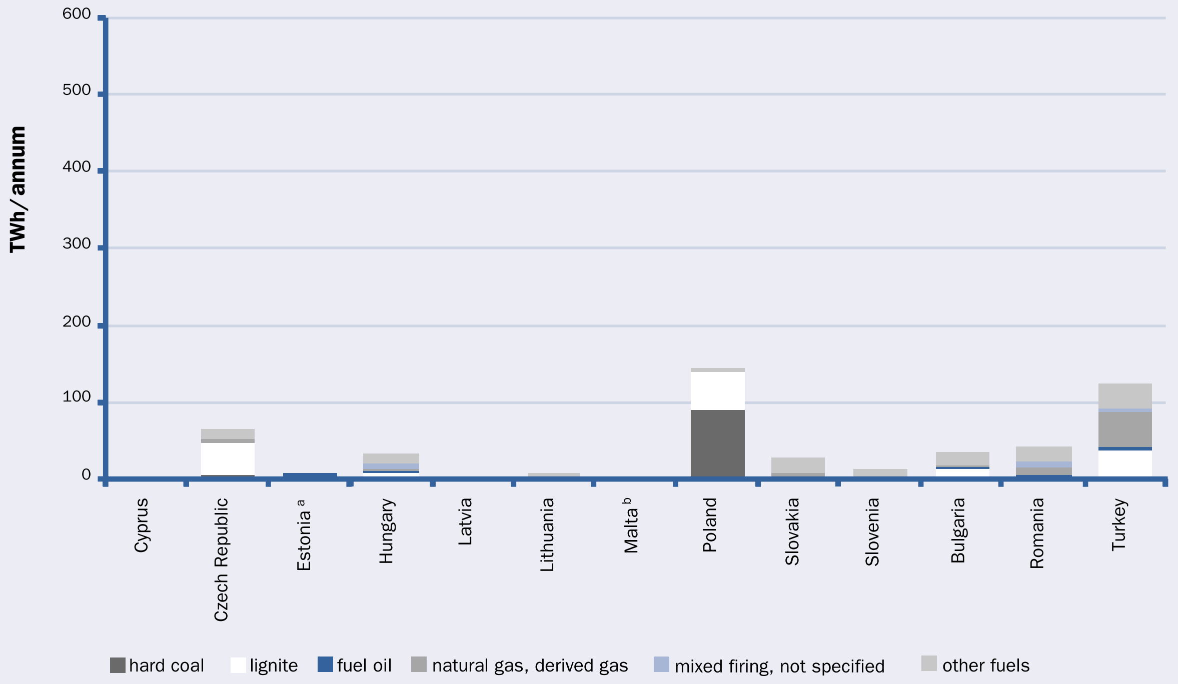
Some of the new member states and others mainly use hard coal and lignite for their fossil fuel based electricity generation. These are Poland, Slovenia, Czech Republic, Bulgaria, Slovakia and Hungary. Natural gas is favoured by Latvia, Turkey and Romania. The majority of these countries use a substantial share of nuclear energy for electricity generation.

Figure 2.2: Total Electricity Generation in EU-15 Countries in 2000



Source: Eurelectric (2002).

Figure 2.3: Total Electricity Generation in the 10 New Member States, Turkey, Bulgaria and Romania in 2000

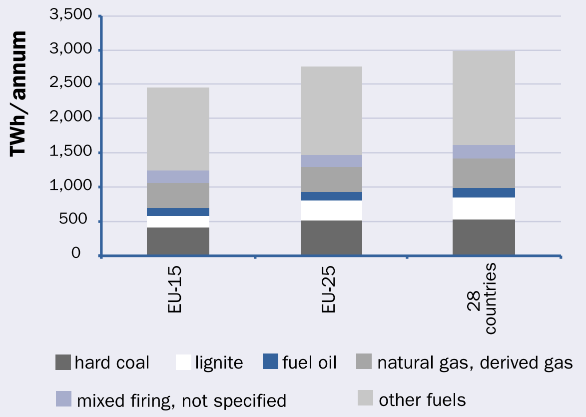


[a] data are from 2002. Source: EWEA (2003b).

[b] no data available.

Source: Eurelectric (2002).

Figure 2.4: Total Electricity Generation in the EU-15, EU-25 and all 28 Countries in 2000

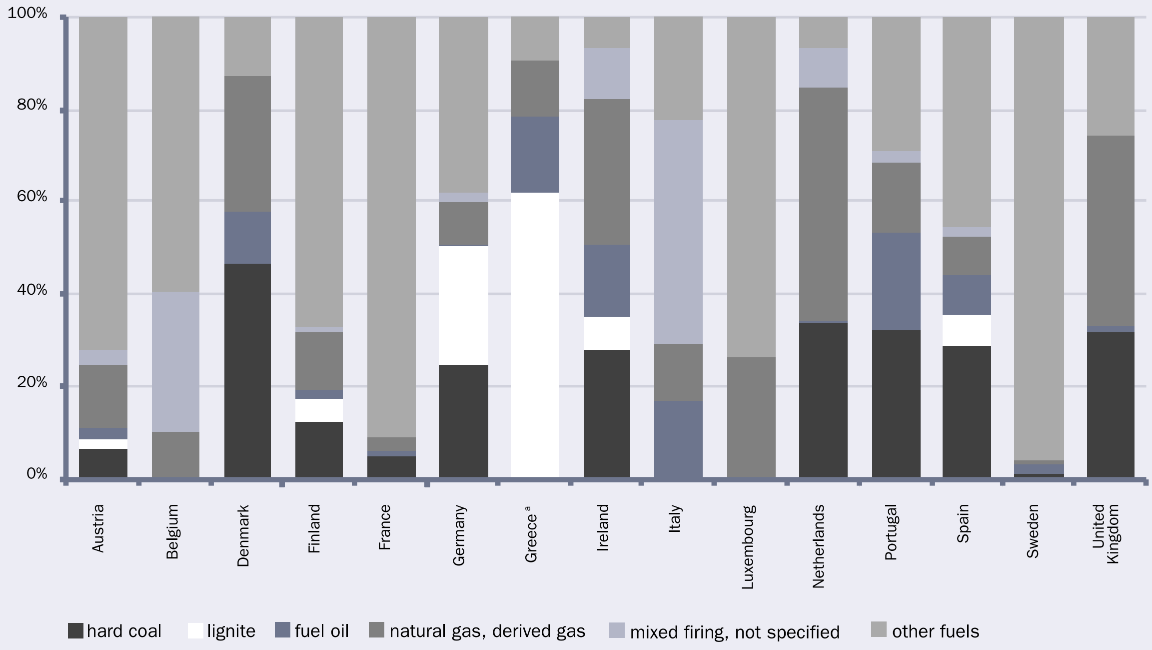


Source: Eurelectric (2002), own calculations. Data for Estonia are from 2002, source: EWEA (2003b). No data are available for Malta.

For a better orientation, the amounts of electricity generation in the EU-15, the EU-25 and in all 28 countries are shown in Figure 2.4. As this figure illustrates, the amount of electricity generation is very low in most of the countries outside the EU-15.

Figures 2.5 to 2.7 provide a detailed picture of the electricity generation fuel mix in the various countries.

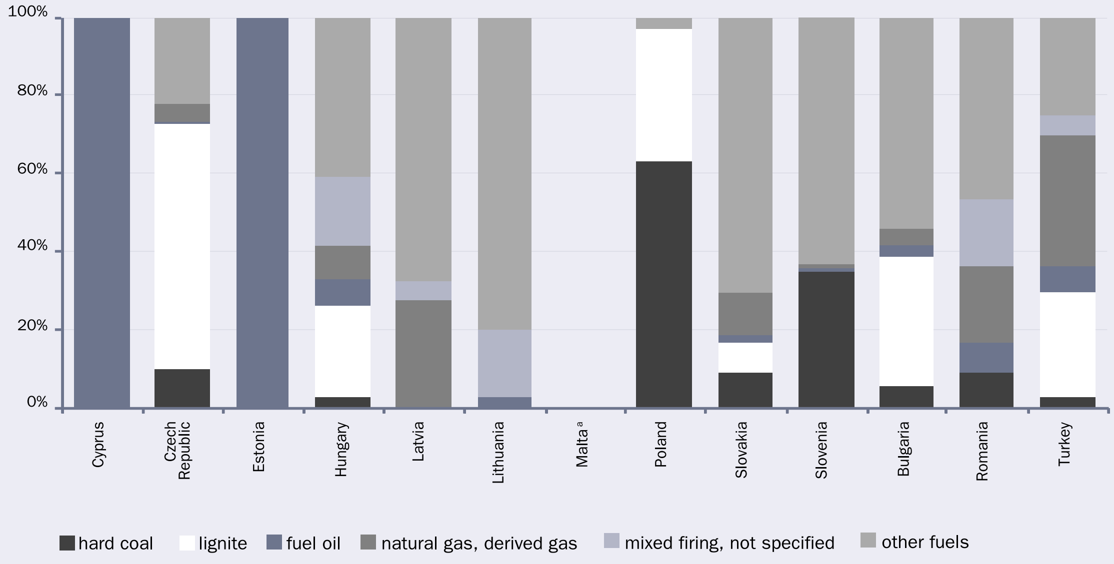
Figure 2.5: Segmentation of Fuels for Electricity Generation in EU-15 Countries in 2000 (%)



[a] data are from 2002, source: EWEA (2003b).

Source: Eurelectric (2002).

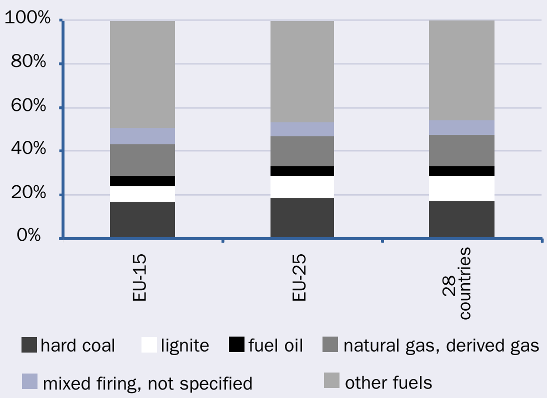
Figure 2.6: Segmentation of Fuels for Electricity Generation in the 10 New Member States, Turkey, Bulgaria and Romania in 2000 (%)



[a] no data available.

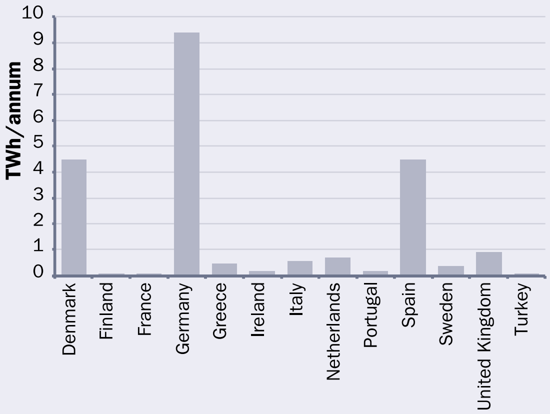
Source: Eurelectric (2002).

Figure 2.7: Segmentation of Fuels for Electricity Generation in the EU-15, EU-25 and all 28 Countries in 2000 (%)



Source: Eurelectric (2002), own calculations. Data for Estonia are from 2002, source: EWEA (2003b). No data are available for Malta.

Figure 2.8: Electricity Generation by Wind Energy in 2000 (TWh/a)



Source: Eurelectric (2002).

Electricity generation by renewable energies is widely spread around the European countries. The specific amount which is covered by renewable energies in each depends on geographical conditions and the country's policies on renewable energies. Therefore, the use of renewables differs widely between the 28 countries. Due to its relatively low internal costs, hydro power is used by most, with Austria and Latvia producing more than half their electricity from hydro power.

The use of wind energy differs very substantially across the 28 countries, with Germany, Denmark and Spain producing more than 4 TWh/annum (2000) and nine other EU-15 member states producing up to 1 TWh/annum. Of all the other countries, only Turkey was using any significant amount of wind energy in the year 2000. Countries generating electricity from wind energy (2000) are shown in Figure 2.8.

If wind energy production is looked at in terms of share of electricity produced, a somewhat different picture emerges, as only Denmark produced more than 10% of its electricity from wind in 2000 (12.8%), while Spain (2.1%), Germany (1.8%) and Greece (1.1%) were way behind. Nevertheless, the situation is changing dramatically; for example in Germany the installed capacity has more than doubled since the year 2000. For 2002, Germany produced 23.1 TWh which represents a share of 4.7% (Ender, 2003), Denmark's wind generation figures for 2002 showed production at 4.9 TWh representing a share of 14.8% (Danish Wind Industry Association, 2003) while Spain's production of 9.5 TWh for 2002 represents 4% (IDAE, 2003).

Here, it is very important to point out that the figures for electricity generation by wind energy have increased dramatically in recent years. In terms of installed wind capacity, Europe experienced a growth of 10,200 MW of total installed capacity from 2000 to 2002. This fact has an impact on the quantification of the benefits of wind energy. However, for the purposes of this study, the figures for electricity generation by wind energy were taken from the year 2000 (Eurelectric, 2002).

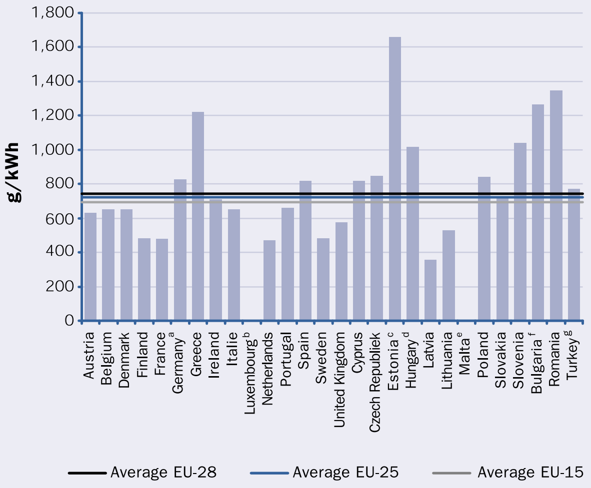
Although wind energy is only used in significant volumes in just four out of the 28 countries, the use of wind energy in the year 2000 has already resulted in significant emission reductions, which are discussed in chapter 2.4 below.

2.2.2 EMISSION DATA

To be able to analyse the possible environmental and health benefits of the use of wind energy we need to know the specific emissions of the electricity replaced by wind. These can be derived by dividing the absolute emissions produced by a type of fuel in kilotons of CO_2/annum used for electricity generation in one country by the electricity produced from this fuel in kWh/annum. For clarity, the emissions statistics for each country are given on the CD attached to this report. Most of the data used for the calculations are from Eurelectric (2002). However, not all the necessary data were available from this source, so some calculations have been based on additional sources.

As explained in chapter 2.1, wind energy is capable of replacing intermediate load conventional power production. The emissions avoided by wind energy depend on three factors: the specific emissions from each type of generation facility; the fuel mix in each country; and the percentage of each fuel replaced by wind energy. A detailed calculation of avoidable specific emissions by wind energy in all the countries studied is shown in chapter 2.4.

Figure 2.9: Specific Average CO_2 Emissions in g/kWh from Fossil Fuel Electricity Generation in 2000



[a] source of CO_2 emission data: Ministry of Environment and Physical Planning: "National Programme for the Reduction of Greenhouse Gas Emissions", Athens (2002).

[b] no emission data available.

[c] all data are from 2002, source: EWEA (2003b).

[d] source of emission data: MVM, Hungary.

[e] no data available.

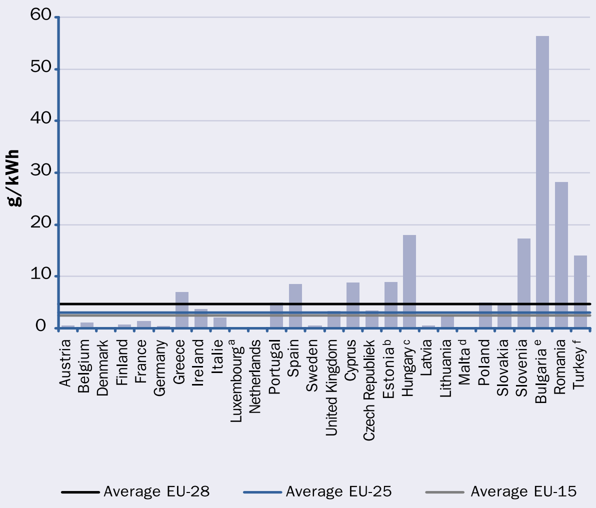
[f] source of emission data: NEK, Bulgaria.

[g] source of emission data: TEAS, Turkey.

Source: Eurelectric (2002), own calculations.

Average emissions per kWh were calculated to provide a starting point for examining the relationship between electricity production from fossil fuels and total emissions from the electricity sector in the different countries (see Figures 2.9 to 2.11). The results include all fossil fuel based electricity not just the intermediate load segment (see chapter 2.4).

Figure 2.10: Specific Average SO_2 Emissions in g/kWh from Fossil Fuel Electricity Generation in 2000



[a] no emission data available.

[b] all data are from 2002, source: EWEA (2003b).

[c] source of emission data: MVM, Hungary.

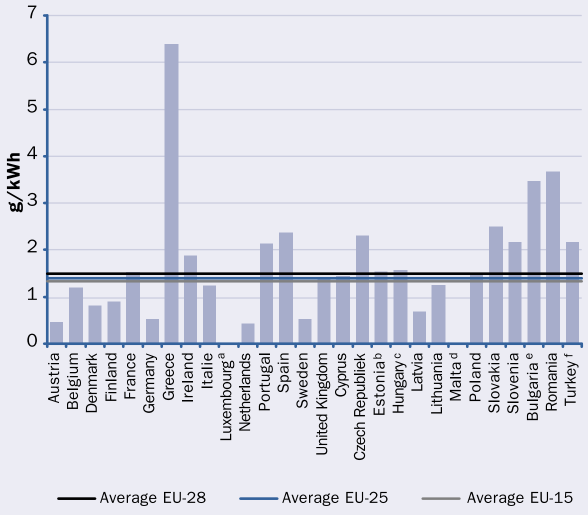
[d] no data available.

[e] source of emission data: NEK, Bulgaria.

[f] source of emission data: TEAS, Turkey.

Source: Eurelectric (2002), own calculations.

Figure 2.11: Specific Average NO_X Emissions in g/kWh from Fossil Fuel Electricity Generation in 2000



[a] no emission data available.
[b] all data are from 2002, source: EWEA (2003b).
[c] source of emission data: MVM, Hungary.
[d] no data available.
[e] source of emission data: NEK, Bulgaria.
[f] source of emission data: TEAS, Turkey.
Source: Eurelectric (2002), own calculations.

In summary, Figures 2.9 to 2.11 show that the southern European EU-15 countries (Greece and Spain), as well as all south-eastern countries (Bulgaria, Cyprus, Romania, Slovenia and Turkey), Hungary and Estonia have rather high emissions from electricity generation. Two of the centrally-located countries (Ireland and the UK), Italy and Portugal, Lithuania, and most of the eastern European new member countries (Czech Republic, Poland and Slovakia) show intermediate emission levels. Countries with rather low emissions are mostly northern or central countries - Denmark, Finland, Sweden, Austria, Belgium, France, Germany, the Netherlands, and Latvia.

Due to this distribution there is a significant increase of specific average emissions from electricity generation from northern to south-eastern Europe.

Figure 2.9 shows that the difference in specific CO_2 emissions is more than a factor of three between the various countries. This is related to differences in fuel mix as well as the fact that some countries have power plants with very low efficiencies.

The distribution of SO_2 emissions per kWh is very different, as shown in Figure 2.10. This is related to the very heterogeneous sulphur content of fuel and the use of desulphurisation in only the most advanced countries.

NO_X emissions differ between the countries according to the combustion process used, the combustion temperature, which is not optimal in all the countries, and the scrubbing technologies employed, as shown in Figure 2.11.

To determine avoidable emissions from the use of wind energy, specific emissions from electricity generation for the different fuels must be calculated. Specific emissions have been evaluated based on total emissions from electricity generation and the amounts of electricity generated in each country. For further information about this calculation see Appendix G.

2.3 The Calculation of External Costs with the EcoSense Model

In order to be able to calculate the external costs avoided by wind energy, it is necessary to model the pathway of emissions from conventional power plants to the different receptors, such as plants, animals and humans, which may be located thousands of kilometres away. As air pollutants can damage a number of different receptors, the task of analysing the impacts of any given emission is fairly complex. To allow such complex analysis, a tool has been developed during the last 10 years in a major co-ordinated EU research effort, the EcoSense model. This chapter explains the basics of the model, which is used in the calculations in chapter 2.4.

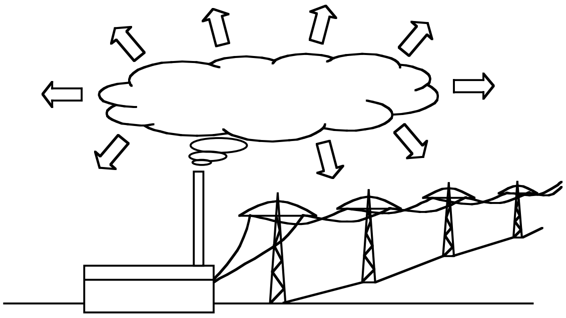
2.3.1 SOFTWARE DESCRIPTION

EcoSense is a computer model for assessing environmental impacts and the resulting external costs of electric power generation systems. The model is based on the Impact Pathway approach of the ExternE project and provides the relevant data and models required for an integrated impact assessment related to airborne pollutants. (For extensive information on the model as well as the approach used, see European Commission, 1994)

EcoSense provides the windrose trajectory model (WTM) for modelling the atmospheric dispersion of emissions, including the formation of secondary air pollutants. For any given point source of emissions (e.g. a coal fired power plant) the resulting changes in the concentration and deposition of primary and secondary pollutants can be estimated on a Europe-wide scale with the help of this model. Developed in the UK by the Harwell Laboratory it covers a range of several thousand kilometres. The reference environment database, which is included in EcoSense, provides receptor-specific data as well as meteorological information based on the Eurogrid-co-ordinate system.

The Impact Pathway approach can be divided into four analytical steps:

- **Calculation of Emissions**



The first step is to calculate emissions of CO_2, SO_2 and NO_x per kWh from a specific power plant.

- **Dispersion Modelling**

Then air pollutant dispersion around the site of the specific plant is modelled. Based on meteorological data, changes in the concentration levels of the different pollutants can be calculated across Europe.

- **Impact Analysis**

Based on data for different receptors in the areas with significant concentration changes, the impacts of the additional emissions on these receptors can be calculated on the basis of so-called dose response functions. Important data on receptors included in the model database are, for example, and population density and land use patterns.

- **Monetisation of Costs**

The last step is to monetise the impacts per kWh caused by the specific power plant. In this stage, the calculated physical damage to a receptor is valued on a monetary scale based on the best available approaches for each type of damage.

2.3.2 INPUT DATA TO THE MODEL

As the EcoSense model requires a specified site as a starting point for its pollutant dispersion modelling we have chosen one typical electricity generation site for each country to assess the impacts and calculate the costs caused by emissions from fossil fuel fired power plants which may be replaced by wind energy.

The co-ordinates at each site are chosen in order to locate the reference plants centrally in the electricity generating activities of each country. Thus, it is assumed that the chosen site represents approximately the average location of electricity generating activities of each country has been chosen. For more information about the input data see Appendix H.

To control for effects caused by this assumption and to prevent extreme data results, a sensitivity analysis was carried out by shifting the geographical location of the plant. This analysis showed a relatively high sensitivity of external costs to the location of the electricity generation facilities. This is due to the very heterogeneous distribution of the different receptors in different parts of a country. For this reason, the specific external costs per kWh may differ by a factor of two. Unfortunately, the area covered by EcoSense is limited to 29° east, so substantial parts of eastern Europe are not included in the analysis and the impacts of eastward emissions due to the prevailing westwind drift are not fully accounted for. Thus, in countries located at the border of the area covered external costs may be substantially underestimated.

In order to run the model, the capacity of the power plant, its full load hours of operation and the volume stream of exhaust gas per hour are required. The assumptions made for the calculations are shown in Table 2.4 for the different fossil fuels.

Table 2.4: Technical Data of the Reference Facilities Assumed for the Calculation

Fuel Type	Capacity (MW)	Full Load Hours per Year	Volume Stream per Hour (m³)
Hard coal	400	5,000	1,500,000
Lignite	800	7,000	3,000,000
Fuel oil	200	2,000	750,000
Natural gas, derived gas	200	2,000	750,000
Mixed firing, not specified	400	5,000	1,500,000

For each country, calculations have been performed for a representative power plant location based on the specific national emission data for each fuel and each pollutant.

2.4 Benefits of Wind Energy - Results

2.4.1 AVOIDABLE EMISSIONS BY THE USE OF WIND ENERGY

As explained in chapter 2.1, electricity from wind energy can replace intermediate load from fossil fuel power plants. Avoidable emissions by wind energy can be calculated based on specific emissions derived in chapter 2.2. Due to the fact that there are no data available on specific emissions per fuel for most countries, specific emission data have been estimated by splitting up the total emissions from conventional thermal electricity generation based upon the shares of electricity generated by the different fossil fuels. Different power plants running on the same fuel are assumed to have the same specific emissions in any one country. Furthermore, it is assumed that the countries have attained the same relative emission abatement level for each fuel type. That is to say, for example, that one country would not rank high on SO_2 emissions from lignite but low on SO_2 emissions from oil. (The calculations are described in detail in Appendix G.)

The specific emissions per fuel and the share of intermediate load generated on the basis of each fuel are used to calculate the specific emissions which could have been avoided per kWh of wind energy in each country in 2000. Results are shown in Figures 2.12 to 2.14. Due to a lack of sufficient data there are no results for Luxembourg and Malta.

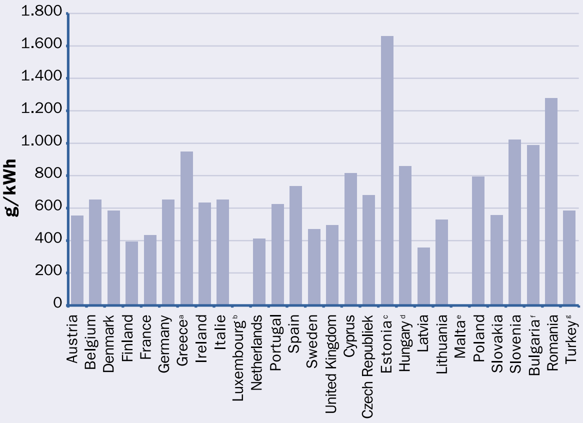
Due to the fact that wind energy replaces only part of the electricity produced by fossil fuels (intermediate load), specific avoidable emissions are different from average emissions from fossil fuel electricity generation. In most cases, avoidable emissions by wind energy are less than average emissions from fossil fuel electricity generation. This is justified by the fact that intermediate load electricity generation by fossil fuels is based on fuel with relatively low emissions (see chapter 2.1 for more information on this point).

As is to be expected, the specific emissions of intermediate fossil power which could be avoided by using wind energy, are higher in most new member states than in most of the EU-15. This is due to less efficient power plants and a lack of SO_2 and NO_x scrubbers. Consequently, new wind energy plants in the countries besides EU-15 countries could induce higher specific emissions. Nevertheless, this may not hold in the long run, as a convergence of technical standards is expected in the next 20 years.

Figure 2.8 reveals that some countries are already avoiding a sizeable amount of fossil fuel emissions through their use of wind energy. Due to the different specific emissions avoided per kWh in each country (Figures 2.12 to 2.14) the total emissions are not directly proportional to the wind energy produced. For Spain, in particular, total emission reductions for SO_2 and NO_x are comparatively high in relation to the electricity replaced. This is due to the high specific emissions of Spanish fossil fuel power plants.

In 2000, approximately 15 Mt CO_2 were avoided by the use of wind energy as shown in Figures 2.15 to 2.17.

Figure 2.12: Specific Avoidable CO_2 Emissions in g/kWh by Wind Energy in 2000



[a] source of CO_2 emission data: Ministry of Environment and Physical Planning: "National Programme for the Reduction of Greenhouse Gas Emissions", Athens (2002).

[b] no emission data available.

[c] all data are from 2002, source: EWEA (2003b).

[d] source of emission data: MVM, Hungary.

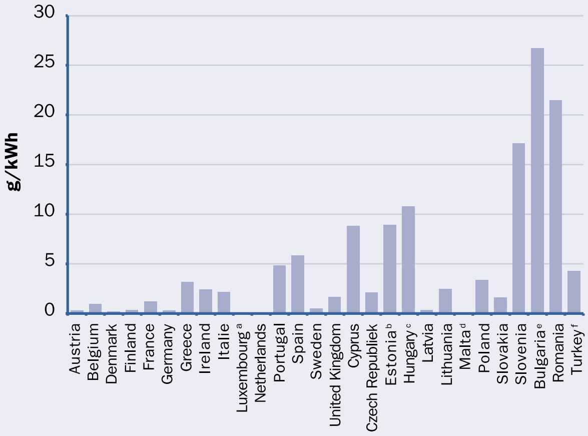
[e] no data available.

[f] source of emission data: NEK, Bulgaria.

[g] source of emission data: TEAS, Turkey.

Source: Eurelectric (2002), own calculations.

Figure 2.13: Specific Avoidable SO_2 Emissions in g/kWh by Wind Energy in 2000



[a] no emission data available.

[b] all data are from 2002, source: EWEA (2003b).

[c] source of emission data: MVM, Hungary.

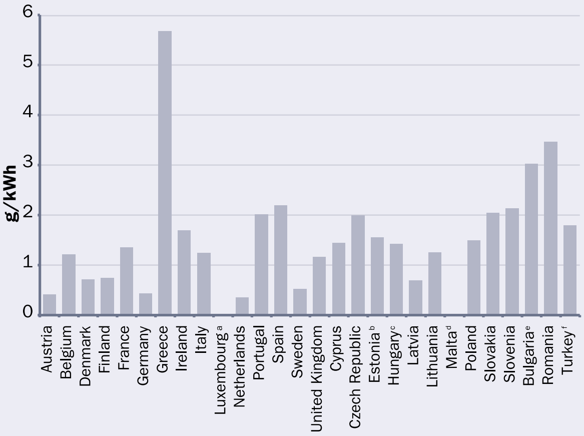
[d] no data available.

[e] source of emission data: NEK, Bulgaria.

[f] source of emission data: TEAS, Turkey.

Source: Eurelectric (2002), own calculations.

Figure 2.14: Specific Avoidable NO_x Emissions in g/kWh by Wind Energy in 2000



[a] no emission data available.

[b] all data are from 2002, source: EWEA (2003b).

[c] source of emission data: MVM, Hungary.

[d] no data available.

[e] source of emission data: NEK, Bulgaria.

[f] source of emission data: TEAS, Turkey.

Source: Eurelectric (2002), own calculations.

2.4.2 AVOIDABLE EXTERNAL COSTS BY THE USE OF WIND ENERGY

To calculate the external costs avoided by the use of wind energy, the external costs resulting from air pollutants such as SO_2 and NO_x (calculated by EcoSense) have to be added to the external costs of the anthropogenic greenhouse effect resulting from CO_2 emissions, which are not calculated by EcoSense.

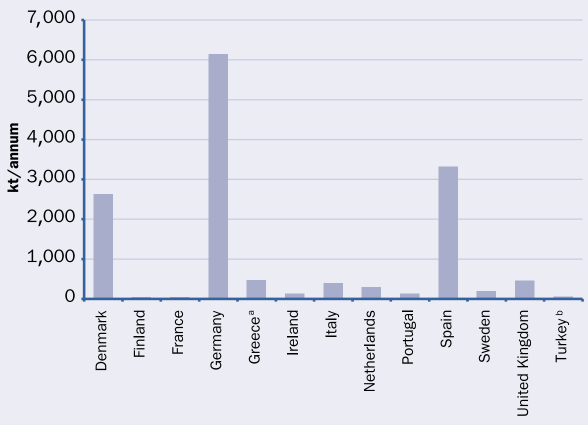
As air pollutants can damage a large number of different receptors, calculations of external costs will generally include a large number of damages, which tend to be restricted to the most important impacts to allow a calculation of external costs with a limited resource input. At present, EcoSense includes the following receptors: humans (health), crops, materials (in buildings, etc.), forests and ecosystems, with monetary valuation only included for human health, crops and materials.

There are two approaches to evaluating effects on human health: value of statistical life (VSL); and years of life lost

(YOLL). The VSL approach measures a society's willingness to pay to avoid additional deaths. This can be seen in spending on improved safety in the aircraft or car industry. In the EU and the US, figures of between US$/€1 million and US$/€10 million per life saved have been found in different studies. Earlier versions of the ExternE project adopted a figure of US$3 million per life saved for VSL calculations. In these calculations a person's age does not matter.

The YOLL approach takes age into account. In the case of chronic disease leading to death in a very old person, only the years of life lost due to the disease as compared to average life expectancy are taken into account. For each year of life lost approximately one-twentieth of the VSL value is used.

Figure 2.15: Total Avoided CO_2 Emissions in kt/annum by Wind Energy in 2000



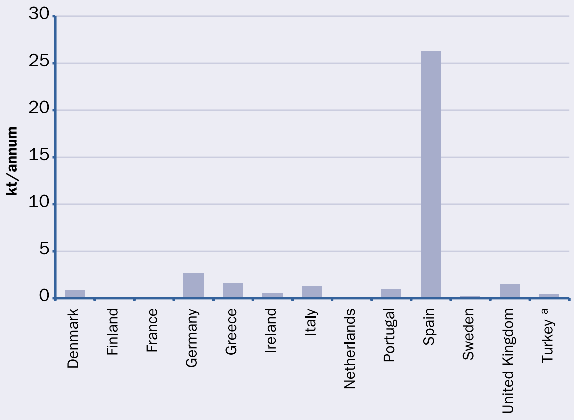
[a] source of CO_2 emission data: Ministry of Environment and Physical Planning: "National Programme for the Reduction of Greenhouse Gas Emissions", Athens (2002).

[b] source of emission data: TEAS, Turkey.

Source: Eurelectric (2002), own calculations.

Using one or other approach may lead to substantially different results of monetised human health damages. Deciding which approach to use is a value judgement, based on society's underlying value system. Thus, calculations of the external costs of human health damages should always give both measures and leave it up to the reader or the policy-maker to decide which approach they think most appropriate.

Figure 2.16: Total Avoided SO_2 Emissions in kt/annum by Wind Energy in 2000



[a] source of emission data: TEAS, Turkey.

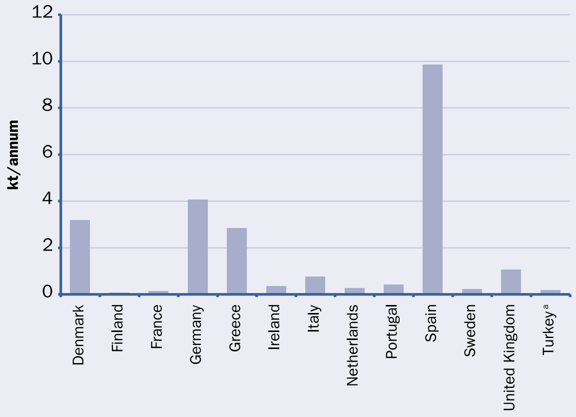
Source: Eurelectric (2002), own calculations.

Unfortunately, EcoSense does not provide a calculation based on the VSL approach. As pointed out above, VSL may lead to substantially higher external costs than the YOLL approach which is applied by the EcoSense model. Results of former ExternE studies estimate external costs based on both approaches. These resulted in VSL results approximately three times higher than those found with YOLL (Umweltbundesamt, 2002).

As the present version of EcoSense does not calculate VSL values, the EcoSense results on human health effects based on the YOLL approach have been scaled. This has been done with a factor of one for low damage cost estimates calculated for human health, a factor of two for medium cost estimates and a factor of three for high estimates.

As EcoSense does not calculate long-term damage from CO_2-induced climate change, the estimates of Azar and Sterner (1996) are used. As CO_2 remains in the atmosphere for about 100 years, most of the damage will occur in the distant future. If these damages apply to human health or irreversible environmental damages Rabel (1999) has strongly argued that no discounting should be applied, as the valuation of the damage increases with the discount rate. Based on a discount rate of 0%, dam-

Figure 2.17: Total Avoided NO_x Emissions in kt/annum by Wind Energy in 2000



[a] source of emission data: TEAS, Turkey.
Source: Eurelectric (2002), own calculations.

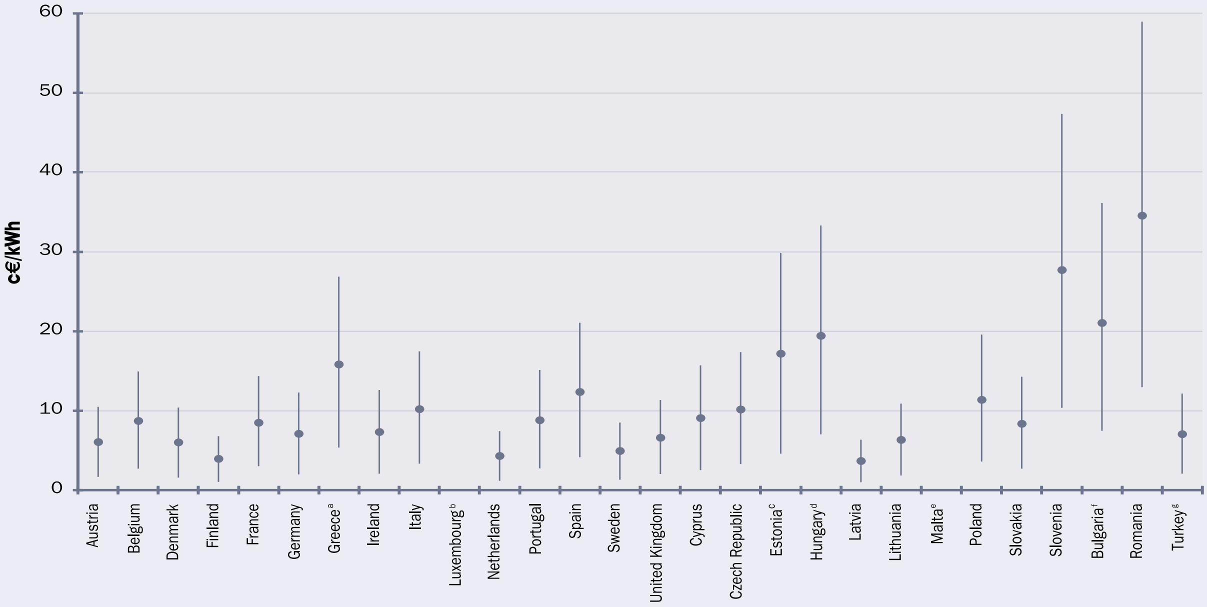
age costs of global warming are calculated by Azar and Sterner (1996) to be € (2000) 87.51 - 607.41/ton of carbon (see Appendix I). Recalculation in terms of CO_2 emissions leads to costs of € (2000) 23.87 - 165.69/ton of CO_2 (Umweltbundesamt, 2002). The remaining large range of the estimate is due to the time period taken into account for the analysed damages (300 or 1,000 years) and the way the question of damage in poor countries is dealt with.

Based on the EcoSense calculation, the avoidable external costs per kWh by wind energy have been evaluated. Results are shown in Figure 2.18.

The total avoided external costs in 2000 are shown in Figure 2.19.

As can be seen in Figures 2.19 and 2.20, an amount of nearly €1.8 billion has been avoided by the use of wind energy electricity generation in 2000. Most of this applies to Germany (38%), Spain (31%) and Denmark (15%).

Figure 2.18: Avoidable External Costs in c€/kWh through the Use of Wind Energy in 2000, EU-25 and other European Countries



[a] source of CO_2 emission data: Ministry of Environment and Physical Planning: "National Programme for the Reduction of Greenhouse Gas Emissions", Athens (2002).

[b] no emission data available.

[c] all data are from 2002, source: EWEA (2003b)

[d] source of emission data: MVM, Hungary.

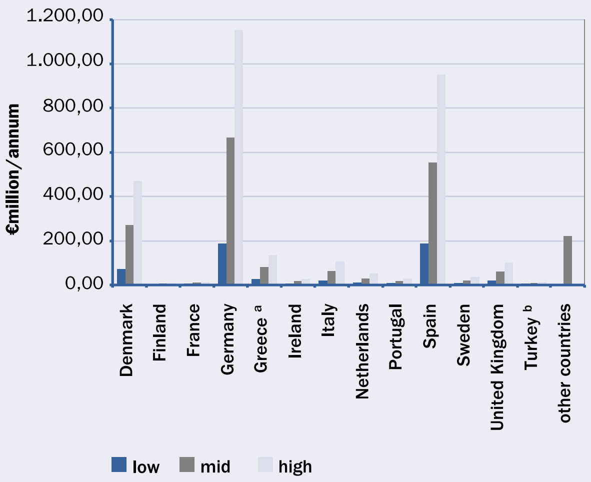
[e] no data available.

[f] source of emission data: NEK, Bulgaria.

[g] source of emission data: TEAS, Turkey.

Source: Eurelectric (2002), own calculations.

Figure 2.19: Total Avoided External Costs in €million/annum by the Use of Wind Energy in 2000

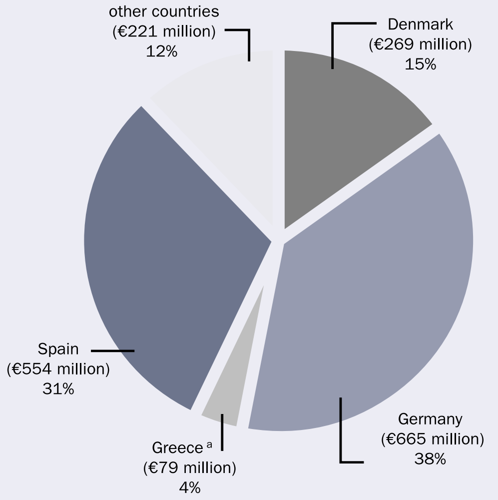


[a] source of CO_2 emission data: Ministry of Environment and Physical Planning: "National Programme for the Reduction of Greenhouse Gas Emissions", Athens (2002).

[b] source of emission data: TEAS, Turkey.

Source: Eurelectric (2002), own calculations.

Figure 2.20: Shares of Total Avoided External Costs by the use of Wind Energy in Europe 2000



[a] source of CO_2 emission data: Ministry of Environment and Physical Planning: "National Programme for the Reduction of Greenhouse Gas Emissions", Athens (2002).

Source: Eurelectric (2002), own calculations. Source of emission data for Turkey: TEAS, Turkey.

3 STANDARD METHODOLOGY FOR CALCULATION OF EMISSION REDUCTIONS

As shown above, the calculation of emission and external cost reductions achieved by the use of wind energy in the EU-15 and the 10 new member states along with Turkey, Bulgaria and Romania can be based either on the EcoSense model on the one hand or the regular reporting of electricity generation and emissions by Eurelectric (2002) on the other.

Forecasts of possible future emission reductions and reductions in resulting external costs can be carried out on this basis. Like the calculation of preceding emission reductions it can be divided into two parts: avoidable specific emissions (in mg/kWh) and avoidable total emissions (in kt/annum).

As the future emission reductions due to the use of wind energy cannot be calculated on the basis of present conventional electricity generating technologies and fuel mix, a forecast of future fuel mix and conventional technologies must be made.

Based on the specific avoidable emissions and the forecasted amount of electricity generated by wind energy, the total amount of avoidable emissions can be calculated.

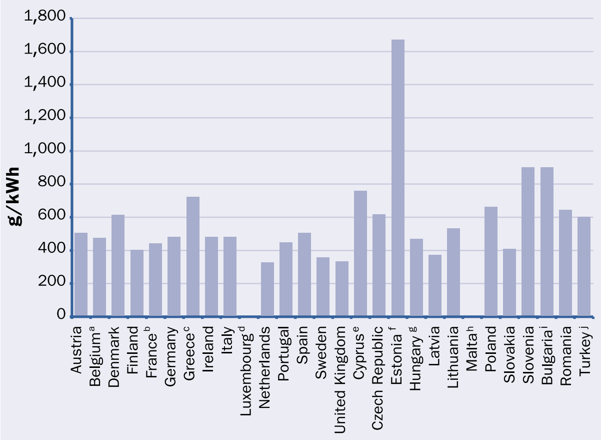
4 ANALYSIS OF EMISSION REDUCTIONS

The potential of future emission reductions has been carried out based on data for 2020. The year 2020 has been chosen as the last available year in Eurelectric forecasts. The options are combined with the volume of conventional electricity replaced by wind energy in Europe forecasted for the year 2020 by the EWEA (2003a).

4.1 Avoidable Specific Emissions through Wind Energy

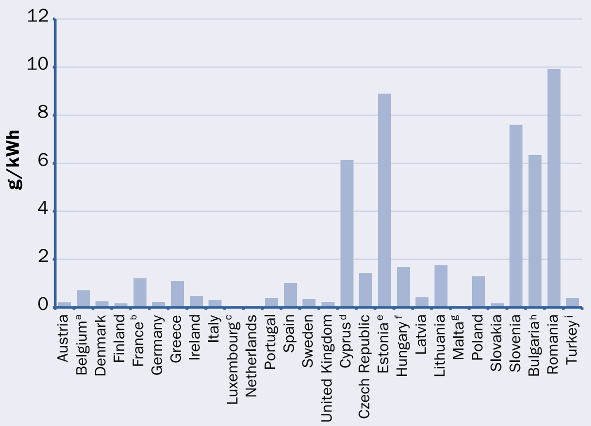
Future avoidable specific emissions through the use of wind energy are shown in Figures 4.1 to 4.3.

Figure 4.1: Specific Avoidable CO_2 Emissions in g/kWh by Wind Energy in 2020, EU-25 and other European Countries



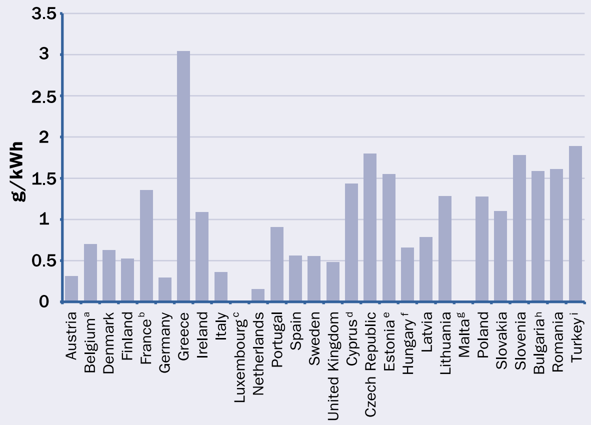
[a] all data are for 2010.
[b] all data are from 2000.
[c] source of CO_2 emission data: Ministry of Environment and Physical Planning: "National Programme for the Reduction of Greenhouse Gas Emissions", Athens (2002).
[d] no emission data available.
[e] all data are for 2010.
[f] all data are from 2002, source: EWEA (2003b).
[g] source of emission data: MVM, Hungary.
[h] no data available.
[i] source of emission data: NEK, Bulgaria.
[j] source of emission data: TEAS, Turkey.
Source: Eurelectric (2002), own calculations.

Figure 4.2: Specific Avoidable SO_2 Emissions in g/kWh by Wind Energy in 2020, EU-25 and other European Countries



[a] all data are for 2010.
[b] all data are from 2000.
[c] no emission data available.
[d] all data are for 2010.
[e] all data are from 2002, source: EWEA (2003b).
[f] source of emission data: MVM, Hungary.
[g] no data available.
[h] source of emission data: NEK, Bulgaria.
[i] source of emission data: TEAS, Turkey.
Source: Eurelectric (2002), own calculations.

Figure 4.3: Specific Avoidable NO_x Emissions in g/kWh by Wind Energy in 2020, EU-25 and other European Countries



[a] all data are for 2010.
[b] all data are from 2000.
[c] no emission data available.
[d] all data are for 2010.
[e] all data are from 2002, source: EWEA (2003b).
[f] source of emission data: MVM, Hungary.
[g] no data available.
[h] source of emission data: NEK, Bulgaria.
[i] source of emission data: TEAS, Turkey.
Source: Eurelectric (2002), own calculations.

The figures show that specific avoidable emissions are going to decrease from 2000 to 2020. This is due to two factors. Firstly, the fuel mix is going to change in coming decades in most of the countries covered by this study. In many cases, high emission fuels will partly be replaced by those with relatively low emissions. Accordingly, the share of fuel oil and, in particular, natural and derived gas will increase significantly. Parallel to this, the amounts of electricity generated by hard coal and lignite are going to decrease or stagnate. This will lead to a lower volume of specific avoidable emissions by wind energy in 2020 compared with 2000.

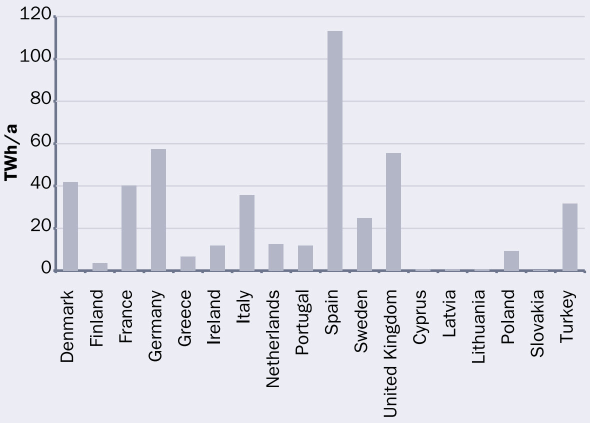
Secondly, there will be a significant improvement in the technology of fossil fuel based electricity generation. The east-European states, in particular, will up-grade their technology by fitting SO_2 scrubbers and improving combustion processes to reduce NO_x emissions.

4.2. Avoidable Total Emissions Through Wind Energy

Based on the expected amount of electricity generated by wind energy, avoidable total emissions have been calculated (see Figures 4.5 to 4.7).

Forecasts of electricity generation by wind energy are based on data from the EWEA (2003a) relating to total electricity generation and on data from Eurelectric (2002) concerning the distribution of generation between the countries.

Figure 4.4: Electricity Generation by Wind Energy in TWh/annum in 2020

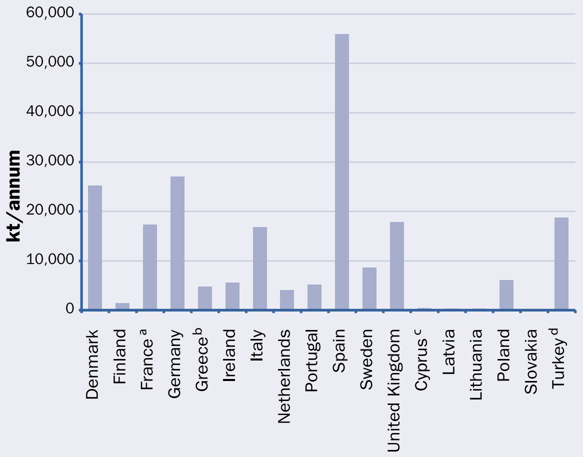


Source: EWEA (2003a), own calculations.

As shown in Figure 4.4, the amount of electricity generated by wind energy will increase strongly from 2000 to 2020. For 2020, a total of 425 TWh/annum is forecasted by the EWEA (2003a) for the EU-25 countries. For all 28, this would lead to a forecast of more than 450 TWh/annum in 2020, an increase of nearly 2,000% within 20 years.

As shown in Figures 4.5 to 4.7, total avoidable emissions depend on the level of specific avoidable emissions in each country. Therefore, the total avoidable emissions are not only related to the amount of electricity generated by wind energy.

Figure 4.5: Total Avoidable CO_2 Emissions in kt/annum by Wind Energy in 2020, EU-25 and Turkey



[a] all data are from 2000. Calculation of electricity generation by wind energy based on data for 2010 resp. 2020.

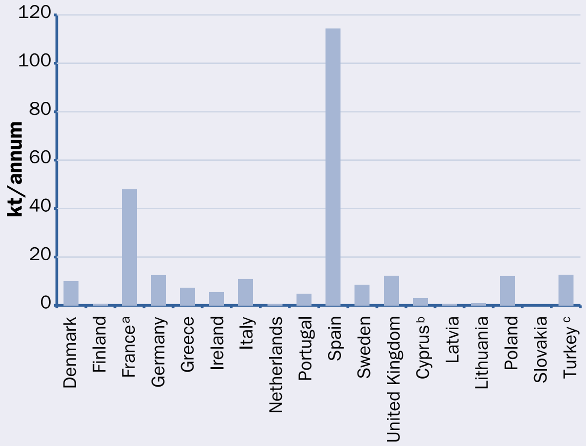
[b] source of CO_2 emission data: Ministry of Environment and Physical Planning: "National Programme for the Reduction of Greenhouse Gas Emissions", Athens (2002).

[c] all data are for 2010. Calculation of electricity generation by wind energy based on data for 2010 resp. 2020.

[d] source of emission data: TEAS, Turkey.

Source: Eurelectric (2002), EWEA (2003a), own calculations.

Figure 4.6: Total Avoidable SO_2 Emissions in kt/annum by Wind Energy in 2020, EU-25 and Turkey



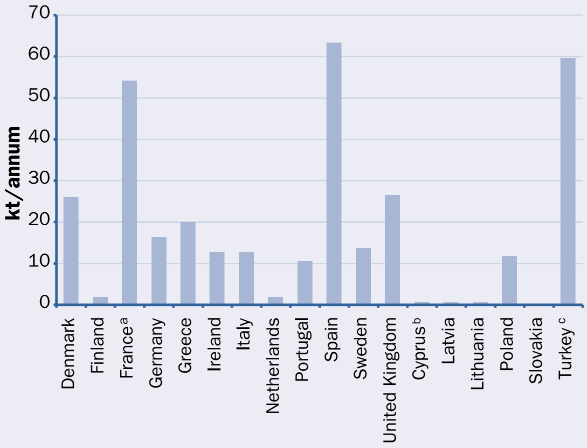
[a] all data are from 2000. Calculation of electricity generation by wind energy based on data for 2010 resp. 2020.

[b] all data are for 2010. Calculation of electricity generation by wind energy based on data for 2010 resp. 2020.

[c] source of emission data: TEAS, Turkey.

Source: Eurelectric (2002), EWEA (2003a), own calculations.

Figure 4.7: Total Avoidable NO_X Emissions in kt/annum by Wind Energy in 2020, EU-25 and Turkey



[a] all data are from 2000. Calculation of electricity generation by wind energy based on data for 2010 resp. 2020.

[b] all data are for 2010. Calculation of electricity generation by wind energy based on data for 2010 resp. 2020.

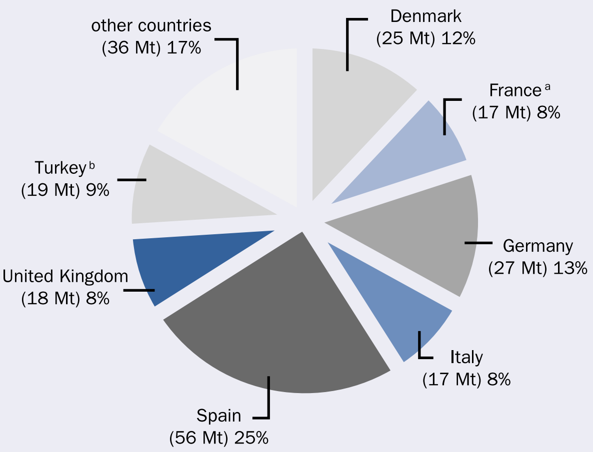
[c] source of emission data: TEAS, Turkey.

Source: Eurelectric (2002), EWEA (2003a), own calculations.

As can be seen in Figures 4.6 and 4.7, the potential for emission reductions is very high in Spain. This is again explained by SO_2 and NO_x emissions, which are forecast to still be relatively high in Spain in 2020 in comparison with other countries.

Figures 4.8 to 4.10 show the shares of total avoidable emissions in Europe in 2020. Again, avoidable emissions in Spain are a lot higher than in the UK, for example, even though wind energy generation in the UK will be at the same level as that in Spain. A comparison of the wind energy electricity generation capacity of Spain and Germany shows that Spain, according to Eurelectric estimates, will be producing twice the amount of wind generated electricity in 2020 than Germany. But the total avoidable SO_2 emissions in Spain will be 10 times higher than Germany's.

Figure 4.8: Avoidable CO_2 Emissions in Mt/annum Wind Energy in 2020

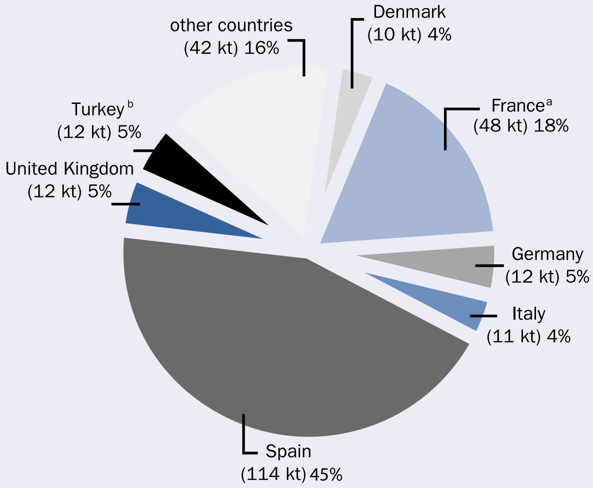


[a] all data are from 2000. Calculation of electricity generation by wind energy based on data for 2010 resp. 2020.

[b] source of emission data: TEAS, Turkey.

Source: Eurelectric (2002), EWEA (2003a), own calculations. Source of CO_2 emission data from Greece: Ministry of Environment and Physical Planning: "National Programme for the Reduction of Greenhouse Gas Emissions", Athens (2002). All data from Cyprus are for 2010. Calculation of electricity generation by wind energy for Cyprus based on data for 2010 resp. 2020.

Figure 4.9: Avoidable SO_2 Emissions in kt/annum by Wind Energy in 2020

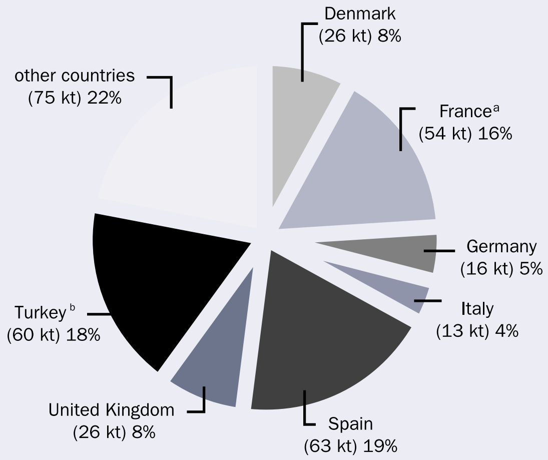


[a] all data are from 2000. Calculation of electricity generation by wind energy based on data for 2010 resp. 2020.

[b] source of emission data: TEAS, Turkey.

Source: Eurelectric (2002), EWEA (2003a), own calculations. All data from Cyprus are for 2010. Calculation of electricity generation by wind energy for Cyprus based on data for 2010 resp. 2020.

Figure 4.10: Avoidable NO_X Emissions in kt/annum by Wind Energy in 2020



[a] all data are from 2000. Calculation of electricity generation by wind energy based on data for 2010 resp. 2020.

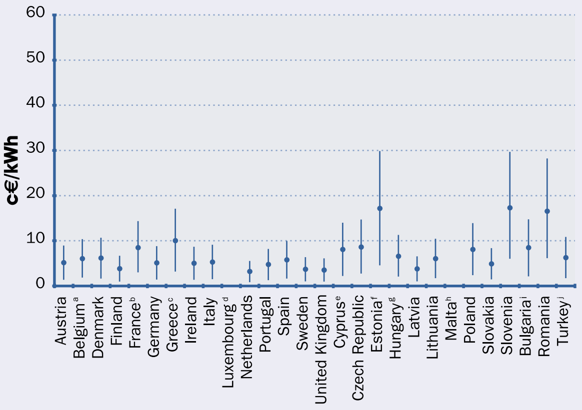
[b] source of emission data: TEAS, Turkey.

Source: Eurelectric (2002), EWEA (2003a), own calculations. All data from Cyprus are for 2010. Calculation of electricity generation by wind energy for Cyprus based on data for 2010 resp. 2020.

4.3 Avoidable External Costs Through Wind Energy

In line with the specific emissions, the avoidable specific external costs in c€/kWh decrease from 2000 to 2020, especially in south-eastern European states where avoidable costs are significantly less than in 2000 (see Figure 4.11).

Figure 4.11: Avoidable External Costs in c€/kWh by the Use of Wind Energy in 2020, EU-25 and other European Countries



[a] all data are for 2010.

[b] all data are from 2000.

[c] source of CO_2 emission data: Ministry of Environment and Physical Planning: "National Programme for the Reduction of Greenhouse Gas Emissions", Athens (2002).

[d] no emission data available.

[e] all data are for 2010.

[f] all data are from 2002, source: EWEA (2003b).

[g] source of emission data: MVM, Hungary.

[h] no data available.

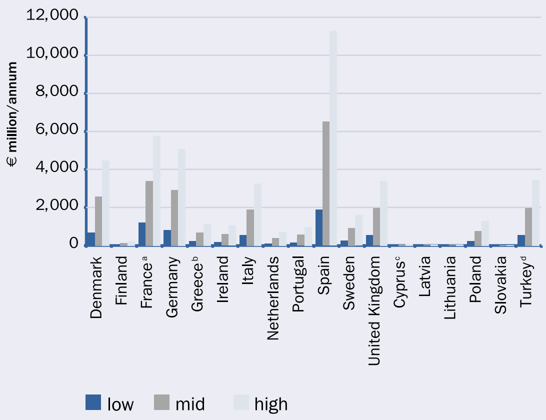
[i] source of emission data: NEK, Bulgaria.

[j] source of emission data: TEAS, Turkey.

Source: Eurelectric (2002), EWEA (2003a), own calculations.

Nevertheless, total annual avoidable external costs in 2020 are much higher than in 2000. They are expected to increase from €1.8 billion in 2000 to more than €25 billion a year in 2020 because of the expected increase in electricity generation by wind energy, from 22 TWh/a in 2000 to more than 450 TWh/a in 2020. While electricity generation by wind energy is expected to increase by nearly 2,000% from 2000 to 2020, avoidable external costs will increase by about 1,400%.

Figure 4.12: Total Avoidable External Costs in €Million/annum by the Use of Wind Energy in 2020, EU-25 and Turkey



[a] all data are from 2000. Calculation of electricity generation by wind energy based on data for 2010 resp. 2020.

[b] source of CO_2 emission data: Ministry of Environment and Physical Planning: "National Programme for the Reduction of Greenhouse Gas Emissions", Athens (2002).

[c] all data are for 2010. Calculation of electricity generation by wind energy based on data for 2010 resp. 2020.

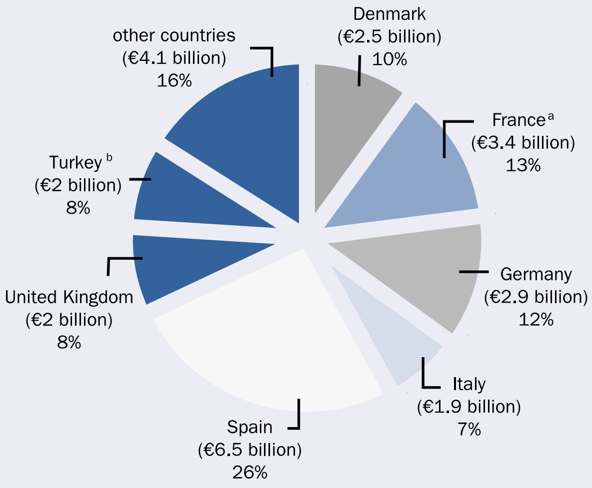
[d] source of emission data: TEAS, Turkey.

Source: Eurelectric (2002), EWEA (2003a), own calculations.

Total avoidable external costs in 2020 are shown in Figure 4.12. Spain will take over pole position from Germany in avoiding external costs by the use of wind energy.

Figures 4.12 and 4.13 show that many more countries will take part in avoiding external costs by the use of wind energy in 2020 than in 2000. Each of the seven countries shown in Figure 4.13 will avoid more external costs in 2020 by using wind energy than all the countries together in 2000 (each more than €1.8 billion a year); some of them are expected to avoid more than three times this amount (e.g. €6.5 billion in the case of Spain).

Figure 4.13: Shares of Total Avoidable External Costs by the Use of Wind Energy in Europe in 2020



[a] all data are from 2000. Calculation of electricity generation by wind energy based on data for 2010 resp. 2020.

[b] source of emission data: TEAS, Turkey.

Source: Eurelectric (2002), EWEA (2003a), own calculations. Source of CO_2 emission data for Greece: Ministry of Environment and Physical Planning: "National Programme for the Reduction of Greenhouse Gas Emissions", Athens (2002). All data for Cyprus are for 2010. Calculation of electricity generation by wind energy based on data for 2010 resp. 2020.

5 PUBLIC ACCEPTANCE ANALYSIS

Previous chapters have reported the environmental benefits of wind energy in the current European electricity supply system and shown its potential future benefits. How much of this potential can be achieved? What are the main obstacles to overcome, so that the sector continues to grow? These questions are being addressed through policy instruments, financial mechanisms, national renewable energy targets, R&D programmes, etc. Combined with increasing public awareness of climate change and sustainability, these are important drivers for a thriving renewable energy sector. But the most important issue is public acceptance, especially by local communities and individuals living at prospective wind farm sites. Whether an installation goes ahead or not often relies on them.

The purpose of this chapter is to give an overview of the environmental impacts and other factors affecting public acceptance of wind energy.

5.1 Environmental Impacts of Wind Energy

Although wind energy is a clean technology, it is not free of impacts on the environment. Wind energy has a number of special features, including:

- More than one wind turbine (WT) is needed for large-scale production.
- WTs are mainly located in remote and rural areas where the wind resource is present.
- The turbines may be visible from a great distance.
- The movement of the blades (flickering) may draw attention.

As well as these visual impacts, wind energy is associated with other environmental issues such as noise, land use and impacts during the construction phase. Some impacts, such as those on birds and flickering can be measured quantitatively; others, such as visual intrusion and noise require more subjective and qualitative criteria.

These impacts are considered in this section. In addition, an analysis of the primary energy consumption of a WT compared with a coal fired power plant is given.

5.1.1 VISUAL IMPACT

The siting of WTs affects the visual or aesthetic properties of the surroundings, especially in locations where people place a high value on the landscape. This is referred to as the ‘visual impact’ of wind energy. Visual impact has a direct effect on amenity, defined as resources available for people’s convenience, enjoyment and comfort, in this case a landscape.

A landscape attracts different perceptions since aesthetic values such as beauty and diversity are subjective (Schwahn, 2002), while its value will also be influenced by use (e.g. national park, wildlife habitat, agricultural land).

Protected areas of national or regional importance are more sensitive to the visual impact of wind energy. In addition, wind energy may compete with other public uses such as recreation, agriculture, tourism, wildlife conservation, and others.

The perceptions of individuals in communities affected by wind energy will depend on their attitudes to scenery and natural beauty, the existing level of visual amenity and their general attitude to WTs (Manwell, 2002).

Modern turbines are becoming larger both in size and capacity, and hence more dominant in the landscape. At the same time, the spacing between turbines is increasing, thus lessening their density in a given area. The development of the technology is therefore changing the visual impact of wind farms from high density groupings with high rotational speeds to fewer, larger machines operating at lower rotational speeds.

Other visual impacts of WTs are lighting and, in the vicinity of airports for example, marking to reduce bird collisions. Ancillary facilities such as stores, substations, transmission lines and roads also impact on amenity.

In order to maintain public acceptance, wind farms need to be designed in such a way as to minimise these various aesthetic and amenity impacts (see Table 5.1).

Table 5.1: Aesthetic Guidelines for Wind Plants

Ensure visual uniformity (direction of rotation, type of turbine and tower, and height)
Avoid fencing
Minimise or eliminate roads
Bury intraproject power lines
Limit or remove ancillary structures from site
Remove inoperative turbines
Avoid steep slopes
Control erosion and promptly revegetate
Remove litter and scrap
Clean dirty turbines and towers

Source: Gipe (1995).

The use of a computer simulation to generate a virtual image of the proposed wind farm can help developers and planners assess its visual impact.

The visual impact of wind energy has a big influence on public perception and acceptance of the technology. Efforts to integrate WTs aesthetically into the landscape and the sharing of economic benefits with local communities may help to soften negative attitudes to wind energy. These aspects are discussed later in this section.

5.1.2 NOISE

Noise is defined as an unwanted sound. It can be measured quantitatively, and regulations exist to limit noise levels, but it also has a subjective element. Manwell (2002) classifies the effects of noise from wind energy into two main categories:

- Subjective effects including annoyance, nuisance, dissatisfaction.
- Interference with activities such as conversation.

Noise from WTs comes from the sound produced by the turning blades and from the gearbox, generator and hydraulic systems (although in modern WTs this mechanical noise has been reduced almost to zero). As with other impacts of wind energy, perception of the noise depends on local features (e.g. rural or urban area, topography), number and distance of residents from the WT site, and the type of community affected (residential, industrial, tourist). The interaction of these factors lessens or enhances the perception of sound from WTs.

Physically, sound is a pressure variation detected by the ear; It depends on the source and the medium through which it travels. The speed of sound is about 340 m/s in atmospheric air. It is important to make a distinction between sound power level and sound pressure level. The former is a property of the source of the sound whereas sound pressure level is a property of the sound at a given observer location. Noise is measured in decibels (dB) and the scale employed (dBA) is weighted to the range perceived by the human ear. Table 5.2 shows a comparison of different power and pressure levels of sound to indicate what can be considered a threshold of hearing or a pain threshold.

The most important factors affecting noise propagation are: type of noise source, distance from source, wind speed, temperature, humidity, precipitation and the presence of barriers and buildings. The factors with the most influence on noise propagation are the distance of the source from the observer and the type of source.

Table 5.2: Level of Sounds

Source	Distance from the Source (m)	Sound Level (dBA)	Environmental Noise*	Subjectivity/ Impression
Civil defence siren	140-130			Threshold of pain
Jet take-off	61	120		
		110	Rock concert	Very loud
Pile driver	15	100		
Ambulance siren	31	90	Boiler room	
Freight train	15	80		
Pneumatic drill	15	80	Printing press	Loud
Motorway traffic	31	70		Moderately loud
Vacuum cleaner	31	60	Data processing centre Department store/office	
Light traffic	31	50	Private business office	Quiet
WT > 1MW	200	49		
WT > 1MW	300	45		
Large transformer	61	40		
Soft whisper	2	30	Quiet bedroom	
	20		Recording studio	
	10			Threshold of hearing
	0			

WT data is an estimation for illustrative purposes (University of Flensburg).
* Environmental noise is shown as an equivalent noise source at the sound level given.
Source: National Wind Co-ordinating Committee (2002).

From the table, it can be seen that distance plays an important role in the perceived sound level. The noise from a WT can reach moderate sound pressure levels (< 50 dBA) when the distance from the turbine to the receptor is between 200 and 300 m. Typically, the sound power level of a modern WT is between 100 and 106 dBA depending on the type of turbine and the wind speed at which the sound is measured (typically 8 m/s).

The decibel scale must be carefully interpreted when evaluating the number of turbines to be placed and their effects. A WT with a capacity higher than 1 MW has a sound power level of 104 dBA for example. The installation of a second turbine with the same sound power level will cause an increase of only 3 dBA. Increasing the energy of a sound by 26% raises the noise power level 1 dBA. Tripling the energy of a sound yields an increase of 5 dBA. The dBA scale is a logarithmic scale. In other words, as the sound power is doubled (two turbines) the index increases by approximately 3 dBA. A sound level of 100 dBA thus contains twice the energy of a sound level of 97 dBA. The sound level decreases with greater distance from the source by approximately 6 dBA every time the distance is doubled (Gipe, 1995).

In summary, the total perceived noise is the relative sum of the ambient or background noise and the WT noise. The ambient noise can mask the turbine noise completely if the turbines are located in an industrial or urban area. Trees may also mask distant WT noise.

Another important factor is time. WT noise can be present for hours, days or for longer periods depending on the wind resource. An excellent wind resource location (e.g. load factors of 40%) can cause the turbines to operate for more than 3,000 hours a year. The frequency of the noise will also affect sound pressure levels.

Regulatory standards for determining acceptable sound pressure levels take this time component into account. The standards are as follows (Renewable Energy Research Laboratory, 2002):

- L_{10}, L_{50}, L_{90}: The A-weighted sound levels that are exceeded 10%, 50%, 90% of the time. For example 45 dBA L_{90} means that the sound level must not exceed the level indicated 90% of the time.
- L_{eq} (equivalent sound level): The average A-weighted sound pressure level which gives the same total energy as the varying sound level during the measurement period.
- L_{dn} (day night level): The average A-weighted sound pressure level during a 24-hour period, obtained after adding 10 dBA to levels measured in the night between 10 p.m. and 7 a.m.

Table 5.3 shows the noise limits of sound pressure levels in some European countries. State-of-the-art turbines with capacities higher than 1 MW generally have sound power levels of between 100 and 106 dBA. Thus, a modern turbine has to be placed at a distance of between 200 m and 300 m from the receptor to reach a sound pressure level of between 45 dBA and 50 dBA (see Table 5.2).

Table 5.3: Legal Noise Limits in dBA

	Commercial	Mixed	Residential	Rural
Germany				
Day	65	60	55	50
Night	50	45	40	35
Netherlands				
Day (L_{eq})		50	45	40
Night		40	35	30
Denmark (L_{eq})			40	45
UK				
High speed (L_{50})				45
Low Speed (L_{50})				40

Source: Gipe (1995).

A noise assessment aims to determine how the turbines affect the existing ambient background noise and also what is an acceptable level of noise from the turbines themselves. The assessment should be able to demonstrate compliance with national noise regulations.

5.1.3 LAND USE

Land use refers to any alteration of current and future uses that can be affected by the installation of WTs.

The wind project developer must contact regional, national and local agencies to check for any land use restrictions in order to seek permission for the development to go ahead. Equally important is the need to assess the views of the local population so that any concerns they may have on land use are investigated and resolved.

Given the diffuse characteristics of wind energy, it is necessary to locate several turbines together to achieve the same capacity as conventional fossil fuel power plants. Thus, wind energy installations require larger areas than conventional power plants. This is due to aspects such as turbine spacing, topography, location of power lines and other associated facilities, in conjunction with other issues such as protected areas, access roads, land use objectives of the community and incompatibility in land-use.

However, only 1% to 3% of the total area is occupied by the turbine (tower base area, the foundations are mostly underground). So up to 99% of the land on which the turbines are sited will still be available for other uses. In Europe, most wind energy sites are located in remote, rural areas where livestock grazing is a common practice (see Figure 5.1).

Figure 5.1: Wind Energy in Rural Areas

Source: University of Flensburg (Lehbek in Gelting. Schleswig-Holstein, Germany).

5.1.4 IMPACT ON BIRDS

The main impacts of WTs on birds are deaths caused by the birds colliding with power lines and blades, and disturbance to migration routes. The main causes are listed as follows (Manwell, 2002):

- Death or injury caused by rotating blades.
- Electrocution from transmission lines.
- Alteration of migration habits.
- Reduction of available habitat.
- Disturbance to breeding, nesting and foraging.

More sensitive areas are those on migration paths and with a high number of birds present. The impacts are variable depending on the species, season and site-specificity (BirdLife, 2002).

According to the latest report by BirdLife (2003), the main potential hazards to birds from WT sites are: disturbance leading to displacement or exclusion, including barriers to movement; collision mortality; and loss of, or damage to, habitats. These aspects are further explained as follows.

Disturbance

The BirdLife report cites several studies showing that within 600 m from WTs bird numbers are reduced. However, the report states that: “The scale of such habitat loss, together with the extent of availability and quality of other suitable habitats that can accommodate displaced birds, and the conservation status of those birds, will determine whether or not there is an adverse impact.” (p.2)

Disturbance to bird populations may also result from increased human activities around the site, for maintenance purposes, etc., as well as WT noise and movement (BirdLife, 2003). In intensively farmed areas, however, the presence of WTs may have little effect on wild and farmland bird populations which will already be depleted due to intensive agricultural practices.

Collision Risk and Mortality

With respect to collision mortality, the two most critical examples are the Altamont Pass. California, USA and La Tarifa in Spain, both of which raised concerns over their impact on birds (National Wind Coordinating Committee, 2002). In the case of Altamont Pass, the issue arose in the late 1980s when the California Energy Commission recorded 99 dead birds in a four-year period from 1984 to 1988 which had been killed by the WT, transmission lines or other unknown cause (Gipe, 1995). The Altamont Pass wind park is characterised by a high density of turbines and the coexistence of turbines of diverse types and size. At Altamont Pass, the main losses were of raptors (birds of prey such as hawks and eagles) while at La Tarifa soaring birds (storks and vultures) were affected. Both areas have high concentrations of birds (BirdLife, 2003). These wind parks are examples of how poor siting and out-moded WTs and tower technology can adversely impact bird populations (Sagrillo, 2003). Subsequent experiences in Germany and Denmark show that such effects can largely be avoided by responsible planning practice.

In 2001, Western EcoSystems Technology Inc. was commissioned by the National Wind Coordinating Committee (NWCC) to study avian collisions with WTs and other structures. The study aimed “to provide a detailed summary of the mortality data collected at windplants and put avian collision mortality associated with windpower development into perspective with other significant sources of avian collision mortality across the United States”.

The study estimated that in 2001 in the US, 33,000 birds were killed by the 15,000 turbines in operation, with the majority of these fatalities projected to occur in California where approximately 11,500 operational turbines exist. Most of the California turbines are older and smaller machines, with a capacity ranging between 100 to 250-kW (Western EcoSystems Technology Inc., 2001). The results indicate that each turbine in the US accounts for 2.19 avian deaths a year for all species combined and 0.033 raptor fatalities per turbine per year.

In Spain, a study carried out in the state of Navarra (EHN, 2003) on the impact of wind parks on bird life showed that 692 turbines located in 18 wind farms do not put any species at risk from death by collision. 88 deaths of medium and large birds were detected, which represents an annual mortality rate of 0.13 dead birds per turbine. In other words, it takes more than seven years for one turbine to kill one bird.

In a study for the Finnish Ministry of Environment, Koistinen (2002) showed that 10 birds were killed by 60 WTs in a one-year period.

The likelihood of bird collisions is determined by wind speed, nature and height of flight, species, age of bird and stage in its breeding cycle. Most studies have been carried out on smaller turbines (BirdLife, 2002); newer, larger turbines may have different effects. Low bird fatality rates do not mean that efforts to reduce the impact of WTs on bird populations are unnecessary; even a low collision rate in a sensitive area may be significant for some bird species.

Habitat Loss or Damage

Loss or damage to habitats is caused by turbine bases, substations, access roads and transmission line corridors. This is not believed to be a major concern to birds outside sensitive areas, such as designated sites of national and international importance (BirdLife, 2003).

Recommendations

Proper siting of turbines is important if adverse impacts on birds are to be avoided. The following criteria have been proposed (Manwell, 2002):

- Avoid migration corridors.
- Avoid siting in specific microhabitats.
- Use appropriate tower design (tubular towers or lattice towers.
- Route electrical lines underground.

These criteria could be incorporated into national or regional planning strategies. An EIA systematically examines the possible environmental consequences of implementing projects, programmes and policies (United Nations, 2002). EU Directive 85/337/EEC requires an assessment of the environmental effects of those public and private projects which are likely to have significant effects on the environment. The Directive was amended in March 1997 by Directive 97/11/EC which included, in its Annex II, installations for the harnessing of wind power for energy production (wind farms). For wind energy developments every EU member state shall assess the project's environmental impacts on a case by case basis.

Impacts on Birds in Context

The impact of wind energy on birds must be placed in context (Youth, 2003). Virtually all threats to birds are human-related (99%), with habitat loss as a result of industrialisation, over-exploitation of natural resources, over-population (human), etc., being the biggest threat. Other threats include hunting, the pet trade, unsustainable fishing practices, oil spills, and oil and natural gas exploration, extraction and transportation. Chemical and pollution threats such as pesticides, lead from spent hunters' shot or sinkers left by anglers are also significant. Structures such as skyscrapers, communication towers and transmission lines kill migrating birds, while climate change poses a new threat to bird habitats.

With respect to wind park developments, location is a critical factor and there is a need for further research on the new, larger, generation of turbines.

In the US, the Western EcoSystems Technology Inc. (2001) study found a range of between 100 million to 1 billion bird fatalities due to collisions with artificial structures such as vehicles, buildings and windows, power lines and communication towers, in comparison to 33,000 fatalities attributed to WTs. The study reports that, "windplant-related avian collision fatalities probably represent from 0.01% to 0.02% (e.g. one out of every 5,000 to 10,000 avian fatalities) of the annual avian collision fatalities in the United States, while some may perceive this level of mortality as small, all efforts to reduce avian mortality are important".

In Finland, Koistinen (2002) reports 10 bird fatalities from turbines, and 820,000 birds killed annually from colliding with other structures such as buildings, electricity pylons and lines, telephone and television masts, lighthouses and floodlights.

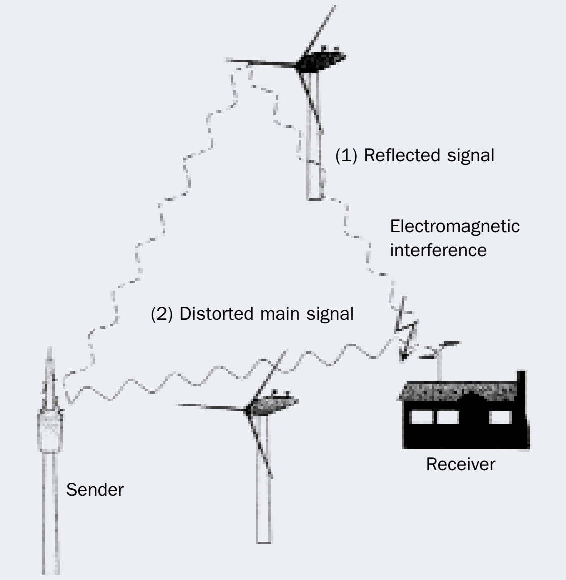
5.1.5 IMPACTS OF CONSTRUCTION ON TERRESTRIAL ECOSYSTEMS

These impacts consist of long-term loss of land from turbine installation and their associated electrical connections, buildings and access tracks. It has to be noted, however, that only the access roads and a very small area around the tower of a WT are lost. Danish and German research shows that agriculture may continue in rural wind parks, which are often used for grazing cattle.

5.1.6 ELECTROMAGNETIC INTERFERENCE (EMI)

WTs or generation equipment can interfere with communication systems that use electromagnetic waves (see Figure 5.2). This is caused mainly by the turbine blades, which sometimes scatter the signals as they rotate. The tower may also reflect signals, so interfering with the original signal arriving at the receiver (Manwell, 2002).

Figure 5.2: Electromagnetic Interference



Source: Manwell *et al*. (2002).

EMI mainly affects television reception, aircraft navigation and landing systems, as well as microwave links. Interference with television reception is the most common effect but it can be easily and cheaply corrected. Other mentioned impacts are unlikely to happen unless the turbines are placed in close proximity to the transmitter or receiver. EMI effects on FM radio, cellular phones and satellite services are very unlikely to occur.

EMI is a site-specific issue. It is recommended that an on-site assessment is performed to identify any effects on radio services in the area as well as the interference zones.

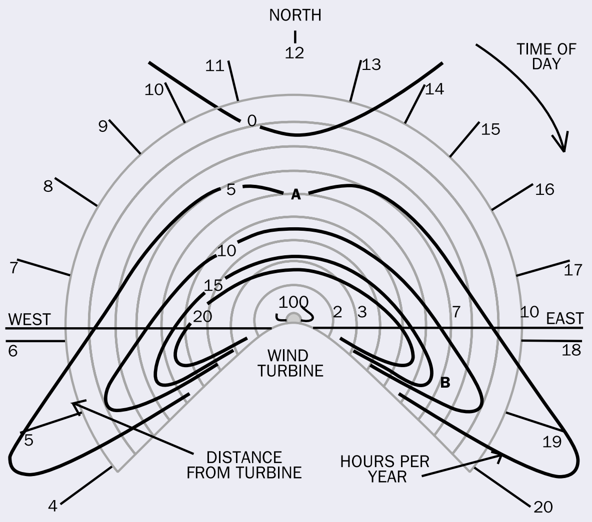
5.1.7 FLICKERING

The rotating turbine blades cast moving shadows which cause a flickering that can affect residents living nearby. Similarly, gloss surface blades flash when they rotate. This effect has been subject to analysis especially in northern Europe where this effect is considered, although it is not seen as an issue in the US (Gipe, 1995).

Figure 5.3 shows an example of the shadow flicker effect. The figure has been constructed for Denmark. The results would vary for different countries due to differences in cloud cover and latitude. There are two houses in the picture marked as A and B which are respectively six and seven hub heights away from the turbine in the centre. The diagram shows that house A will experience a shadow from the turbine for five hours per year. House B will experience a shadow for up to about 12 hours per year. Seasonal variation is also included in the calculation but is difficult to show without undue complication (European Commission, 1999).

In Germany, a court has ruled that the maximum allowable shadow flicker a year is 30 hours (Danish Wind Industry Association, 2003). Programmes exist that automatically shut the turbine down when conditions make flickering likely.

Figure 5.3: Shadow Calculation



5.1.8 CONSUMPTION OF ENERGY (ENERGY BALANCE)

In a conventional coal fired fossil power plant, the fuel cycle consists of exploring, mining, processing and transporting coal, as well as manufacturing and installing the equipment, the power plant operation and the disposal of waste. In the case of a renewable source like wind, the fuel cycle includes only the activities required to produce, install, maintain and decommission the turbine and its ancillary systems. The activities in the fuel cycle require an input of energy to make possible the production of energy from a wind turbine.

How long does a WT take to recover the energy spent in its fuel cycle, and how much energy does it produce? According to a study by the Danish Wind Industry Association (1997), modern WTs recover all energy inputs in three to four months (see Table 5.5) and will save between 63-78 times the energy input required to operate a coal fired plant over a 20 year period.

The study estimated the energy requirements of a typical Danish 600 kW WT during its 20-year lifetime (see Table 5.4).

Table 5.4: Energy Use During Life Cycle, 600 kW WT

Gross energy use	total (TJ)
Manufacture of turbine	1.9
Installation of turbine	0.495
O&M (20 years)	0.774
Total excluding scrapping	***3.169***
Scrapping, energy use	0.522
Scrapping, recovered energy	-0.733
Total including scrapping	***2.958***
Total incl. scrapping MWh	***821***

Source: Danish Wind Industry Association (1997).

The study then estimated how much energy usage (primary energy consumption) is required in a coal fired plant to produce the same amount of electricity as the turbine producers in one year.

Table 5.5 shows that to produce the same quantity of electricity per year, the WT requires far less energy input (821 MWh) than the coal-fired power plant. (3,202 MWh/2,598 MWh).

It should be noted that these are conservative estimates since the primary energy consumption does not include coal fired plant construction and operation or indirect energy use during the coal firing process. Furthermore, the comparison assumes a thermal efficiency of 45% which is well above the average figure for coal fired plant in the EU. In general, therefore, the WT energy recovery period will be even shorter (European Commission, 1999)

Delivery of the WT to a remote site makes very little difference to the above figures. For example, even if a 65 tonne turbine had to be shipped 10,000 nautical miles, this would only increase its net energy use by 1.5%.

R&D programmes continue to develop shorter WT energy recovery periods.

5.2 Environmental Impacts of Offshore Wind Energy

This section introduces the environmental impacts of offshore wind energy developments. It is based on a comprehensive study funded by the European Commission aimed

Table 5.5: Energy Recovery Time for a Wind Turbine

Wind Turbine Site Roughness Class (MWh/Year)	(A) Wind Turbine Electricity Production (MWh/Year)*	(B) Coal-Fired Plant Primary Energy Consumption* (MWh)	(C) Wind Turbine Energy Use (MWh)	(D) Wind Turbine Energy Recovery Period (year)	(E) Wind Turbine Energy Recovery Period (months) E = D x 12	(F) Wind Turbine Energy Saving Period** F = (B x 20)/C
Class 1	1,393	3,202	821	0.26	3.1	78
Class 2	1,130	2,598	821	0.32	3.8	63

* Input of energy required in a coal fired plant to produce 1,393 and 1,130 MWh/year of electricity considering only coal mining, transportation, energy content of coal and a plant efficiency of 45%.

** Wind energy saving over a 20 year period operation.

at gathering and distributing knowledge on all aspects of offshore wind energy, including: offshore technology; electrical integration; economics; environmental impacts; and political aspects (Garrad Hassan and Partners *et al*., 2001).

Questionnaires were sent to developers, utilities companies, consultants, research institutes and universities in different European countries in order to identify the relevant issues and collect information on factors such as public acceptance, environmental impacts, conflicts of interest and the political aspects of offshore wind development. With respect to environmental impacts, the survey found that birds, visual effects and impacts on recreation are the top European concerns.

Table 5.6: Ranking Environmental Impacts

Impacts	Indicator*
Birds	1.5
Visual effect	1.5
Recreational areas	1.8
Noise	2
Hydrography	2.1
Fish	2.2
Marine biology	2.3
Sea mammals	2.4
Sea currents	2.4
Marine archeology	2.4
Seabed	2.5
Water quality	2.5
Raw Materials	2.6

* 1 = high importance
2 = medium importance
3 = low importance

Source: Garrad Hassan and Partners *et al.* (2001).

Table 5.6 illustrates the average ranking of environmental impacts. The scale used is from 1 to 3, where 1 corresponds to an issue of high importance and 3 to one of low importance. The potential environmental impacts listed in Table 5.7 are the expected impacts identified by the study according to current knowledge. Further research is needed to improve understanding of these impacts, and identify others.

Table 5.7: Potential Negative Environmental Impacts

Birds:

- Collisions with turbines.
  - turbines acting as obstacles for migrating birds.
- Disturbance to feeding/breeding areas due to:
  - noise from turbines in operation and vessels during construction, maintenance and dismantling;
  - movements of blades or serious disruption to the food chain, e.g. due to new sediment structure or “unnatural” reef effect; and
  - accidents.

Mammals:

- Loss of habitat due to:
  - noise;
  - movement of blades;
  - food chain changes;
  - electromagnetic fields and vibrations (affecting the animals’ sonar system); and
  - accidents.

Fish:

- Impacts on fish and fish larvae from sedimentation/turbidity, underwater noise, vibrations and electromagnetic fields.
- Effects from unnatural reefs.
- Accidents.

Benthic fauna and flora:

- Changes in sediment structure.
- Direct loss from foundation and cable footprints.
- Impact from foundations/hard substrates and electromagnetic fields.
- Disturbance/destruction of the seabed due to accidents with ships/aircrafts.

Coastline:

- Impact on coastline due to current/sediment changes caused by cables.
- Impact on coastline due to accidents.

Visual impact:

- Intrusive artificial obstacles in an otherwise pristine landscape.

Noise impact:

- Increased blade tip speed and the ability of sound to propagate more efficiently on sea surface may lead to noise impacts.
- Impact on birds, sea mammals and fish from underwater noise.

Source: European Commission (2002a).

In comparison with onshore wind energy development, the identification and understanding of offshore wind development impacts and their respective mitigation measures are still in their infancy. Easy assessment of potential impacts substantially facilitates development.

Table 5.8 lists some general recommendations for mitigating the expected impacts of large-scale offshore wind energy developments (Garrad Hassan and Partners *et al*., 2001).

Table 5.8 General Recommendations for Offshore Wind Energy Developments

Fish, birds and other groups.
- Identify and avoid sensitive areas.
- Avoid site works during sensitive time periods.

Birds:
- Design to accommodate migratory flight paths.

Sea mammals:
- Minimise noise levels during construction, operation and dismantling.

Fish:
- Minimise effects of structures and cabling on stocks.

Seabeds:
- Minimise sedimentation and turbidity.

Hydrographic, currents and water quality:
- Use appropriate foundation design.
- Avoid use of pollutants when protecting the foundation, tower and turbine from the marine environment.

Visual:
- Early assessment to take account of distance from shore, marking lights and nature of viewpoints.
- Well-balanced marking lights to take account of safety issues and visual impacts.

Noise:
- Ongoing public relations work to counter poor publicity.
- Maintain good standards of noise emissions despite increases in turbine size and tip speed.

Social conflicts:
- Promotion of openness and local involvement.

Risk management:
- Develop risk management methods and emergency procedures in order to reduce risks of ship collision and minimise consequences of collisions.

Source: European Commission (2002b)

5.3 Factors Affecting Public Acceptance of Wind Energy

The environmental impacts of wind energy are often seen as amenity issues which are mainly borne by local communities; but are they the only factors that need to be considered?

Society as a whole has a general understanding and awareness about the importance of environmentally friendly technologies, not only as a means of generating cleaner electricity but also to conserve natural resources and minimise waste. This recognition of renewable energy sources and other issues such as climate change, depletion of the ozone layer and the sustainable use of energy is often the result of government information programmes and campaigns, energy saving initiatives run by utility companies, media reports, etc.

Where such understanding and awareness is absent, getting the message across about environmentally friendly technologies, such as wind energy, is much more difficult. An informed society, on the other hand, will drive demand for environmental technology.

There is no guarantee that wind energy projects will be successfully implemented. The reasons lie in the distance between the costs (impacts borne by local communities) and benefits (for general society). This is the so-called NIMBY syndrome ("not in my back yard"), which is sometimes a response to unknown technology and impacts. The support of local communities is essential if a wind project is to go ahead. Support is more likely to be forthcoming where there has been a clear assessment of the impacts and the mitigation measures have been properly explained. Other factors are also relevant, however.

Local community participation is an essential element in project development in order to secure public acceptance. Such participation has the following advantages:
- Information is shared with the community and feedback becomes part of the planning process.
- Decision-making and control stays local.
- The permitting process is facilitated.

Local participation does not have to be limited merely to passing information between the parties but can also include economic involvement through:

- share ownership;
- cooperative association ownership;
- electricity bill discounts; or
- tax rebates.

Public involvement and investment has been a decisive factor in the successful expansion of wind energy in Denmark and Germany. The next chapter provides a summary of research aimed at exploring the public acceptance of wind energy in Europe, which builds on some of the ideas introduced here.

6 PUBLIC ACCEPTANCE IN THE EU

Some EU countries have carried out surveys on public acceptance of wind energy. Despite differences in methodology and focus, these surveys give an indication of the degree of acceptance of wind energy. This section summarises results from different studies. The findings of a pan-EU public opinion survey on energy-related issues are reported, followed by research from a number of EU member states on public acceptance of wind energy.

6.1 Attitudes of EU Citizens to Energy and Energy Technology Issues

The pan-EU survey "Energy, Issues, Options and Technologies" was commissioned by the European Directorate for Research. The aim of the survey was to gather information on the public view of energy-related issues, including scientific and technological aspects, and prospects for the future. Over 16,000 people were interviewed across the EU-15 during February and April in 2002. The survey did not focus on wind energy, but it does reveal general perceptions on issues such as climate change and renewable energy technologies, including wind energy.

The study analyses the perceptions of Europeans about energy sources. In general, the responses reflect the current situation for oil, coal and gas, but overestimate the use of both nuclear and renewable energy sources (see Figure 6.1).

Figure 6.1: Europeans' Perception of Energy Sources

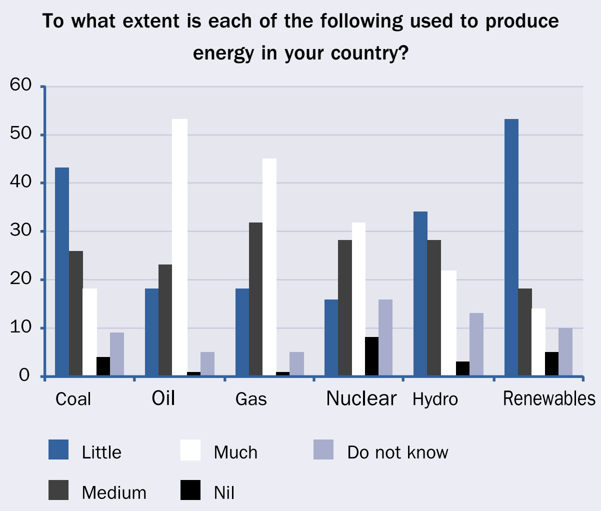


Table 6.1: Perception on Electricity Energy Sources

More than half of the electricity used in the EU comes from coal	
Yes, it is the case	21%
No, it is not the case	49%
Do not know	31%
More than one quarter of electricity produced in EU comes from nuclear power stations	
Yes, it is the case	55%
No, it is not the case	16%
Do not know	29%
More than a quarter of the electricity produced in EU coming from renewable energy sources, such as hydroelectric energy, wind or solar power	
Yes, it is the case	30%
No, it is not the case	43%
Do not know	27%

When asked about energy sources for the production of electricity (see table 6.1), there is an inaccurate perception regarding coal usage for electricity production in the EU. 49% of the respondents do not think that more than half of the electricity used in the EU comes from coal and 31% do not know. However 55% are correct in that more than one quarter of electricity produced in the EU comes from nuclear power stations; and 43% also rightly believe that it is incorrect that more than a quarter of the electricity produced in EU is generated from renewable energy sources.

One of the survey's main findings is that the public sees climate change as a serious issue (88% of respondents). Fossil fuels are recognised as one of the main causes of climate change (75%), along with transport emissions (74%).

With regard to energy dependency, 37% of respondents agree that this is an urgent issue and around a half think that more energy sources should be developed combined with greater encouragment for energy efficiency. A quarter want to see a reduction in imports of fossil fuels and uranium.

When asked about the future, environmental protection and low prices are the top priorities (72% and 62% respectively); 30% believe that ensuring uninterrupted energy supply should be a priority.

Europeans would like to know more about: how to save energy at home (53%); the use of renewable energy sources at home (42%); alternatives to petrol and diesel in vehicles (39%); nuclear safety and radioactive waste (36%); new energy options such as fuel cells (27%); EU activities in energy-related research and development (23%); and how to save energy at work (13%). The study concludes that *"energy, and in particular aspects of energy affecting them personally, is thus a subject on which Europeans appear to want to be better informed"*.

When asked about what will happen in 2050, 40% of respondents predict that the least expensive energy sources will be renewables like solar, wind and biomass, followed by hydroelectric power (24%) and natural gas (21%). Moreover, 27% consider that renewables will provide the greatest amount of useful energy and 67% think that renewable energy sources are the best environmental option. The report concludes that *"overall, the perceptions Europeans have of energy options in 20 and 50 years from now is clearly influenced by their own instinctive preferences for renewable energy sources"*. EU citizens expect that energy research will bring significant environmental benefits, more diverse energy sources (69%) and cleaner transport (51%). The following Figures illustrate these results.

Figure 6.2: Energy Resources Perception in 2050 – Least Expensive Source

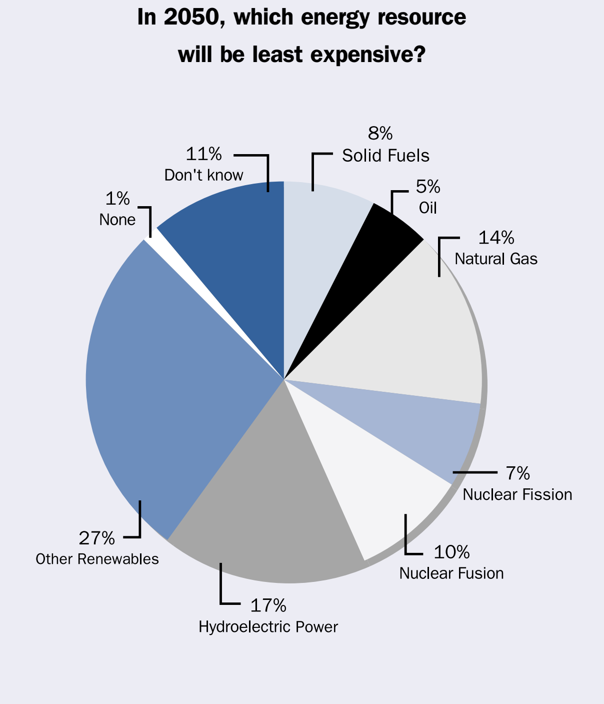


Figure 6.3: Energy Resources Perception in 2050 – Source with Greatest Amount of Useful Energy

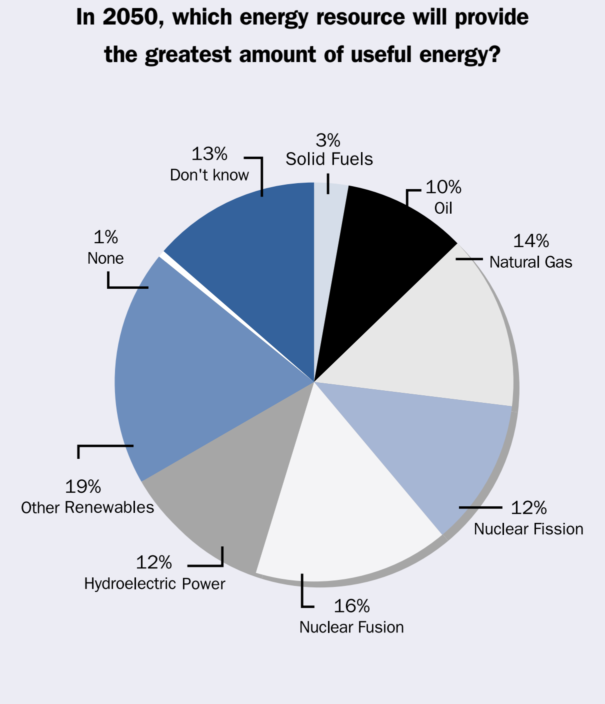


Figure 6.4: Energy Resources Perception in 2050 – Best Source for the Environment

In 2050, which energy resource will be the best for the environment?

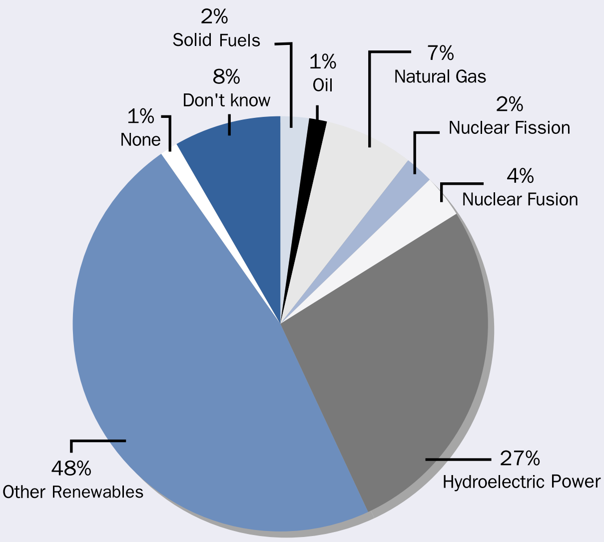
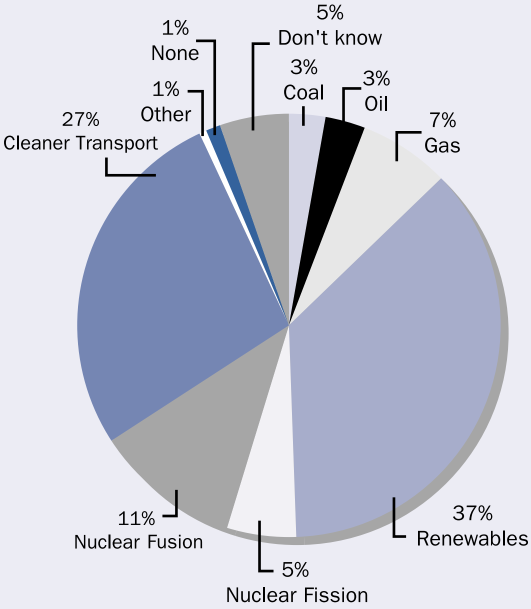


Figure 6.5: Energy Resources Perception in 2050 – More Research in the EU

In which areas should there be more energy-related research in the EU?



Finally, the survey found that attitudes vary according to country. For example, new energy sources and clean transport were chosen as priorities more often in Sweden, the Netherlands and Denmark.

6.2 Public Acceptance in Spain

Although there has been no national assessment of public acceptance of wind energy in Spain, regional information is available. The APPA (Spanish Renewable Energy Association) has provided valuable information on one of the most important developers, EHN, which is responsible for 30% of the wind capacity installed in Spain (36 wind parks as of December 2001). On behalf of the developer, CIES, a member of the Spanish Association of Opinion and Market Studies, carried out a survey on public acceptance of EHN’s wind farms in different regions, with particular emphasis on the regions of Navarra (see Figure 6.6) and Castilla – La Mancha.

The development of wind parks has an important environmental component. Environmental impact assessments maximize the use of existing roads; and allocate existing and new infrastructure, and restoration of areas impacted during construction and installation. During the first five years of wind park operation, potential impacts – especially with regards to birds and other fauna - were evaluated. Great attention was paid to the integration of wind parks with the existing architecture, surroundings and the landscape. For example, substations were designed with the same facades as existing infrastructure.

Figure 6.6: Substation, Ibargoiti Wind Park in Navarra (22 MW)

Source: EHN (2001).

The development of wind parks in the states of Navarra and Castilla has generated 2,000 jobs. In 2001, 400 MW wind energy capacity was installed in the state of Navarra. CIES carried out 1,369 interviews in Navarra and found a very high acceptance for WTs (85%) (see Table 6.2). Even though the number of WTs increased dramatically over the period 1995 to 2001, the level of support has remained stable.

Table 6.2: Public Acceptance in Navarra

Year	1995	1996	1998	2001
Number of turbines*	6	40	217	600
Positive/very positive	85%	81%	81%	85%
Negative	1%	3%	3%	1%

* Mostly turbines of 660 kW capacity.
Source: EHN (2001).

A previous study carried out by CIES for EHN in 1998 on public perceptions in wind park areas in Navarra found:

El Perdón: 82% see the wind park as a step forwards whereas 2% think it is a step backwards. With regard to effects on the landscape, 41% say it makes no difference, 32% think it spoils the landscape, and 24% think it improves it.

Leitza-Beruete: 74% think the wind park is beneficial, 8% find it acceptable and 7% consider it damaging. With regard to effects on the landscape, 56% say it makes no difference while 36% think it does have an impact.

Guerinda: 76% see the wind park as beneficial and 4% consider it damaging. With regard to effects in the landscape, 56% say it makes no difference while 42% think it does have an effect.

Alaiz-Izco: 81% give positive support to wind parks whereas 6% are negative. With regard to effects on the landscape, 45% say it makes no difference, 29% think it spoils the landscape, and 19% think it improves it.

In Albacete province in the state of Castilla – La Mancha where 600 WTs are installed, a public acceptance assessment in 2001 found that 79% were positive about the WTs and 1% were negative.

In October 2002, a study carried out by CIES on behalf of Energías Eólicas Europeas (EEE) showed that 79% of respondents consider wind energy to be a benefit and 1% think it is damaging. The study also found that 62% think that wind parks make no difference to the landscape while 23% think they do have an effect.

The high acceptance of wind energy is due to environmental, energy-related and socio-economic reasons. Acceptability values higher than 70% were found in all areas surveyed, with 88% seeing wind as a clean energy source and 48% considering that it creates wealth and jobs. 69% of those surveyed thought that wind energy was the best energy source to produce electricity. This compares to 17% who support hydro, 2% thermal power and 1% nuclear.

A recent study carried out in Tarragona province (CERES, 2002) in the region of Cataluña also shows a majority favouring wind power (83%) over nuclear or fossil fuel technologies. Another interesting finding is the link between educational attainment and perceptions of wind energy. The higher the level of education, the greater the reluctance to accept certain aspects of wind energy such as visual intrusion. The Centre for Sociological Research, an autonomous state agency attached to the Office of the Presidency, carries out regular public opinion surveys. The last survey, in March 2003, showed that 65.4% backed further research on clean energy sources and 1.2% wanted to see more work on nuclear power.

6.3 Public Acceptance in the United Kingdom

The UK government aims to generate 20% of the UK's electricity from renewable energy sources by 2020, with the major focus on offshore wind energy. The latest poll to measure public support for this target shows that 74% support both the 20% goal and increasing the use of wind power.

Aggregating data from 42 surveys carried out between 1990 and 2002 shows, on average, that 77% of the public are in favour of wind energy with 9% against (British Wind Energy Association, 2003).

A summary of research on attitudes to wind power from 1990 to 1996 (Marie *et al.*, 1996), concludes that an "overwhelming majority of residents in areas with a wind project are pro-wind, both in theory as a renewable energy source and in practice in their area, with an average of eight out of 10 supporting their local wind farm".

A survey of people living within 20 km of four wind farms in Scotland was carried out in 2000 for the Scottish Executive (System Three Social Research, 2000). The sample was divided into three zones of 5 km from the farm, 5-10 km and 10-20 km. The main results are as follows:

- 67% of respondents said there was something they liked about the wind park, this proportion increased to 73% for those living in the 5 km zone.
- With respect to visual impacts, 21% liked the look of the wind park whereas 10% thought it spoiled the view.
- Regarding future developments, there was a positive attitude towards wind parks; 14% of respondents would be concerned if extra turbines were added to the existing park.

A recent survey conducted for the Scottish Executive by MORI in 2003 (EWEA, 2003f) shows that people living close to Scotland's 10 largest wind parks strongly support wind energy, with 82% wanting an increase in electricity generated from wind, and more than 50% supporting an increase in the number of turbines at their local wind park. The MORI poll (see Table 6.3) covered 1,800 residents living within a 20 km radius of a wind park. Its main findings are:

- 20% of respondents think their local wind park has a broadly positive impact on the area while 7% felt that it has a negative impact. The majority are neutral.
- Before the construction of the wind park, 27% of respondents were concerned about landscape changes, 19% were concerned about traffic during construction and 15% about noise during construction. During the construction phase and afterwards, these figures fell to 12%, 6% and 4% respectively.
- 54% would support a 50% increase in the number of turbines at their local wind farm, 9% would not.
- With respect to other technologies, respondents want to see a decrease in nuclear, coal and oil power. Clean electricity production technologies are strongly supported with 69% in favour of wave energy and 82% in favour of wind energy.

Table 6.3: Results of MORI/Scottish Executive Poll

Question: What effect, if any, would you say the presence of the wind farm has had in your local area? Would you say it has had…

	%
A completely positive effect	7
A generally positive effect	13
Neither positive nor negative effect	51
A generally negative effect	5
A completely negative effect	2
Don't know/ No opinion	23

Question: Was the wind farm already here when you moved in, or has it been built since then?

	%
Wind farm already here	10
Built since moved in	77
Don't know	14

Question: I would like to know what you anticipated it might be like having a local wind farm (before it was built/ before you moved here), and then I will ask you about what it has actually been like.

Question: Which of the following problems, if any, did you think having a wind farm in the area might cause?

Question: And which, if any, have actually turned out to be problems caused by having a wind farm in the area?

Base: All who have lived in the area before the wind farm was built (1,547)

	Thought might be problems %	**Have been problems %**
Noise from the turbines	12	2
The look of the landscape being spoiled	27	12
Interference with TV and radio reception	6	1
Damaging effect on local business	3	1
Damage to plants or animals	12	3
Noise or disturbance during construction	15	4
Extra traffic during construction	19	6
A reduction in house prises	7	2
None of these	54	82

Question: To what extent would you support or oppose increasing the number of turbines at the wind farm by 50%? Would you…

(Base: All)

	%
Strongly support	26
Tend to support	28
Neither support nor oppose	25
Tend to oppose	5
Strongly oppose	4
Don't know	11

To what extend would you support or oppose increasing the number of turbines at the wind farm by 100%? Would you…

(Base: All)

	%
Strongly support	19
Tend to support	23
Neither support nor oppose	24
Tend to oppose	11
Strongly oppose	10
Don't know	14

Question: I am going to read out some different ways of generating electricity. For each one, I would like you to tell me whether you think the proportion of electricity generated in Scotland should increase, reduce or stay at about current levels over the next 15 years? First of all…

(Base: All)

	Increase	Keep same	Reduce	Don't know
	%	%	%	%
Coal fired power	9	24	60	6
Oil fired power	9	32	48	10
Nuclear power	7	17	68	9
Wind energy	82	11	2	6
Wave energy	69	11	3	17

Source: EWEA (2003f).

Two opinion polls have been carried out in Scotland to determine the effect, if any, of wind farms on tourism to the region. The first poll, of visitors to Argyll and Bute, revealed that wind parks "are not seen as having a detrimental effect... and would not deter tourists from visiting the area in the future" (MORI Scotland, 2002). The second concluded that the visual impacts of wind farms are a concern, especially in protected areas such as Areas of Outstanding Natural Beauty (NFO, 2002).

Table 6.4: Results of MORI Scottish Tourist and Visit Scotland Poll

Results of MORI Scottish Tourists Poll:

Question: What effect, if any, would you say the presence of wind farms has had on your impression of Argyll as a place to visit?

A completely negative effect	1%
A generally negative effect	7%
Equally positive and negative effect	43%
A generally positive effect	28%
A completely positive effect	15%
Don't know	6%

Question: Has the presence of wind farms in Argyll made you any more likely to visit the area in future, made it less likely, or has it made no difference?

Less likely	2%
No difference	91%
More likely	4%
Don't know	3%

Results of Visit Scotland Poll:

Views of development of wind farms as a means of generating power	(%)
Good idea - ecologically friendly	39
Good idea generally	17
Good idea - save digging fossil fuels	11
Good idea - need different sources of power	5
In favor of them	5
Necessary evil - better alternative to nuclear	4
Necessity but an eyesore	4
Against - can't generate enough power	2
Good idea - natural resource	1
If not too many - good idea	1
Other positive	1
Other negative	7
Don't know	5

Impact on further holidays in the Scottish countryside if the number of wind farms was to increase	(%)
Would make no difference	63
Steer clear of the area	15
Less likely to come back	10
Depends on the area	6
Minimal impact	2
Other	2
Don't know/not stated	5

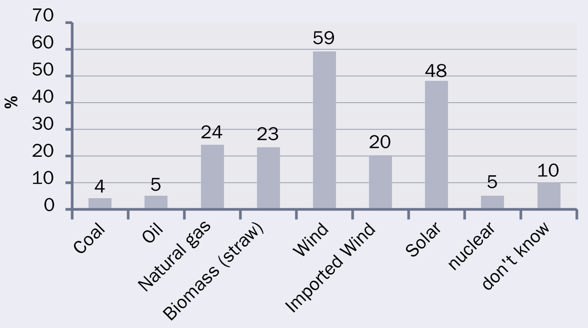
Source: EWEA (2003f).

6.4 Public Acceptance in Denmark

In Denmark, public opinion of wind energy over the last 10 years has been positive (Danmarks Vindmølleforening, 2002).

A survey (see Figure 6.7) carried out in 2002 shows that 59% would buy electricity from a renewable source, while 24% would not. Results from a study in 2001 illustrate that 86% of the population support wind energy with 68% wanting Denmark to install more WTs and 18% thinking that existing capacity is sufficient.

Figure 6.7: Energy Sources Preferences in Denmark



Source: Danmarks Vindmølleforening (2002).

A 1997 study carried out in the municipality of Sydthy, where 98% of electricity supplied to the 12,000 inhabitants is generated by wind, found that people with a high degree of knowledge about energy generation and renewable energy in particular tend to be more positive about wind power. In addition, 58% of householders in Sydthy have shares in their local wind park (Damborg, 1998).

In Denmark, 150,000 families are involved in wind energy projects due to the possibility of receiving financial benefits and/or a positive stance regarding the environmental benefits of wind energy (EMU and Hammarlund Consulting, 2003).

6.5 Public Acceptance in Germany

The northern state of Schleswig-Holstein in Germany had, as of December 2002, 1,800 MW of installed wind capacity, with a share of nearly 30% of the state's energy consumption (DEWI, 2003). An analysis of wind energy in Schleswig-Holstein was prepared for the state's Energy Ministry in 2002. Some issues of relevance to public acceptance are summarised here (Eggersglüß, 2002).

Germany's approach to wind energy has changed dramatically over the years. Initially, individuals who were interested in using wind energy, such as farmers, could install a WT on their own land. Then, the growing interest of non-local investors made it possible to develop wind parks on designated areas. In the meantime, many "citizen's wind parks" have emerged funded by companies who offer shares to local small-scale investors. These have proved very popular.

In general, the siting of a wind park is accepted by most people in a particular area when the following principles are followed:

- Sufficient distance from residential areas.
- Quiet turbines are chosen.
- The population is kept properly informed.
- There is some sort of financial benefit for the local community.
- The developer has its head-quarters and administration situated in the area.
- Land owners' views are sought when choosing a site.

Although wind energy is seen as a clean way of producing electricity and preserving natural resources, concerns have been raised about changes to the landscape, noise, flickering and effects on birds. Other worries include higher electricity prices and financial rewards for a few land owners and WT operators.

A study to assess the effects of onshore and offshore wind parks on tourism was undertaken by the Schleswig-Holstein tourist board (Günther, 2002). This concluded that the wind industry does not affect tourism in the region. Visitors are aware of the increasing number of turbines in the landscape, but they do not influence visitors' behaviour.

Research carried out by the EMNID Institute for the German science magazine *P.M.* in 2003 found that 66% of Germans are in favour of further construction of wind farms. The institute also conducted a survey in 2002 (see Table 6.5) showing that 88% supported the construction of more wind parks in Germany, with 86% agreeing that the share of wind power in the energy mix should increase (EWEA, 2003f).

Table 6.5: Results of EMNID Poll, 2002

Question: Which statements would convince you to support the erection of further wind turbines?

Wind turbines produce green electricity	89.2%
Wind power is a new technology that creates thousands of jobs	62.1%
Wind turbines are easy to control and secure	66.3%

Question: Gas, oil and coal are limited resources, whilst the use of wind power constitutes an alternative. Do you believe that the share of wind power in the energy mix is already sufficient?

Yes, it is sufficient	9.5%
No, it should be increased	86%
Don't know	4.5%

Question: Wind farms must fulfil certain criteria, such as there have to be minimum wind speeds, there has to be enough space between single wind turbines, additional standards in residential and nature conservation areas have to be met. Do you support the construction of further wind farms when those criteria are fulfilled?

Yes	88.3%
No	9.5%
Don't know	2.2%

Question: If we assume that offshore wind farms also have to meet strict standards, would you support their construction far away from the coast?

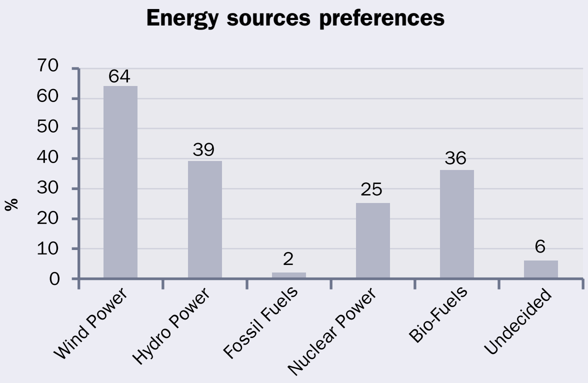
Yes	88.3%
No	9.5%
Don't know	2.2%

Source: EWEA (2003f).

6.6 Public Acceptance in Sweden

A recent survey in Sweden (see Figure 6.8) shows that wind power would be the preferred electricity production option, with 64% support (SIFO, 2002).

Figure 6.8: Energy Sources Preferences Sweden



Source: SIFO (2002).

Wind energy was the second choice for 25% of those respondents who placed nuclear power as a first option.

The SIFO survey also found that 73% of respondents thought that Sweden should increase its proportion of electricity generated from renewable sources.

With regard to tourism, a public acceptance study from 1988 to 2002 found that tourists have a negative attitude to onshore wind farms, especially in rural landscapes, but are more positive about offshore developments (EMU and Hammarlund Consulting, 2003). In some areas, opposition to onshore wind farms was mainly from tourists and non-permanent residents who place a greater value on landscape amenity than do permanent residents.

6.7 Public Acceptance in Austria

In July 2003, a national poll was conducted to determine the Austrian public's knowledge about renewable energy sources, their acceptance of renewables and their future energy preferences. The Gallup Institute conducted the poll of 1,500 people for the Austrian Utilities Association Verband der Elektrizitätsunternehmen Österreichs (VEÖ). When asked about renewable energy, 45% of respondents knew what it was. Solar, hydro and wind were the most recognised renewable energy sources at 39%, 33% and 30% respectively.

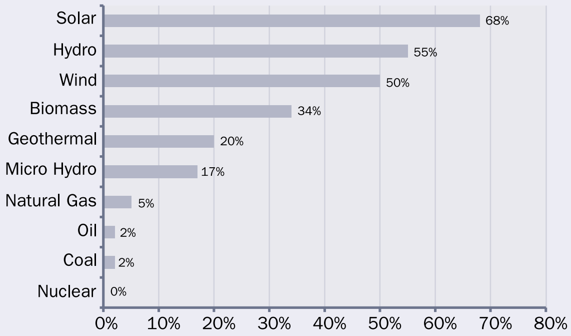
Hydro, solar, wind and micro hydro are the most popular energy sources when scored on a scale of 1 to 5 where 1 is very popular and 5 is very unpopular (see Table 6.6). With respect to future energy sources, 68% of respondents prefer solar, followed by hydro, wind and biomass. Fossil fuel has little support and nuclear none, as can be seen in Figure 6.9.

Table 6.6: Popularity Energy Sources

Source	Indicator*
Hydro	1.27
Solar	1.31
Wind	1.41
Micro Hydro	1.44
Geothermal	1.92
Biomass	1.97
Natural Gas	2.88
Oil	3.21
Coal	3.27
Nuclear	4.53

* 1 = very popular and 5 = very unpopular
Source: VEÖ (2003).

Figure 6.9: Future Preferred Energy Sources



Source: VEÖ (2003).

6.8 Public Acceptance in Belgium

A survey of residents living on the Belgian coast, a popular tourist area, was carried out in 2002 by the West Flemish Economic Study Office. It revealed that 78% of those surveyed have a positive or neutral attitude towards the construction of a wind farm 6 km offshore. However, the survey also found that 30% of the residents disapprove of wind farms in their surroundings. Table 6.7 summarises the attitudes of different groups of residents and tourists towards offshore wind parks in their immediate surroundings.

Table 6.7: Public Perception of Near Shore Wind Farms at 6 km from the Shore

Group	Very to Moderately Negative	Neutral to Very Positive
Residents	31.3%	66.5%
Second residence	10.2%	88.8%
Frequent tourists	18.7%	81.3%
Occasional tourists	19.5%	80.5%
Hotel, restaurant, pub with view of sea	6.8%	89.3%
Other	15.3%	84.7%
Total	20.7%	78.3%

Source: EWEA (2003f).

6.9 Conclusions

The countries mentioned here account for 88.8% of the total wind energy capacity in Europe (22,558 MW in 2002). Germany, Spain and Denmark accounted for 84.3% of that capacity in 2002 (EurObserv'ER, 2003).

The attitudes of EU citizens to renewable energies, and their awareness of climate change impacts, indicates that the environmental benefits of renewable energy sources, including wind, are understood. Fossil fuel and nuclear energy sources have less support, as shown by the data from Denmark, Sweden, Austria and Spain.

The surveys cited in this report point to very positive support for wind energy, with acceptance depending on perceptions of the technology and the way in which developers deal with local communities.

In Denmark and Germany, where many local citizens are financially involved and decisions are taken at the local level, there is a high public acceptance of wind energy. Efforts to minimise impacts and integrate wind parks into the landscape in an aesthetic way, combined with local participation, have yielded good results in Spain.