A Integrated assessment

A

Integrated assessment

PART A

1 Environment and quality of life

1.1 Europe's environment — rich and diverse but under pressure

Europe has a rich and diverse environment. With its beautiful landscapes, historical cities and cultural treasures, it remains one of the world's most desirable and healthy places in which to live, and to invest, and is one of the most frequently visited global travel destinations.

Extending from the Arctic Circle to the Mediterranean and from the Caucasus to the Azores, Europe is home to an array of natural and semi-natural habitats and ecosystems, featuring a wide range of species and genes. This biodiversity, though limited in comparison with other continents, is our environment's 'insurance', as it ensures the environment's ability to adapt to change and renew itself.

In Europe, as everywhere, humankind depends on the Earth's ecosystems for the services they provide — for resources such as food, water, timber, fibre and fuel; for functions such as climate regulation, the absorption of wastes and the detoxification of pollution; and for protection as afforded by the atmospheric ozone layer. Over the last 50 years we have changed these ecosystems more rapidly than ever before to improve human well-being and sustain economic development. At the same time, the full ecological and economic costs associated with these gains are only now becoming apparent.

The alteration or loss of natural resources, together with changing climate conditions, are making us ever more vulnerable to the forces of nature. In 2004, weather-related disasters across the world caused economic losses of more than EUR 86 billion (USD 105 billion), almost twice the total in 2003. Some 12 000 weather-related disasters since 1980 have caused more than 600 000 deaths and cost just over EUR 1 trillion (USD 1.3 trillion).

Europe is one of the most urbanised continents. Today some 75 % of Europe's population lives on just 10 % of its land area. Urbanisation is beneficial to the environment, inasmuch as resource consumption and soil sealing tend to be lower per person, and the provision of environmental services such as waste management and wastewater treatment are cheaper per person, than for more dispersed populations. Nonetheless, in recent decades, the increasing trend towards the dispersal and sprawl of urban settlements is leading to an increasing fragmentation and loss of valuable landscape amenities.

Europeans are now living in a part of the world where rapid changes are shaping landscapes as never before, and bringing with them a different quality to our surroundings. Wetlands are being drained to make way for urban development; the use of mountains and upland areas are changing as farms make way for skiing and other kinds of recreation. Forest management has also had to adapt in the face of developments in the timber trade brought on by increased competition in the global economy.

The European environment remains under pressure, but now, to sustain our standards of living, we are exporting this pressure by importing more and more resources from elsewhere in the world to meet our European needs. We have become disproportionately more responsible for the consumption of global resources than almost any other region. At around 5 'global hectares' per person, the ecological footprint of the 25 Member States of the European Union (EU-25) — the estimated area required to produce the resources we consume and absorb the wastes we generate — is approximately half that of USA, but is still bigger than other large economies, including Japan.

The average European's footprint is also more than double his or her counterpart in Brazil, China or India, as well as the global average. Already the total global use of ecological resources is some 20 % higher than what the planet's natural systems can renew each year. Hence, unless Europe, and other developed nations, reduce their ecological footprint through using fewer resources and through efficiency measures, and make ecological space available for emerging economies, then more severe ecosystem damage, more material shortages and greater pressures on the global climate are likely.

Growing appreciation of the links between economic performance and the environment are encouraging much greater 'eco-efficiency' in our use of energy and resources. Such 'eco-innovation' has the double benefit of optimising the use of scarce resources — both renewable and non-renewable — and helping Europe compete in the global economy.

The operation of the global marketplace and the liberalisation of trade are expected to continue changing Europe's ecological footprint. Food, clothing and electronic goods now routinely come from the other side of the planet and these trends are expected to continue. Since the price of few products properly reflects the environmental damage caused by the production process and resource depletion, Europe will often be buying foreign environmental assets at a discount.

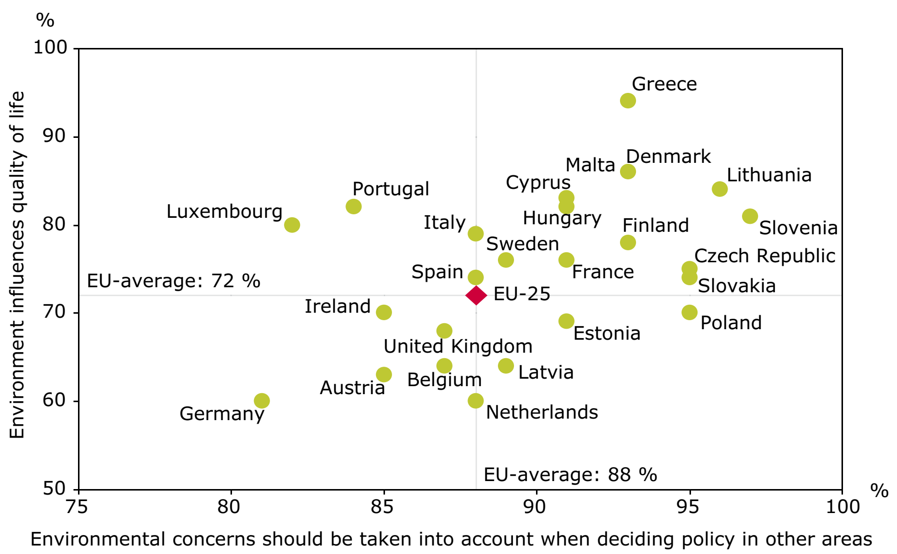
In the second half of the 20th century, global trade in raw materials grew by a factor of six to eight, and in manufactured goods as much as 40-fold. Thus, Europe is not alone in its increasing dependence on ecological creditors abroad. However, with the planet's resources expected to come under increased pressure as the demands from other parts of the world grow, this dependence is expected to become less sustainable for both the EU and the rest of the world.

1.2 Connecting to Europe's citizens

The task for environmental authorities and other actors is to address these new challenges adequately whilst maintaining the support of voters and other stakeholders. Such support, at least from results of opinion polls, appears considerable.

According to Eurobarometer polls, a large majority of EU-25 citizens want policy-makers to consider the environment equally alongside economic and social

Figure 1.1 European opinions on the environment's influence on the quality of life and the perception of the environment's importance in the policy-making process



Source: Eurobarometer 217, 2005.

policies (Figure 1.1). Furthermore, they consider environmental protection policies an incentive for innovation (67 %) and not an obstacle to economic performance (80 %).

In the same survey almost two-thirds of respondents gave priority to protecting the environment over economic competitiveness. Additionally, they felt that the EU was the most suitable level at which to address environmental issues, given the transboundary nature of many problems and their wish for more harmonised approaches to relevant policy-making. An endorsement for the EU, which has stimulated up to 80 % of environmental policy measures at Member State level over the last 25 years.

People's main environmental concerns are, however, related to their local day-to-day living conditions, such as the state of their water, air pollution and the perceived threats from chemicals. Even anxieties about such global issues as climate change were expressed in local terms. Over 70 % of Europeans therefore see the environment as having a significant influence on their quality of life and want to see the environment taken into account when policies are decided in other areas. They understand the interconnections between their environment and the activities in economic sectors such as transport, energy and agriculture, and perceive the benefits of more integrated approaches.

Our well-being and quality of life depend on the state of the environment and the services, such as climate regulation, provided by natural ecosystems. Improving human well-being and human development in the coming decades will thus largely depend on our ability to ensure the sustainable use of the environment — a task made more complex by the changing nature of human activities that impact it most.

1.3 Europe's changing environmental problems

Within Europe, progress in dealing with environmental pressures has been evident in several areas, and these are to a large extent consistent with people's day-to-day concerns. There have been substantial reductions in acidifying air emissions, and consequent improvements in some aspects of air quality, in substances that deplete the ozone layer, and in point source emissions to water. Much of this has been achieved through the application of abatement technologies and through resource substitution, both of which have been encouraged by EU and Member State environmental regulations.

The protection of biodiversity, through the designation and protection of habitats, has gone some way in improving the maintenance of ecosystem productivity and landscape amenity. At the same time, action on waste management has not led to an overall reduction in waste volumes, which reflects the fact that progress here is more intimately related to general economic and social development.

Many changes in climate and their impacts on ecosystems and human health are already visible in Europe, particularly in southern Europe where water shortages, fires and droughts are increasingly apparent, along with more unpredictable weather patterns. Meanwhile, the scientific evidence of climate change is getting firmer, with the manifestation of more robust indicators suggesting a much faster rate of change than previously thought.

There is also an increasing threat to human health from exposure to new forms of invisible, time-delayed and more systemic pollution and chemicals. Rising rates of cancer, asthma and neurodevelopmental diseases, particularly in children, are damaging the current and future health, and therefore wealth, of our societies.

Many of today's most challenging environmental pressures are proving more difficult to tackle than those which have registered greatest progress in recent decades. The sources of treatable pressures were then easily identifiable — industrial plants or car exhausts — and so could be dealt with adequately through regulatory standards and the application of abatement technologies.

Five sectors — transport, energy, agriculture, industry and households — contribute most to current problems and are expected to continue doing so in the future. In these sectors, many pollution sources are much more diffuse, numerous and varied, thus proving more difficult to control. Even where new technologies have been introduced, their effectiveness has often been overwhelmed by increased demand.

It is becoming clear that a mix of instruments, which encourage societal shifts to less damaging forms of behaviour and promote increased technical and economic efficiency are needed. Such integrated approaches, if well designed and fully implemented, can be cost-effective by addressing environmental and economic considerations together, and tackling cross-sectoral problems. Making progress on such approaches takes time, as can be seen when looking at the development of environmental policy over the past three decades.

1.4 Solutions to deal with change

Environmental policy measures at international level and in Europe are relatively new compared with economic and social policies. Nonetheless, over the past 30 years or so, significant progress has been made in establishing a comprehensive system of environmental regulation in the EU. Action began in Stockholm in 1972 when the United Nations conference on the human environment first drew global attention to environmental issues. At the European level six successive European environment action programmes followed, based on a combination of thematic and sectoral approaches to ecological problems.

The first environment action programme, adopted in 1973, established the principles of the polluter paying, of prevention at source and of the appropriateness of action at the European level: principles which later became EU Treaty obligations. The fifth environment action programme (1992–2000) focused on reducing pollution levels, implementing legislation that would benefit EU citizens and integrating the environmental dimension into all areas of the Commission's policies, especially its main sectors — transport, energy, agriculture and industry.

The sixth environment action programme (6EAP), which runs to 2012, gives a new sense of purpose and direction to the Community's environmental policy. The programme puts forward a series of actions to tackle persistent environmental problems in four priority areas: climate change; nature and biodiversity; environment, health and quality of life; and natural resources and waste.

The strategic approach of the 6EAP is underpinned by five major objectives: to improve the implementation of existing environmental legislation at national and regional levels; to integrate environmental concerns into other policy areas; to work closely with business and consumers in a more market-driven approach to identifying solutions; to ensure better and more accessible information on the environment for citizens; and to develop a more environment-conscious attitude towards land use planning.

Thematic strategies are one component of the actions foreseen within the 6EAP. This concept was introduced as a specific way of tackling key environmental issues which require a holistic approach because of their complexity, the diversity of actors involved and the need to find multiple and innovative solutions. Seven such thematic strategies will be developed according to a common approach — soil protection; protection and conservation of the marine environment; sustainable use of pesticides; air pollution; urban environment; sustainable use and management of resources; and waste recycling.

Policy-making in the 1970s and early 1980s focused on the local point sources of pollution which were managed, in general, by directives and regulation. The past 20 years have seen a shift in focus towards regional and global problems, caused mostly by diffuse sources of pollution. For example, it was in the late 1980s that global issues like the 'ozone hole' emerged as a serious and urgent problem which required global and regional measures to be implemented if environmental policy was to be successful.

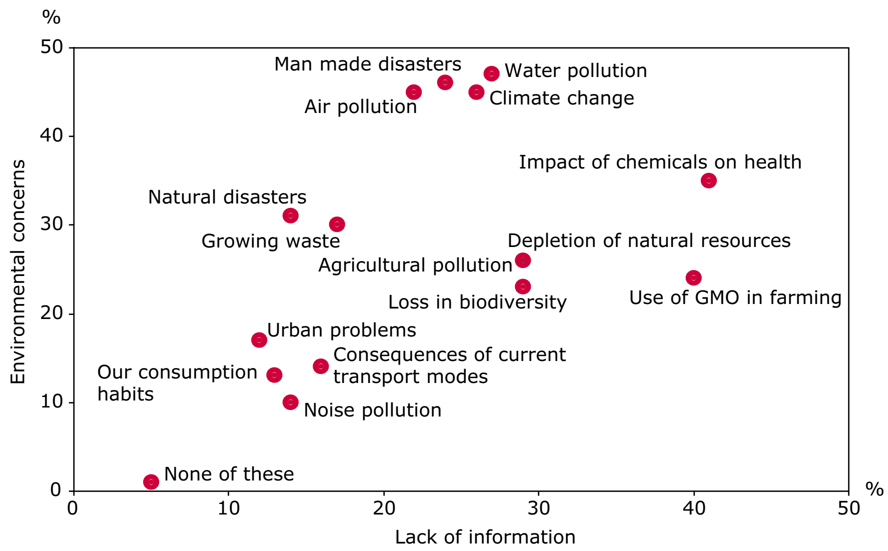
Such issues demanded economic incentives and the provision of better information to both companies and citizens, as supplements, or sometimes substitutes, to regulation. Most Europeans would like to have more information on environmental problems, and particularly on their solutions (Figure 1.2). Indeed, people also feel that enforcing existing regulations, making them stricter, increasing fines for those who break them, and increasing public awareness are the most effective tools for solving environmental problems.

Another important shift came in the early 1990s when the emissions and environmental supply-side measures of the 1970s and 1980s were supplemented by more upstream sectoral integration and demand-side management policies in the 1992 fifth environment action programme and the Maastricht Treaty. Further, the 1998 'Cardiff process' focused on integrating environmental considerations into the thinking of those economic sectors causing the problems, such as agriculture and transport.

The 1990s also saw the emergence, for the first time, of global companies looking seriously, and in concert, at the emerging environmental agenda, as illustrated in the 1992 World Business Council for Sustainable Development report 'Changing course: A global business perspective on development and environment'. This report, by 46 major companies, also introduced the concept of eco-efficiency which the companies felt was essential in the communication of sustainable development. Ten years after, a counterpoint book 'Walking the talk: the business case for sustainable development' demonstrated results achieved by several companies and recognised that the business of business had changed.

The greater scientific complexity and uncertainty surrounding current environmental hazards such as climate change, ecosystem integrity and health hazards from chemical and other pollutants mean that more sophisticated policy-making has come into

Figure 1.2 Comparison between environmental concerns and lack of information Europeans have



Source: Eurobarometer 217, 2005.

play. This involves a greater use of long-term tools, including scenarios and expert approaches, such as the precautionary principle which was incorporated into the EU Treaty in 1996.

The process of devising policy measures to better reflect an interconnected reality has also brought efficiencies from 'cost spreading'. For example, policies on acid rain and climate change, originally handled separately, have produced large cost-effectiveness improvements after being handled in a more integrated fashion.

Nonetheless, more integrated policy approaches bring their own transaction costs in that they are much more difficult to implement. They involve many actors from across the main economic sectors, such as transport, energy and agriculture, as well as consumers. Additionally, their increased flexibility can often mean greater implementation and enforcement difficulties at regional, national and European levels.

The lessons to be learnt from the past decades are, however, clear: environmental policies, when properly developed and implemented, have led to significant and cost-effective improvements in several fields, whilst stimulating innovation in the development of environmental technologies and services. Currently, the global market for such technologies and services is worth about EUR 425 billion (USD 515 billion) a year and is forecast to expand at a rate of about 3 % a year.

Overall, such progress has been brought about through 'traditional' measures, regulating products and production processes, and protecting important natural sites. These policy areas are covered by well-established EU legislation. However, more integrated policies, including further market-based instruments designed across environmental problems, sectors and scales, and over time, remain a challenge.

1.5 Looking ahead

This chapter began with a description of what is special about Europe's environment and how it contributes to the quality of our daily lives, then considered how Europe's citizens want to see its character maintained in the face of changing, and increasingly global, socio-economic challenges, and discussed how policy measures have been developing in response.

What is clear is that with rapidly changing economic developments within Europe and across the world, now and in the coming decades, it will become increasingly difficult to balance these various considerations. Bearing this in mind, subsequent chapters consider the environmental challenges Europe faces now and in the future, as well as how it could respond through further policy development.

Chapters 2–8 look in more detail at the changing face of Europe's land, as one of the key underlying resources needed to sustain our well-being; and the state of the continent's environment, including prospects for the future, across the main environmental priorities that underpin the 6EAP — climate change, biodiversity, use of natural resources and health issues. These chapters also explore, to differing degrees, the ways in which the benefits of our ecological resources and services are being eroded, at considerable actual and future costs to people's health, Europe's economy and the well-being of the rest of the world.

Chapter 9 summarises the main findings from previous chapters and then considers the past performance and future prospects of four economic sectors — transport, agriculture, energy and households — in creating environmental pressures and taking measures to deal with them.

The concluding Chapter 10 then analyses how these pressures and impacts on the environment can be dealt with in the future through more integrated action that focuses on three areas: the institutional structures needed to implement more coherent and integrated action; the internalisation of the costs of environmental damage into prices, through the use of market-based instruments such as emissions trading, financial incentives and taxes; and prospects for the eco-innovations needed to substantially reduce environmental pressures and to improve ecological resource productivity.

The chapter ends by considering how such measures can help Europe adapt to the challenges of ensuring continued prosperity in the face of global competition and expected demographic changes.

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2 The changing face of Europe

2.1 The face of Europe: a mosaic of changing landscapes

The history of human culture suggests that 'landscape' is one of the earliest and most obvious concepts for perceiving and describing our environment. However, there is not just one idea of landscape — a landscape can be perceived from a variety of observations and viewpoints — but, in contrast to the notion of 'wilderness', the term landscape is frequently associated with human interference or influence. It is at the landscape level that changes in terms of land use, naturalness, culture or character become meaningful and recognisable for human interpretation.

Landscape is as much vision as it is reality. The way we perceive landscapes, the attraction we feel to some of them, and our feelings when conflicts arise over the use of land, are all matters of extreme importance for conservation and future human welfare. A landscape is essentially a photograph of what is going on; it reveals, in short, who we are. At the same time landscapes are also dynamic expressions of continually changing natural processes (climatic, physical, biological) and changes caused by human activity.

It is clear that landscape analysis requires the consideration of different factors not equally easy to apply. The spatial dimension must be considered, as must the temporal component. It is especially important to know both where and when change is happening, given the uneven distribution and value of ecological goods and services across Europe, the vast range of activities that impact on them and the changing character and intensity of these impacts over time.

One strategy for preserving landscapes has been the establishment of protected areas. Early protection measures focused on preservation of landscape scenery, but during recent decades nature reserves have been designated mainly to minimise the probabilities of extinction and maximise the conservation of species. However, we now know that many species require a range of habitat types during their lives, and different species use the environment on different scales. Scientists are therefore embracing the idea that biodiversity should be dealt with not only at the habitat or species level but also at the scale of landscapes.

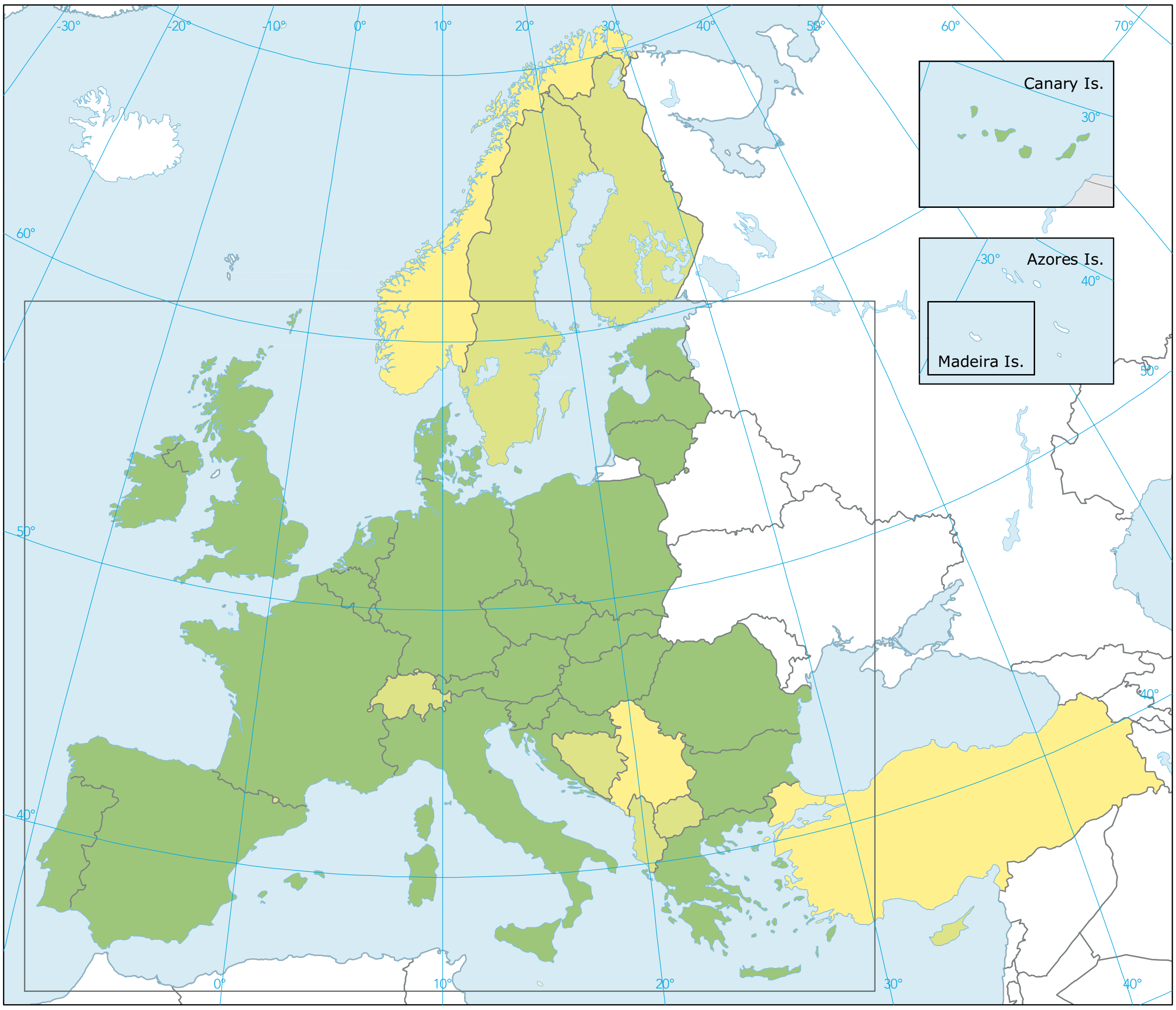
2.2 Landscapes: photographs of human uses of land

Human decisions have a strong influence on the shape of landscapes and the social, economic and political conditions needed to let such landscapes — or environments — develop. International, national and regional policies (on agriculture or the environment, for example), demographic trends (such as the migration of populations between countries and regions, from cities to the countryside or vice versa, and population growth), together with ecological factors are all interlinked.

Scientists, planners and policy-makers are increasingly aware that adequate decisions cannot be made solely at the site level. This is especially important in a European context where landscapes are dominated by human influence. Most human activities, particularly industrial activity, urban development and transport, have an impact on the landscape, but these impacts are relatively localised compared with the wide role played by agriculture in shaping our surroundings. Land use patterns have undergone revolutionary changes in the past; today, though less drastic and visible, changes keep on altering our environment leaving large, often irreversible, land use footprints. Patterns of changing land use across Europe show that tensions are rising almost everywhere between the needs of society for resources and space, and the capacity of the land to support and absorb these needs.

There is increasing confirmation that the drivers of many environmental problems affecting European land originate outside the actual territory where the changes are observed. A global market economy, the measures of the common agricultural policy (CAP), trans-European traffic networks, large-scale demographic and socio-economic changes, cross-boundary (e.g. air-borne) pollution, as well as differences in land-planning mechanisms at the national, regional and local level, are

Map 2.1 Availability of Corine land cover data



Availability of CLC2000 and CLC change data

- Areas covered by CLC change data *
- Areas covered by CLC 2000 data only
- Areas with CLC 2000 in preparation
- No data

* Data for Croatia were not processed in time for this publication

Note: The large box in the map indicates the geographical coverage for Maps 2.3., 2.4 and 2.5 that follow later in this chapter.

the main drivers of change and environmental pressure. There is now a rising awareness of the added benefits of considering the territory as a unit of analysis and as a basis for stimulating better coordination of policies.

Europe is debating a stronger and more balanced territorial focus for its policies. This debate has been developed by the Member States and the European Commission within the 1999 European spatial development perspective (ESDP). This process has led to commonly agreed policy orientations around better territorial balance and cohesion, improved regional competitiveness, access to markets and knowledge, as well as to wiser management of natural and cultural resources.

The policy orientations reflect the ongoing geographical concentration of many parts of European society in highly urbanised areas. The long-term aim is to see a European territory with many prospering regions and areas, geographically well spread, all playing an important economic role for Europe and providing a good quality of life for their citizens.

Polycentric spatial development is the main concept related to the aim of territorial cohesion. The concept can be described as a bridging mechanism between economic growth and balanced development. Thus, polycentric development can bridge the different interests of the Member States by encouraging more balanced and coordinated competitiveness. Interest in polycentric development is also fuelled by the hypotheses put forward in the ESDP that polycentric urban systems are more efficient, more sustainable and more equitable than either monocentric urban systems or dispersed small settlements.

2.3 Maintaining landscapes in future

While territorial cohesion is the subject of continuing debate, the links between territorial cohesion and economic and social cohesion — two fundamental aims of the European Union (Article 16 of the Treaty) — remain to be further clarified. There is thus a need to have a broader vision of cohesion that encompasses many dimensions of the development of territories and of their inter-relationships.

In this respect, a territorial dimension has been proposed for the conception of structural policies after 2007. The Commission has also proposed European territorial cooperation as an objective for Structural Funds interventions for 2007–2013 in support of territorial cohesion within the EU.

At the same time, although the Lisbon strategy has no explicit territorial dimension, one of its three main priorities calls for Europe to be made an attractive area in which to invest and work. This priority includes considerations relating to access to markets and the provision of services of general interest as well as to factors relating to the creation of a healthy environment for enterprises and families.

The implementation of the Lisbon strategy and of future structural policies will take place in regions, in national territories and at European level. Therefore, a key question for policy-makers at different levels is to explore, identify, understand and select potential areas for development within their own territory in order to contribute effectively to this overall European strategy.

The rest of this chapter analyses and discusses changes in Europe's territory (land cover) from both a spatial (landscape) and temporal (statistical change) perspective. In the context of the factors mentioned earlier, this allows us to understand what is happening and where it is happening, and to put these in the context of the particular policies that most influence change.

2.4 Dominant landscape types and changes in land cover

Wherever we live in Europe, and whether surveying our surroundings or taking in the view from an aeroplane, landscapes powerfully characterise our sense of place. Their slowly shifting patterns both reflect and support Europe's many cultures, societies, economies and environments. We see many different images when looking across Europe, but the EEA has categorised these landscapes into seven dominant types (Map 2.2), which reflect prominent functions of the land. These seven landscape types in turn give an indication of where the highest potential remains for preserving the amenities and services that land provides, and hence where changes in land cover (and land use) can have the most impact on nature.

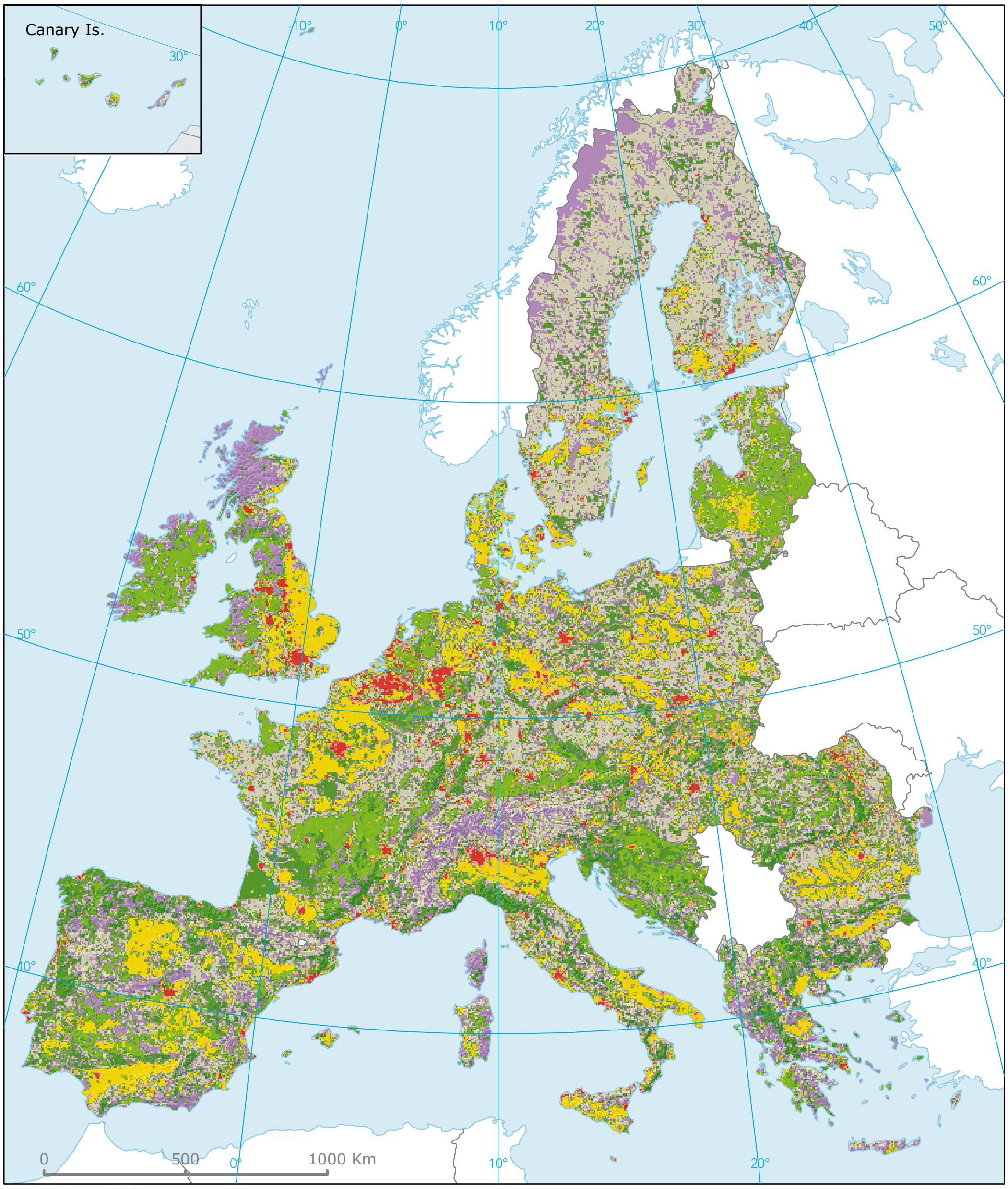
The diversity and distribution of the landscape types in 2000 indicate where the continent's main reservoirs of 'naturalness' are located: in the Mediterranean and northern European regions, and in many coastal zones and major mountain ranges such as the Alps and the Carpathians. Forested land dominates in the Baltic states, Germany, Scandinavia and Slovenia. Agricultural landscapes are widespread across the continent, with broad patterns of arable land seen, for example, in Denmark and the United Kingdom (England), while pasture and mosaics, which make room for more symbiosis with nature, can be observed in Alpine and other regions. Urban settlements represent an important share of the total territory in terms both of the space they consume and of their much higher impact on natural habitats. The famous north-western urban 'pentagon' is visible from the dominant landscape map, as well as concentrations in other areas, including along coastlines and river corridors.

The image of seven dominant *landscape types* for the year 2000 was preceded by decades of rapid change in land cover and land use across Europe. The changes for the decade from 1990 are presented for the eight aggregate *land cover types* in Table 2.1 below (a total of 23 countries have included an assessment of change in their CLC2000 programme: Austria, Belgium, Bulgaria, Czech Republic, Denmark, Estonia, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, the Netherlands, Poland, Portugal, Romania, Slovenia, Slovakia, Spain, United Kingdom).

Table 2.1 Land cover 1990, 2000 and change — sum of 23 EEA member countries

	Artificial areas	Arable land and permanent crops	Pastures and mosaics	Forested land	Semi-natural vegetation	Open spaces/ bare soils	Wetlands	Water bodies	Total km²
Land cover 1990	**160 785**	**1 171 098**	**798 607**	**1 003 905**	**257 503**	**515 60**	**45 283**	**125 334**	**3 614 073**
Consumption of initial land cover	1 821	24 456	17 400	39 119	8 929	2 284	1 357	198	95 563
Formation of new land cover	10 493	18 096	15 066	44 602	4 087	1 772	181	1 267	95 563
Net Formation of land cover (formation-consumption)	**8 658**	**– 6 400**	**– 2335**	**5 474**	**– 4 816**	**– 454**	**– 1 043**	**916**	**0**
Net formation as % of initial year	5.4	– 0.5	-0.3	0.5	-1.9	-0.9	-2.3	0.7	
Net formation as % of total land cover	0.24	– 0.18	– 0.06	0.15	– 0.13	– 0.01	– 0.03	0.03	
Total turnover of land cover (consumption and formation)	**12 313**	**42 552**	**32 466**	**83 721**	**13 016**	**4 056**	**1 538**	**1 464**	**191 127**
Total turnover as % of initial year	7.7	3.6	4.1	8.3	5.1	7.9	3.4	1.2	5.3
Total turnover as % of total land cover	0.34	1.18	0.90	2.32	0.36	0.11	0.04	0.04	5.3
No land cover change	**158 964**	**1 146 642**	**781 206**	**964 786**	**248 574**	**49 276**	**43 926**	**12 5136**	**3 518 510**
No land cover change as % of initial year	98.9	97.9	97.8	96.1	96.5	95.6	97.0	99.8	97.4
Land cover 2000	**169 443**	**1 164 698**	**796 271**	**1 009 379**	**252 687**	**51 106**	**44 240**	**126 250**	**3 614 073**

Map 2.2 Dominant landscape types of Europe, based on Corine land cover 2000



- Urban dense areas
- Dispersed urban areas
- Broad pattern intensive agriculture
- Rural mosaic and pasture landscape
- Forested landscape
- Open semi-natural or natural landscape
- Composite landscape

Land cover change is important both in terms of the total amount or net change in types of cover, and the actual locations where these changes occur. To understand the potential impacts on nature, both change information and spatial information are needed.

Starting with Europe as a whole, the net change in land cover between 1990 and 2000 highlights the increases in urban and other artificial land development and forest area, and the decrease in agricultural and natural area (Figures 2.1–2.3). The net change in artificial land area is a good indicator of urban sprawl, which is mostly an irreversible one-way process. The trends for total turnover confirm that urban sprawl was a key process in Europe in the 1990s, driven by economic growth and increasing consumption, suburbanisation and the implementation of the internal market (including transport infrastructure).

This sprawl is partly at the expense of natural land, and this development has important consequences for the long-term potential of the land to continue to provide ecological services and amenities.

In addition to demographic trends in rural areas, which in many places took the form of depopulation, the changes in agriculture and forestry can be ascribed mainly to the extension of the common agricultural policy, combined in some countries with rapid economic growth fostered by their accession to the EU and access to the internal market.

In the following sections, the three major components of the overall change in land cover are analysed in more detail, both at the European level and for some selected regions where the observed patterns and dynamics illustrate interesting policy perspectives. The three major components are:

- development of urban and other artificial land;
- decreases in the agricultural area resulting from a range of changes in use; and
- increases in the area of forest and decreases in the area of natural land.

Figure 2.1 Total land cover 2000 (%)

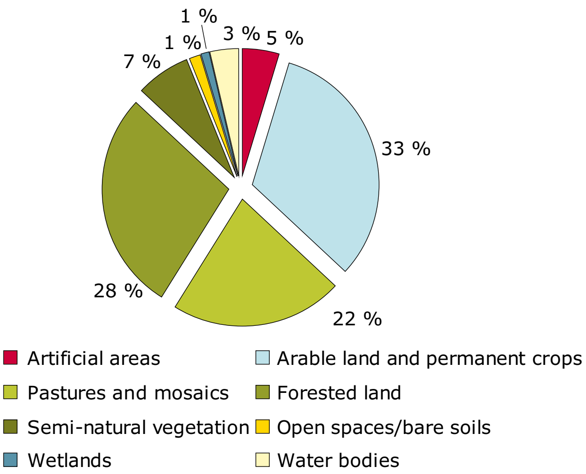


Figure 2.2 Net change in land cover 1990–2000 — EEA-23 (ha)

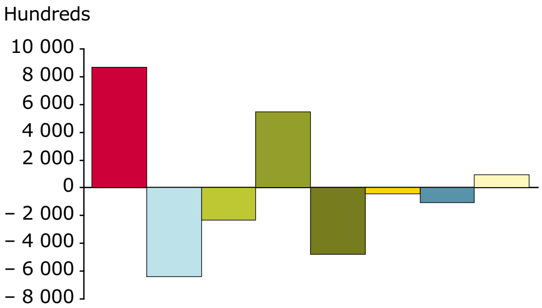
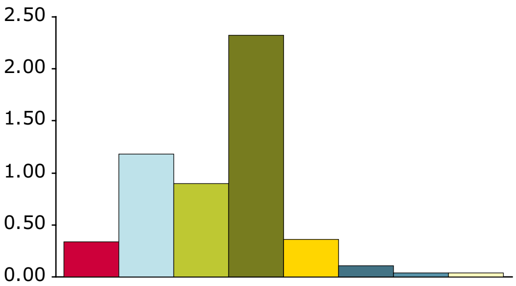


Figure 2.3 Total land cover turnover 1990–2000 as % of total territory for EEA-23



2.5 Urban sprawl and other artificial land development

Spatial perspective

Urban areas and infrastructure increased by more than 800 000 ha between 1990 and 2000, a 5.4 % increase and equivalent to the consumption of 0.25 % of the combined area of agriculture, forest and natural land. These percentages may seem small, but urban sprawl is concentrated in particular areas which tend to be where the rate of urban growth was already high during the 1970s and 1980s, and running alongside the emerging problems of rural depopulation. On a straight extrapolation, a 0.6 % annual increase, although apparently small, would lead to a doubling of the amount of urban area in little over a century. This needs careful consideration as we look ahead to the type of Europe we would like to see in the next 50–100 years, in the context of possible climate change and the many impacts and adaptation challenges it would pose.

A closer look reveals that sprawl around large agglomerations is continuing, but new development patterns can also be observed (Map 2.3). Urban development often takes place at a distance from large cities, around smaller towns or in the countryside. Further analysis shows that this is more visible for residential sprawl and the development of economic activities, in turn linked to the development of transport networks. Together, these factors contribute to the sealing of soil and the fragmentation of the natural landscape. This is largely a consequence of increasing passenger and freight transport demand, as well as increases in the price of urban land. The attractiveness of living in cities has fallen, while the quality of life associated with more rural areas, being closer to nature, has increased. This represents a planning challenge for small municipalities attempting to maintain their populations and attract small and medium-sized enterprises.

The extremely low price of agricultural land (in most cases good agricultural land) compared to already urbanised land (e.g. brownfield sites) or former industrial sites, is also an important factor underlying urban sprawl. In many development projects, the cost of agricultural land acquisition is relatively low and enables better profits to be realised than for already urban land or the use of former industrial waste land, even if no remediation is needed (non polluted sites). This factor is particularly important in the economic heart of Europe (also known as the Pentagon zone). The trend of good agricultural land being deliberately and artificially maintained at a low value is reinforced by the broad use of expropriation tools. A direct side effect of these combined tools — low value, future use not taken into account, and expropriation — is clearly demonstrated by the development of villages near cities, for residential or business purposes.

Urban sprawl is particularly important in coastal areas, and not just in the hinterland of urban coastal agglomerations. One of the world's 34 biodiversity hot spots, the Mediterranean area is particularly affected by these changes, although the level of artificiality of the coastline was already high before 1990. In the long run, this calls into question the sustainability of economic development based on tourism. Consequences in the immediate hinterland include the knock-on need for road infrastructure to accommodate the inland spread of individual housing.

Other areas with visible impacts of urban sprawl are in countries or regions with high population density and economic activity (Belgium, the Netherlands, southern and western Germany, northern Italy, the Paris region) and/or rapid economic growth (Ireland, Portugal, eastern Germany, the Madrid region), particularly where countries or regions have benefited from EU regional policies. New Member States, where little urban sprawl is detected, may follow the same path of urban development, and the accompanying environmental impacts will be all the higher because the very areas that are poised for change still host large amounts of natural landscape.

Drivers and impacts of artificial land development

On the European scale, the main drivers of urban development are housing (including related services), recreation, and industrial and commercial sites outside the urban fabric (Figure 2.4).

In several western countries, residential sprawl is accompanied by growth in recreational facilities, dominated by golf courses (Austria, Denmark, Ireland, Luxembourg, Spain, Portugal and the United Kingdom). Most of the development of these areas has been at the expense of agricultural land, mostly arable, but the picture varies from country to country. As much as 15 % of the land used for construction has been forest or semi-natural land, even higher than this in some particular regions.

Some 59 000 ha previously used by agriculture and 23 000 ha of forested and natural land on the 10-km strip of Mediterranean coast (five countries) were developed for housing, transport infrastructure and other needs between 1990 and 2000 (Figure 2.5). During the same period, 24 000 ha of natural land were converted to agriculture. This situation is typical of coastal zones on which agricultural land is scarce.

Figure 2.4 Drivers of artificial land development

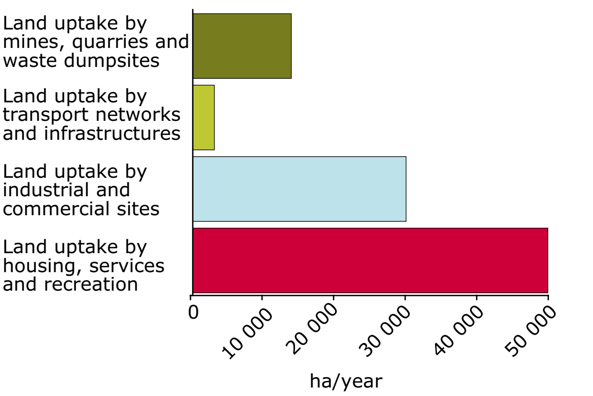
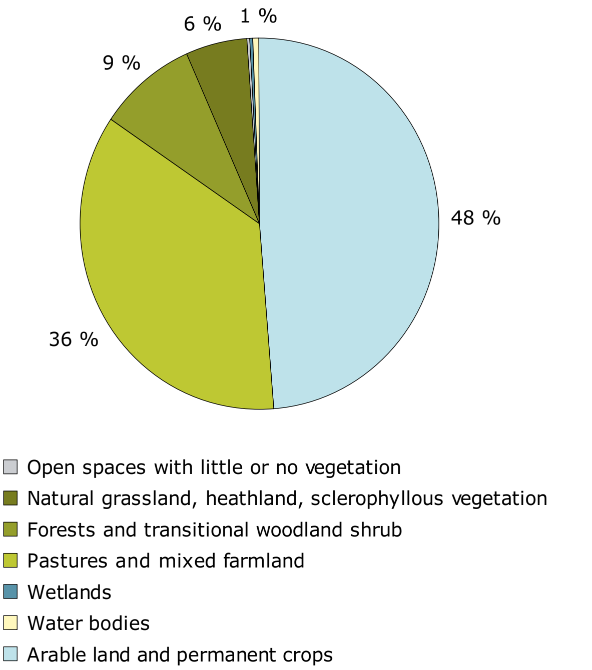


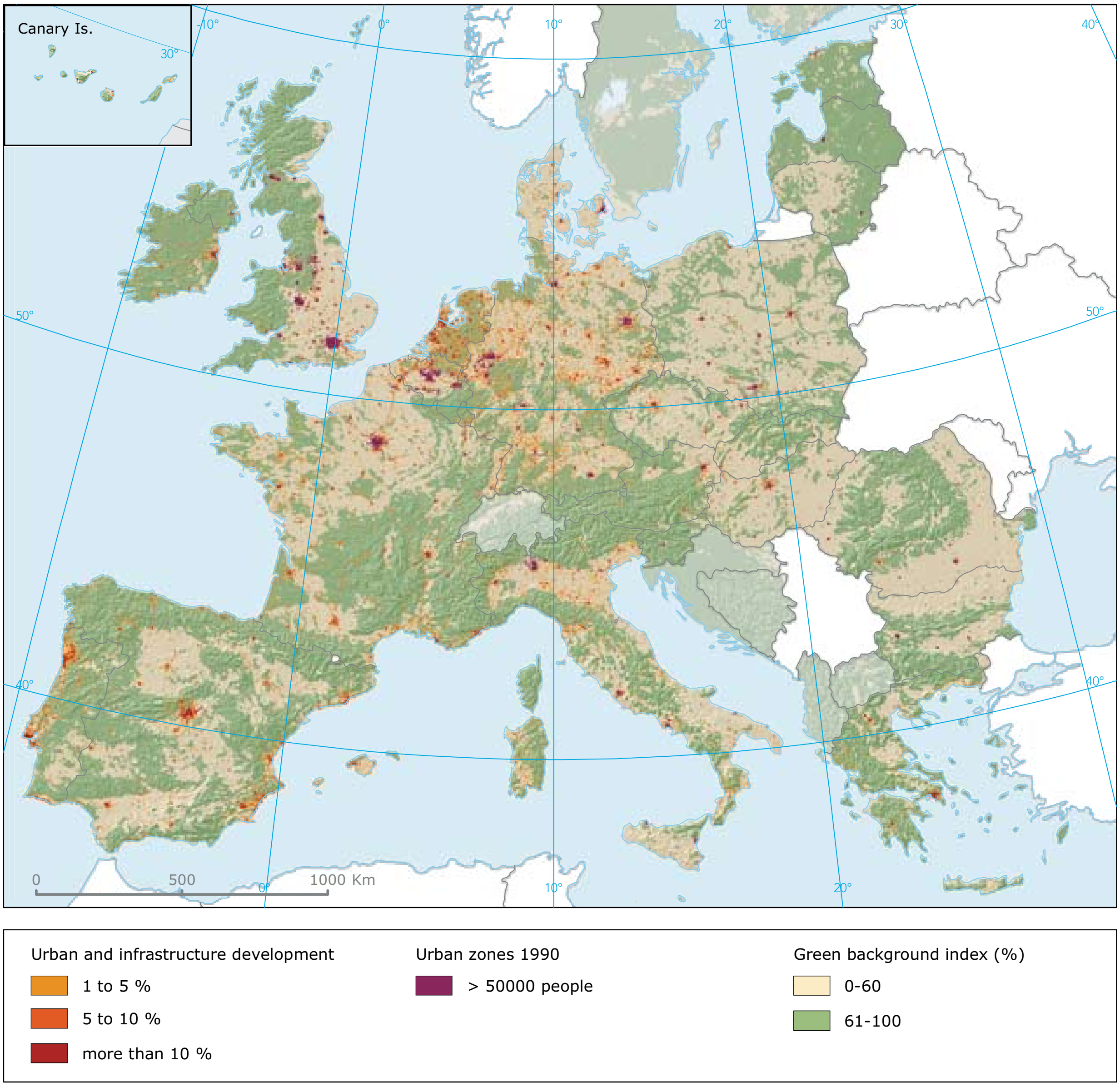
Figure 2.5 Origin of artificial land uptake 1990–2000, EEA-23 (%)



Country comparisons

At the country level, urban sprawl and associated developments during 1990–2000 were most intense in the densely populated the Netherlands and in Ireland, which was until recently particularly rural. Looking at the overall annual increase in urban/artificial land cover during 1990–2000, Ireland has the highest rank due to its very low initial level of urbanisation and strong economic development, closely followed by Portugal and Spain (Figure 2.6). All these countries were recipients of substantial transfers of funds under the EU cohesion policy. Germany, Greece and Luxembourg are among a group of countries close to the European average. The lowest values are generally found in the new Member States but also in Belgium and the United Kingdom.

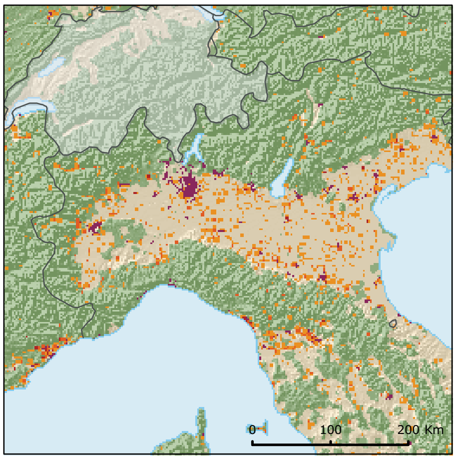
Map 2.3 **Sprawl of urban and other artificial land development, 1990–2000**



Typical change patterns

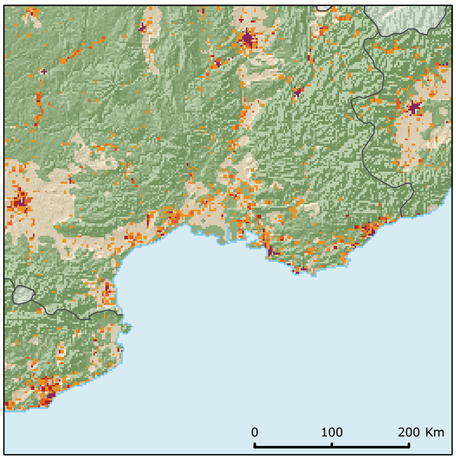
Sprawl in the countryside is observed in most countries or regions. Northern Italy, Ireland, the United Kingdom, and several regions of France, Germany and Spain can be given as examples. The contrast is marked between sprawl in the EU-15 and what we see in the other European countries. It is linked mainly to spatial planning developments for commerce and housing, which drive land price increases and conversion from agriculture, as well as the growing dependence on cars for commuting. This kind of diffuse urban sprawl meets the desires of people for more space, but also creates higher pressures on surrounding natural habitats. The type of discontinuous urban fabric that covers most of Belgium and the Netherlands is a good example of this phenomenon.

Map 2.3a



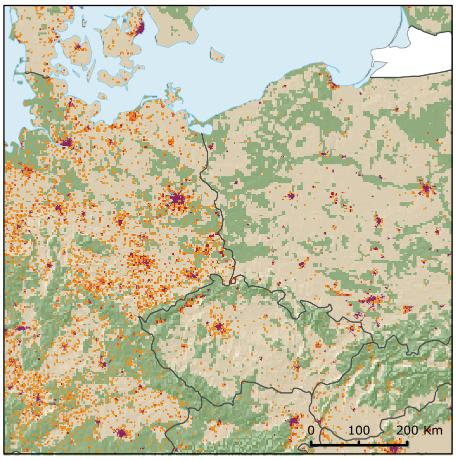
Sprawl along transport axes and the coastline: In large countries, transport networks — especially roads — often follow river corridors towards the sea. The so-called 'inverse T' of urban sprawl along the Rhône river down to the Mediterranean coast can be observed. The coasts themselves attract urban development for a range of reasons related to their attractiveness to tourists, and to urbanites looking for a higher quality of life by buying second homes. As a result, 1990–2000 was a period of marked change for the Mediterranean.

Map 2.3b



Time lags and uneven development. The 1990–2000 window is too early to capture many of the developments in the new EU Member States and the accession countries. Economic development in many of these countries is now accelerating, partly through their own dynamism and partly through their greater access to EU markets and the cohesion and structural funding that accompany membership. Comparisons between eastern Germany and Poland for the period 1990–2000 may provide insights for the future. Eastern Germany has benefited from large monetary transfers from western Germany since 1990, making it one of the fastest changing regions in Europe. Further east, in Poland, where EU membership is more recent, there has been less change during 1990–2000 and the contrast with Germany is still marked. This contrast is accentuated because of the region's history.

Map 2.3c



Do these numbers matter?

From cross-checking Corine land cover results for land uptake for artificial surfaces with other statistical surveys, it is most likely that there is an underestimation in the CLC results. This results, in particular, from the resolution of CLC, which cannot monitor small villages (< 25 hectares) and most roads and railways (narrower than 100 metres). Hence the overall picture of extension of artificial surfaces and their impact on landscapes and nature is probably more extensive than CLC reveals. Further information on data quality and methodological issues can be found in the two boxes at the end of the chapter.

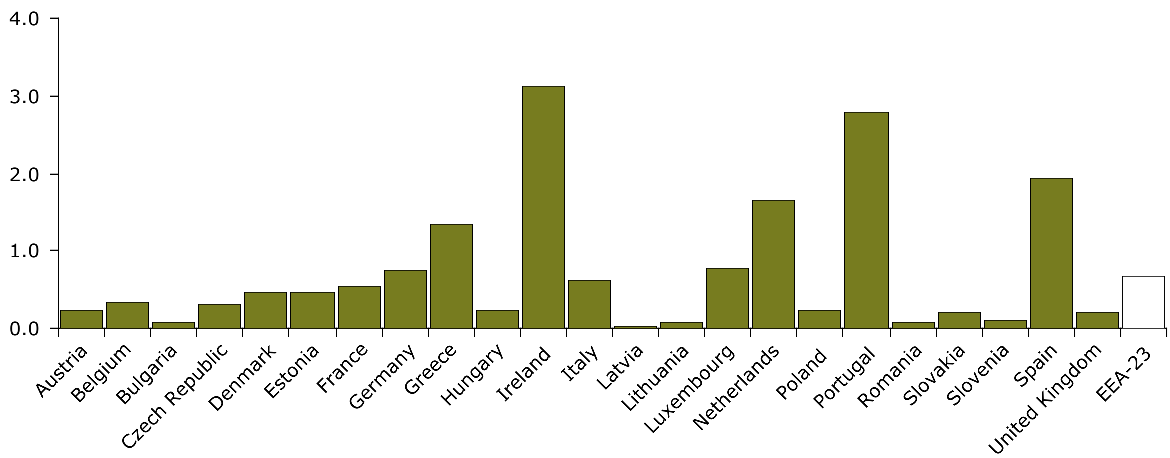
Even though the annual increases in land uptake for most countries seem small, extrapolation into the future merits consideration. In order to see how the future might appear under certain assumptions, the 'rule of 70' — according to which an annual increase of 1 % in land uptake for artificial areas sees a doubling of urban development in 70 years — can be applied, as shown in the following table:

Annual rate of increase	1 %	2 %	3 %	4 %	5 %	7 %	10 %
Number of years for doubling	70	35	23	18	14	10	7

Source: Levy, Michel Louis, Comprendre les Statistiques, Seuil, Paris, 1979

We can conclude that if countries follow the Irish urban development rate of more than 3 % per year, they will double their artificial areas in just over 20 years; the Spanish rate brings a doubling in 40 years, the Dutch rate in 50 years, and so on. It is also possible, using this perspective, to ascertain the future(s) of the new Member States and accession and candidate countries which are just starting new development of their urban and transport infrastructures. This may be especially relevant in the context of how European cohesion funds are allocated and spent in the 2007–2013 period.

Figure 2.6 Mean annual urban and infrastructures land take as % of artificial land cover 1990



It is also interesting to consider the contribution of different countries to total urban land uptake in Europe (Figure 2.7). On this measure, Germany (21 %), France (14 %) and Spain (13 %) are the main contributors, due to their large surface area, followed by Italy (9 %) and the Netherlands (6 %). While the contributions of Portugal and Ireland are both below 5 %, these nevertheless represent large areas given the size of these countries.

The share of urban land uptake can be compared with total land cover turnover in the period 1990–2000 (Figure 2.8). This indicator needs to be interpreted carefully. For example, Ireland, Portugal and Spain have very low values because of the size and dynamism of their agricultural and forest sectors. Urban sprawl accounts for more than 50 % of total land cover change in the Netherlands, highlighting the competition for land between agriculture and urban development. Luxembourg, where agriculture is not as important, has a similar value to those of Austria, Belgium, Denmark and Germany.

2.6. The differentiation of European rural landscapes

Agriculture is the most dominant land use in Europe, covering twice as much land as forestry and more than 10 times as much as urban areas. European agriculture

Figure 2.7 Mean annual urban and infrastructures land take as % of total EEA-23 urban land take

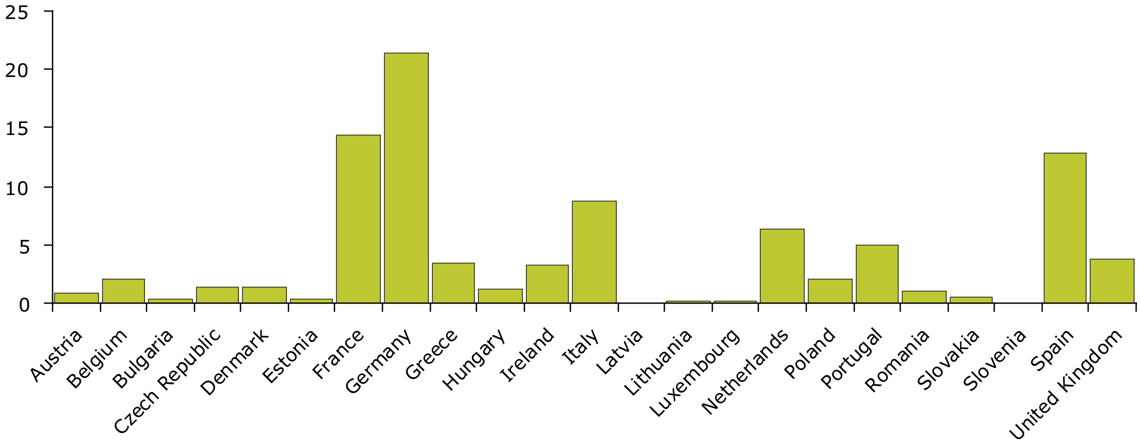
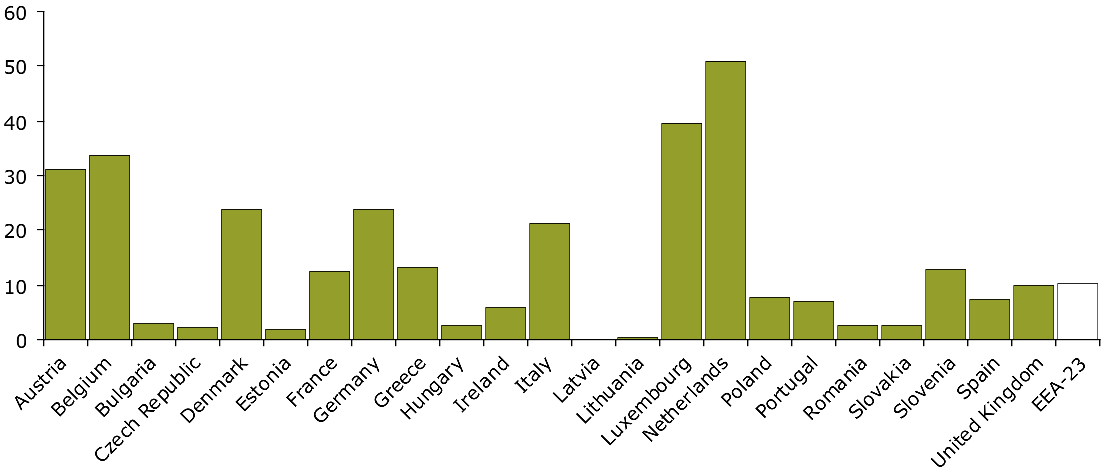


Figure 2.8 Mean annual urban and infrastructures land take as % of total land cover change 1990–2000



comprises a diverse mosaic of farming systems. The second half of the 20th century saw the transformation of many areas of traditional rural landscape into modernised, more intensive agriculture in response to the post-war drive for food security in Europe. This objective was initially at the heart of the common agricultural policy and has largely been achieved. The CAP has now been reorientated towards a wider rural policy perspective, more explicitly embracing environmental considerations and rural development issues. The accession of the new European countries, where western agricultural productivity levels have not yet been reached, has opened a new debate on reconciling development needs with the protection of semi-natural areas, in particular the dry grasslands that are such a characteristic element of the landscapes of Europe.

Spatial perspective

Due to the multiple drivers at work during the decade, land cover change in agriculture shows highly contrasting trends. Farmland abandonment coexists with intensification in the same countries, sometimes even in the same regions (Map 2.4).

The patterns that have emerged are largely a result of farmers' responses to changing economic and market conditions. Important contrasts have appeared between the more dynamic and productive areas, and the more stable areas that are prone to abandonment. Withdrawal of farming is often associated with knock-on conversions between pasture and crops elsewhere.

Conversion of new marginal land to agriculture appears to have taken place in Portugal and Spain and to a smaller extent in the south-west of France, eastern Germany and Hungary. This process is due in part to the scarcity of good land in some countries, where farmland is being used for other purposes, especially urban development.

Conversions between pasture and cropland are shown, with extensification — a possible prelude to farmland abandonment — sometimes occurring in the same region as intensification. Trends in eastern Germany and Hungary are very typical of these diverging trends, and can be linked to economic reforms in agriculture. The protection of pastureland in the Czech Republic is clearly evident, as well as the conversion from pasture to crops in south-east Ireland and other regions, often driven by more intensive livestock farming and the resulting demand for animal feed. Farmland abandonment has taken place in some mountain regions in southern Europe, in some parts of Germany and in new Member States such as Hungary and Slovakia. Abandonment and conversion of marginal land to agriculture are seen to coexist in some regions. Both trends are potentially detrimental to biodiversity.

Drivers and impacts

The main trend in Europe has been towards a conversion of arable land and permanent crops to pasture, set-aside and fallow land (Figure 2.9). There are three major aspects to consider: the conversion of agricultural land to urban sprawl (described in the previous section); conversion and rotation from pasture to arable land and vice versa within agriculture; withdrawal of farming with or without forest creation and conversion of forested and natural land to agriculture.

Long-term conversion between pasture and arable land is often linked to a switch between intensive arable agriculture and extensive livestock grazing. However, this is rarely the full story: for example, some pastures are intensively managed and cannot be considered as an extensive, low-input use of land. Country differences are important, with the Czech Republic and Germany accounting for more than half of the total extension of set-aside, fallow land and pasture.

At the European level, conversion of forest and natural land to agriculture is balanced by withdrawal of farming with or without woodland creation (Figure 2.10). National variations are important, and the maps show that opposite processes can happen in neighbouring regions and even in the same region.

The above conversions, even within the same region, seem to be either market orientated, with a clear link to scarcity of land in some places, or a purely individual choice linked to farmers deciding to retire for example.

Where conversions are not the desired ones, some tailor-made policies would be useful. Clearly, extensive practices might not be economically viable in their own right.

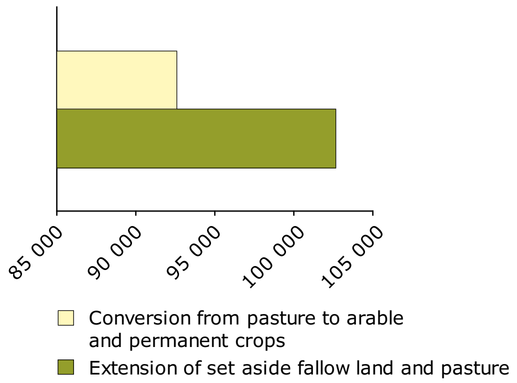
Country comparisons

Internal rotations within agriculture and conversions to and from agriculture represent more than half of the total turnover of land cover (2.8 % out of a total of 5.3 % land turnover as a percentage of initial year).

In most countries, the agricultural area has decreased at the expense of cropland or pasture/mosaic land (Figures 2.11 and 2.12). These changes are moderate in net terms except, as previously mentioned, in Ireland, where there has been an increase in crop production for animal feed, and in the Czech Republic, where farmland abandonment has been mitigated by an incentive policy to farmers for keeping or expanding pastures. Also notable is a small extension of arable land cover in the Baltic countries.

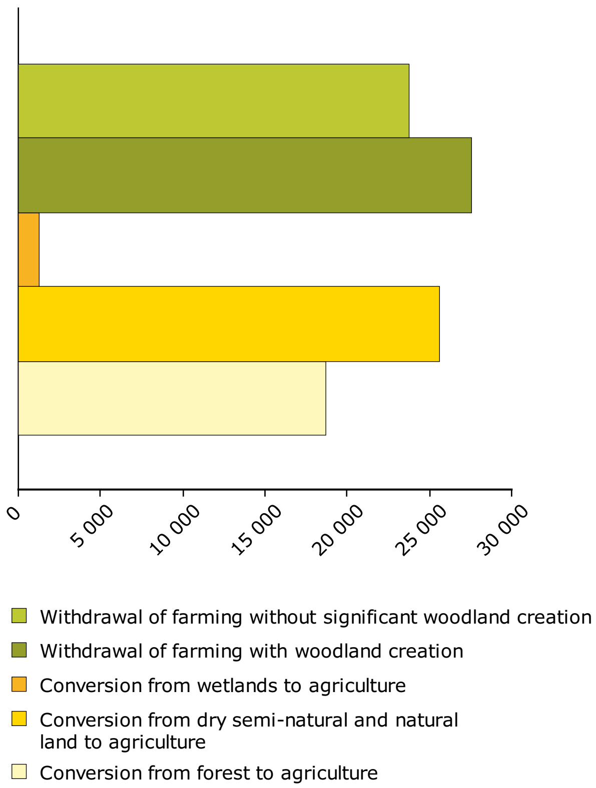
These overall net changes mask a range of changes and conversions that have taken place within countries. While no trend can be detected at the national level in most countries, major regional and local conversions can be identified.

Figure 2.9 Main annual flows of agricultural conversions in ha per year 1990–2000, EEA-23



Withdrawal of farming with and without woodland creation, and conversion of forest and other semi-natural land to agriculture vary between countries (Figure 2.13). High turnovers are observed in Hungary and Slovakia, where withdrawal of farming is the main component; in Spain, where conversions to agriculture are the main change; and in Portugal, where both processes take place.

Figure 2.10 Main annual conversions between agriculture and forest/semi-natural land cover in ha per year 1990–2000, EEA-23



Map 2.4 Internal and external conversions of agriculture 1990–2000

Net conversion of pasture to crop land

- Net increase of set aside/fallow land >30 %
- Net increase of set aside/fallow land 5 % to 30 %
- Net conversion of pasture to arable 5 % to 30 %
- Net conversion of pasture to arable >30 %

Withdrawal of farming (total)

- 2 % to 10 %
- more than 10 %

Conversion of land to agriculture

- 2 % to 10 %
- more than 10 %

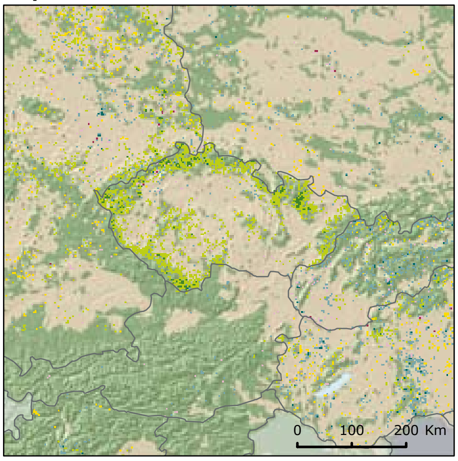
Green background index (%)

- 0-60
- 61-100

Typical change patterns: differentiation of agricultural landscape

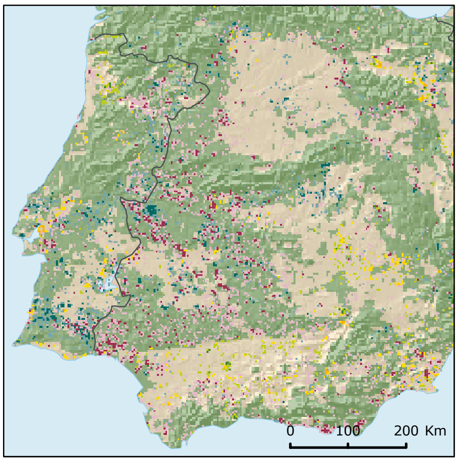
Conversion of arable land to pasture or forest: To mitigate the effects of transition to a market economy, the Czech Republic created incentives for farmers to keep farmland managed as pasture wherever possible. This policy has been a huge success, resulting in a wide extension in pastures (bright green) during the period. A different approach was adopted in Slovakia where land was returned to its previous owners, who may not necessarily have been interested in farming. As a result, some withdrawal of farming with woodland creation has taken place. These two situations coexist in many parts of Europe.

Map 2.4a



Withdrawal of farming and conversion of marginal land to crops: In the Iberian Peninsula, withdrawal of farming accompanied by woodland creation can coexist with new cultivation of open natural land. Part of the process is due to multiannual rotations between forested land (including transitional woodland and shrubs) and agro-forestry, with alternations of clearings and natural recolonisation. The rest results from reforestation policies, development of tree plantations and agricultural subsidies for crops such as olives. If not managed carefully, such changes can lead to the loss of valuable extensively managed habitats.

Map 2.4b



Conversion of arable land to pasture and withdrawal of farming: In overall terms between 1990 and 2000, France showed a slight decrease in agricultural area. This small overall change masks some regional contrasts, however. Areas south of Paris (dark blue) show withdrawal of farming, but conversions from pasture to arable land are visible (pink and yellow) in the wider *Bassin Parisien*.

Map 2.4c

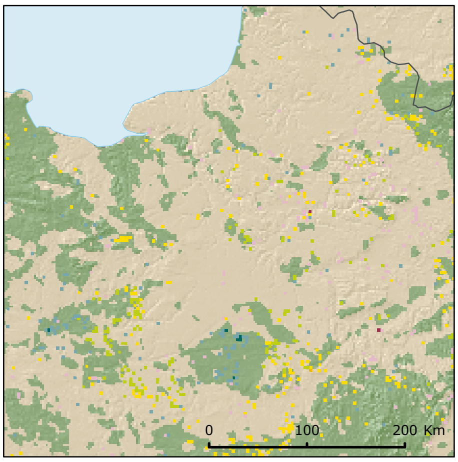


Figure 2.11 Net formation of agricultural land 1990–2000, as % of initial year, EEA-23

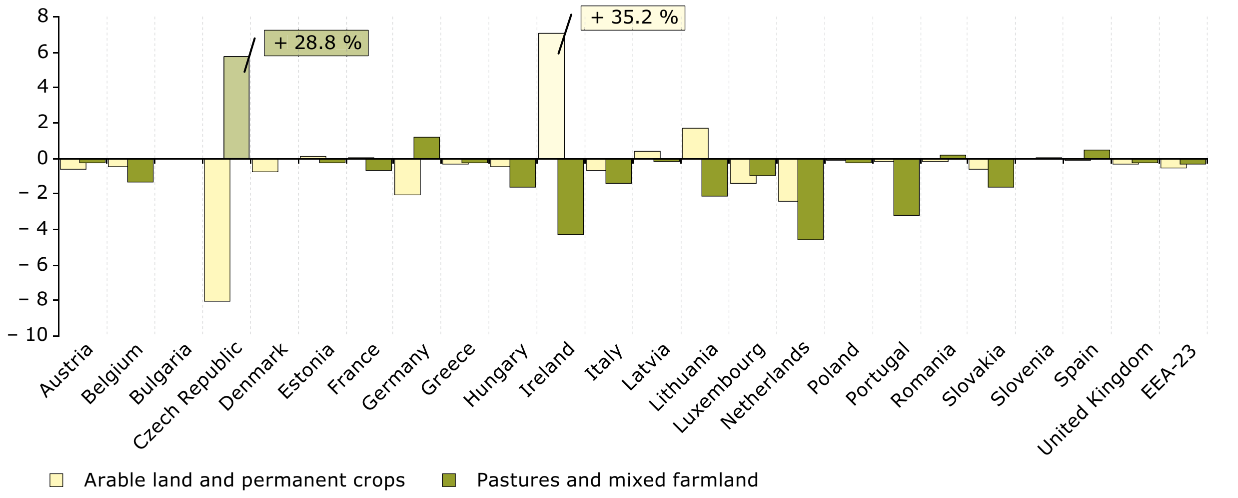


Figure 2.12 Net conversion from pasture (+) to arable land and permanent crops (−) ha/year, EEA-23

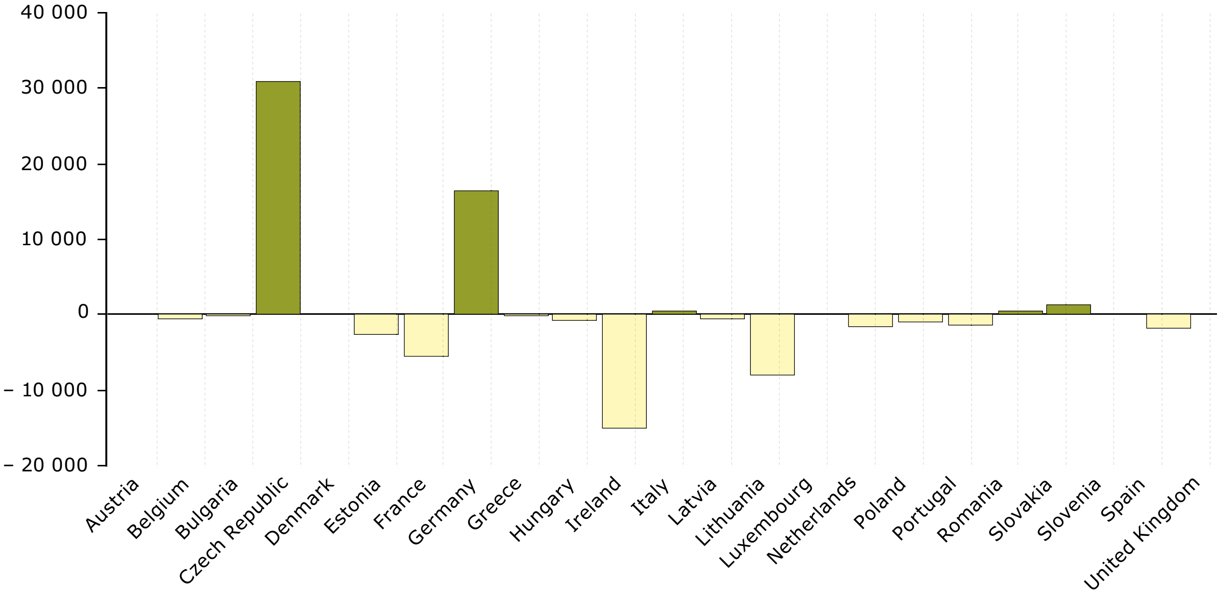
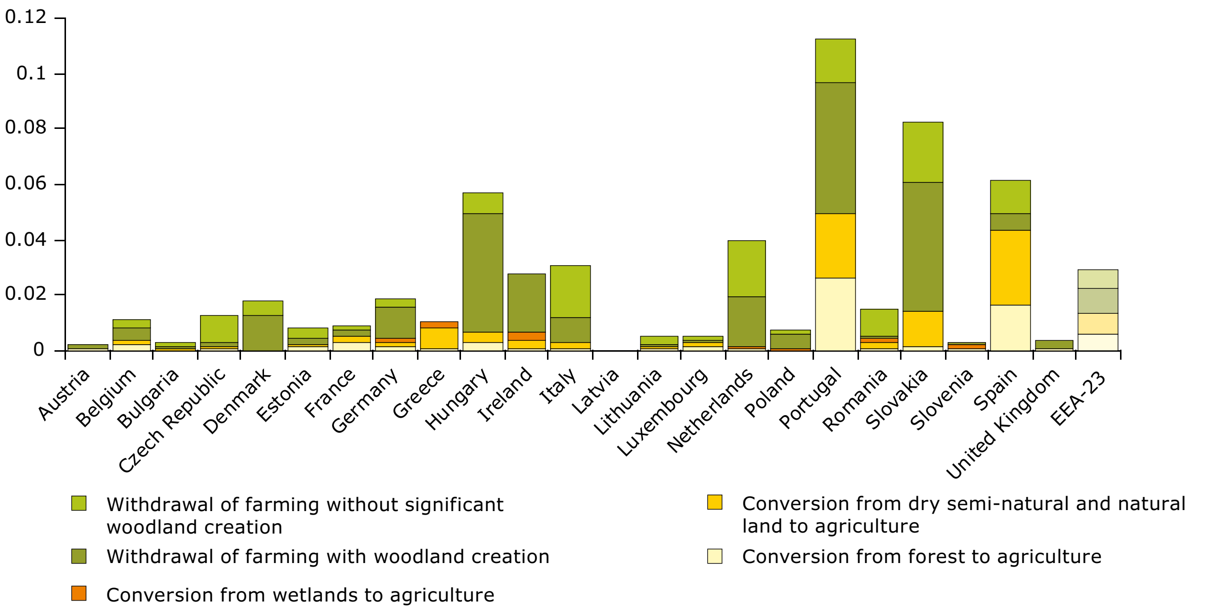


Figure 2.13 Conversions between agriculture, forest and natural land, as % of country area 1990–2000



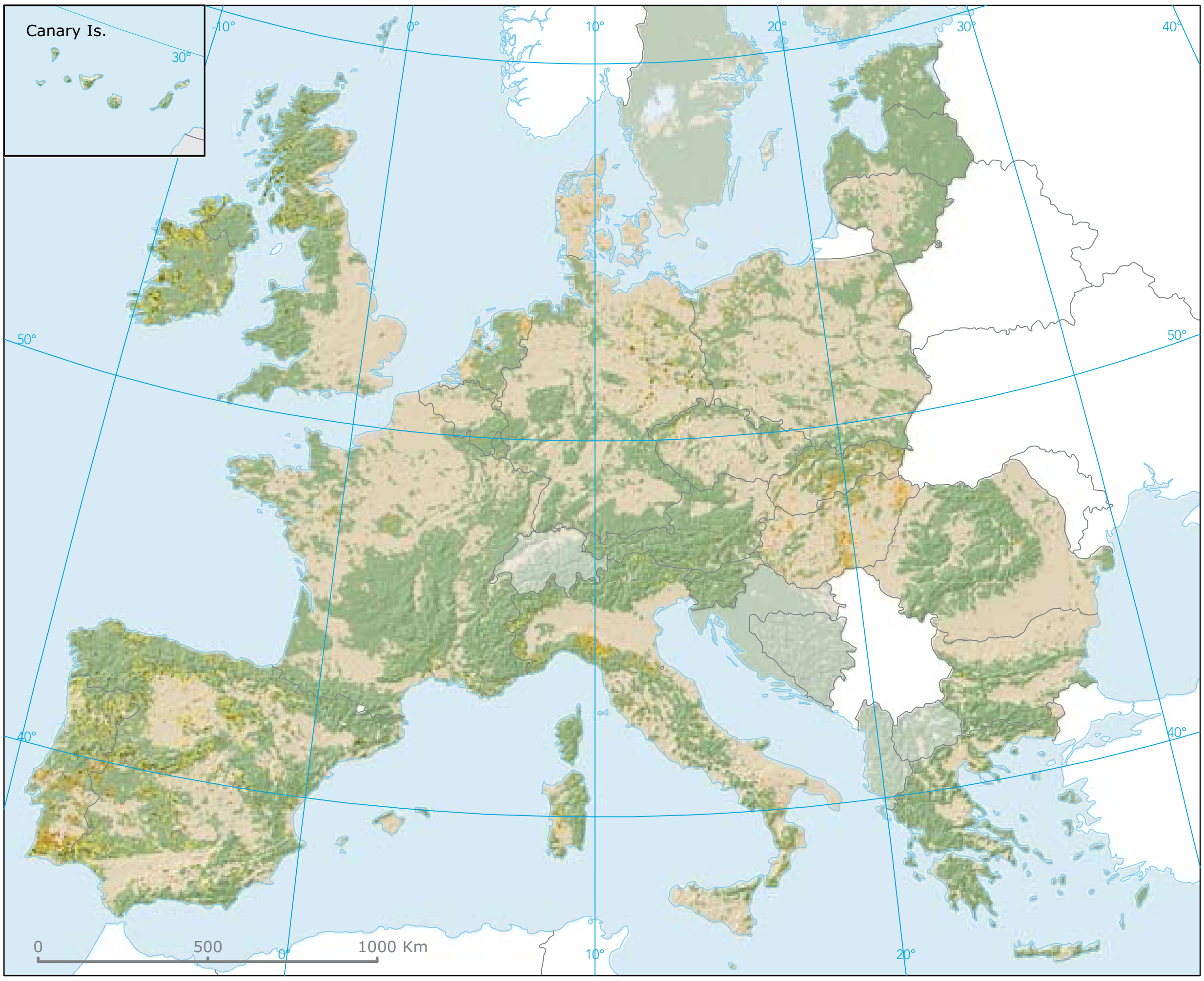
2.7 The extension of forested land in peripheral regions

The total forested area of Europe has increased by 0.5 % in 10 years. During the decade, however, the forest territory has experienced significant rotations, up to 8 %, mainly as a result of felling and replanting. Of 1 million ha of new forested land, a quarter is the result of the withdrawal of farming (Map 2.5).

Spatial perspective

There has been major afforestation in Ireland, Portugal, Spain and the United Kingdom (Scotland). Afforestation of farmland is often an alternative source of income for farmers in regions where agriculture faces difficulties and has been subsidised by the CAP. For instance, Regulation (EEC) N° 1257/1999 provides for an aid scheme to promote afforestation as an alternative use of agricultural land and to develop forestry activities on farms.

Map 2.5 Afforestation in Europe, 1990–2000



Creation of forest
- 2 % to 10 %
- more than 10 %

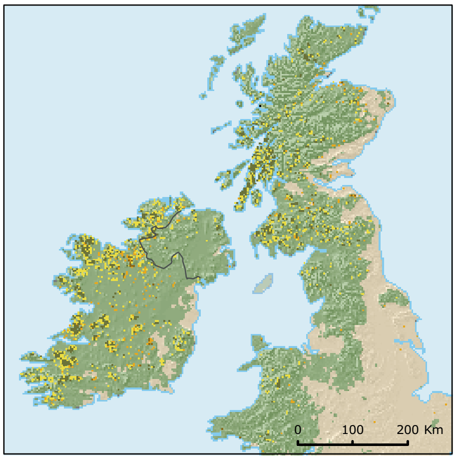
Withdrawal of farming with woodland creation
- 2 % to 10 %
- more than 10 %

Green background index (%)
- 0-60
- 61-100

Typical change patterns: afforestation of semi-natural land

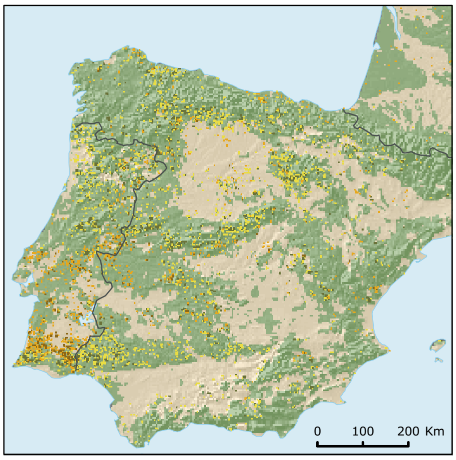
In Scotland, efforts to protect and plant native woodland (especially birch and oak) have continued; however, most new plantations are coniferous, which accounted for around 20 % of forested land in 2000. Ireland's forest cover has increased to approximately 10 % of the total land area, towards a target of 17 % by 2030. A limiting factor has been the scarcity of suitable and affordable land, with planting on blanket bog in the past because of its low agricultural value. Since the mid-1990s, policies have been aimed at switching away from planting on upland blanket bogs to wet mineral soils — of marginal value for agriculture, but very productive for forestry.

Map 2.5a



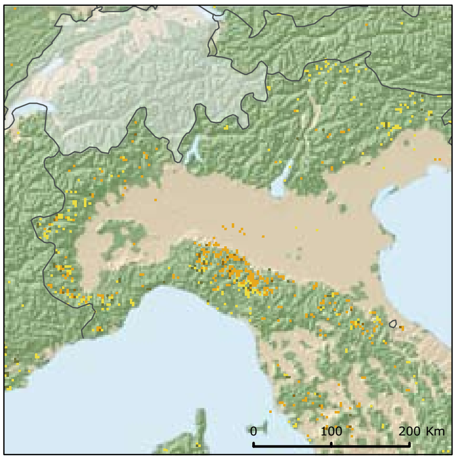
The total forest area of Spain increased during the 1990s, a sign of the success of afforestation plans. Policies have also contributed to maintaining the most valuable forests. New forest areas consisting of broad-leaved and mixed — rather than coniferous — trees, have mainly replaced transitional woodlands or dry semi-natural areas. In Portugal, forest creation was the main land cover change recorded. Continuing land abandonment, coupled with the withdrawal of management by burning, cutting and grazing, has allowed scrub encroachment and tree establishment in many areas throughout the country.

Map 2.5b



In Italy, withdrawal of farming and afforestation in the Alps and Apennine mountains has resulted from the abandonment of pastures and the decline of arable farming on terraces. This has been supported by common agricultural policy reform measures, notably EC Regulation 2080/92 on afforestation of agricultural land. In the French Mediterranean, forest creation is largely a result of the reforestation of semi-natural degraded land that had been damaged by fire.

Map 2.5c



Drivers and impacts

Due to their role in maintaining the equilibrium of landscapes across Europe, changes in forest cover and types are important. There are specific ecological factors at work: for example, the rapid development of production forests in southern Europe not only creates poor ecosystems, but may also contribute to making these forests more prone to recurrent fires. Afforestation can lead to adverse effects as well: some natural dry land or wetlands used for plantations may have a high conservation value that is destroyed by afforestation.

Between 1990 and 2000 some deforestation took place for urban/infrastructure and agricultural uses (Figure 2.14). The deforested areas were on average small, but these changes can in some cases impact on the regional ecosystem. Forest creation on previously agricultural land, together with afforestation of open natural land, is a significant development in some countries (e.g. Ireland, the Netherlands, Spain, and the United Kingdom).

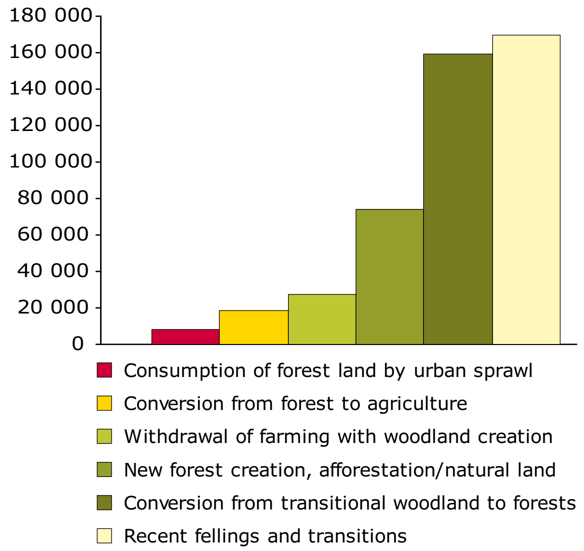
Woodland creation is also observed in peripheral countries or regions of the Atlantic and in some new Member States, as well as to a more limited extent in the Mediterranean mountain areas.

The other two categories of land cover change for forests are conversion from transitional woodland to forest and recent felling (Figure 2.14). The data for these two Corine land cover classes are not as accurate as forest inventories in each country, but the observed patterns are similar. The main advantage of the Corine approach is that it allows users to track the spatial distribution of forest trends in a consistent way across Europe.

Country comparisons

In general, the area of forest land across Europe has increased only slightly with the exception of Ireland, which had been the country with the least forest in Europe but where major afforestation has been undertaken (Figure 2.15). However, the area of open semi-natural and natural land (wetlands, dry grassland, heathland, sand and bare rocks, and glaciers in Austria and Italy) has generally decreased.

Figure 2.14 Main trends in woodland and forest formation, ha per year 1990–2000, EEA-23



The net formation of forest and natural land masks the much larger internal rotations that are taking place. These are important because they are a significant factor in determining forest age and ecological quality.

Careful management is a critical determinant of the ecological health of a forest. Extensive felling can degrade ecological quality, which is restored only when trees are allowed to come to maturity. If changes in the internal rotations of forests seem to balance out overall in Europe, significant rotations take place at the country level, including in countries where land cover change during the period has been slow such as Denmark, Latvia, Lithuania, and Luxembourg (Figure 2.16).

Afforestation on open natural land and woodland creation resulting from withdrawal of farming, has been an important shift in countries such as Hungary, Portugal and Slovakia. In terms of relative increase of forest area, Ireland is followed by Portugal, Slovakia, Spain, Hungary and the United Kingdom (Figure 2.17). When expressed as a share of total European forest and woodland creation, Spain and Portugal are the largest contributors, followed by Ireland and the United Kingdom.

Figure 2.15 Net formation of forest and natural land 1990–2000 as %, EEA-23

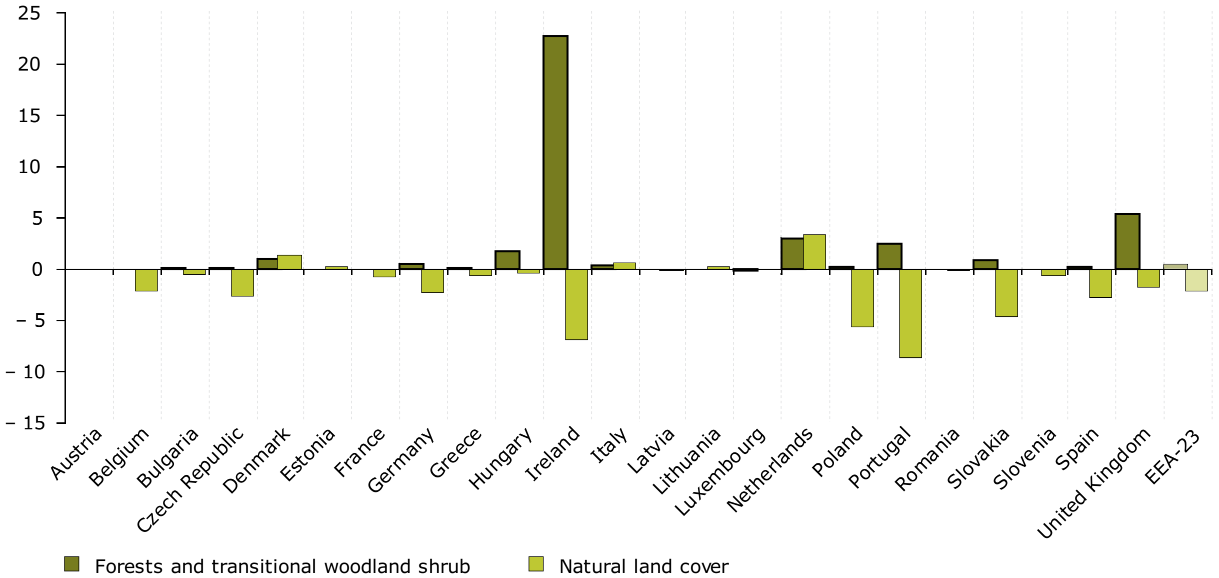


Figure 2.16 Internal rotations of forests ha per year as % of forest territory 1990, EEA-23

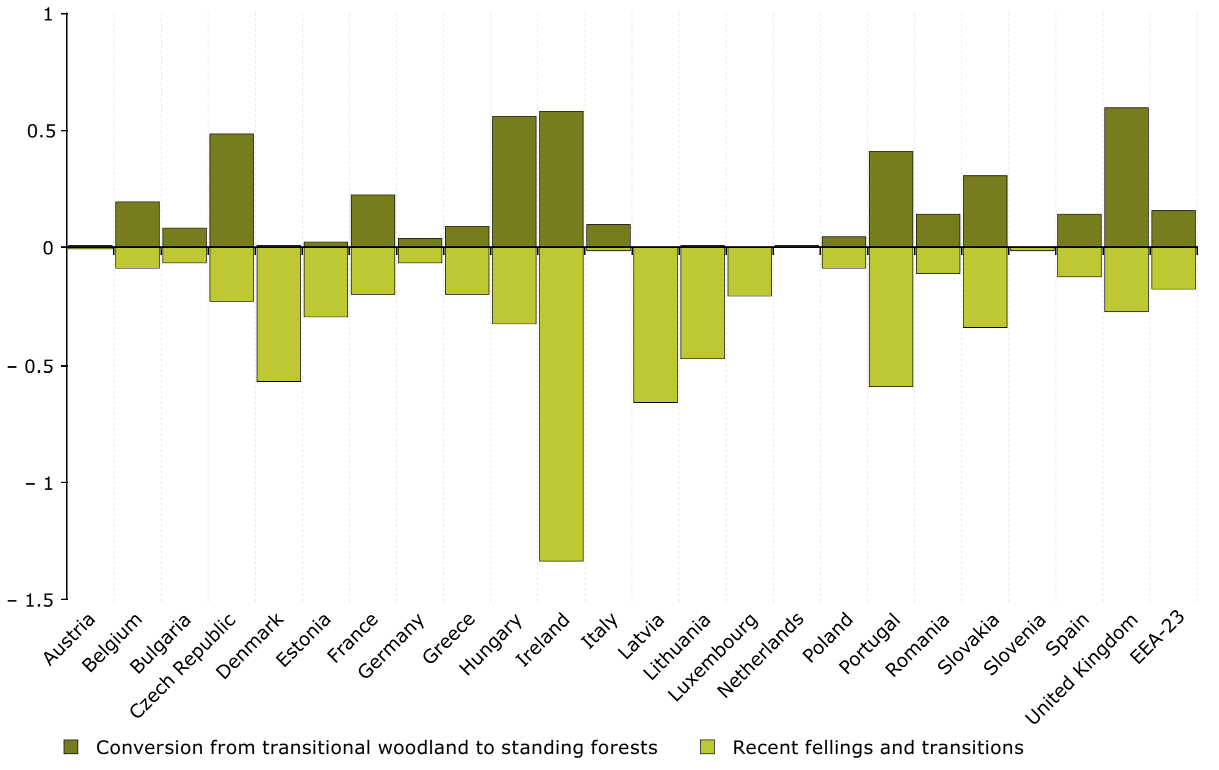


Figure 2.17 Contributions to total European forest and woodland creation (%)

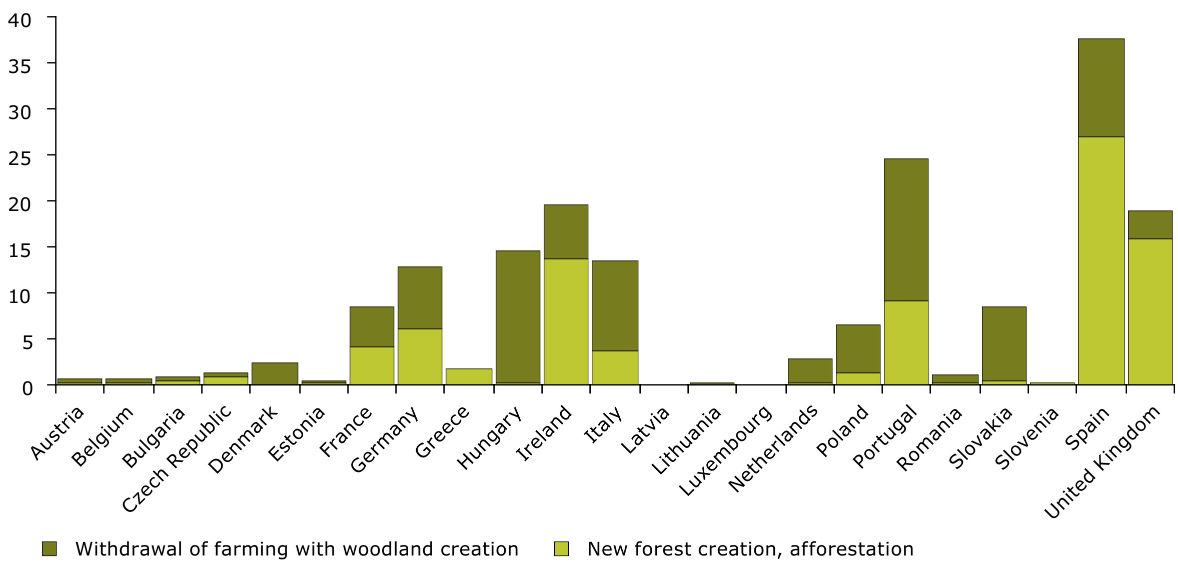
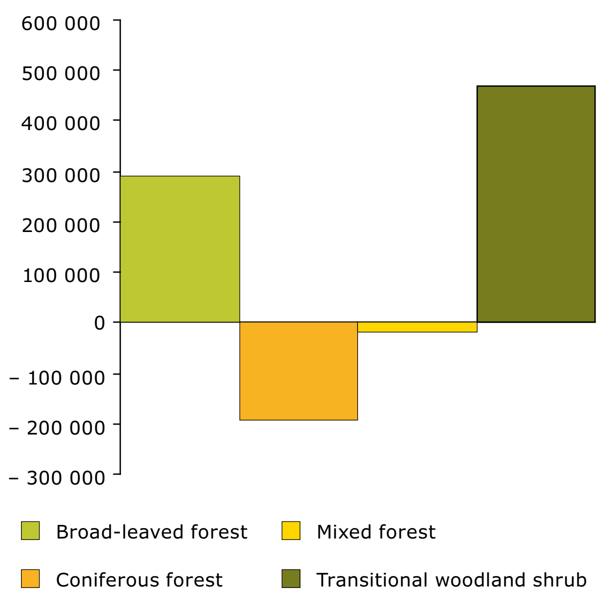


Figure 2.18 Change in the composition of European forests in ha 1990–2000, EEA-23



Analysis of the composition of forests shows the importance of internal rotations linked to the forest cycle of felling and replantations as well as a slight decrease in coniferous forest, and an increase in broad-leaved forest (Figure 2.18).

2.8 Summary and conclusions

The way in which we perceive landscapes and are attracted to some of them, and our feelings when conflicts arise over the use of land, are all matters of extreme importance for conservation and future human welfare. Landscapes change as a result of natural processes and human influence. It is as important to know where change is happening as to know when. This is especially so given the uneven distribution of ecological goods and services across Europe, the vast range of activities that impact on them and the changing character and intensity of these impacts over time.

Land use patterns across Europe show that tensions are arising almost everywhere between our need for resources and space and the capacity of the land to support and absorb this need. Globalisation, agriculture, transport networks, demographic changes and land-planning mechanisms at the national level are the main sources of environmental pressure. There is now rising awareness of the value of considering the territory as a unit of analysis and as a basis for stimulating better coordination of sector policies.

In the 1990s in Europe, changes in land cover were mainly characterised by increases in urban and other artificial land development and forest area at the expense of agricultural and natural areas. Urban areas and infrastructure increased by 6 %; on a straight extrapolation this would lead to a doubling of the amount of urban area in Europe in little over a century. Urban sprawl is concentrated in particular areas, which tend to be those where the rate of urban growth was already high during the 1970s and 1980s. Urban sprawl is also significant in the coastal zones. In the context of possible climate change and the many impacts and adaptation challenges we will face as a result, these perspectives deserve careful consideration.

Some 1 million ha of new forested land were created in Europe in the 1990s, with about a quarter the result of the withdrawal of farming. There has been major afforestation in Ireland, Portugal, Spain and the United Kingdom (Scotland). Afforestation of farmland has been subsidised by the CAP and is often an alternative source of income for farmers where agriculture is difficult.

Agriculture is the most dominant land use in Europe and comprises a diverse mosaic of farming systems. The accession of the new European countries, where western agricultural productivity levels have not yet been reached, has opened new debates on reconciling development needs with the protection of semi-natural areas, in particular dry grasslands. In the 1990s, land cover change in agriculture showed highly contrasting trends with farmland abandonment coexisting with intensification in the same countries and sometimes even in the same regions.

These diverging trends can be linked to economic reforms in agriculture. Conversion from pasture to crops is often driven by more intensive livestock farming and the resulting demand for animal feed. Farmland abandonment has taken place in some mountain regions in southern Europe and in some new Member States. Abandonment and conversion are both potentially detrimental to biodiversity. Future CAP reforms could help mitigate such impacts.

In policy terms, Europe is debating a stronger and more balanced territorial focus for its policies through the European spatial development perspective. The long-term goal is to see a European territory with many prospering regions and areas each playing an important economic role for Europe and providing a good quality of life for its citizens.

References and further reading

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Data source and quality

Corine land cover (CLC) is a globally unique, independent inventory: it is built on a single European classification of land cover types which makes it an invaluable tool for Europe-wide assessments and for comparisons between countries, regions and other zones of interest.

The first Corine land cover map was finalised in the early 1990s. The updated Corine land cover 2000 (CLC2000) is based on the results of IMAGE2000, a satellite imaging programme undertaken by the Joint Research Centre of the European Commission, together with the EEA. Today 29 countries and more than 100 organisations are involved in the production and dissemination of the CLC2000 data. This updated Corine used the same methodological rules and comprised an independent mapping of the change in land cover and a revision of the 1990 database.

The strength of CLC is in its use with other spatial environmental databases. Across the European territory, 44 different land cover types are distinguished and mapped using photo-interpretation of satellite images by national teams in the participating countries. These national land cover inventories are then integrated into a seamless land cover map of Europe. The resulting European database uses a standard methodology and nomenclature, resulting in a powerful tool for use both within and between participating countries. Given the huge amounts of satellite data and other information used, processing and validation across the 29 participating countries takes several years to complete. This is why the use of data from the 2000 inventory only began in earnest in 2005.

However, as with any data set, CLC has limitations related to the observation tool and methodology used. CLC is an analysis and mapping of landscape units on the basis of their physiognomy and radiometric characteristics. It is not, however, a classification of pixels, nor a survey of hectares of a given homogeneous type (as monitored by farm surveys or area-sampling surveys). Rather it is an appropriate background reference for analysing potential conflicts in the use of land and the impacts of land use pressures on biodiversity, and for organising and integrating other sources of information accordingly.

The smallest mapped and classified unit in CLC is 25 ha. Thus, more or less all CLC classes, monitored from satellite imagery, may include significant heterogeneous micro-areas of less than 25 hectares. CLC therefore cannot deliver a very accurate assessment of surfaces (e.g. as needed for agriculture statistics used for calculating crops and related subsidies). As a result of the 25-ha limitation, the Corine classification also includes mixed classes ('discontinuous urban fabric' and 'land principally occupied by agriculture with significant areas of natural vegetation'). These classes have a high interest from an ecological perspective.

CLC land units will disappear or pop up when they come just below or just above the 25-ha threshold. This is consistent with monitoring landscape systems. Considering the mapping of changes in CLC2000, the smallest mapped change is 5 ha. It may therefore happen (but very rarely) that a 5–24 ha change results in the creation or deletion of a small zone. In order to avoid any misinterpretation, the user will have access to and can compare three datasets: CLC1990-revised, CLC change 1990–2000 and CLC2000. These will be available on the EEA website from early 2006.

CLC2000 has been prepared and its quality controlled by the EEA. CLC1990, an experimental programme using images from 1986 to 1994, did not meet the same standards but, after 10 years of extensive use, can now also be considered as of good quality. Moreover, the original CLC1990 was revised during the CLC2000 process in order to fix possible errors and eliminate geometric discrepancies that could generate false change. However, problems still remain, especially for some of the countries which were pioneers of applying the Corine methodology in the 1980s and because of the different time periods in countries between the production of CLC1990 data and the CLC2000 updates. These are being resolved through using the data and improving it in consultation with national experts.

Using accounting methods to analyse spatial changes

The land and ecosystem accounts method (LEAC), as developed by EEA, provides a framework for analysing spatial land cover changes. Considering Corine's 44 land cover classes, there are approximately 1 900 possible one-to-one changes from one Corine class to another. LEAC essentially presents a typology of these changes, classifying the changes into types of flows. The flows are classed as: 'urban land management', 'urban residential sprawl', 'sprawl of economic sites and infrastructure', 'agriculture internal conversions', 'conversion from forest and natural land to agriculture', 'withdrawal of farming', 'forest creation and management', 'water-body creation and management' and 'changes due to natural and multiple causes'. Flows are then combined with the 1990 and 2000 stocks to assess the relative importance of the various processes. Making full use of CLC, land cover accounts are computed at the most detailed level, and tables and indicators can be produced and mapped for any kind of geographic zone, from countries or river basins to regions or small areas. The EEA's full land and ecosystem accounts compendium and associated statistics are available at www.eea.eionet.eu.int/Public/irc/eionet-circle/leac/library?l=/leac_stat&vm=detailed&sb=Title — accessed on 18/10/2005.

In addition to indicating land cover, land accounts are designed as a framework into which other data and statistics can progressively be introduced. Some of these data will relate to changes in the structure, patterns, productivity, species composition and quality (health) of the land cover units considered as images of ecosystems. Other statistics will specifically address the land use issue. Land use relates to the many economic and social functions of land: housing, food production, industrial activities, services, transport, recreation and nature protection. There can be many uses of land on the same land cover unit, and their various functions need to be described using socio-economic statistics. Because of the common infrastructure provided by land cover accounts (based on CLC), ecosystem accounts and land use accounts are bridged in a system that facilitates analysis of the interactions between the economy and the environment.

Land cover change in terms of numbers of total changes or a net balance of surfaces is not particularly useful in terms of interpreting environmental impacts. The actual locations where the changes take place matter more, particularly when looking at the potential impacts of land use on nature. These impacts result from the sealing of soil and fragmentation by the development of artificial surfaces and linear infrastructures, which lead to the quasi-irreversible destruction or degradation of natural ecosystems, and from noise and pollution, generated by transport and other intensive land uses. Other degradation may result from the conversion of forests and natural land to agriculture and, in particular contexts, from the use of natural land (including wetlands) for productive afforestation. In addition to the direct and irreversible loss of land occupied by natural habitats, these various intensive uses contribute to creating barriers that risk fragmenting the ecological network. Background landscape maps have proved to be efficient for analysing and presenting land cover changes in their proper context. These 'dominant landscape types' and 'green background' maps are presented and discussed in this chapter.

3 Climate change

3.1 What is climate change?

Weather is something we experience every day. It relates to whether the sun is shining or whether it is raining, what the temperature is, and the direction and force of the wind. Climate is the average weather over a long time period.

The climate is not static: it has changed in the past, over centuries, millennia and even longer periods of time. The natural causes of this include fractional changes in solar radiation, volcanic eruptions that can shroud the Earth in dust, and natural fluctuations in the climate system itself, such as, for example, the North Atlantic Oscillation.

Recent research into past climate — involving detailed analysis of tree rings, ice cores, ocean sediments, and coral and plant remains — reveals a period of about 8 000 years of overall stability, with global average temperatures moving only by small fractions of a degree Celsius. Over the last millennium, the first 900 years saw only small fluctuations in average global temperatures in the northern hemisphere of less than 1 °C, followed by rapidly rising temperatures in the last 50 years or so (Figure 3.1).

Average global temperatures are now about 0.7 °C above pre-industrial levels, and are currently rising faster than at any time in modern human society. Nine of the 10 warmest years in a detailed thermometer record extending back for 150 years have occurred in the past decade, with the four hottest years globally in 1998, 2002, 2003 and 2004. Projections for the next 100 years show a continuation in this trend, estimates of the global increase ranging from 1.4 °C to 5.8 °C.

In Europe, temperature rise has been even greater than the global average during the 20th century, namely 0.95 °C. The greatest warming has been in the Iberian Peninsula, north-west Russia and parts of the European Arctic. In Europe, the eight warmest years on record have all been since 1990, with the hottest in 2000. The European average temperature is projected to further rise by 2.0 °C to 6.3 °C in the next 100 years.

Initial scientific concern that this global warming might to a large extent be due to emissions of greenhouse gases caused by human activities has now grown to near certainty. The UN Intergovernmental Panel on Climate Change (IPCC), a global organisation of scientists, was set up by the World Meteorological Organization and the United Nations Environment Programme in 1988 to review the evidence. It concluded in 2001 that, while many of the fluctuations in temperature until the mid-20th century could be due to natural events such as volcanic eruptions and variations in solar activity, 'there is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities, in particular to the emission of greenhouse gases'.

The important factor is the large rise in concentrations of greenhouse gases in the atmosphere. These gases trap heat that is radiated from the surface of the Earth and prevent it escaping to space. The effect has been known for more than a century, and is now directly measurable in the atmosphere. The prime culprit is carbon dioxide (CO_2), a gas emitted when (fossil) fuels are burnt. The main fossil fuels are coal, oil and natural gas. These are made up of plant and animal matter millions of years old. Another cause of the increase of CO_2 in the atmosphere is the large-scale cutting of forests (deforestation).

Human activity is currently sending around 25 billion tonnes of CO_2, the most relevant greenhouse gas, into the atmosphere each year. The gas typically persists in the atmosphere for around a century before being absorbed by the oceans and ecosystems on land. Because of its long atmospheric lifetime, these CO_2 emissions have caused a steady rise in concentration of the gas in the atmosphere: the current rate is between one and two parts per million each year. A pre-industrial atmospheric concentration of the gas of between 250 and 280 parts per million (ppm) has risen to around 375 ppm today — higher than at any time in the past 500 000 years.

Man-made emissions of other greenhouse gases such as methane, nitrous oxide and fluorocarbons have raised concentrations of these gases in the atmosphere too.

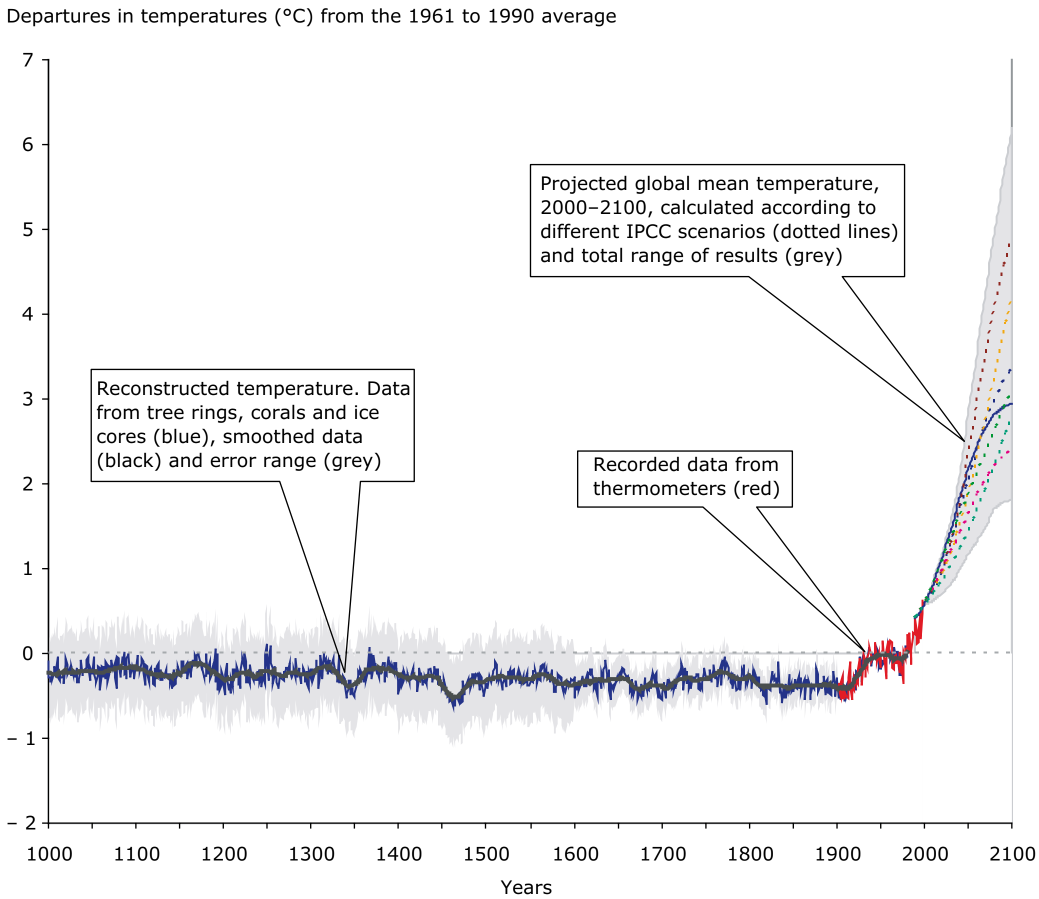
These increases have been sufficient to have the same warming impact as a further 50 ppm of CO_2. The IPCC scientists have concluded that, taken together, these accumulations of greenhouse gases are the prime cause of recent climate change — and the likely cause of future warming.

3.2 Indications of climate change

Indications of climate change are already visible across the world. Most obviously, warming is leading to most of the world's mountain glaciers and the Greenland ice sheet melting. In general, warming is highest in polar regions. There, melting ice means that more of the solar energy reaching the Earth's surface is absorbed, and less is reflected back into space. Rises in Arctic winter temperatures have reached 5 °C in some places already, seven times the global average rise.

There are other indications that weather patterns are shifting around the world, due to extra heat energy in the climate system caused by rising temperatures. In the Pacific Ocean, the periodic fluctuations known as

Figure 3.1 Reconstructed and measured temperature over the last 1 000 years (northern hemisphere) and projected temperature rise in the next 100 years



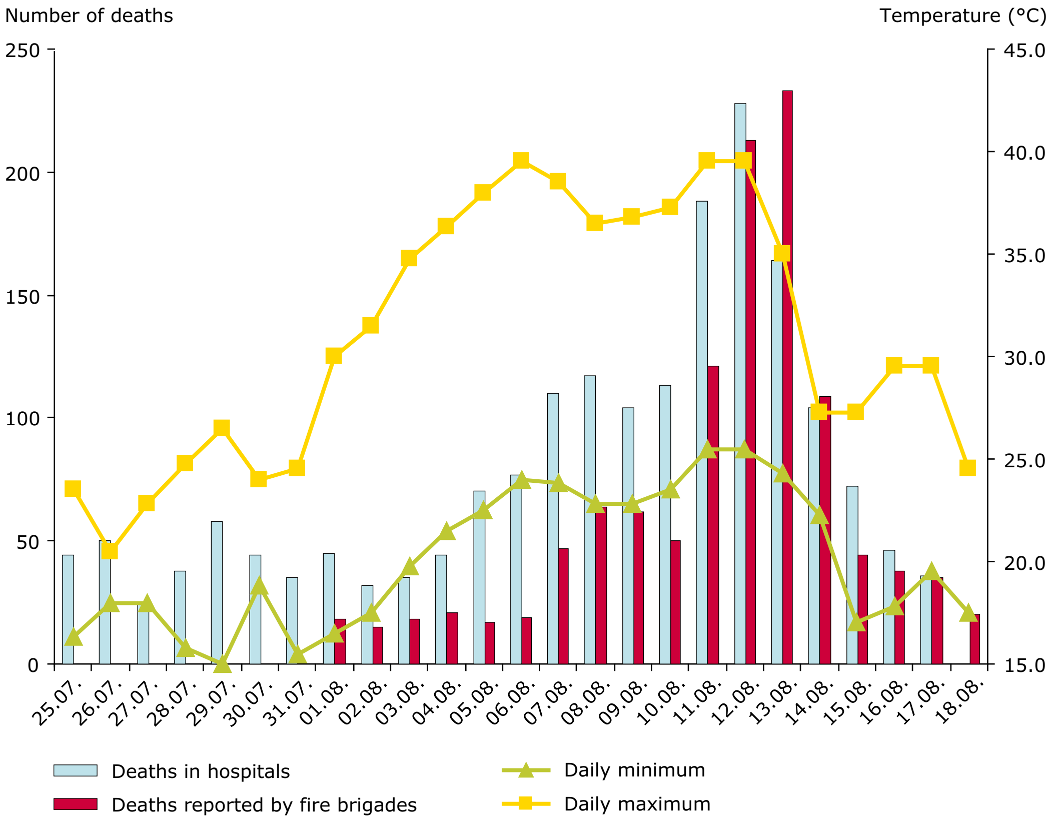
Source: Mann *et al.*, 1999 (last 1 000 years); IPCC, 2001 a (projections for the next 100 years).

El Niño events appear to be becoming more frequent and intense. Tropical storms are afflicting new areas. In the Southern Ocean, weather systems that once brought rain to south-west Australia now often do not make landfall. Other weather systems are hitting the Antarctic Peninsula where once they were unknown.

The greater energy in the atmosphere is also causing a rise in extreme conditions of all sorts, including drought, heavy rain, heatwaves and sometimes even intense cold. Europe has seen an increase in floods in recent years — there were 238 flood events between 1975 and 2001, and 15 major floods in 2002 alone — and in heatwaves and forest fires. As crops fail and floods make some areas increasingly inhabitable, these events are starting to have a negative effect, especially on vulnerable societies and economies. Rises in temperatures in the Arctic and the loss of sea ice are damaging ecosystems and the indigenous cultures that depend on them.

Two of the most visible impacts of higher temperatures in Europe are melting ice and reduced snowfall. Eight out of nine glaciated regions in Europe show significant retreat of glaciers in the past century. In the Alps, glaciers lost a third of their area and half of their mass between 1850 and 1980. This retreat has gathered pace since 1980, in line with accelerating climate change. A further quarter of the Alpine glaciers had gone by 2003, with 10 % disappearing during the hot summer of 2003 alone. Studies into past

Figure 3.2 **Number of reported deaths and minimum and maximum temperatures in Paris during the heatwave in summer 2003**



Source: IVS, 2003.

climates suggest the region has not seen a change of this scale for at least 5 000 years.

Across Europe there is less snowfall and more rain. As a result, winter snow-cover has decreased significantly across Europe since the 1960s.

In the Arctic north of Europe, warmer air and water have caused melting of sea ice. Recent measurements point to the lowest recorded area of sea ice since 1978 when satellite records became available. The current rate of shrinkage is estimated at 8 % per decade; if this continues, there may be no ice at all during the summer of 2060. Meanwhile, ice thickness has also decreased by an average of around 40 %, while the period of summer melt across the Arctic has increased by more than five days since 1979.

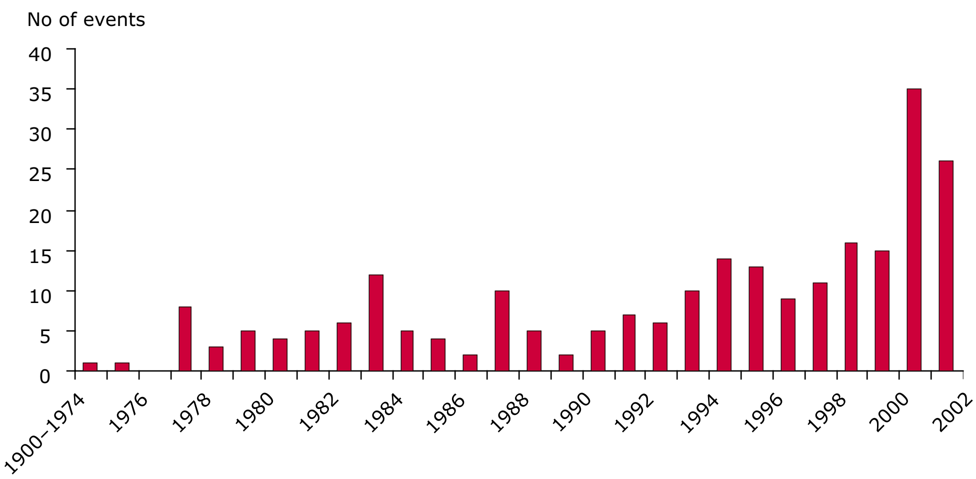
Chapter 8 examines the effects of climate change on biodiversity. At a landscape level, it is worth noting that the average annual growing season for plants has lengthened by 10 days across Europe since 1960, and plant productivity has risen by 12 % in the same period. Taken together, these two factors have increased the continent's 'greenness', although the picture is variable.

Growing water shortages and excessive temperatures in southern Europe are starting to shut off this trend, and climate models suggest that much of the continent may start to 'yellow' in future, as deserts advance.

It is often difficult to disentangle the effects of climate change from other factors such as changing land use. Across Europe, however, climate change already appears to be impacting many sectors of society. Higher temperatures and more intense droughts are producing a rising trend in the number and severity of forest fires in the Mediterranean. These threaten forestry, farming, tourism and the suitability of the land for habitation. Meanwhile, disappearing glaciers are damaging winter tourism in the Alps. Changes in rainfall and flows from glaciers are altering river flows, sometimes causing floods or emptying reservoirs. Higher summer temperatures are intensifying photochemical smogs, raising ozone concentrations to levels that increase the likelihood of damage to health.

It is impossible to say whether the heatwave across Europe in 2003 was caused directly by climate change. Extreme events usually have many causes, but undoubtedly, by raising average temperatures,

Figure 3.3 Number of flood events



Source: WHO-ECEH, 2003.

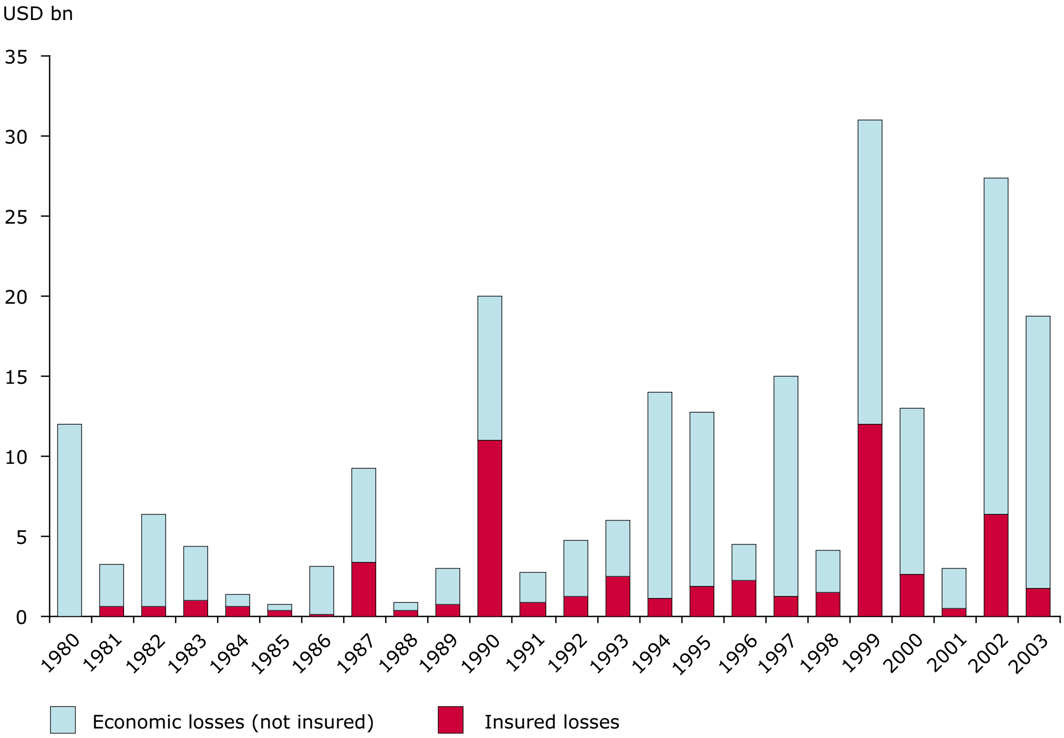
climate change makes such extreme heatwaves more likely. Climate models suggest that the likelihood of the occurrence of heatwaves has doubled in recent years and that they are likely to become increasingly frequent in future.

High temperatures are a threat to human health. The 2003 heatwave saw 20 000 more people die in Europe than in the same period in other years, some 14 000 of them in France. Most people died from heat stroke, and heart and respiratory ailments, as daily maximum temperatures rose to 40 °C and, perhaps of equal importance, night-time minimum temperatures stayed above 25 °C on the warmest nights (Figure 3.2).

The World Health Organization (WHO) is concerned that the annual death toll from heatwaves might multiply by mid-century as a result of climate change. Personal efforts to stave off the worst effects of the heat are likely to result in a big increase in the use of air conditioning across much of Europe. This will, of course, have a knock-on effect on energy generation and consumption and of subsequent greenhouse gas emissions.

According to WHO, higher temperatures also increase the incidence of a wide range of diseases, from allergies such as hay fever through asthma attacks triggered by ozone smogs to food poisoning, which has a well-established association with temperature, and even the spread of tick-borne ailments such as Lyme disease. Potential malaria risk areas may increase, and a doubling of epidemic potential over Europe is predicted by UNEP-Grid/Arendal.

Figure 3.4 Economic and insured losses caused by weather and climate related disasters in Europe



Source: NetCat Service, Munich Re, 2004.

Climate extremes are creating ever greater risks of catastrophic events of all sorts. Flood events in particular have soared in Europe and, although better warning and rescue systems have prevented a commensurate rise in deaths, the loss to property has been substantial (Figures 3.3 and 3.4). The severe flooding in Austria, the Czech Republic, Germany, Hungary and Slovakia in August 2002 caused economic losses of about EUR 25 billion. Flooding occurred again in eastern Europe in 2005.

3.3 Possible future impacts

Rising temperatures and changes in precipitation

The IPCC has stated that if the world continues on its current economic and technological trajectory, without any specific climate change policy being introduced, the projected increase in temperatures worldwide is expected to be between 1.4 °C and 5.8 °C by 2100.

The future temperature will depend on how sensitive the climate is to the 'forcing' effect of greenhouse gases, and on the pace and type of global development. Recent studies during preparation for the next assessment from the IPCC, due in 2007, suggest the temperature may be towards the upper end of this range.

According to model calculations, on current trends Europe can expect a rather bigger increase in temperatures than the global average over the coming century — between 2.0 °C and 6.3 °C — but the change will not be uniform across the continent. Within Europe, temperature rise is expected to be marginally greater in Greece, Italy and Spain, as well as in the north-east of the continent, but it is likely to be less along the Atlantic coastline, where the moderating influence of ocean temperatures will continue to be felt. By 2080, on current trends, nearly every summer in many parts of Europe will be warmer than the current hottest summers.

Meanwhile, precipitation rates are also changing. There are strong differences in regional and local trends, of course, but during the 1990s rainfall in northern Europe was 10–40 % greater than long-term averages, while southern Europe was 20 % drier. Such changes may be exceptional, due in part to natural climate cycles like the North Atlantic Oscillation, but climate models suggest this continent-wide trend of a wetter north and a drier south will persist and strengthen. Furthermore the current trend towards more drought and intense rainfall events in different parts of Europe will probably continue.

People will try to adapt to these changes. For example, in farming, more crops may be able to be grown as the growing season extends, particularly in northern Europe. In some places new farming areas might open up or new crops be grown. However, it is expected that such changes will be offset by adverse effects on agriculture in many parts of Europe.

In the droughts and higher temperatures in southern Europe, there will probably be lower yields and abandonment of farmland. High temperatures will mean that the effective period when some plants grow may actually shorten. Farmers will need more irrigation water (and to use it more efficiently) to survive in southern Europe. The expected decline in rainfall will often leave rivers running dry, and the impact of fewer water resources could be even more damaging for farmers than higher temperatures. Meanwhile, crops may be at greater risk from pests and diseases, including invaders against which the plants have no defence.

Adaptation will not only be necessary for agricultural activities. As climate zones shift, the flora and fauna associated with them will show different distribution trends as well. Some species will be able to adapt within a certain range, some will expand into new territories, whilst others, including many of those in mountain ecosystems, will be left with little habitat available. Studies suggest that in the Alps a 1 °C warming could lead to the loss of 40 % of the area's endemic plants and a 3 °C warming up to 90 %, while a 5 °C warming could bring about a 97 % loss. An evaluation of the coherence and adaptability of networks of protected areas is urgently needed in order to identify ways of reducing this risk.

Melting of ice and snow can be expected to continue apace. By 2050, three-quarters of today's glaciers in parts of the Alps are expected to have disappeared. Melting in the Arctic will be even greater if, as expected, warming continues at more than double the rate in lower latitudes. The area of the Arctic Ocean covered by sea ice is projected to shrink by 80 % by 2050.

The disappearance of ice could open up sea lanes in the Arctic, increasing the potential for trade, industry and the exploitation of resources such as oil and natural gas. Warming will cause permafrost to melt, damaging infrastructure such as roads, buildings and pipelines. As shore ice melts, low-lying coastal areas will be exposed to flooding during storms at sea. Indigenous lifestyles around hunting fish and polar bears and herding reindeer are already being affected as changes in the ice alter migration patterns. Such lifestyles could be extinguished if the changes continue.

Sea level rise and the impact on the marine environment

Sea levels are already rising globally. This is a result of both the thermal expansion of ocean water as it warms and the melting of ice on land. The rise in sea levels around the shores of Europe during the 20th century has been between 0.8 centimetres a decade in the western approaches of Brittany in France and Cornwall in the United Kingdom, and up to 3 centimetres a decade on the Atlantic coast of Norway. The variable trend is caused by local conditions and movements in the height of the land surface. Although the changes in sea level may not seem substantial, in low-lying areas even small changes can flood large areas of land.

This trend of rising sea levels is expected to double or even quadruple in the 21st century. There will be even more to come, because of the very long time lags in transmitting rising air temperatures into the ocean depths and through large masses of ice: it takes decades or centuries for the heat to penetrate.

Warming in the open ocean has so far been restricted to the topmost 200 or 300 metres, but ultimately it will work its way down to the ocean floor. As the warming penetrates, thermal expansion will continue. Even if air temperatures were stabilised today, a combination of thermal expansion of the oceans and melting ice pouring more water into the oceans would continue to raise sea levels.

Rises in sea levels, when coupled with increased risk of extreme storms, will often require big increases in investment in sea walls along Europe's long shoreline. Some governments, for example in the United Kingdom, have endorsed the concept of 'managed retreat', where in some low-lying rural areas the sea is allowed to have its way.

Rising sea temperatures are also having direct effects on Europe's coastal ecosystems. Warming has so far been greatest in isolated basins like the Baltic and in the western Mediterranean. Blooms of phytoplankton grow in the warmer waters, especially when fertilised by flows of nutrients from the land.

These blooms reduce oxygen levels and are sometimes toxic for fish and other wildlife, and even to humans. Meanwhile, zooplankton and the fish that feed on them have followed temperature trends and migrated up to 1 000 kilometres north.

The threat of abrupt climate change

There is growing scientific concern that climate change may prove to be more rapid and pronounced than current projections from the IPCC suggest. The next report of the IPCC is expected to reflect this. In particular, there are fears that the climate system contains the potential for abrupt change, that is, change that, once triggered by warming, can not be reversed even by the subsequent lowering of greenhouse gas concentrations or global temperatures.

The IPCC scientists are still uncertain, but there are theories that much of the climate system may be programmed to operate in a series of relatively steady states, but that, under stress, it may jump from one state to another in just a few years.

One such change could be the rampant melting of the large ice sheets on Greenland and West Antarctica.

These two huge masses of ice have the potential to raise sea levels worldwide by 13 metres. Once begun, say some glaciologists, melting of the Greenland ice cap would be hard to stop because melting itself would raise local temperatures. It would do this in two ways: first by reducing the ice cover that reflects solar radiation back into space, leaving more to be absorbed; and, second, by lowering the level of the ice surface, where it would experience higher air temperatures.

The irreversible melting of the Greenland ice cap could be triggered by local warming of less than 3 °C, according to recent research. The accelerated warming of Arctic regions so far suggests that local warming of 3 °C might be triggered by a global warming of just 1.5 °C, so we are already more than halfway to this point as a result of past emissions.

Another abrupt impact of climate change with potentially large consequences for western Europe in particular is the collapse of the ocean thermohaline circulation. This is a global ocean circulation, part of which includes the North Atlantic Current that brings warm water north from the tropical Atlantic. It largely prevents Europe experiencing temperatures more typical of its latitude — such as those of a Siberian winter.

The thermohaline circulation appears to be either switched on or off, with little in between. It may have switched off thousands of years ago, plunging Europe into much cooler temperatures. This thermohaline switch may have been one of the triggers that pushed the world into and out of ice ages.

The circulation itself is driven by salinity differences in the ocean, particularly within European territory in the far North Atlantic. Circulation might be switched off within a few decades, if the water in that region of the ocean became less saline. This could happen as a result of greater melting of ice in Greenland or greater precipitation in the Arctic region generally, both of which would cause large amounts of freshwater to flow into the critical region, so reducing seawater salinity. Both are possible consequences of climate change.

The effects of a collapse of the North Atlantic circulation on European climate remain uncertain. It might simply moderate the effects of global warming in western Europe, but at the other extreme it could push temperatures further downwards, creating what some have termed a 'new ice age' in Europe. Given our limited state of knowledge on the ocean climate at present, it is not possible to predict whether or when this might happen.

Other potentially catastrophic events could include:

a. The release of large amounts of the greenhouse gas methane from frozen tundra and continent shelves, where it is known to be trapped in frozen lattices known as hydrates. This could send global temperatures soaring even faster than current models suggest.

b. A change in how terrestrial ecosystems exchange CO_2 with the atmosphere. Currently, they act as a net sink for atmospheric CO_2, absorbing some of the emissions from burning fossil fuels. Some models suggest that as temperatures rise and ecosystems such as the Amazon rainforest die, they could by 2050 be converted into net sources of CO_2 releases into the atmosphere. This could again accelerate climate change.

3.4 International efforts to halt climate change

In 1992, at the Earth Summit in Rio de Janeiro, Brazil, most of the world's governments signed the UN Framework Convention on Climate Change (UNFCCC). It set as its long-term objective 'the stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner'. More than

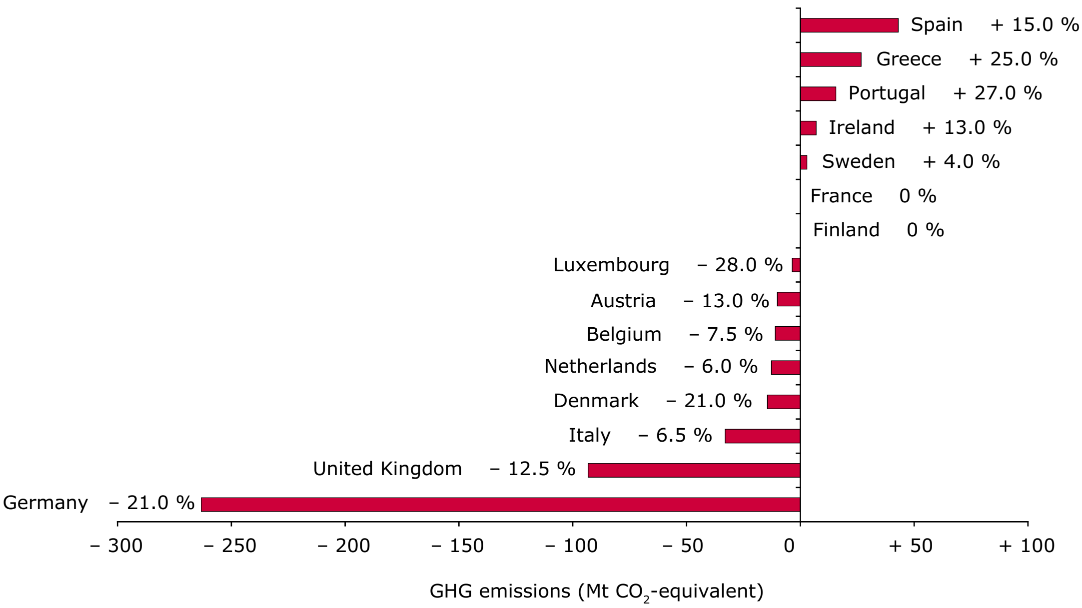
175 countries have ratified the climate convention, including all large industrialised countries.

The first legally binding outcome of this declaration was the agreement in 1997 of a supplement to the climate convention, called the Kyoto Protocol. After prolonged negotiations over its rule-book, and a long period to get sufficient industrialised countries to ratify, the Kyoto Protocol finally came into force in February 2005. The protocol agreed targets for emissions of six key greenhouse gases: carbon dioxide, methane, nitrous oxide, and three groups of fluorinated gases. For the time being, these targets apply to 35 industrialised countries and cover the period 2008 to 2012, known as the protocol's first compliance period. USA and Australia decided not to ratify the protocol, although they remain committed to the climate convention declaration to prevent dangerous climate change.

The commitment of industrialised countries, as a whole, in the Kyoto Protocol was to reduce their emissions of a basket of six greenhouse gases to 5.2 % below their levels in a given base year (1990 in most cases) by the period 2008–2012. Since not all those countries have ratified the protocol, the total reduction target of those that did ratify is about 2.8 % below their 1990 emissions.

Countries are meant to meet their targets by cutting domestic emissions but are entitled to also use the protocol's 'flexible mechanisms'. These include direct trade in emissions permits (called assigned amount units, or AAUs) between countries with targets, and investment in projects in other developed or developing countries, known respectively as Joint Implementation and the Clean Development Mechanism, that cut emissions which would otherwise be made. Countries are also allowed to use increasing carbon uptake by forests and other ecosystem sinks.

Figure 3.5 Kyoto burden-sharing targets for EU-15 countries



Source: EEA, 2004.

The then 15 Member States of the European Union (EU-15) accepted an 8 % reduction target at Kyoto, and subsequently have agreed to a burden-sharing agreement among themselves (Figure 3.5). Thus each of the 15 was given a national target. Eight countries received reductions targets, two had targets for emissions on parity with 1990 levels, while five countries were allowed increases.

Since the burden-sharing targets were negotiated, 10 more countries have joined the EU. With the exception of Cyprus and Malta, these countries all have their own targets under the protocol, with cuts in emissions ranging from 6 to 8 per cent.

As part of its effort to reach its Kyoto target, the EU has introduced an emissions trading system. At the heart of the scheme is the common trading 'currency' of emission allowances. One allowance represents the right to emit one tonne of CO_2. Member States have drawn up national allocation plans for 2005–2007 which give each installation in the scheme permission to emit an amount of CO_2 that corresponds to the number of allowances received. Allowances that are not needed can be traded between companies either directly or through exchanges or sold to any person within the EU.

The aim is to stimulate innovation and give reductions in emissions a market value. This ensures that emissions are reduced in the most cost-effective way. The emissions trading scheme is linked to Kyoto's Joint Implementation and Clean Development Mechanism, which will allow European companies to earn carbon credits by investing in climate-friendly technologies in other countries. A formal market for the first trading period (2005–2007) opened for business in March 2005.

3.5 Reaching the Kyoto targets

Although EU-15 emissions in 2003 were 1.7 % below their 1990 level, it seems that policy measures already decided upon in Member States will not be sufficient to allow them to reach their collective target under the Kyoto Protocol through domestic action. While emissions fell during the 1990s, they have grown overall since 2000, driven by ever-increasing transport demand and small increases in the use of coal and lignite in power generation, which had previously decreased substantially during the 1990s.

Since 1990, reductions in emissions have been mostly from waste (largely methane) and industrial processes. There have also been more modest reductions in the energy sector and in agriculture, but emissions from transport have increased by more than a fifth. Within the transport sector, emissions from aviation and shipping rose the most. Among the EU-15, emissions from domestic transport are projected to increase by 31 % between 1990 and 2010, with increased mileage more than offsetting improvements in the energy efficiency of new vehicles.

The most recent estimate is that emissions within the EU-15 in the first compliance period from 2008 to 2012 will be 1.6 % below the 1990 level, compared with a targeted 8 % reduction. Nevertheless, if all the planned domestic measures and use of Kyoto mechanisms that Member States have so far stated they intend to implement are introduced, then emissions are expected to be reduced by more than the target (9.3 %).

The prospects for the eight new Member States meeting their Kyoto commitments — Cyprus and Malta have no targets — are rather better. Many of them are still recovering from the economic breakdown and restructuring of the 1990s, which caused emissions to drop sharply. As a group, they are expected to have emissions in the first Kyoto compliance period that are about 19 % below 1990 levels, substantially below their national targets.

3.6 Strategy for the future

Setting future targets

As the Kyoto Protocol came into force, countries began to discuss what should follow it, taking into account the commitment in the UNFCCC to prevent 'dangerous' climate change. The UNFCCC has not defined this term, so what it means is inevitably a political as much as a scientific judgment. In March 2005, the EU Council of Environment Ministers concluded that — based on the scientific evidence of likely consequences, including the risk of abrupt irreversible changes to the climate system — the world should strive to avoid exceeding an average of 2 °C warming above pre-industrial temperatures. In addition, scientists have proposed that to help natural systems and human society adapt to inevitable change, the world should act to prevent warming ever proceeding faster than 0.2 °C a decade. (The current rate is 0.18 °C a decade).

The European Council meeting in March 2005 reaffirmed this position, saying that the European Council confirmed that 'with a view to achieving the ultimate objective of the UN Framework Convention on Climate Change, the global annual mean surface temperature increase should not exceed 2 °C above pre-industrial levels'.

What does such a target imply? Temperature rise around the world is only a third of the way to a 2 °C warming, but on current trends a 2 °C warming is likely to be exceeded between 2040 and 2070. Time lags in the natural system of two or three decades mean that, in practice, there is little time left to head off such a rise.

Preventing a rise of 2 °C will require stabilising concentrations of greenhouse gases in the atmosphere at some level. Although in practice it will involve an aggregation of a number of greenhouse gases, this level is usually expressed as being equivalent to a certain concentration of the prime gas of concern, CO_2.

Unfortunately, it is as yet unclear precisely what concentration of greenhouse gases can ensure that the world does not exceed a 2 °C average warming. This is because of continuing scientific uncertainty about how sensitive the climate system is to the 'forcing' of greenhouse gases. The EU Council of Environment Ministers in 2004 suggested that, taking an estimate of 'medium climate sensitivity', the world could sustain a rise to the equivalent of around 550 ppm of CO_2. Allowing for expected changes in other greenhouse gases, this figure roughly corresponds to a concentration of CO_2 itself of around 450 ppm.

That compares with baseline scenarios that suggest concentrations would rise to 935 ppm CO_2-equivalent by 2100, or 675 ppm for CO_2 alone.

Since the Council took its decision in 2004, the situation has begun to look even more difficult. New estimates have suggested that 550 ppm CO_2-equivalent may be too high to prevent a 2 °C warming. On new estimates of climate sensitivity, it could still leave a 70 % chance of temperatures exceeding the 2 °C threshold, and, in order to minimise the risk of an overshoot, it may eventually be necessary to bring concentrations back down to 450 ppm CO_2-equivalent, or less than 400 ppm of CO_2 itself.

With current levels less than 25 ppm short of these concentrations, that would be exceedingly hard to do. A concentration of 450 ppm CO_2-equivalent could be reached in little more than a decade on current trends.

To meet the 2 °C temperature target, the EU Council of Ministers proposed in December 2004 that global greenhouse gas emissions should peak around 2020 and then fall by anything between 15 and 50 % below 1990 levels by 2050. The precise figure would depend on future scientific judgments about the sensitivity of the climate system and the greenhouse gas concentration targets chosen.

Whatever the appropriate target, it is clear that if the world is to reach any sensible, stable level of greenhouse gas concentrations in the atmosphere, major cuts in emissions will have to be made. These cuts will have to come first from the industrialised countries, which currently have the highest per capita emissions, but ultimately will have to involve almost every nation.

Discussions at an international level on how to continue after the Kyoto commitment period were initiated at the UNFCCC conference in Buenos Aires in 2004 and will continue at forthcoming UNFCCC conferences, starting in Montreal, Canada, in November/December 2005.

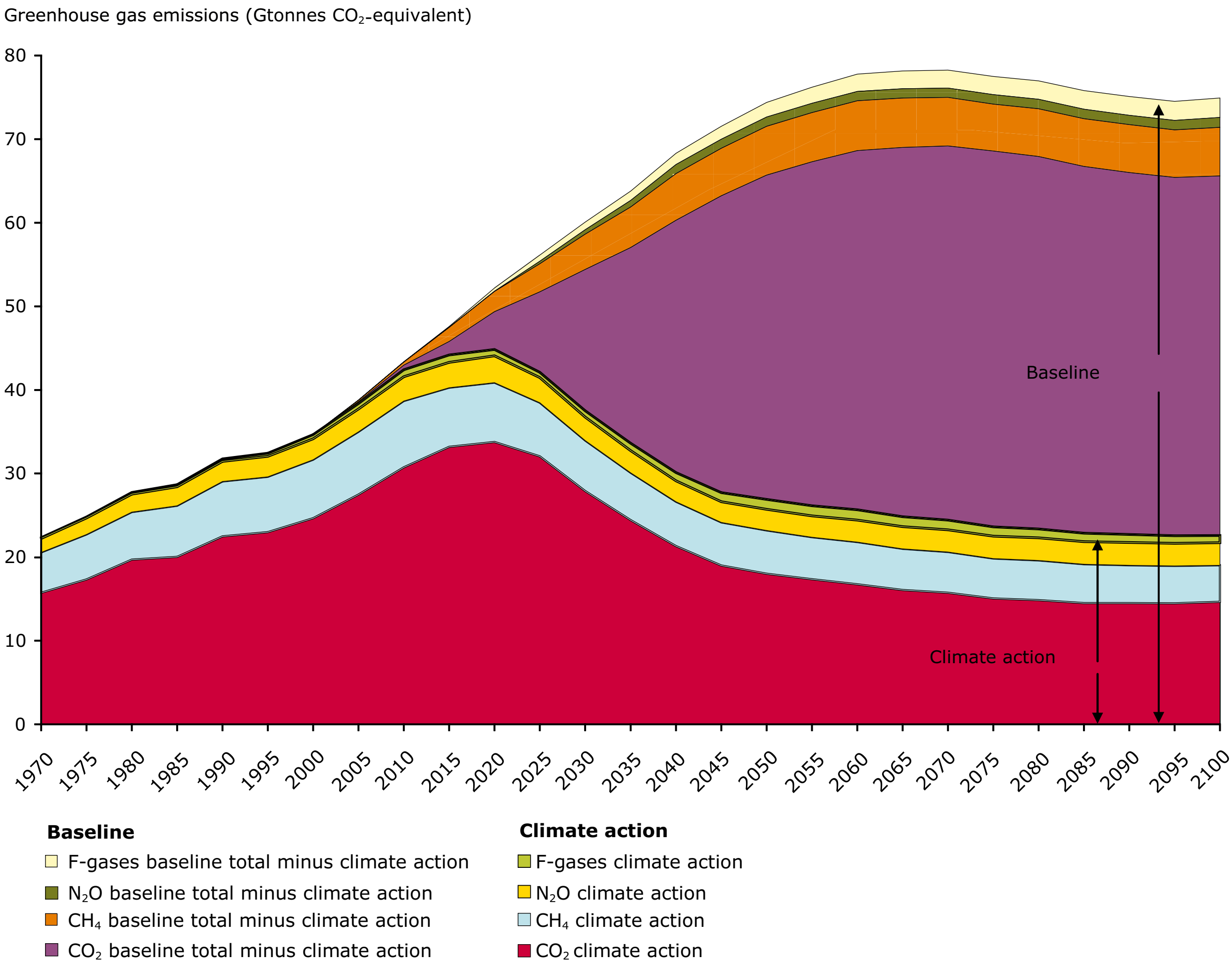
The G8 Summit in Gleneagles in June 2005 affirmed the commitment of the leaders of the world's richest nations. The longer-term perspective — to consider what actions are necessary after 2012, the end of the first commitment period of the Kyoto Protocol — taken by the G8 is another step on general political action to adapt to and remediate global climate change.

Ensuring globally fair shares

Once the international community has decided on appropriate maximum allowable global greenhouse gas emissions, it will have to address the question of how those emissions are shared out between countries.

A number of different models have been proposed. One is the per capita approach, often known as 'contraction and convergence', in which emissions permits are given to countries strictly on the basis of their populations. Another approach is a system based on 'carbon intensity' targets that allocate emissions

Figure 3.6 GHG emissions for baseline and climate action scenarios



Source: EEA, 2005.

permits according to the amount of gross domestic product (GDP) countries generate for each tonne of carbon emitted. Likely formulas could combine these approaches. These and other options are expected to be discussed at UNFCCC conferences in years to come.

The EU Environment Council in March 2005 mentioned that to provide emissions 'space' for developing countries to raise their emissions sufficiently to develop their economies, it will be necessary for industrialised countries to reduce their emissions by the order of 15–30 % by 2020 and 60–80 % by 2050. In the light of those calculations the EU has been trying to chart paths to such a sustainable 'low-emissions' future.

3.7 Pathways to a low-emissions future

Among other institutions, the EEA has worked through a number of scenarios aimed at assessing what changes would be needed to ensure a low-emissions future (Figure 3.6). They all use existing technology and rely on a market in carbon emissions to make investments cost effective. This section does not aim at reviewing them all but at sketching some of the conclusions reached and constraints addressed.

The central assumption in the EEA scenarios is that EU greenhouse gas emissions should fall to 20 % below 1990 levels by 2020, 40 % below by 2030 and as much as 65 % by 2050. In the early years, the EU would rely considerably on using Kyoto Protocol flexible mechanisms in order to meet these targets. The reliance on such mechanisms would fall in subsequent years, when it is hoped that internal EU and national low-emissions policies will have become fully effective.

As already stated, CO_2 emissions in the EU-15 have been rising since 2000. On present policies — and despite continued reductions in the energy intensity of the European economy, through improvements in energy efficiency and structural changes such as the reduced importance of high-energy manufacturing — this rise will continue after 2010. The EEA baseline scenario projects for the EU-25 an overall 14 % rise above 1990 levels by 2030 (Figure 3.7).

EEA studies conclude that the key to switching from that trajectory to a low-emissions development pathway will ultimately lie primarily in reducing energy consumption and improving energy efficiency, and changing the way Europe generates and uses energy for all purposes, including transport. There are a number of ways to do this, and most will have to be used.

The low-carbon energy pathway (LCEP) scenario analyses how the European energy system would change if a CO_2 permits price rise were introduced, one which reaches EUR 65 per tonne of CO_2 in 2030. This would, the scenario suggests, lead to energy-related CO_2 emissions being 11 % lower in 2030 than in 1990 (Figure 3.7). A higher penetration of renewables could increase that to a possible 21 % emissions decline from 1990; a nuclear phase-out could reduce it to 8 %. This range represents a reduction on the 2030 baseline emissions of between 17 and 31 %.

Energy efficiency

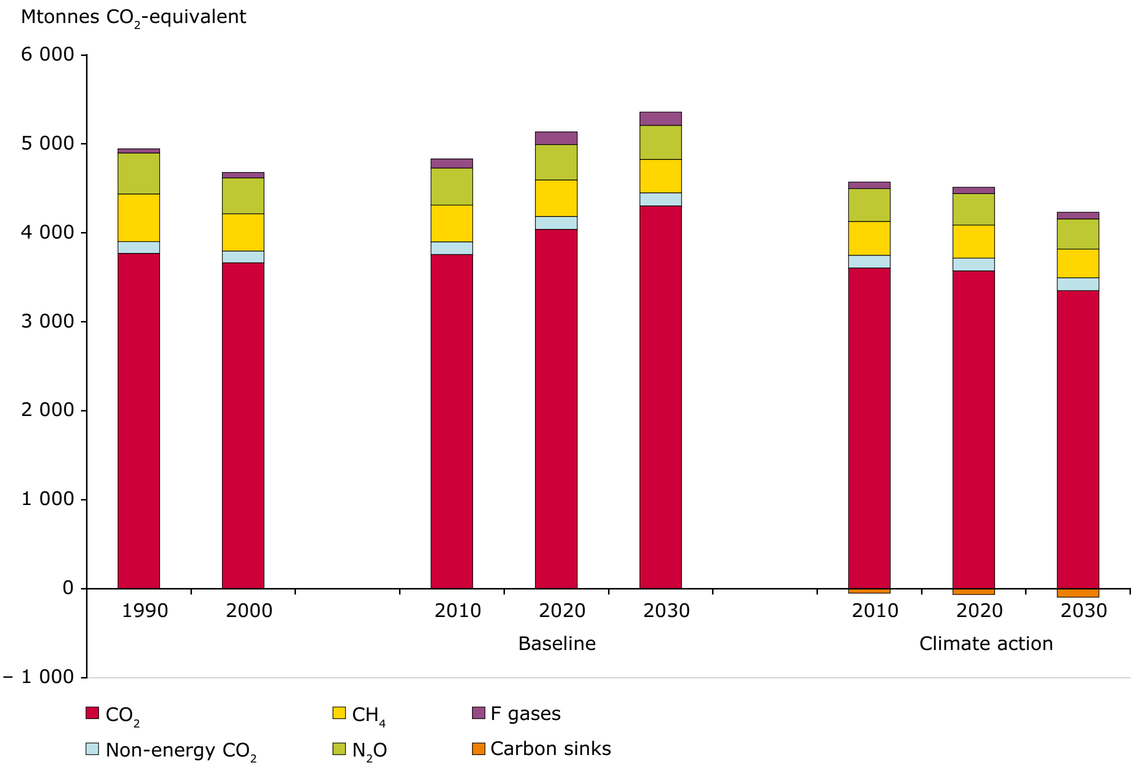
Many cost-effective strategies for improving energy efficiency remain heavily underused. This occurs on both the energy supply side, where more efficient power stations could be employed (those, for example, that use heat that would otherwise be wasted), and on the demand side, where many homes and workplaces use energy wastefully. More goods, including computers, stereo systems, mobile phones, household appliances and air-conditioning systems, are being purchased, and households are generating more waste and using more water and energy. Although new equipment is sometimes less wasteful of resources, this is not always the case. For example, many electronic goods run on stand-by mode when not in use, and so use substantially more electricity than their predecessors.

Supply-side improvements in efficiency will rely considerably on market mechanisms, but those on the demand side will probably be more dependent on awareness-raising among end-use consumers and regulations on technical standards. However, improved energy efficiency does not necessarily mean that absolute cuts in energy consumption will follow, because the baseline is on a rising trend. Since 2000, gains from improved efficiency in energy generation and declining energy demand from industry have been wiped out by rising energy consumption by consumers/households and in the service sector.

A proposed EU directive on energy efficiency on the demand side sets a target for Member States to save 1 % of energy put into supply each year between 2006 and 2012, compared with the baseline scenario. If this progress on energy efficiency was extended beyond 2012 along the lines of the EU energy efficiency action plan, it could cut energy consumption by almost a fifth from the baseline between 2000 and 2030. The recent green paper on energy efficiency states that as much as 20 % of energy savings could be realised in a cost-effective way by 2020, according to available studies. However, this would require both the implementation of adopted legislation as well as additional policies and measures. The EEA scenarios suggest that improved efficiency and reduced consumption could account for almost half of emission reductions by 2010, decreasing to a one-third contribution beyond 2012.

Passenger cars, in addition to freight transport, have been the largest element of rising consumer demand. There have also been significant increases in energy use from domestic electrical appliances and for heating

Figure 3.7 Total greenhouse gas emissions in EU-25 (baseline and LCEP scenarios)



Source: EEA, 2005.

and air conditioning. Europeans are demanding ever greater energy services in their homes and workplaces. There is a great deal of potential to counter this trend in the household and service sectors, for example by adopting cost-effective improvements to energy efficiency in electrical appliances, and through better thermal insulation of buildings. Stemming the rising demand for energy for transport, however, is likely to be a bigger challenge, with the aviation sector in particular needing attention.

Fuels switch and renewables

If the EU is to make the progress it desires towards a low-emissions economy, a change in the fuel mix, especially for electricity generation, appears inescapable. Indeed, CO_2 emissions from public power plants (EU-15) between 1990 and 2002 remained almost stable despite a substantial increase in electricity production, through a combination of efficiency improvements and fuel switching, which produces a one-off benefit (Figure 3.8). However, as a result of increased power generation overall, the increased uptake of coal in the power generation mix and the loss of the once-off fuel switch benefit, CO_2 emissions in this sector are currently increasing again.

There is no blueprint for the right mix of low- and no-carbon energy technologies. Much will depend on technological developments, markets and political developments. The EEA scenarios suggest that further changes in the methods of power generation would account for more than 70 % of the emissions cuts likely

Air travel: a growing issue

Air travel is increasing, and rapidly. Globally, air passenger traffic has risen by an average of 9 % every year for the past 45 years — more than twice as fast as GDP. In large part, this increase has been driven by falling prices. The real cost per passenger-kilometre of air travel has fallen by 80 per cent since 1960, and halved since the late 1980s. The trend is forecast to continue, and the world aircraft fleet is expected to double by 2020.

Emissions have risen accordingly. CO_2 emissions from international aviation rose by 73 % between 1990 and 2003. They now amount to 12 % of national emissions from transport.

For frequent air travellers, emissions from the aircraft in which they travel are likely to be their biggest personal contribution to climate change. A return flight for two passengers across the Atlantic produces as much CO_2 as an average European passenger car does in a whole year.

This is only part of the climate impact of aircraft. Aircraft also emit nitrogen oxides and water vapour, both of which contribute directly or indirectly to climate change. They also create condensation trails, which may affect cirrus cloud coverage and thus add to global warming. The IPCC estimates that the total impact of aviation on climate is between twice and four times the effect of its CO_2 emissions alone.

Greenhouse gas emissions from international flights are, however, not accounted for under the Kyoto Protocol because there has been no agreement on how the emissions should be allocated. Moreover, international treaties on civil aviation prevent national or EU initiatives to impose taxes on kerosene or other restrictions without the approval of the International Civil Aviation Organization.

Aircraft, and the road transport they generate around airports, create other environmental problems. There is growing concern about aircraft noise near airports, particularly at night, and about emissions on the ground from both aircraft and other traffic. Nitrogen oxide emissions from major airports can also threaten local air quality targets.

There is a growing concern about implementing policy instruments that aim to reduce the environmental effects of international aviation by giving aircraft manufacturers incentives to improve fuel economy and reduce emissions of nitrogen oxides, or incentives to airlines to operate in an environmentally better way. Including the aviation sector in the emissions trading scheme is one option being considered within the EU as recently proposed by the European Commission in a communication on reducing the climate change impact of aviation (COM (2005) 459 final).

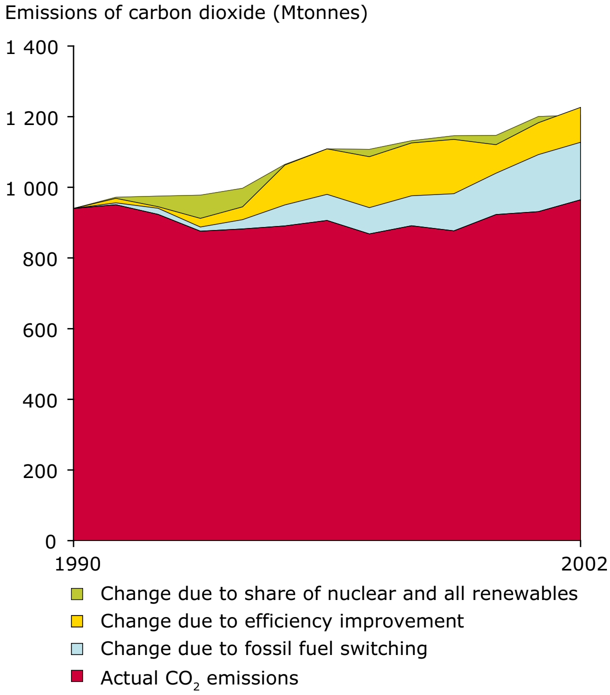
The rise of low-cost airlines is a double-edged trend. The operators are carrying more people on fewer flights than conventional airlines, but their low prices stimulate more journeys. Overall, air travel is expected to double its share of passenger transport between 2000 and 2030, from 5.6 % to 10.5 %, representing almost a tripling of air passenger-kilometres.

by 2030. For instance, under the LCEP scenario, the share of electricity generated by burning fossil fuels would be substantially lower (13 %) by 2030 compared with the baseline development. Renewable sources and perhaps nuclear power would take up a greater share. Within the fossil fuels sector, natural gas, which contains about 40 % less carbon than coal or oil per unit of energy, would increase its share from 18 % in 2002 to 42 % in 2030 at the expense of solid fuels. Additionally, natural gas power plants are more efficient than existing power plants and new coal-fired power plants. The size of the fossil-fuel burning industry today is such that even modest improvements in the thermal efficiency of its power plants could have major impacts on Europe's CO_2 emissions.

Fuel switching could be substantially stimulated by market-based emissions trading. Carbon dioxide permit pricing would improve efficiency in both the supply and use of energy by, for example, stimulating the spread of more efficient fossil-fuel technologies such as combined cycle turbines and combined heat and power (CHP). It would also stimulate the further substitution of low-carbon fuels like natural gas for coal and it could promote investment in zero-carbon renewable energy sources, even though additional measures will be needed to substantially increase their share.

There would be significant additional benefits from the spread of renewables as a replacement for fossil-fuel burning. Besides reducing CO_2 emissions, renewables would improve the diversity, security and self-sufficiency of European energy supplies. A vibrant renewables industry would also generate jobs and exports. The EU has already charted renewables as an appropriate way forward and has set 'indicative' targets to generate 12 % of total energy consumption from renewables by 2010 in the EU-15 and to generate 21 % of electricity from renewables in the EU-25 by the same year. However, so far since 1990, the share of renewable electricity in gross inland electricity consumption has risen only marginally, from 12.2 % to 12.7 % in 2002. The share of renewables in total energy consumption increased from 4.3 % to 5.7 % over that period. Significant further efforts will have to be made if the 2010 targets are to be met (Figure 3.9).

Figure 3.8 CO_2 reductions in EU-15 for electricity and heat production, 1990–2002



Notes:

1. Emissions data for Luxembourg is not available and so this country is not included in the calculation for the European Union.

2. The chart shows the contributions of the various factors that have affected CO_2 emissions from electricity and heat production. The top line represents the development of CO_2 emissions that would have occurred due to increasing electricity production between 1990 and 2002, if the structure of electricity and heat production had remained unchanged from 1990 (i.e. if the shares of input fuels used to produce electricity and heat had remained constant and the efficiency of electricity and heat production also stayed the same). However, there were a number of changes to the structure of electricity and heat production that tended to reduce CO_2 emissions and the contributions of each of these changes to reducing emissions are shown above. The cumulative effect of all these changes was that CO_2 emissions from electricity and heat production actually followed the trend shown by the red area at the bottom of the graph.

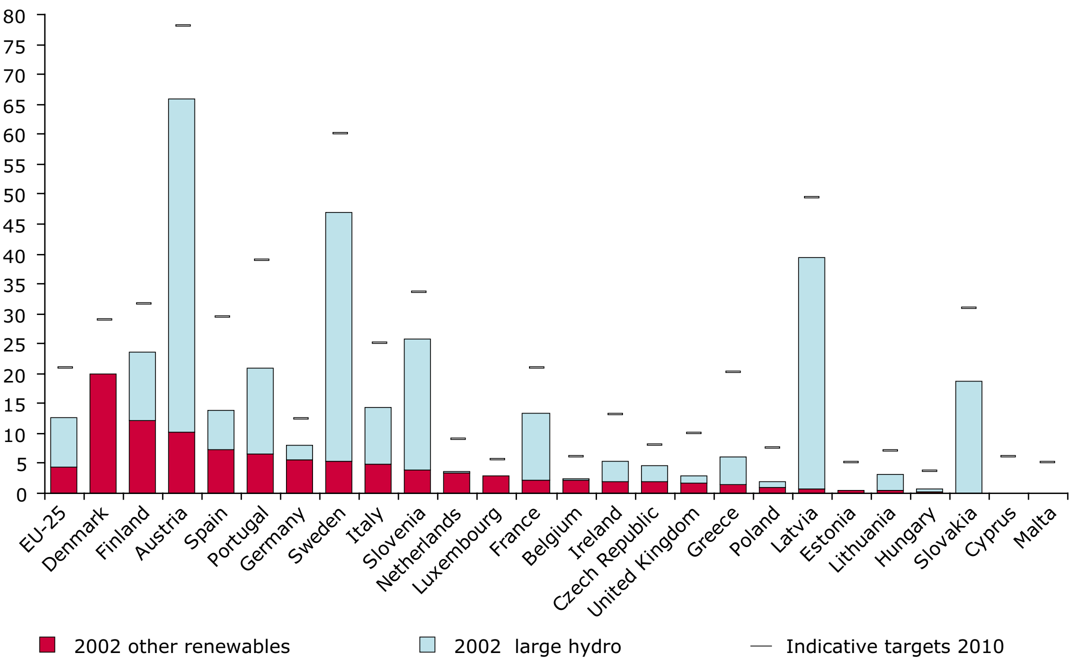
Source: EEA and Eurostat, 2005.

Today biomass and hydropower account for around 90 % of total energy and electricity produced from renewables. Due to environmental constraints and lack of suitable sites, large hydropower is not expected to increase substantially in the EU-25 as a whole, while wind and biomass are expected to continue to grow rapidly. Wind is already a significant energy source in several countries, including Denmark, Germany, Spain and the United Kingdom.

In 2007, the EU is to set formal European targets for the use of renewable fuels in the period after 2010. Currently a 20 % target for renewable energy in 2020 has been proposed as an EU-25 target, building on the EU-15 target of 12 % by 2010. Such targets should provide long-term signals for industry, investors and researchers. Yet energy research and development in Europe has been in decline since 1990, despite the growing public acceptance of the need for innovation in the sector. So what is the longer-term potential?

Of renewable sources of electricity generation, the LCEP scenario suggests that wind and biomass are the most promising. At least until 2030, solar and geothermal power will make only modest contributions to energy production. The study sees renewables generating 28 % of EU electricity in 2030, roughly double the present contribution. There could also be a substantial expansion in the burning of biomass fuel in CHP plants. If additional incentives for the deployment of renewables were introduced, the share of renewables electricity would increase to almost 40 % in 2030, and account for 22 % of total energy consumption (Figure 3.10). Such a variant of the LCEP scenario indicates that this would further significantly lower CO_2 emissions to 21 % below 1990 levels.

Figure 3.9 Share of renewable electricity in gross electricity consumption in the EU-25 in 2002



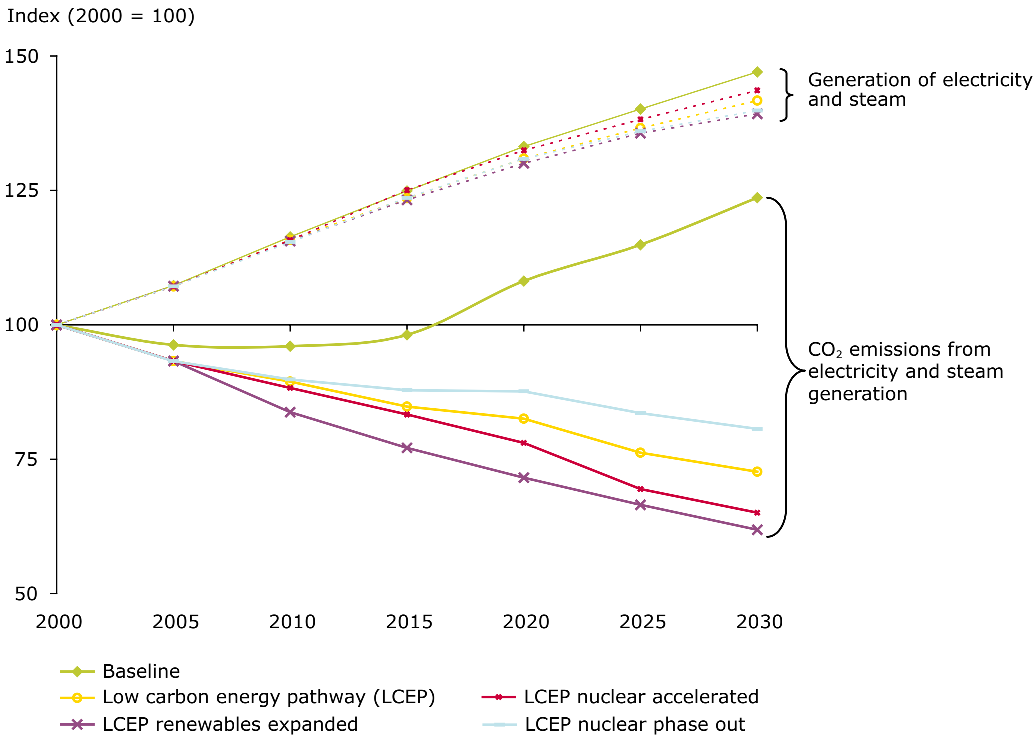
Source: EEA, 2005.

There is potential for biofuels in the transport sector in the next two decades. Due to competing demands for the land needed to grow the bioenergy crops, attention has to be paid to nature conservation requirements and other environmental objectives such as less intensive agriculture.

While a CO_2 permits price is expected to stimulate renewables development in coming decades, this alone will not be enough. Other instruments are likely to be necessary. They will include the removal of harmful subsidies for other fuels and government intervention to ensure that fuel prices reflect environmental externalities, such as the effects of acid deposition on ecosystems and the effects of particulates and ozone on human health. Energy subsidies within the EU-15 amounted to almost EUR 30 billion in 2001, with more than 73 % oriented towards the support of fossil fuels.

One conclusion of the LCEP scenario is that, all things being equal, increasing the share of renewables would further substantially decrease European CO_2 emissions. If nuclear energy were phased out, that would increase CO_2 emissions, while a higher share of nuclear energy could contribute to further reductions (Figure 3.10). Increasing nuclear energy, however, would have to take into account other considerations, including cost, public concerns, waste disposal and the global politics of nuclear proliferation.

Figure 3.10 Development of gross inland energy consumption and energy related CO_2 emissions according to different scenarios — EU-25



Source: EEA, 2005.

Carbon capture and storage

An emerging new option, not considered in LCEP scenarios, is the capture and storage of CO_2 from power stations and industrial stacks. The technology could potentially contribute significantly to the mix of measures that is required to meet the tough long-term targets on cutting emissions.

The International Energy Agency suggests that by 2030 substantial amounts of CO_2 could be captured in Europe. The gas would be sent by pipeline or tanker for burial in geological formations that are impermeable to CO_2, and so kept out of the atmosphere for a long period of time. These stores might include emptied oil and gas wells, unmineable coal seams and saline aquifers. There are, however, still some questions regarding storage in saline aquifers.

Some of the technology's promoters argue that carbon capture and storage offers the potential for continued use of fossil fuels, while dramatically reducing CO_2 emissions. Others see it as a transitional technology, as 21st century economies move to lower-carbon energy systems.

The technology works best at large stationary sources such as power stations, oil refineries and coal gasification plants, where there are economies of scale in extracting and moving the gas. Some of these facilities could be attached to hydrogen production facilities in any future hydrogen economy (see Section 3.10), provided they use a pre-combustion technology.

One possibility of carbon capture involves passing flue-gas emissions through chemical scrubbers containing amines that react with and trap CO_2. Similar technology is already used in some places to remove CO_2 from natural gas to boost the proportion of hydrogen. Separation of CO_2 prevents the release to the atmosphere of 85 % or more of CO_2 emissions, but requires energy and reduces the efficiency of the power station or production plant.

After capture, the CO_2 is best compressed and transported by pipeline for injection underground. This technology, too, has been developed, largely in USA, where CO_2 is pumped into oil wells to help the removal of remaining hydrocarbons. Similarly, injection of CO_2 into coal mines could recover methane, another valuable fuel. An EU trial on this is under way in Poland.

Europe's largest potential CO_2 storage arena is likely to be deep saline aquifers and depleted oil and gas fields in the North Sea, mainly in the Netherlands, Norway and the United Kingdom. It is, however, not yet clear to what extent deep saline aquifers provide a long-term safe storage opportunity. The Norwegian state oil company Statoil already strips 1 million tonnes of CO_2 each year from natural gas at its Sleipner gas field and buries it in a saline aquifer beneath the ocean floor, without ever bringing it to land.

Non-CO_2 emissions cuts

Significant cuts in greenhouse gas emissions can be achieved by tackling gases other than CO_2. Several of these gases have large projected emissions increases under the baseline scenario, and the first target would be to moderate those increases. Up to 2030, it may be cost effective to achieve about a quarter of the overall reductions in greenhouse gas emissions in this way.

Methane is the most important man-made greenhouse gas after CO_2. Methane emissions have more than doubled since pre-industrial times. Contributions have come from a wide range of activities, from agriculture to the exploitation of fossil fuels and waste disposal. Molecule for molecule, methane is a much more potent greenhouse gas than CO_2. However, its relatively short lifetime in the atmosphere means that emissions have a strong warming effect for about a decade. So cuts in emissions would have a substantial short-term effect in reducing the greenhouse gas burden in the atmosphere.

Methane is produced in large quantities as organic waste biodegrades. Gases seeping out of landfill sites are a major source. The EU's 1999 landfill directive aims to cut these emissions by requiring alternative disposal routes for biodegradable waste, such as incineration, composting and recycling. The directive also requires the recovery of methane emissions from new landfill sites from the start of operations and from existing sites from 2009. The aim is to cut emissions from waste by at least 50 % by 2030. Further cuts could be made by capping old landfill sites to prevent methane venting.

Methane is also emitted from farm manure and directly from the guts of ruminant farm animals. Anticipated declines in animal numbers in the EU should reduce these emissions by 25 % by 2030. Further cuts may be possible by changing animal diets.

Other potential ways of cutting Europe's methane emissions include reducing the emission from coal mines, natural gas pipelines and other parts of the hydrocarbon supply chain. Low-cost measures to seal leaking pipes and tap gas as it leaves mines could cut mining emissions by 60 % and gas industry emissions by about a third by 2030.

Nitrous oxide is another significant greenhouse gas with a variety of sources. Major steps have already been taken to reduce industrial emissions. These include preventing releases from plants manufacturing adipic acid, which is used in nylon production. The chemicals industry overall has cut emissions by some 60 % since 1990. Another source to be tackled is soils treated with nitrogen fertilisers. Anticipated reductions in fertiliser application on Europe's farms are expected to reduce these emissions by 8 % by 2030, matching a similar decline since 1990.

Fluorinated gases such as the hydrofluorocarbons (HFCs), which are used in refrigeration and air conditioning, currently amount to about 1 % of overall EU greenhouse gas emissions. Baseline scenarios see emissions continuing to grow substantially, particularly in new EU countries. However, low-cost measures to reduce leakage and adopt alternatives should be able to cut projected emissions by 50 % in 2030, but that would still represent an increase of around 60 % on 1990 levels.

There is an additional factor to be considered in the overall picture: as ozone depleting substances are phased out of use as refrigerants and also for certain other uses, in accordance with the Montreal Protocol and Regulation (EC) No. 2037/2000, they are to a large extent replaced by substances that are greenhouse gases, such as HFCs.

3.8 Adaptation measures required

The Kyoto Protocol also includes provisions for limiting the impacts of climate change. Considerable climate change is now inevitable because of time lags, partly in climate systems and partly in economic, political and technological systems. Considerable adaptation will be necessary to cope with changing climate zones, with the growing risk of extreme events and with the continuing rise in sea levels. The EU Environment Council has recognised the challenge and the need for actions to adapt both in developed and developing countries.

Adaptation measures will range from improved flood defences and holding back rising sea levels to changed farming systems and climate-proofing infrastructure, and better public health systems to fight new diseases. The circumstances and thus the priorities for action will differ among EU Member States but common methodologies can be used within the EU for assessing vulnerability. Equally, it will be vital to integrate these assessments with other strategies on biodiversity, water, agriculture and other areas to ensure maximum effectiveness.

As ever it is the poorest, least developed countries around the world that are among the most vulnerable to the effects of climate change, having the least financial and technical capacity to adapt to droughts, floods and other climatic disasters. The EU is taking up its responsibility to help the developing world meet the challenge of climate change through aid programmes.

3.9 Carbon sinks

The EU has not included expansion of natural carbon sinks substantially — through, for example, extending forests or changing agricultural practices — in its portfolio of actions to meet the Kyoto targets, even though there is provision to do this in the protocol. Efforts to meet future long-term targets would likely involve an expansion of Europe's carbon sinks, and they have been included in the low-emissions scenarios.

Most of the world's forests are currently absorbing more CO_2 than they release because of the fertilising effect of rising CO_2 levels in the atmosphere and because of changes in forest management, for example when remote areas cannot be harvested economically. In 2010, the EEA estimates that the forests and other natural carbon sinks of the 25 EU countries will be absorbing around 50 million tonnes of CO_2 annually. This is equivalent to around 1 % of emissions from fossil-fuel burning.

Scientists warn that by mid-century forests could begin to release some of this absorbed CO_2 as temperatures increase further. So there is a danger that these carbon sinks could one day switch from being part of the solution to being part of the problem.

3.10 A possible hydrogen economy

The transport sector is one of the most difficult areas in which to reduce CO_2 emissions. With continued fast rises in demand for transportation, the transport sector shows increased CO_2 emissions. A baseline scenario sees a 31 % rise in transport emissions above 2000 levels by 2030. Four-fifths of these expected emissions will come from road transport.

There are possible technical improvements for road transport to reduce emissions of individual vehicles. They include: better internal combustion engines, hybrid vehicles that combine the internal combustion engine with an electric motor, and replacing hydrocarbon fuels with biofuels such as alcohol made from starch crops and diesel from oil seeds (Table 3.1).

Governments could encourage all these developments through research and development, regulation, market-based mechanisms or consumer information to promote efficient vehicles and their more efficient use. However, the LCEP scenario still sees a rise in transport emissions of 20 % above 2000 levels by 2030.

Technical changes should thus be complemented by government strategies to improve average loading factors of vehicles, to shift transport from energy-intensive to more efficient transport modes and to provide mobility of people and goods with less transportation, e.g. through reduced travel distances. This could be achieved through transport charges that better reflect environmental costs, investment in more energy-efficient transport modes and through improvements in urban planning to reduce distances and streamline itineraries.

In the longer run, hydrogen may be the basic energy carrier for a low-carbon society. It can be used for electricity production as well as for fuel in transport systems.

Hydrogen production is most commonly carried out by steam reformation of natural gas and electrolysis. The problem is that this process itself requires large amounts of energy. In terms of the contribution of hydrogen fuel to reducing climate change, everything therefore depends on the original source of energy to manufacture the hydrogen.

If the hydrogen is manufactured using electricity generated by burning fossil fuels, the gains are small or even negative. However, if renewable sources are used — or if the chance is taken to capture and store CO_2 emissions from a hydrogen manufacturing plant — then the benefits could be considerable. In the medium term, renewable electricity will in many cases contribute more to CO_2 reduction if it substitutes fossil fuels directly rather than if it is used to produce hydrogen. Some suggest that places with profuse geothermal, hydroelectric or wind power could become global centres for the clean manufacture of hydrogen. Policy-makers in Iceland, for instance, have discussed the possibility of the country becoming the hydrogen-economy equivalent of an oil state.

Although hydrogen, when used in combustion, is relatively pollution free, it can be transported into the stratosphere very rapidly, where, through its reaction with ozone, it can increase the amount of stratospheric water. This could, in turn, rapidly intensify stratospheric ozone depletion. A prerequisite of any hydrogen-based energy or transport system, therefore, should be the strict control of losses of hydrogen.

Although the basic vehicle technology already exists for hydrogen-fuelled transport, further development is needed to achieve mass production at a reasonable price. There would also be substantial costs in developing the global infrastructure to deliver fuel to a whole new generation of hydrogen filling stations. Hence, widespread hydrogen use will take at least 20 years to happen.

3.11 Costs and benefits

Converting Europe to a low-carbon energy system will not be a cost-free enterprise. However, many early initiatives, particularly in improving energy efficiency in the household and service sectors, may have low or even negative costs, and there is still potential for reducing fossil fuel consumption at low or even no cost. The costs of a transition to a global and European low-carbon energy system can be minimised by implementing policies and measures in all sectors, by the participation of all major emitting countries in an international effort to address climate change, by the optimal use of the Kyoto flexible mechanisms (and internal EU emissions trading); by international cooperation on technology research and development, and by the removal of potentially environmentally harmful subsidies.

Globally, the costs of a low-carbon energy system increase the lower the assumed level at which greenhouse gas concentrations should stabilise. Assuming a stabilisation of 550 ppm CO_2-equivalent (or about 450 ppm CO_2) would lead to costs of about 1 to

Table 3.1 Attributes of alternative engine and fuel technologies

Attribute	**Engines**			**Fuels**	
	Advanced ICE	**Hybrid**	**Fuel cell electric**	**Biofuels**	**Hydrogen**
Vehicle emissions	Reduces CO_2 and regulated pollutants	Reduces CO_2 and regulated pollutants	Virtually no tailpipe emissions, may be upstream emissions	Tailpipe emissions reduced; fuel cycle CO_2 emissions reduced, but may be some N_2O and PM increase	Tailpipe emissions reduced or eliminated; fuel cycle emissions vary greatly according to production method
Speed and drivability	Probably improved	Probably improved	Probably improved	Some types may adversely affect performance of conventional engines	Engine-dependent
Refueling infrastructure	Uses existing infrastructure	Uses existing infrastructure	Probably requires major new infrastructure	Significant new infrastructure	Major new infrastructure
Cost of motoring	Potentially higher, but lower fuel consumption	Potentially higher, but lower fuel consumption	Uncertain	Probably increased costs	Probably increased costs
Timescale for widespread deployment	Short (from 2005)	Short and medium (2005–2030)	Long (post 2030)	Short and medium (2005–2030)	Long (post 2030)

Source: Adapted from Kroger *et al.*, 2003.

4 % of GDP by 2050, depending on the IPCC scenario used. The EEA scenario work showed costs of about 1 % of GDP by 2040, in line with IPCC lower estimates.

Current estimates in EEA scenarios indicate that for the EU-25 the additional annual costs of low-emissions scenarios would represent about 0.6 % of EU GDP in 2030, or some EUR 100 billion. Average electricity generation costs in 2030 in a low-emissions scenario are likely to be 25 % higher than in the baseline scenario. The additional energy bill for households would be EUR 110–120 per household per year compared with the baseline, which already projects an average increase in household energy costs in the EU-25 of about EUR 2 300 per year by 2030. Scenarios that include stronger emphasis on renewables — which offer the greatest long-term potential for emissions reductions — would add another EUR 10–20 to household bills.

There are great uncertainties in such calculations, especially in the longer term beyond 2030. Many economic models with high estimates of the cost of cutting emissions assume a close relationship between carbon emissions and GDP, which would be very costly to break. They see a baseline future in which cheap carbon fuels remain the main source of energy. Models with lower estimates, however, assume that even without efforts to halt climate change the world is slowly moving towards lower use of carbon fuels. Such a transition would be faster and cost less with appropriate policies and measures, as mentioned above.

A second important element that distinguishes the models is their handling of the nature of technological change. Many treat technological change as largely independent of economics, as something that just happens. Others take a more sophisticated view in which innovation is mainly driven by need, economic incentives and the day-to-day process of 'learning by doing'. It is, in the jargon, 'induced technological change'.

The two approaches have important implications for policy. Traditional models suggest that there is an advantage in delaying the adoption of new technology because it will become cheaper with time. However, if most technological change is induced, then early adoption is vital to encourage further innovation and drive down costs. Models that include induced technological change also predict much lower eventual costs for meeting stabilisation targets.

Investment in diversifying away from fossil fuels would bring substantial ancillary benefits. They range from improved energy security and self-sufficiency to reduced urban pollution from fossil-fuel emissions, with resulting better health and ecological recovery. There would also be gains in jobs and exports as similar technologies are adopted around the world, especially if alternatives to fossil fuels are more labour intensive.

There are other reasons to believe that costs to combat climate change may not be too high for society. Predictions of high economic costs often assume that energy costs are a major element in the global economy. In fact, in recent decades energy costs have represented 3–4 % of world GDP. The dire predictions also tend to disregard the fact that funds put towards combating climate change will only delay the continued growth that economists regard as almost inevitable. Thus even a 4 % cut in global GDP by 2050 — among the highest cost estimates to achieve a CO_2 stabilisation level of 450 ppm according to the IPCC — would only delay a given level of global production by two or three years.

Reducing greenhouse gas emissions generates benefits in the form of avoided damages from climate change. The potential benefits depend to a large extent on the availability and costs of adaptation technologies and policies, and the sensitivity of the climate to rising concentrations of greenhouse gases in the atmosphere. It is especially relevant to analyse the global damage cost if the EU target of a global average temperature increase of 2 °C were not achieved. However, only a few studies are available on the costs of inaction. A recent study has found that the 'social cost of carbon', i.e. the cost to society of the emissions of every tonne of CO_2 into the atmosphere, was around EUR 60, with a range from EUR 30–120. Other studies have produced cost estimates per tonne as far apart as more than EUR 1 000 and virtually zero.

There are a number of reasons for the wide range. An important difference between studies is the extent to which different types of impacts are included in the analysis. For example, many studies do not properly address agriculture, ecosystem changes, biodiversity loss, loss of wetlands and impacts on water resources. Another difference is in the way that economists give a cash value to the lives and welfare of the poor. National accounting would largely ignore such lives, but most models adjust this cold calculation with an equity weighting. The value of the weighting varies. Models that give a value to the lives of the poor closer to those of the rich will give a high social cost for carbon emissions.

Some experts believe that very long-term impacts, such as the rising of sea levels due to the melting of the Greenland ice cap over thousands of years, should be discounted to zero. Most just ignore the potentially enormous cost of such catastrophic irreversible changes. Others argue that this is immoral, given that we have no alternative planet to inhabit.

The economic consequences of climate change can already be seen today. In Europe, over the past 20 years, the insurance sector has seen more than a doubling of economic losses (measured in real terms), partly resulting from weather and climate-related events, though other factors such as increasing pressure on coastal areas and floodplains, and more widespread insurance coverage, have also contributed to this increase. As will be seen in later chapters, considerable impacts on different economic sectors in different regions can be expected in future, although not all regions and locations, and not all economic sectors, will be equally affected.

3.12 Summary and conclusions

Global temperatures are rising faster than ever before and Europe exceeds the global average. Increasing precipitation, melting glaciers and ice sheets, increased frequency of extreme weather events, rising sea levels and increasing stress on terrestrial and marine ecosystems and species are among the most visible impacts on the environment. Moreover, more extreme weather is becoming a real threat to human health and our economic well-being, causing deaths and economic disruption from excessive heat, forest fires and flooding.

Burning fossil fuels remains the number one source of greenhouse gas emissions, and neither renewable energy nor nuclear energy is being developed fast enough to replace fossil fuels. In addition, increasing transport demands (road, aviation and shipping) now pose a serious threat. While emissions fell during the 1990s, they have grown overall since 2000. The EU's short term (Kyoto) targets for greenhouse gas emissions reductions are expected to be met only if all actual and planned additional policies and measures are fully implemented.

Air travel shows similar trends to other transport modes in terms of rising contributions to emissions, but to an exaggerated degree. Globally, air passenger transport has risen by an average of 9 % per year for the past 45 years, driven in large part by falling prices. Emissions have risen accordingly. International flights are currently excluded from the Kyoto Protocol targets because there is no agreement on how the emissions should be allocated. Moreover, international treaties prevent EU initiatives to impose taxes on kerosene or other restrictions without approval of the International Civil Aviation Authority. One option is for airlines to agree to participate in the EU carbon trading regime. The European Commission has recently made a proposal in this regard.

Longer-term EU targets for emissions (2020) and temperature reductions (2050) are not expected to be met. However, there is potential for a massive reduction (up to 40 % by 2020) in EU greenhouse gas emissions. This is technically feasible but requires a major shift in the EU energy system towards alternative energy sources (including nuclear) and unprecedented efficiency improvements through the increased uptake of environment-friendly technologies, especially by households.

Further emission reductions could be achieved in parallel through implementation of Kyoto flexible mechanisms in co-operation with developing countries. However, to ensure fair shares, emissions 'space' for developing countries need to be built in so that these countries can raise emissions and develop their economies. To do this, industrialised countries will have to reduce their emissions by 15–30 % by 2020 and 60–80 % by 2050. This reinforces the case for substantial reductions.

The EU has enjoyed some success with its policies, for example its emissions trading scheme. Many cost-effective strategies for improving energy efficiency remain heavily underused, such as better running of power stations and awareness-raising in households. However, efficiency measures alone will not be sufficient. Faster development of nuclear energy and renewable energy is urgent. Changes in fuel mix are now inescapable, and hydrogen needs to become the ultimate fuel. The implementation of new ideas, such as carbon capture, is also critical.

Climate change is inevitable now, and even if the correct measures are taken today, there will still be a time lag of two to three decades. The cost of inaction to society could be enormous. Some estimates put the cost at between EUR 30–120 per tonne for CO_2 emitted into the atmosphere. On the other hand, converting Europe to a low-carbon energy system will not be a cost-free enterprise either. Current estimates put the average electricity generation costs at being EUR 110–120 per household per year higher than at present.

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4 Air pollution and health

4.1 Introduction

Air pollution moves across both natural and political boundaries. Acidifying gases can disperse for thousands of kilometres before being deposited as acid rain on some distant habitat. Even urban smogs can spread far and wide in the calm air of a hot summer. Thus, the control of air pollution in Europe is necessarily an activity best addressed by countries in cooperation with each other. One of the early defining activities of European environmental regulation was action on the sulphur emissions that contribute to acid rain and damage human health.

Europe has made great strides in reducing many forms of air pollution in order to protect human health and ecosystems. A range of limit and target values have been set to ensure protection (Table 4.1).

In particular Europe has eliminated winter smoke smogs and reduced the threat from acid rain. However, high concentrations of fine particulates and ground-level ozone, in particular, are still causing human health problems in many cities and surrounding areas, and also problems for ecosystem health and crops across large areas of rural Europe. Despite reductions in emissions, concentrations of these pollutants remain high — often above existing targets — exposing populations to concentrations that reduce life expectancy, cause premature death and widespread aggravation to health.

Recent estimates suggest that every day people across Europe have some difficulty breathing because of air pollution. The most common effects are coughs and other respiratory problems such as bronchitis, but asthmas and allergies may also occur. Cardiovascular

Table 4.1 EU ambient air quality limit (LV) and target (T) values for the protection of human health and ecosystems (1999/30/EC, 2002/3/EC, 2001/81/EC)

Pollutant	Value (average time)	Number of exceedances allowed/ minimum exceedance area	To be met in
Human health			
Ozone (T)	120 µg/m³ (8h average)	< 76 days/3 year	2010
PM_{10} (LV)	50 µg/m³ (24h average)	< 36 days/year	2005
PM_{10} (LV)	40 µg/m³ (annual mean)	None	2005
SO_2 (LV)	350 µg/m³ (1h average)	< 25 hours/year	2005
SO_2 (LV)	125 µg/m³ (24h average)	< 4 days/year	2005
NO_2 (LV)	200 µg/m³ (1h average)	< 19 hours/year	2010
NO_2 (LV)	40 µg/m³ (annual mean)	None	2010
Ecosystem protection			
Ozone (T)	AOT40c of 18 (mg/m³).h (5 year average)	Daylight hours May–July	2010
Ozone	AOT40c of 6 (mg/m³).h (5 year average over 22 500 km²)	Reduction > 33 % compared to 1990	2010
Acidification	Critical load exceedances (year, average over 22 500 km²)	Reduction > 50 % compared to 1990	2010
NO_x (LV)	30 µg/m³ (annual mean)	> 1 000 km²	2001
SO_2 (LV)	20 µg/m³ (annual mean)	> 1 000 km²	2001
SO_2 (LV)	20 µg/m³ (winter average)	> 1 000 km²	2001

function, too, can be affected both by pollution-induced inflammation and even impacts on brain to heart stimulation.

There are wide variations in the susceptibility of people to air pollution. The largest effects are generally seen in people already with cardiovascular and respiratory diseases. Children, the elderly and those taking in large amounts of air while exercising outdoors in polluted conditions also appear to be vulnerable. However, the threshold below which no effects occur either do not exist or are yet to be properly identified for some air pollutants.

To meet the objectives of the sixth environment action programme (6EAP), air pollution targets need to be progressively tightened. The 6EAP called for the development of a thematic strategy on air pollution with the objective of attaining 'levels of air quality that do not give rise to significant negative impacts on, and risks to human health and the environment'. Following its communication in 2001 on the EU's Clean Air for Europe programme (CAFE), the scientific and technical underpinning of the thematic strategy, the European Commission has examined whether current legislation is sufficient to achieve the 6EAP objectives by 2020. This analysis showed that significant negative impacts will persist even with effective implementation of current legislation.

The thematic strategy on air pollution therefore, through further actions aims at cutting, by 2020, the life-years lost from particulate matter by almost half and acute mortality from ozone by 10 % compared with the 2000 levels. It also aims at reducing substantially the area of forests and other ecosystems suffering damage from airborne pollutants (acidification, eutrophication and ground-level ozone).

It is estimated that the new strategy will deliver health benefits worth at least EUR 42 billion per year through fewer premature deaths, less sickness, fewer hospital admissions, improved labour productivity, etc. This is more than five times the cost of actually implementing the strategy, which is estimated at around EUR 7.1 billion per annum or about 0.05 % of EU-25 gross domestic product (GDP) in 2020.

It is impossible to estimate the true cost to Europe's population and economy of air pollution over past years. One estimate puts the annual cost of health damage caused by air pollution at between EUR 305 billion and EUR 875 billion. From another angle, it has been estimated that in the absence of past emissions reductions brought about by regulations and technological developments, Europeans would have had to reduce their driving by 90 % in order to maintain the levels of air quality we experience today. The positive effects of past actions on Europe's social cohesion and economic competitiveness are evident.

4.2 Acid rain and ecosystem health

Removing the worst of acid rain has been a major success story for collaborative European environment policy. Acid rain is caused by fallout from emissions of sulphur dioxide, nitrogen oxides and ammonia. Sulphur dioxide comes mostly from burning coal and oil ships, power plants and industrial boilers. Nitrogen oxides also come partly from power plants and boilers, but in largest measure from ship and vehicle emissions. The main source of ammonia is from evaporation from slurry in animal stockyards and manure application on farms.

In 2002, 40 % of acid emissions came from sulphur dioxide, 32 % from nitrogen oxides and 28 % from ammonia. Of land-based sources, energy industries made up 32 % of emissions, agriculture 25 %, transport 13 % and industry 11 %. The greatest contribution to the reduction in emissions since 1990 came from the energy industry (52 %), followed by other industry (16 %) and transport (13 %). Over the same period ship emissions of SO_2 and NO_X have continued to grow, such that they are set to exceed all land-based sources combined.

Ever since the industrial revolution, these gases have posed problems. They erode buildings and statues, prevent trees growing near major industrial areas and contribute to widespread lung and heart disease. This last effect was most obvious during major smog episodes seen in European cities up to the 1960s.

Scientific verification of the extent and ecological significance of the spread of this pollution in rain clouds became apparent much more recently.

The first firm evidence of extensive ecological damage from long-range acid deposition came from the acidification of Scandinavian lakes and rivers in the 1960s and 1970s, resulting in thousands of lakes becoming too acidic for many fish species to survive. It gradually became clear that the acidification was largely caused by run-off from soils that had been chemically altered by acid rain. Later, during the 1980s, it appeared that large areas of forests in central Europe were also succumbing to acid rain, partly through the direct effects on foliage and partly through acidification of the forests' soils.

Europe began a programme to reduce acid emissions after the Stockholm environment conference in 1972. The 1979 United Nations Economic Commission for Europe (UNECE) Convention on Long-range Transboundary Air Pollution (CLRTAP) started with a protocol aimed at reducing sulphur emissions by at least 30 % and continued with protocols further cutting sulphur emissions and limiting those of nitrogen oxides. By the late 1980s, Europe had adopted an integrated approach, addressing the problems of acidification, eutrophication and ground-level ozone. The 1988 large combustion plant directive, revised in 2001, the 1999 protocol to abate acidification, eutrophication and ground-level ozone, and the 2001 national emissions ceiling directive (NEC directive) all addressed these problems taking a 'critical loads' approach, capping emissions of sulphur dioxide, nitrogen oxides, ammonia and non-methane volatile organic compounds.

The scientific study of acid emissions and their impacts has improved substantially since the first discovery of dead lakes in Scandinavia. It has become clear that acid deposition is often greater in southern and eastern Europe, even though the ecological damage has been greater further north. This is partly because the cumulative load of acid fallout onto soils over past decades has been higher in the north, and also because the soils in the north have less capacity to neutralise the acid than those further south.

Nitrogen emitted as nitrogen oxides or ammonia can cause acidification and eutrophication in freshwater and terrestrial ecosystems as well as eutrophication of marine ecosystems. Eutrophication is the consequence of an excess input of nutrients that disturb ecosystems. A common outcome is excessive blooms of algae in surface waters.

Advances in scientific knowledge have prompted a change in policy-makers' approach to reducing emissions. They have decided to target emissions reductions in those areas that cause acid deposition over the most vulnerable ecosystems. Many ecosystems now have an assessment of the 'critical load' of acid deposition that they can absorb without significant harmful long-term effects — with these limits deliberately erring on the safe side. Critical loads in regions with thin soils or those vulnerable to eutrophication are often many times lower than in areas with better-buffered soils.

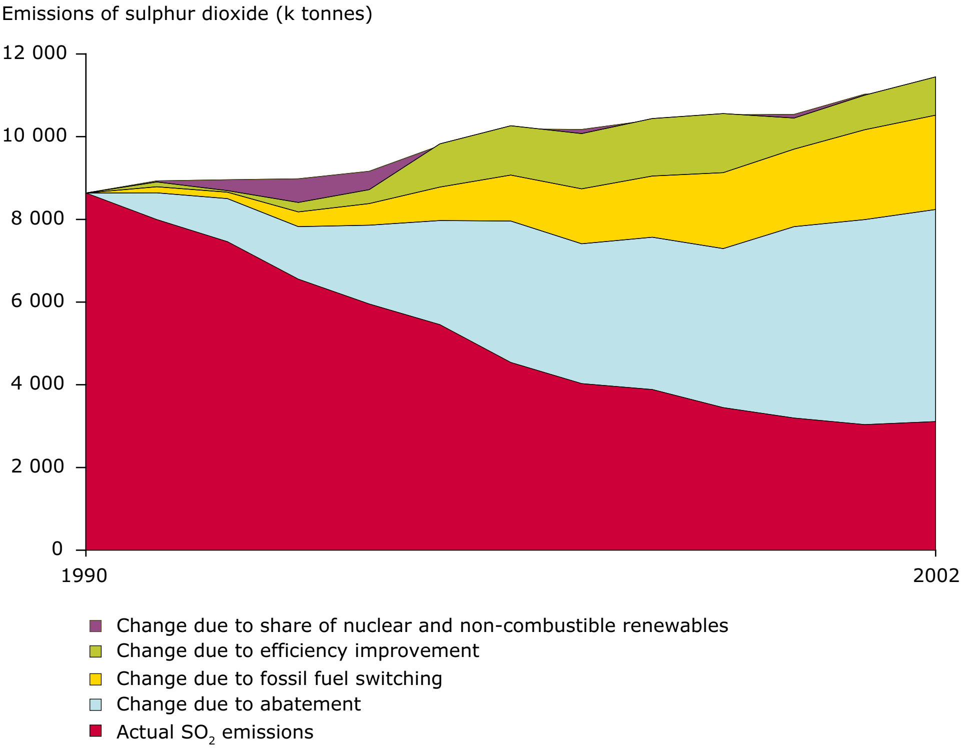
Today the emission targets set by the European Union are somewhat stricter than those of the CLRTAP. In response to various legislation, many large fossil-fuel-burning power stations in Europe — the predominant source of sulphur dioxide — installed flue-gas desulphurisation equipment to remove sulphur dioxide from stack emissions. Others have reduced their emissions by burning coal or oil with lower sulphur content or by converting to natural gas.

Largely as a result of these changes, sulphur dioxide emissions peaked in the EU in the late 1970s and have fallen by two-thirds since 1980. Emissions from public electricity and heat production have been achieved as a result of efficiency improvements, fuel switching, and the use of flue gas desulphurisation technologies (Figure 4.1). Some countries have made substantially greater reductions: emissions have fallen by more than

90 % in Austria, Denmark, Germany and the United Kingdom.

The cuts in sulphur dioxide emissions, however, have not been universal. Some Mediterranean countries have seen small increases. Additionally, one important economic activity has remained largely outside the controls on sulphur dioxide emissions. That is shipping which, as a result of continued burning of high-sulphur fuel and the extensive clean-up elsewhere, now contributes 39 % of sulphur dioxide emissions among the EU-15 nations. Until recently, shipping emissions were on track to exceed all land-based emissions within 20 to 30 years; latest estimates suggest even sooner. As a result, EU environment ministers have now agreed to reduce the maximum allowed sulphur content of

Figure 4.1 Reductions in SO_2 emissions from public electricity and heat production in the EU-15



Notes:

1. Emissions data for Luxembourg are not available and so this country is not included in the calculation for the European Union.
2. The chart shows the contributions of the various factors that have affected SO_2 emissions from electricity and heat production. The top line represents the development of SO_2 emissions that would have occurred due to increasing electricity production between 1990 and 2002, if the structure of electricity and heat production had remained unchanged from 1990 (i.e. if the shares of input fuels used to produce electricity and heat had remained constant, the efficiency of electricity and heat production also stayed the same and no additional abatement technologies had been introduced). However, there were a number of changes to the structure of electricity and heat production that tended to reduce SO_2 emissions and the contributions of each of these changes to reducing emissions are shown by the first four coloured areas. The cumulative effect of all these changes was that SO_2 emissions from electricity and heat production actually followed the trend shown by the red area at the bottom of the graph.

Source: EEA and Eurostat, 2005.

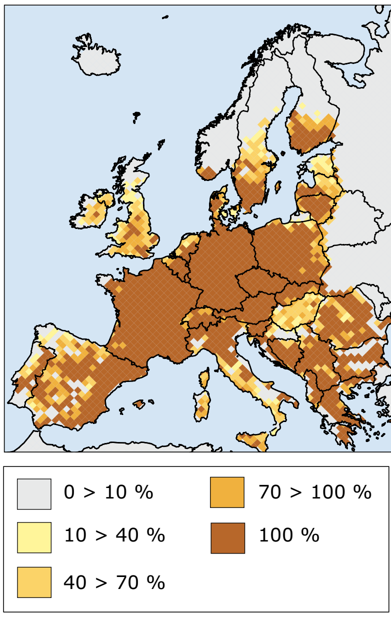
marine fuel from 5 % to 1.5 % from 2006. This should have some effect in reducing emissions. The current average content of sulphur is 2.7 %.

Reductions in nitrogen oxides, which come mainly from road transport, have been less than those for sulphur dioxide. They are down by more than a quarter on 1990 levels in the EU-15. The reduction has been mainly due to the introduction across Europe of catalytic converters attached to the exhaust pipes of most cars. These remove most of the nitrogen oxide emissions, as well as other pollutants, but the effectiveness of this technological innovation has been undermined by increased road traffic. Again, shipping has been exempt from EU regulation on NO_X, and as mentioned earlier, emissions from ships in EU seas are set to exceed all land-based emissions within 15–20 years. It is harder for the EU to regulate NO_X rather than SO_2 emissions from ships, since the UN Convention on the Law of the Sea limits the ability of coastal states to regulate the construction and design of vessels flagged outside the EU. These vessels are responsible for over 50 % of the ship movements in EU seas. The International Maritime Organization (IMO) is therefore the preferred forum to tackle this problem, and the IMO is now working to develop tighter standards for NO_X emissions from ships by 2007.

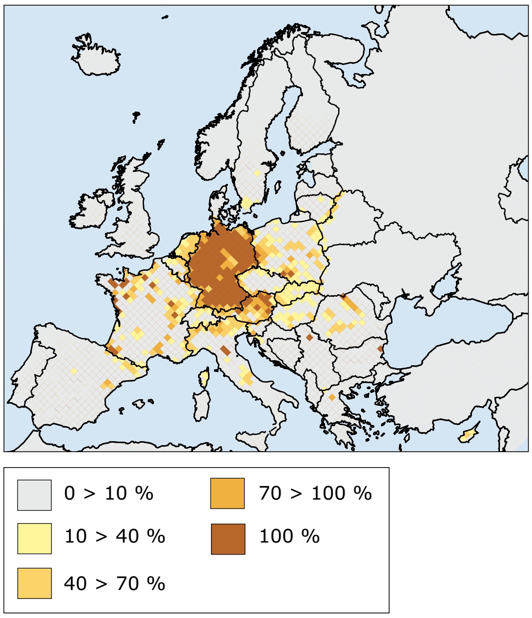
Ammonia emissions from agriculture are difficult to calculate and harder to control. They are believed to have largely stabilised, along with livestock numbers on European farms. As a result of the reductions in

Map 4.1 Excess of nitrogen deposition in 2000 and 2030

Year 2000



Year 2030
MTFR scenario



Note: Percentage of total ecosystems area receiving nitrogen deposition above the critical loads (database of 2004). Data reported for the EEA countries except from Iceland and Turkey, although the maps show areas without data as belonging to the '0 > 10 %' class. MTFR is the maximum technically feasible reduction scenario.

Source: EEA, 2005.

emissions of other acid emissions, their contribution to overall acid deposition has grown dramatically, however. They now represent 25 % of all acidifying emissions.

Overall, emissions of acidifying gases have decreased across Europe by more than 40 % in the EU-15 and almost 60 % in the EU-10, and by more than half in industry and power generation.

These emission reduction measures have resulted in more ecosystems throughout Europe receiving depositions of acidifying compounds lower than their critical load. Nonetheless, roughly 10 % of European ecosystems still received acid deposition above their critical loads in 2004. This includes 18 % of forests in the EU-15 and 35 % of forests in the EU-10.

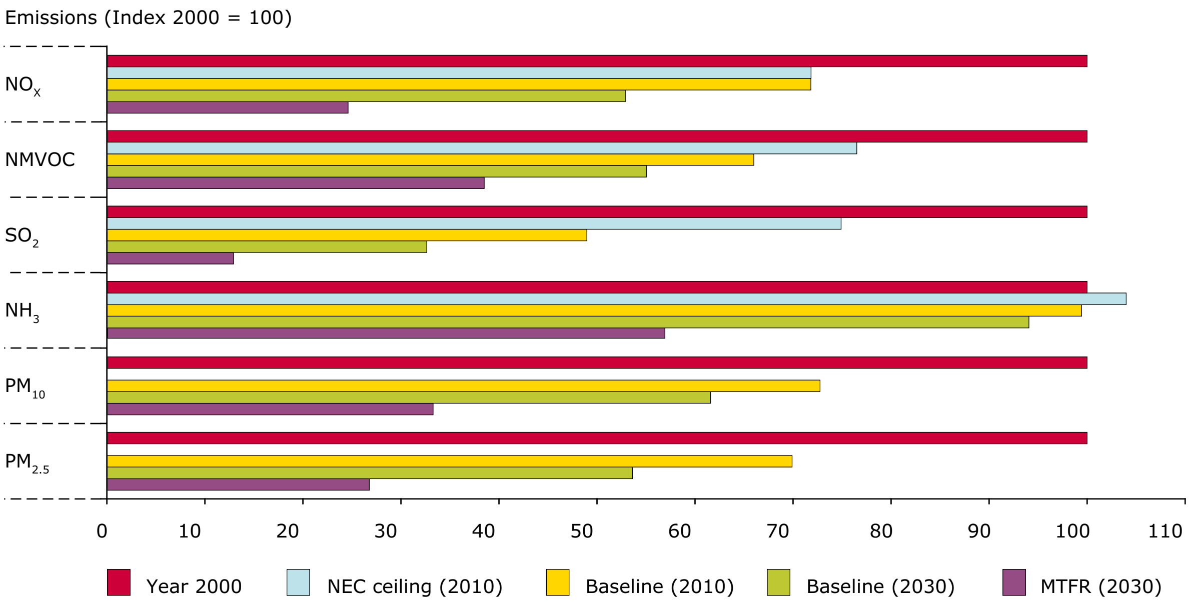
Even when loads below the assessed critical level are attained, some ecosystems will not recover because of historic damage. Today, some 14 000 Swedish lakes remain affected by acidification, with 7 000 being limed regularly to prevent further acidification. It could be decades or even centuries before many recover.

The health of Europe's forests deteriorated until the mid-1990s. Since then a period of recovery has been followed by some further deterioration. Over a fifth of the forests are still classified as 'damaged'. The causes of these trends are not completely clear, and may not all be the result air pollution. Droughts and climate change could also be playing a role.

Europe clearly still has some way to go before it recovers from the legacy of past decades of acid deposition. So what is the prognosis and how much more can be done?

Acid deposition is expected to continue declining, thanks to the implementation of the national emissions

Figure 4.2 Emissions of air pollutants based on different scenarios — EU-25



Note: MTFR is the maximum technically feasible reduction scenario.

Source: EEA, 2005.

ceilings directive and corresponding protocols under the CLRTAP. Sulphur dioxide emissions in the EU-25, for instance, will, on current projections, drop by 51 % from 2000 by 2010, by which time they will be lower than at any time since about 1900. By 2030, under low-emissions scenarios, they will have been reduced by nearly two-thirds from a 2000 baseline (Figure 4.2).

Existing measures will see a decline of EU-25 emissions of oxides of nitrogen by 47 % between 2000 and 2030, with further reductions technically feasible. In contrast, ammonia emissions are projected to decrease only slightly by 6 % up to 2030 (Figure 4.2).

The expectation is that, overall, planned measures to reduce acid deposition will reduce forest areas at risk by more than 50 %. If the maximum feasible reductions in emissions were attained, then fallout over all Europe's forests, bar a handful in Benelux and Germany, could be brought below their critical loads. Similarly, the percentage of EU ecosystems at risk of eutrophication could be brought down from 55 % in 2000 to 10 % in 2030 (Map 4.1).

4.3 Particulates and human health

Particulate pollution is a recurring problem. Before acid rain became a concern in the 1970s, the number one air pollution problem in Europe was coal-based urban winter smogs. After a series of major disasters, many European countries took action to ban coal-burning in urban areas. The smoke problem appeared to have been solved. Illness and death from lung diseases such as emphysema and pneumonia fell as a result.

We now know, however, that smaller, largely invisible, particles continue to be hazardous to Europeans' health. These particles are generally categorised by their size. Those less than 10 millionths of a metre in diameter, known as PM_{10}s, are the most frequently measured. However, there is growing concern that a subset of these, $PM_{2.5}$s or fine particles with a diameter of less than 2.5 millionths of a metre, may be the most dangerous as they penetrate deeper into the lungs.

The primary source of most of these particulates, especially $PM_{2.5}$s, is fuel-burning in power stations, industrial plants and vehicle engines, most notably diesel engines. Some fine particulates are also produced during chemical reactions in the atmosphere, particularly during smog episodes.

Most studies conclude that particulates are the main pollutants causing deaths in Europe today. Recently the CAFE programme has put the number of premature deaths due to exposure to anthropogenic $PM_{2.5}$ particulates at 348 000 for the year 2000. Geographically, CAFE studies suggest that the greatest damage to health occurs in the Benelux area, in northern Italy and in parts of Poland and Hungary. In these areas, the average loss of life expectancy from particulates may be up to two years.

European policy-makers have reacted to this mounting evidence. Clean-up measures have substantially reduced particulate emissions since 1990 (Figure 4.3); for example, PM_{10} emissions in Germany and the United Kingdom have been cut by more than 50 %. Further cuts should follow as vehicle technology improves, particularly with the introduction of filters on diesel emissions.

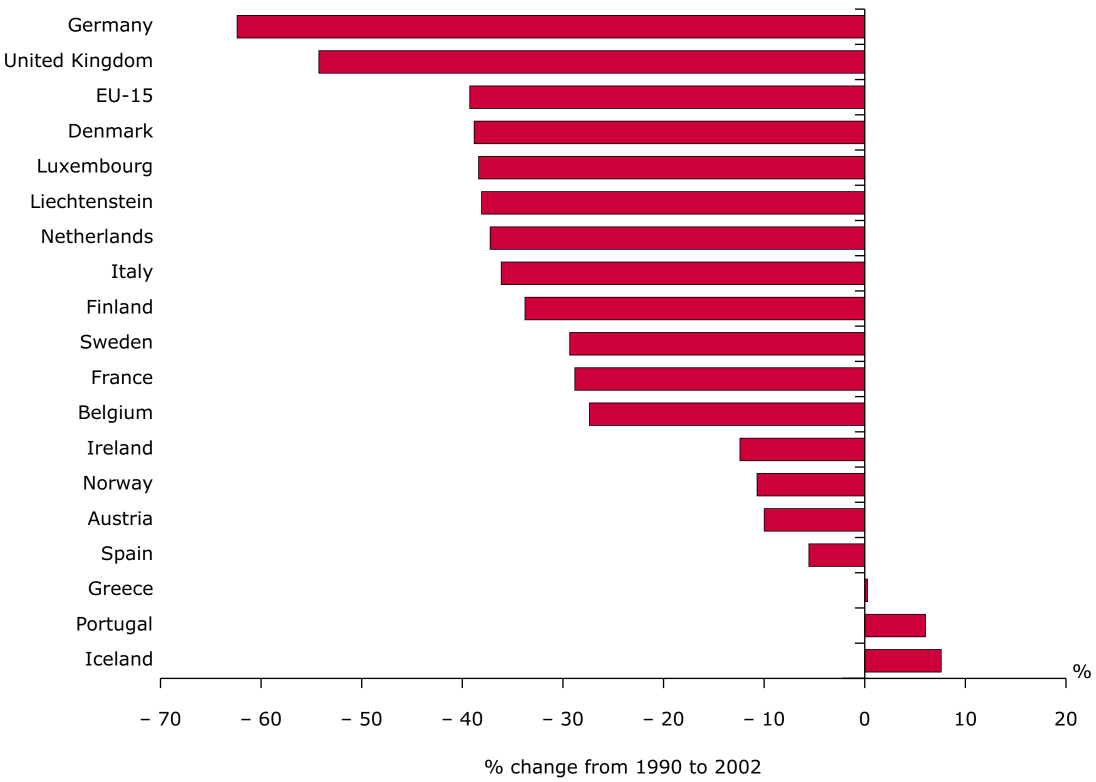
Baseline scenarios, which assume that current and planned policy measures will be fully implemented, estimate that a cut could be achieved in emissions of PM_{10} between 2000 and 2030 of 38 %, and a cut in $PM_{2.5}$ emissions of 46 % (Figure 4.2). On the face of it, such cuts should be reflected in declining air concentrations of particulates. If so, they would be enough to cut the annual number of life-years lost from particulates by around a third from the current 4 million, and to reduce serious hospital admissions by a similar proportion from the current 110 000 a year.

Unfortunately, this is not certain. There is growing concern that recent declines in emissions are not being reflected in falling concentrations in the air we breathe, though we do not have long enough time series for concentrations of PM_{10} to establish clear trends. Concentrations are strongly influenced by meteorological conditions, linked to changing production of secondary particulates within smogs. There is also a concern that emissions from transport are not falling as quickly as expected due to test cycles not reflecting real-world driving conditions, the chip-tuning of diesel cars and other non-combustion emission sources (brakes, car tyres) that increase in line with traffic growth and congestion. As for SO_2 and NO_X, shipping is a major source of particle emissions which has not yet been addressed; modelling and measurement suggest ships may be contributing 20–50 % of secondary particles in port and coastal areas.

In any event, it remains likely that for some decades to come, many urban areas in the EU-25 will continue to have unsafe concentrations of particulates, largely because of the continued growth in road transport but also due to contribution from other activities such as small combustion. Passenger transport volumes in the EU-25 have risen by 20 % in the past decade, and freight transport has risen by 30 %, the rise almost exactly tracking that in GDP.

End-of-pipe technological innovation, such as the installation of particulate traps in diesel cars, is not enough to keep up with this growth in demand. Moreover, such innovations generally entail a slight increase in fuel consumption, thus potentially increasing emissions of carbon dioxide (CO_2).

Figure 4.3 Change in emissions of primary and secondary fine particles (EFTA-3 and EU-15), 1990–2002



Source: EEA, 2005.

Clearly there is a need for changes in the way transport is used. In recognition of this, regulators, in addition to encouraging further technological development, are increasingly looking at the possibility of influencing the behaviour of motorists, through incentives to buy the cleanest vehicles, road pricing, the promotion of more environment-friendly modes of transport, and environmental zoning.

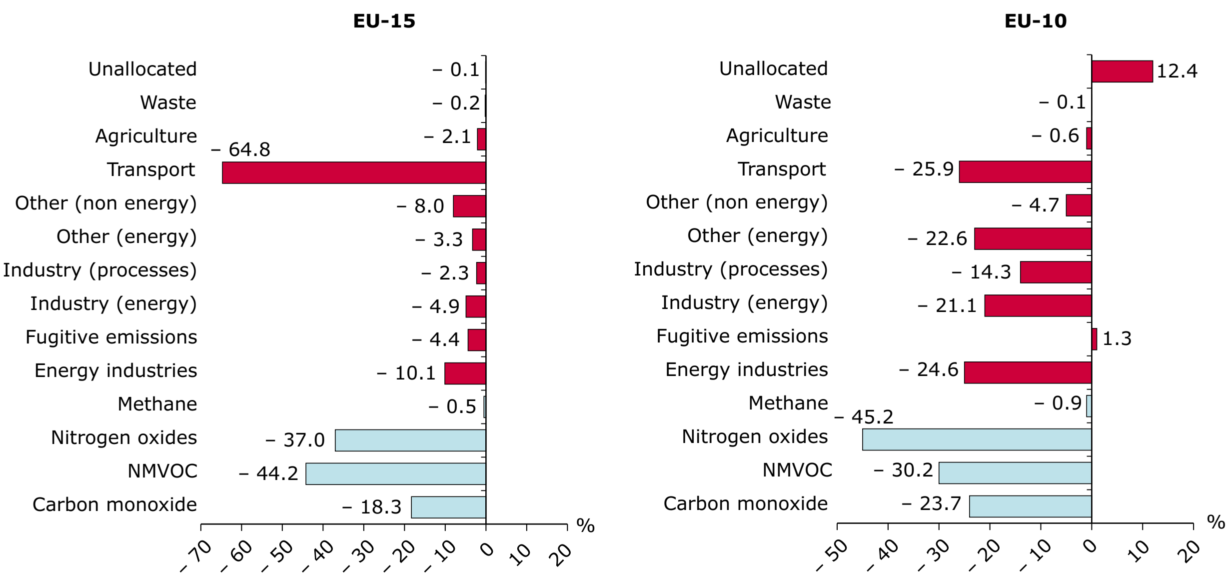
4.4 Ozone impacts on people and ecosystems

Ozone occurs naturally in the atmosphere, especially in the stratosphere, where it forms a chemical shield that protects life on the planet's surface from too much harmful ultraviolet radiation from the sun. That is why the world has acted to eliminate the manufacture and use of substances that have been damaging the ozone layer. Human activities also lead to ozone accumulation at ground level, where it can be a health hazard. In places, ozone levels are sometimes above what are deemed safe limits, largely because of the considerable year-to-year fluctuations caused in major part by weather conditions.

Ozone is not directly emitted into the atmosphere. It forms as a result of photochemical reactions, more intensively in summer, involving nitrogen oxides and volatile organic compounds (VOCs). A part of VOCs with high ozone formation potential, known as non-methane volatile organic compounds (NMVOCs), are produced from vehicle exhausts as well as nitrogen oxides. Nitrogen oxides are also emitted from power stations and industrial boilers, and NMVOCs also evaporate from solvents in paint, glue and printing.

Catalytic converters were introduced on petrol-fuelled passenger cars in Europe at the beginning of the 1990s. They effectively reduce emissions of carbon monoxide, nitrogen oxides and NMVOCs (Figure 4.4). Without this kind of technology, emissions would by now be

Figure 4.4 Contribution to change in ozone precursors emissions for each sector and pollutant 1990–2002



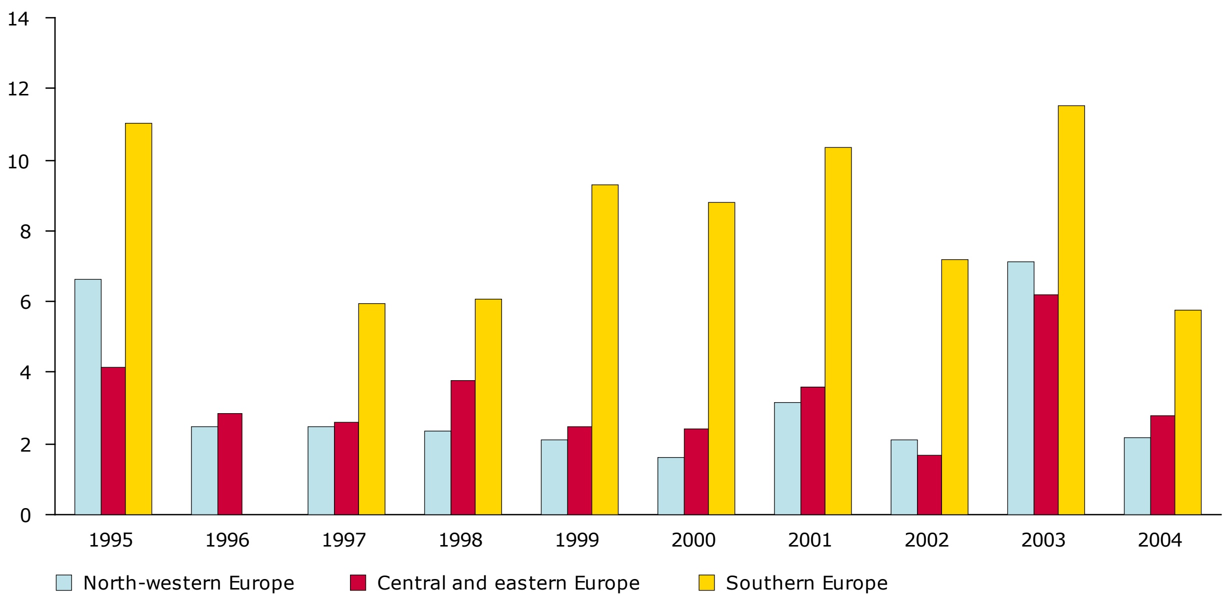
Source: EEA, 2005.

far above the levels of the early 1980s, and air quality would be falling fast.

Ozone concentrations are highest during episodes of photochemical smog, itself a complex chemical cocktail. Besides ozone and its chemical precursors and products, chemical smog can also contain other pollutants like sulphur dioxide. Fine particulates, too, are an important product of photochemical smog. Once formed, smog can persist for days and travel long distances from the urban areas in which it usually forms. Along the way, it can change its chemical composition, sometimes becoming more toxic by the time it reaches rural areas. Indeed, some of the highest concentrations of ozone eventually occur in these rural areas away from the sources of the compounds that cause the smog.

Ozone is a health hazard to humans because it inflames airways and damages lungs. It causes coughing, can trigger asthma attacks and aggravate breathing difficulties, and, ultimately, can cause death from respiratory and heart diseases. While it is hard to distinguish the health effects of ozone from other air pollutants, such as particulates, ozone is thought to hasten the deaths of up to 20 000 people in the EU each year. Further, it is responsible for people vulnerable to its effects taking medication for respiratory conditions for a total of 30 million person-days a year.

Figure 4.5 Average occurrence of exceedances for stations, which reported at least one exceedance, by EU region



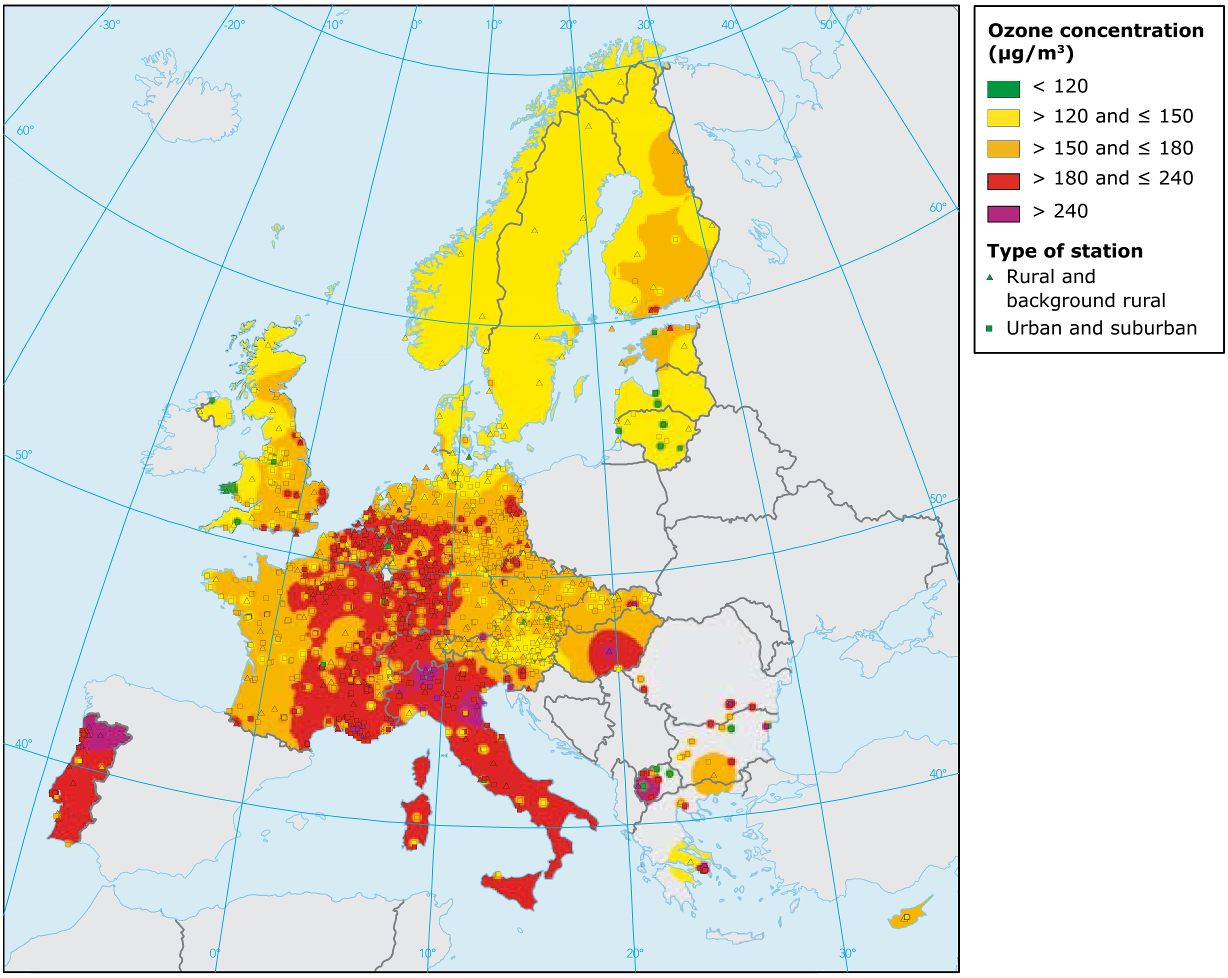
Note: North-western Europe: United Kingdom, Ireland, the Netherlands, Belgium, Luxembourg and France north of latitude 45 °.
Central and eastern Europe: Germany, Poland, the Czech Republic, Slovakia, Hungary, Austria and Switzerland.
Southern Europe: France south of latitude 45 °, Portugal, Spain, Italy, Slovenia, Greece, Cyprus and Malta.
Northern Europe has not been included in this figure because of the low number of exceedances.

Source: EEA, 2005.

Most of the damage appears to be done in the intense smog episodes that sometimes form in still summer air, when there is no rainfall or wind to remove the pollutants and slow the reactions that create them.

Public health authorities in Europe now regularly issue warnings during smog episodes so that vulnerable people can stay indoors and avoid heavy exercise.

Map 4.2 Maximum one-hour ozone concentrations observed during the summer period 2004 (April–September)



Source: EEA, 2005.

To counteract these problems, legislation has been introduced that has brought about a decline in emissions of the precursors of ozone — nitrogen oxides and NMVOCs — by about a third since 1990 (Figure 4.4). This has been mainly due to the widespread introduction of catalytic converters for cars and the EU solvents directive, which controls emissions of industrial solvents. The largest reductions have been in Germany, at 53 %, and the United Kingdom, at 46 %. However, emissions have increased in Greece, Portugal and Spain, and it is in these countries that ozone levels are highest. High NO_X and VOC emissions from shipping activities in the Mediterranean are also contributing to the southern European ozone problem.

Reductions in precursor emissions have been even greater among the 10 new EU nations, where the closure of old, heavily polluting industrial plant has helped. The Czech Republic, Estonia, Latvia, Lithuania and Slovakia have all seen reductions of more than 40 % since 1990.

Most countries should meet EU emissions ceilings for ozone precursors set to come into force in 2010. However, in the complex chemical environment of urban smog, reduced emissions of these 'precursor' pollutants will not necessarily produce equal reductions in concentrations of ozone and fine particulates in smogs. Their production depends on non-linear chemical processes, as well as on temperatures and sunlight. It is probably for this reason that the past decade has seen declining emissions of precursors accompanied by a slight increase in annual average ozone concentrations, especially in city centres.

Specifically, the EU target for ozone requires that every year the 26th worst smog (averaged over three years and measured as a daily maximum of eight-hour average ozone concentrations) should not have an ozone concentration greater than 120 micrograms in a cubic metre of air. Despite declining emissions of the ozone precursors, the average occurrence of exceedances of the EU target for ozone increased between 1997 and 2003, particularly in southern Europe. Occurrences of exceedances fell back substantially in 2004 (Figure 4.5). The highest maximum one-hour concentrations in the summer of 2004 were observed in northern Portugal, northern Italy, Albania, Macedonia, and some of the Greek islands (Map 4.2).

The toxicity of ozone smog is aggravated by other toxic compounds in the chemical cocktail. Some, such as benzene, particles and poly-aromatic hydrocarbons, are direct emissions from vehicle exhausts; others, such as nitrogen dioxide and some particulates of sulphate, are formed inside the smog itself.

Nitrogen dioxide, for instance, is created by the oxidation of nitric oxide from car exhausts. Like ozone, concentrations of nitrogen dioxide (NO_2) have stabilised in recent years, whereas before 2000

Asthma

Some of the worst and most distressing respiratory problems triggered by air pollution are among children. Asthma is now the most common respiratory disease among western European children, afflicting 7 % of children aged 4 to 10 — though there is large variation between countries.

The explanation for soaring asthma rates remains uncertain. There is a clear association between epidemics of asthma attacks in the community and local peaks in air pollution. Ozone levels in smogs may be most critical during these acute episodes, but there is much less evidence to support the thesis that long-term trends in ozone levels can explain the growing number of children who suffer asthma attacks. Nor is there much evidence that parts of Europe with more air pollution have more asthma. In fact, asthma is generally less frequent in parts of central and eastern Europe, despite air pollution levels that are higher than in western Europe.

Most researchers conclude that asthma has a range of linked causes. Air pollution seems most likely to trigger attacks among children who are already susceptible to asthma, but other factors may create that susceptibility. These could include genetic predisposition, diet and even, it has been suggested, excess hygiene in the home.

a downward tendency of NO_2 concentration was recorded. Many parts of urban Europe regularly record levels of nitrogen dioxide in the air that are above target levels. Recordings of 15–30 % above targets are typical, but some stations record levels more than twice the target level.

Ozone smogs in the lower atmosphere have ecological as well as health effects. Ozone in the air stunts crop growth and damages the foliage of trees. As long-term exposure to ozone in the lower levels of the atmosphere does the most damage to plant life, Europe has established separate targets on average ozone concentrations to reflect this. Part of Europe already complies with these limits, but a large part of southern and central Europe, from Spain to Poland, does not. The year 2003 was particularly bad for such pollution, and it is thought that high ozone levels could have been as important as high temperatures and drought conditions in that year's poor crop yields in southern Europe.

4.5 Other airborne pollution issues affecting health

Carcinogens

Little is known about the root causes of many cancers. There are genetic factors, of course, but, for some cancers at least, the environment may play a crucial role. In general, children may be at greater risk from environmental carcinogens than adults. A small but significant increase in childhood cancers has been noted since the mid-1980s, some of which may be attributable to environmental exposures. Several studies show a positive association between local traffic density and childhood leukaemia.

However, the evidence is that most cancers in children are initiated before birth, sometimes because of foetal exposure to carcinogens. Such exposure is especially dangerous because the rate of cell division in the foetus is extremely high. Thus, the chance of mutations arising from exposure to a carcinogen is that much greater.

Known carcinogens in the environment include polycyclic aromatic hydrocarbons (PAHs), a group of chemicals created by the incomplete burning of

The ozone conundrum

While the chemicals that form ozone smogs are most emitted in urban areas, the highest concentrations of ozone in the air are often recorded in rural areas. This is because the 'cocktails' of pollutants in smogs have a complicated life. In the lower parts of the atmosphere, under solar radiation, ozone is formed by the photolytic reaction of nitrogen dioxide (NO_2), itself an oxidation product of nitric oxide (NO). Nitric oxide is released from vehicle exhausts and other sources of emissions and is oxidised in the air to form NO_2. The molecules of NO_2 then take part in photochemical reactions with volatile organic compounds (VOC), also mainly from vehicle exhausts, to create ozone (O_3).

The prevailing way of oxidation of NO to NO_2 is through reactions with ozone. During those reactions, the ozone molecule is destroyed. Hence ozone concentrations decline in the presence of higher concentrations of NO such as in urban areas.

Actual ozone concentrations within the smog can vary greatly. Close to the sources of NO emissions — such as near dense urban traffic, major highways and industrial sources — ozone levels will be lower because significant amounts of it are being destroyed. Reciprocally, away from these areas, in the suburbs and rural areas round cities, the air still contains plenty of NO_2 and non-methane volatile organic compounds (NMVOCs) to create ozone, but little NO to destroy it. It is in these places that ozone levels are usually highest.

These complications can have important implications for efforts to reduce ozone levels. A reduction in emissions of the precursor gases will reduce the rate of formation of ozone, but they will also reduce the rate of destruction, especially in city centres. Under some circumstances, a reduction in emissions might lead to higher rather than lower ozone levels in city centres.

anything from coal to garbage. PAHs form part of vehicle emissions but they may also reach the air from incinerators, landfill sites, some factories and even fast-food restaurants. Some studies suggest that men working with PAH may pass on an increased risk of brain cancer to their children.

One omnipresent airborne cancer threat is ultraviolet (UV) radiation from the sun. This is the main cause of skin cancer, accounting for approximately 80–90 % of all cases. Rates of skin cancer are rising in Europe as Europeans sunbathe more and take more holidays in places nearer the equator, where UV levels are higher. However, rising levels of UV radiation, caused by a thinning ozone layer, may also play their part. Many sunscreens do not effectively protect against UV-A radiation, which is receiving more attention because of its potential contribution to one of the more lethal skin cancers, malignant melanoma.

Another possible threat is electromagnetic fields, including the low-frequency fields from power lines and the higher frequency fields from mobile phones and radio transmitters. There is no strong evidence of any link at typical environmental levels, but government-sponsored assessments have pointed out that studies involving mobile phone use, for instance, have not yet had time to reach firm conclusions about long-term effects. Recent studies, when considered together, indicate a correlation between low frequency electromagnetic fields and childhood leukaemia, although the evidence is not conclusive.

Many potential carcinogens are found at highest concentrations inside buildings. Indoor pollutants of concern include furnishings and paints, household cleaners and other chemicals, as well as building materials and the by-products of human activities such as cooking and smoking. Significantly, Europe's children spend 90 % of their time indoors rather than outdoors.

Concentrations of many of these pollutants have risen in many homes, particularly in northern Europe, because of better insulation and other efforts to avoid wasting heat. Any reduction in ventilation may also raise humidity in the home which can stimulate the growth of mites, moulds and bacteria, and often increase the release of toxins from construction materials, such as formaldehyde and benzene.

Another source of concern is the naturally occurring radioactive gas radon, a decay product of uranium that seeps out of some rocks and soils and can accumulate in buildings. There is a strong relationship between domestic exposure to radon and the development of lung cancer. Recent estimates suggest that radon is responsible for up to 30 000 deaths from lung cancer in Europe every year.

While scientists and health professionals are aware of this blend of problems, much less is known about the private indoor environment of Europeans than about the public outdoor one. While there are several successful European directives regulating outdoor air quality, there are none yet to control indoor air quality.

Neurotoxins and endocrine disrupters

Some toxins disrupt neurological development in children and damage their behaviour, memory and ability to learn. Symptoms can range from dyslexia to autism. The prevalence of autism and attention-deficit hyperactivity disorder (ADHD) seems to be increasing across Europe, and there is concern among health professionals that environmental factors may be involved. Finding the mechanisms and causes, however, has so far proved elusive.

Lead is mostly closely linked to neurological damage in children. Even low doses have been implicated in reduced IQ and behaviour and learning disorders in children. Since lead accumulates in bones, from where it may be released in later life, it also poses a potential hazard to the elderly. The largest source of exposure used to be lead in car exhausts, as lead was once a universal additive in petrol. Europe has been in the forefront of removing lead from petrol over the past 20 years, resulting in lead levels in the blood of most European children falling dramatically.

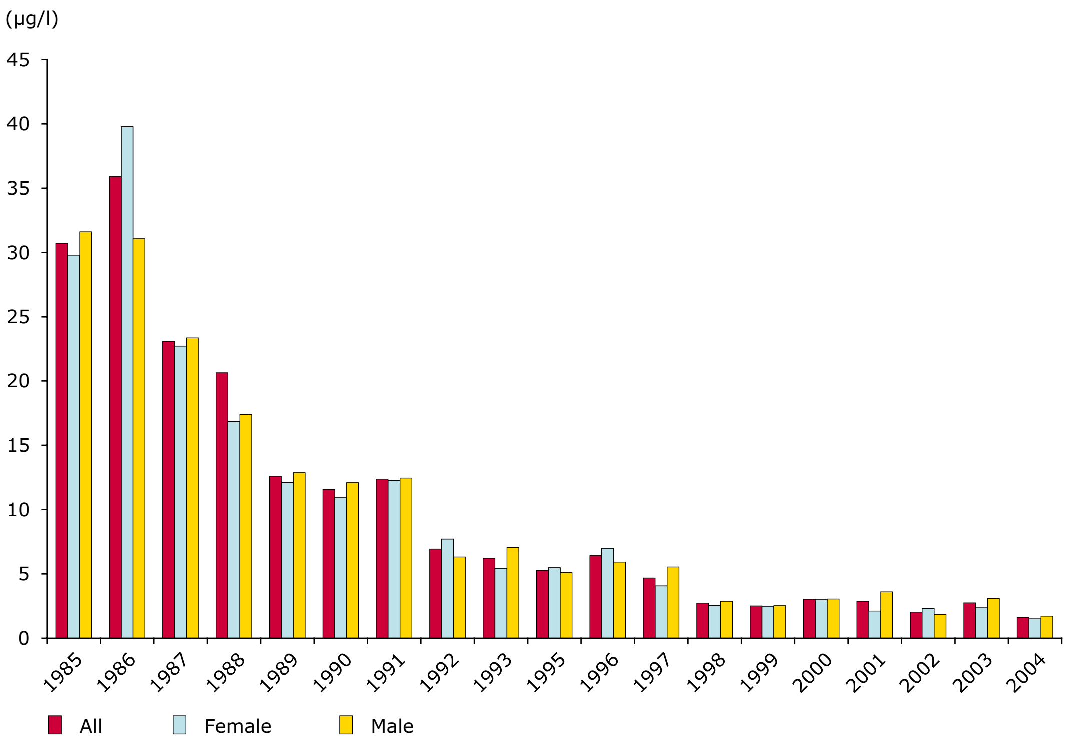
It nevertheless took many years to convert warnings over the neurological effects on children of lead in petrol into action. When taken, it was as much because petrol containing lead additives poisoned catalytic converters as because of health concerns.

Mercury, released in significant quantities from coal-burning power plants, is another heavy metal implicated in neurodevelopment damage. In the environment, mercury is often converted into an organic form, methyl mercury, which is toxic and easily crosses from blood to brain and, via the placenta, into the foetus. Humans mostly encounter methyl mercury when eating fish. In early 2005, Europe adopted a new tougher strategy for reducing exposure to mercury.

Also considered dangerous is a range of chemicals known as persistent organic pollutants (POPs), many of which contain chlorine or bromine. POPs tend to accumulate both in ecosystems and in the bodies of animals and humans. Many are also known to be toxic, interfering with basic body functions such as the hormonal system and neurological development. For instance, several appear to interfere with the function of thyroxin, the hormone which regulates a number of genes responsible for brain development.

Many POPs have been banned in Europe for some years. This has caused major reductions in their concentrations in the European environment and in the bodies of Europeans. Pentachlorophenol levels in the blood of Germans, for instance, have fallen more than 90 % since the chemical was banned in the late 1980s (Figure 4.6). POPs are now being phased out globally following the Stockholm Convention from 2001.

Figure 4.6 Pentachlorophenol (PCP) in German human plasma



Source: German Environmental Specimen Bank, 2005.

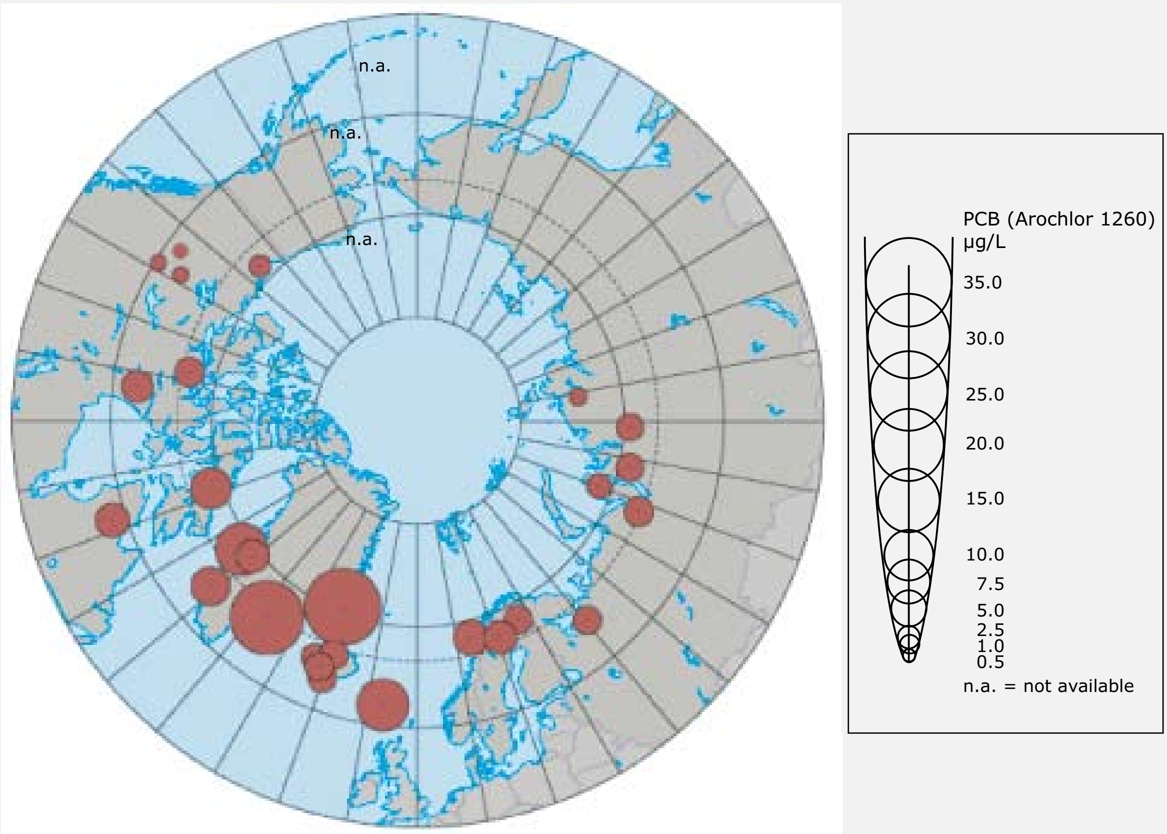
POPs in the Arctic

Some persistent pollutants in the atmosphere defy breakdown and can travel long distances, before eventually reaching the Arctic. There, the cold air can no longer hold them, they condense on to the ice or into the ocean, and enter the food chain. Many then become concentrated in the large amounts of body fat on animals such as whales, seals and polar bears living in the cold terrain.

Mercury is known to be accumulating in the European Arctic, along with metals like platinum, palladium and rhodium, which are manufactured today for use in the catalytic converters fitted to cars. Now Norwegian polar bears have been found with sufficient POPs in their systems to cause marked feminisation.

The Inuit people in Greenland and Canada face high exposure to polychlorinated biphenyls (PCBs) and mercury through eating meat from fish, whales and seals in their traditional diets (Map 4.3). Dietary intake of mercury and PCBs exceeds guidelines, and in some communities with traditional diets researchers have reported evidence of neurobehavioural effects among their children. Despite the passing of international treaties banning the use of POPs, the continued presence of these chemicals in the global environment makes it likely that their concentrations will continue to rise in parts of the Arctic.

Map 4.3 PCB levels found in human blood samples from Arctic peoples



Note: PCB (as Arochlor 1260) concentrations in blood of mothers and women of child-bearing age.

Source: AMAP, 2003.

The problem, however, is not over. POPs can last for decades before degrading, and can travel long distances during that time. Many evaporate into the air and travel on the winds. Some appear to accumulate in Arctic environments where they condense out of the cold air. Thus, the far north of Europe could become a final resting place for some of them.

Some POPs form part of a wider group of chemicals commonly found in the environment — endocrine disrupters; other chemicals in this group include phthalates, which are found in many plastics. These disrupt the orderly release of hormones through the body — the endocrine system that controls almost every function of the body, from sexual differentiation before birth to digestion and the functioning of the heart. The science in this field remains uncertain, but endocrine disrupters have been linked to a worldwide decline in sperm counts in the past 50 years, while fathers exposed to a range of environmental pollutants from the air and other pathways seem to produce fewer boys.

Anti-pollution measures over the past half century have dramatically reduced the presence of many known toxins in the environment, especially those emitted into the atmosphere. However, the number of chemical additives in consumer products, pharmaceuticals and the wider environment has grown. Exposure to individual chemicals may be small but the timing of exposures, along with combined exposures from multiple sources — the 'cocktail effect' — suggest that more preventive action would be useful to take account of inherent complexities and uncertainties.

Nobody is immune. Results from biomonitoring of chemicals in our bodies clearly show an increased burden of some persistent and bio-accumulative chemical substances. When WWF, the international conservation agency, tested the blood of 14 EU environment ministers, it found that all contained traces of PCBs, pesticide residues, brominated flame-retardants and phthalates.

4.6 Summary and conclusions

Reducing acid rain has been a major success story for collaborative European environment policy. If maximum feasible reductions in emissions are attained, then fallout over Europe could be brought below critical loads and thus protecting forests and soil from further deterioration.

Particulate pollution continues to take a heavy toll on Europe's health, and represents the biggest air pollution killer in Europe today being responsible for 348 000 premature deaths in year 2000. Clean-up measures have substantially reduced particulate emissions since 1990. Further cuts should follow, particularly with the introduction of filters in diesel cars. Nevertheless, it remains likely that, for some decades to come, many urban areas in the EU-25 will continue to have unsafe concentrations of particulates resulting from road transport but also from other sources such as small combustion.

Ozone smogs are thought to hasten the deaths of 20 000 people in the EU each year. Emissions of the precursors of ozone have declined by a third since 1990 and most countries should meet EU emissions ceilings set to come into force in 2010. Unfortunately the complex chemical environment of urban smog means that, despite declining emissions of ozone precursors, annual ozone concentrations have increased slightly.

Transport is the major cause of the most intractable air pollution problems Europe faces today. The dramatic improvements made by technologies such as catalytic converters in cars are being overwhelmed by increases in demand. Without such converters, however, some emissions would be 10 times the level they are now. While our air is generally cleaner, the trends are not good enough to meet air quality targets for 2010. End-of-pipe technological innovation is not enough. Current social trends, ranging from growing suburbanisation and the declining availability and rising cost of public transport and growing demand for imported consumer goods increasing the volume of shipping in EU seas, emphasise the many dimensions of action required. Options for action include incentives to buy the cleanest vehicles, road pricing, environmental zoning and changes in spatial planning to minimise urban sprawl and port charging which reflects the external costs of shipping.

There are several other chemicals that are present in the air, including benzene and polycyclic aromatic hydrocarbons, which are carcinogenic. In general, children are at a greater health risk from exposure to them. Several studies show a positive association between local traffic density and childhood leukaemia. These chemicals are also found in high concentrations inside buildings where Europe's children spend 90 % of their time.

Lead is another pollutant most closely linked to damage to children. The largest source of exposure used to be lead in car exhausts, but Europe has been in the forefront of removing lead from petrol in the past 20 years. As a result, lead levels in the blood of most European children have fallen dramatically.

Persistent organic pollutants (POPs) such as polychlorinated biphenyls (PCBs), are produced during waste incineration and are known to be toxic. In Europe a great number of POPs have been banned for some years. They form part of a wider group of chemicals found in the environment known as endocrine disrupters. They disrupt the orderly release of hormones in the body. Endocrine disrupters have been linked to a reported 50 % decline in sperm counts in the last 60 years.

It is impossible to estimate the true cost of such a wide variety of threats from air pollution. One estimate puts the annual economic costs of health damage in Europe caused by air pollution at between EUR 305 billion and EUR 875 billion. What is clear is that there is an emerging history of threats to human health and the environment that were well understood but largely ignored. The cost of that delay was measured both in lives lost and in damaged ecosystems that ultimately cost far more to clean up than it would have cost to avoid the problem in the first place. The lesson is that even when scientific uncertainties remain, and when the cost-benefit analyses of action are hard to assemble, it is often advisable to adopt a precautionary stance.

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5 Freshwaters

5.1 Introduction

Water is both a vital ecological and economic resource and an essential feature of the natural landscape. It is also a renewable resource. Water abstracted from rivers and underground reserves returns to the natural environment, finding its way to the sea, and from there it evaporates and falls onto the land again as rain. Human activity is an important element in the water cycle. We need water but can do great damage to the natural aquatic environment if we abstract too much or pollute it. That damage will also impact our own ability to maximise the benefits of water.

Managing the water cycle is thus a case study in sustainable use of a key natural resource. Since 2000 the water framework directive (WFD) has been in place as the main European legislation to protect our water resources. With its two main principles focusing on the 'good status' of all water bodies, and assessing them in relation to activities in the river basin, the WFD follows an integrated approach to water resource management.

5.2 Supply and demand

European countries meet their freshwater needs from surface water such as rivers, lakes and reservoirs, and from groundwater. The share of each source varies among countries and according to regional characteristics. Countries such as Norway, Spain and the United Kingdom, for example, use more surface water, while Austria, Denmark and Germany use more groundwater. In southern Europe, there is growing use

Water framework directive

In 2000, Europe adopted the water framework directive to bring together and integrate work on water resource management.

The basis for the directive's work is the river basin. Most water, once it falls to the ground in precipitation, remains within a single river basin, flowing by gravity either to the sea or into groundwater reserves. Human management of the water cycle almost invariably follows this pattern. Water is sometimes moved between river basins, and this may be required more in dry climates in the future. Such bulk transfers usually involve pumping against the forces of gravity and are very expensive — cripplingly so for many uses, including agricultural irrigation.

The directive's second principle is to restore every river, lake, groundwater, wetland and other water body across the Community to a 'good status' by 2015. This includes a good ecological and chemical status for surface waters and a good chemical and quantitative status for groundwater. It requires managing the river basin so that the quality and quantity of water does not affect the ecological services of any specific water body. Thus, any abstraction has to maintain ecologically sustainable flows in rivers and preserve groundwater reserves. Discharges and land-based activities have to be restricted to a level of pollution that does not affect the expected biology of the water. In particular, the directive means that new measures will have to be taken to control the agricultural sector so as to manage both its diffuse pollution sources and its abstractions of water for irrigation.

The WFD will repeal several older pieces of legislation, such as the surface water directive, the freshwater fish and shellfish directives and the groundwater directive. In future, the objectives of these directives will be covered in a more coherent and integrated way by the WFD and daughter directives. Only four water-related directives will stay in place: the urban waste water treatment directive, the bathing water directive, the nitrates directive and the drinking water directive. Measures and objectives to combat extreme floods and droughts beyond securing a good quantity of groundwater are not covered by the WFD but will be dealt with by an action programme and a directive which are currently under development.

Europe has also recognised that, to achieve the aims of the water framework directive, 'the role of citizens and citizen groups will be crucial'. The implementation of the directive will require careful balancing of the interests of a wide range of stakeholders. The greater the transparency in the establishment of objectives, the imposition of measures and the reporting of standards, the greater the care Member States will take in implementing the legislation in good faith, and the greater the power of citizens to influence the direction of environmental protection. Caring for Europe's waters requires more involvement of citizens, interested parties and non-governmental organisations, especially at the local and regional levels. Thus the framework directive has established a network for the exchange of information and experience to ensure that implementation will not be left unexamined until it is already behind schedule or out of compliance.

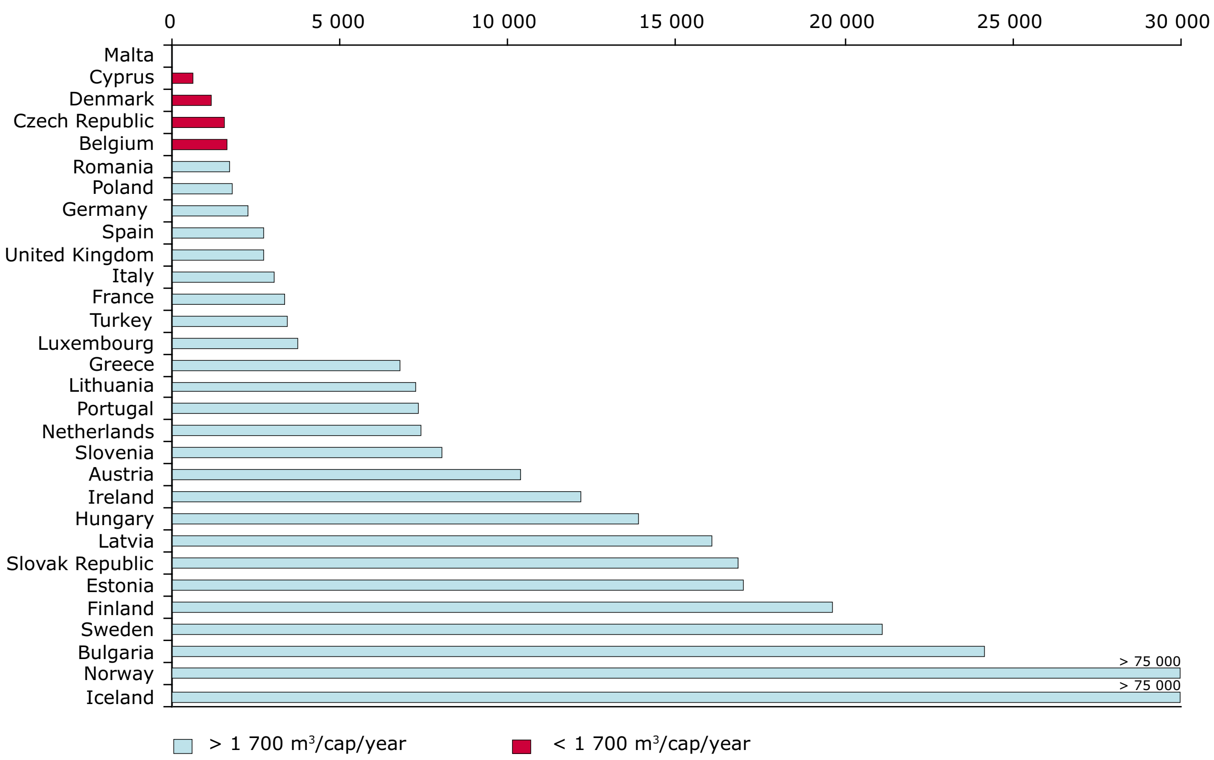
of desalinated sea water, notably on Mediterranean islands where there is heavy seasonal water demand from tourists. Furthermore, several countries, including Spain, plan to greatly increase their desalination capacity as an alternative to bulk transfer of water between river basins.

Total rainfall over Europe is around 3 500 cubic kilometres a year, rather more than 10 times the 300 cubic kilometres of water withdrawn every year from the natural environment for all human activities. Although, on face value, there appears to be enough water, many of the major centres of population are in the drier parts of the continent, whereas the water is mostly in the thinly populated north. Regional demand and regional availability often do not match.

Precipitation is greatest in the west, where the winds carry moisture off the Atlantic Ocean, and in the mountains, where rising air squeezes out the last of that moisture. In western Norway, rainfall is around 2 000 millimetres a year. Downwind, inland and in the lee of mountains rainfall is much less — around 500 millimetres a year in much of eastern Europe and around 250 millimetres in southern and central Spain.

Much of Europe's water never reaches water bodies where it can be tapped for human use, particularly in hotter areas. Annual potential evaporation around the Mediterranean reaches nearly 2 000 millimetres a year, eight times the rainfall. In parts of Spain only a tenth of rainfall reaches rivers. Evaporation is also a major drain on water storage in reservoirs in the region.

Figure 5.1 **Annual water availability per capita by country, 2001**



Source: EEA, 2003.

For such reasons, the continent's water abundance is more theoretical than real. Annual freshwater availability per head varies from less than 1 000 cubic metres in Cyprus and Malta, through around 3 000 cubic metres in France, Italy, Spain and the United Kingdom, to more than 10 000 cubic metres in mountainous countries such as Austria and Slovenia, and more than 75 000 in Norway and Iceland (Figure 5.1).

Though few Europeans suffer devastating water shortages, this imbalance of supply and demand has already created hydrological 'hot spots', where local water abstraction far exceeds supply, with knock-on effects for the functioning and long-term viability of the ecosystems. Shortages are most notable around some large cities, on small islands and in some Mediterranean coastal tourist areas. Moreover, significant fluctuations in water supply, both from month to month and year to year, can cause shortages. This is particularly the case in southern Europe where demand, especially from agriculture, is usually greatest when supply is least.

Countries where withdrawals are greater than 20 % of total available supplies are generally regarded as water stressed. Four countries — Cyprus, Italy, Malta and Spain — already fall in that category. Others are likely to join them as climate change is expected to influence both the supply and demand for water. More details on the relationship between water abstraction and renewable freshwater resources are described by the water exploitation index.

5.3 Water use

Roughly a third of the water abstracted in Europe for human use is intended to irrigate crops. Just under another third is for use in power station cooling towers. A quarter is for household use such as taps and toilets. The remainder, about 13 %, is consumed in manufacturing (Figure 5.2).

This sectoral share-out varies quite widely across the continent, however. In Belgium and Germany, for instance, more than two-thirds of water is abstracted for cooling towers at power stations. Irrigation, meanwhile, currently accounts for less than 10 % of water abstractions in most of the temperate countries of northern Europe, but in southern Europe, in countries such as Cyprus, Greece and Malta and parts of Italy, Portugal, Spain and Turkey, irrigation accounts for more than 60 % of water use. In the EU-15, 85 % of the irrigated land is in the Mediterranean countries. Among candidate countries, Romania and Turkey have the biggest share of land under irrigation.

Abstraction statistics need to be treated with care, however. They are often taken as a measure both of water use and of the potential impact of water abstraction on the aquatic environment. Some withdrawals are indeed 'consumptive', with the water being incorporated into products such as crops or manufactured goods and not returned to the river basin, but others are not. Much of the water abstracted from rivers is eventually returned in a polluted or partially cleaned form, after use in manufacture or in houses and offices. Considerable amounts are returned quickly and little changed — notably when abstracted to supply cooling towers.

Overall in Europe, 80 % of the water used in agriculture is either absorbed by crops or evaporates from fields. In manufacturing and households, 80 % is returned to the local environment, albeit often polluted and at a different location or catchment. In electricity generation, 95 % of the abstracted water is returned, a little warmer than it left but otherwise generally unchanged. Warmer water can, however, negatively impact on local ecosystem structures.

These contrasting fates of abstracted water need to be taken into account when considering recent trends and future projections for water in Europe. For instance, gross water abstraction has been in decline since the early 1990s, a trend which is expected to continue, with a predicted further reduction of about 11 % in abstractions between 2000 and 2030, to around 275 cubic kilometres a year (Figure 5.2). This, however, does not necessarily mean that there is more water in Europe's rivers.

In most places, that reduction has and will be a result of the introduction in the power sector of cooling towers that use far less water than existing cooling systems. They are expected to allow around a two-thirds reduction of water abstractions for cooling across Europe, even if current projections of a doubling in thermal electricity production come true (Figure 5.2). However, as most water abstracted for cooling is returned to the river — and since actual water losses through evaporation in these new systems are higher than for conventional cooling systems — the apparent reduction in abstractions is unlikely to result in commensurate increases in water in rivers.

Meanwhile demographic and economic trends are likely to raise water use in other sectors. Domestic use, currently around 25 % of the European total, can be expected to rise with wealth and with diminishing household size, a function, among others, of Europe's ageing population. The increase in second homes and mass tourism, including water-intensive activities such as watering golf courses, also raises per capita water use. It is possible, however, that trends to increase domestic water use could be moderated by regulations or economic incentives to encourage people to switch to more water-efficient lavatories and household appliances.

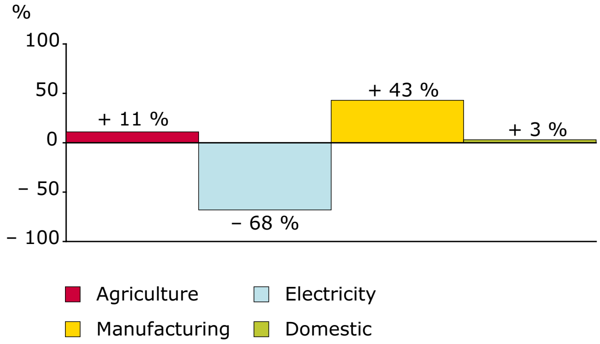
Water use in manufacturing is likely to be dependent on the future of the heavy industries that currently use around 80 % of the water in this sector (such as iron and steel, chemicals, metals and minerals, paper and pulp, food processing, engineering and textiles). Increases are expected to be greatest among the industrialising candidate EU countries, but use may decline elsewhere as heavy industry declines or adopts more water-efficient industrial technologies.

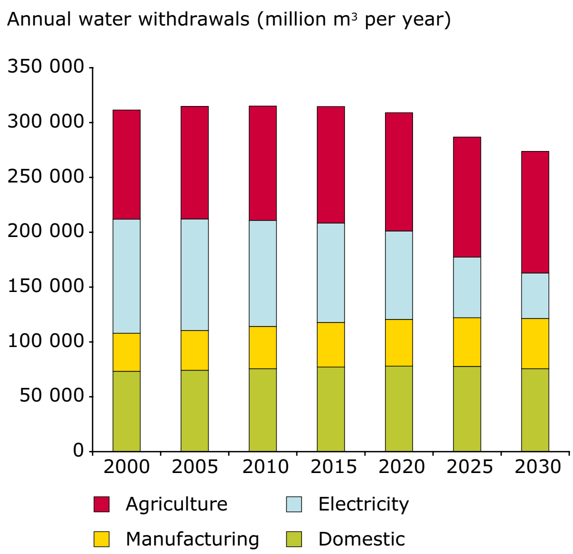
Geographically, water demand has shown different trends in different parts of Europe, and this is likely to continue. Northern Europe is likely to see substantial reductions in water withdrawals, as power plants change to modern cooling systems. With other uses probably stable until 2030, however, there may be little

Figure 5.2 Water abstraction in Europe (EEA-31 without data for Iceland)

Sector	Withdrawals in 2000
Agriculture	99.6 km³ (32 %)
Electricity	95.0 km³ (31 %)
Manufacturing	39.8 km³ (13 %)
Domestic	73.2 km³ (24 %)

Changes in annual water withdrawals (2000 to 2030)





Source: EEA, 2005.

change in overall consumptive use of water. Use could, in fact, rise if climate change causes increased use of irrigation in agriculture in this region.

Higher temperatures are likely to have an even bigger impact on water demand in southern Europe, where the need for irrigation of crops will undoubtedly increase. Baseline assumptions foresee a 20 % increase in the area of southern Europe under irrigation by 2030. In many places, there is simply not the water to meet this demand, so there will be strong pressure for significant improvements in the efficiency of irrigation systems (Map 5.1).

Even allowing for such improvements, current projections see a rise of 11 % in water demand for agriculture. The question remains whether this water will be available in practice, and how countries will meet the competing needs of agriculture and the ecological protection of aquatic ecosystems. This will raise further questions about the sustainability of certain patterns of agriculture, particularly in southern Europe, in the light of projected changes in climate in already water-short areas.

Among new EU Member States, domestic water use declined during the 1990s. The collapse of some heavy

Hydroelectricity

Hydroelectricity represents 1.5 % of overall energy consumption in Europe. Countries such as Austria, Portugal, Slovakia, Slovenia and Sweden rely for significant amounts of their power on hydroelectricity generated at dams that trap river flows. Water use for hydropower does not involve abstraction of water, but is nonetheless economically and ecologically vital. River ecosystems rely on river flow, of course, as do commercial river fisheries.

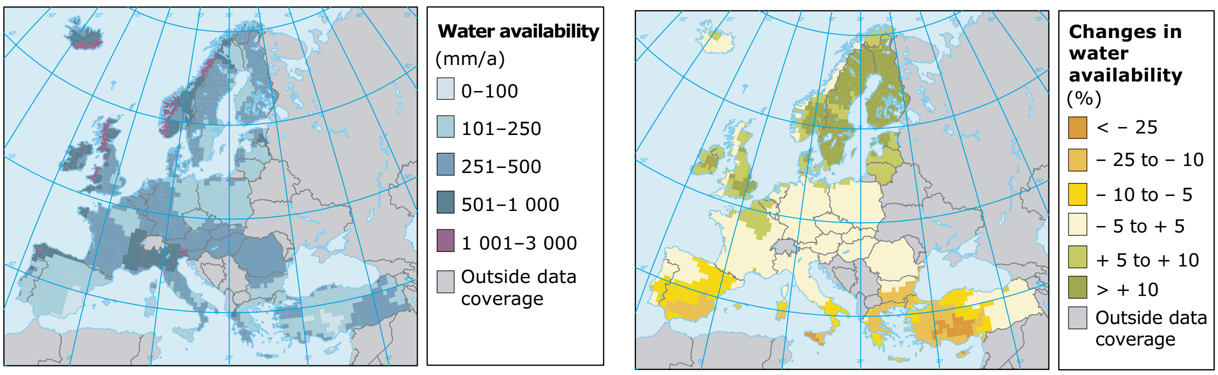
Most appropriate sites for large hydroelectric dams are already occupied. Concerns about the ecological effects may constrain further development. These concerns range from altered flow and temperature regimes that destroy fish-spawning areas, handicap fish migration, kill fish in turbines and dry out wetlands, to the capture of sediment and nutrients behind dams, which can reduce the fertility of the waters downstream and may also increase erosion of river banks. For instance on the River Rhône, dams have reduced the sediment carried into Lake Geneva by some 50 %.

Climate change could make many hydroelectric power plants less reliable in future. While some plants in northern Europe could generate more power, studies suggest that output from hydroelectric dams in Bulgaria, Portugal, Spain, Turkey and Ukraine could fall by 20–50 % because of declining rainfall.

Map 5.1 Current water availability and changes expected by 2030

Current water availability in European river basins

Changes in average annual water availability under the LREM-E scenario by 2030



Source: EEA, 2005.

industries cut industrial water use in parts of central and eastern Europe by up to two-thirds during the decade. A crisis in farming also led to declines in abstraction for irrigation — as many irrigation districts went unwatered. Abstractions for public water supply also declined, typically by 30 %, both because of disruption of supply and because of the market effect of the introduction of water meters and more realistic water charges.

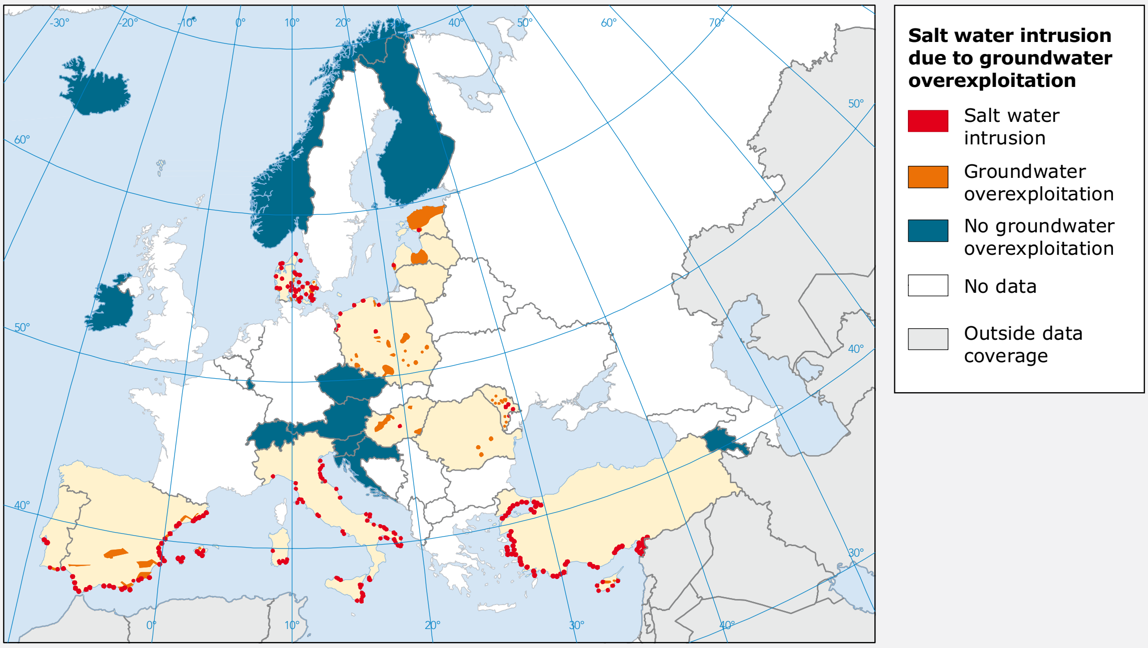
Among new members, current domestic water use is around 40 cubic metres per person per year, compared

Groundwater

Groundwater flows through the subsurface, both into and out of natural underground reservoirs, also known as aquifers, usually in the pores of porous rocks. In many areas of Europe, groundwater is the dominant source of freshwater. In a number of places water is being pumped from beneath the ground faster than it is being replenished through rainfall (Map 5.2). The result is sinking water tables, empty wells, higher pumping costs and, in coastal areas, the intrusion of saltwater from the sea, which degrades the groundwater. Saline intrusion is widespread along the Mediterranean coastlines of Italy, Spain and Turkey, where the demands of tourist resorts are the major cause of over-abstraction. In Malta, most groundwaters can no longer be used for domestic consumption or irrigation because of saline intrusion, and the country has resorted to desalination. Intrusion of saline water due to excessive extraction of water is also a problem in northern countries, for example in Sweden.

Sinking water tables can also make rivers less reliable, since many river flows are maintained in the dry season by springs that dry up when water tables fall. Groundwaters also help sustain surface reservoirs of water such as lakes and wetlands that are often highly productive ecosystems, and resources for tourism and leisure activities. These, too, are threatened by over-abstraction of groundwater.

Map 5.2 Groundwater overexploitation



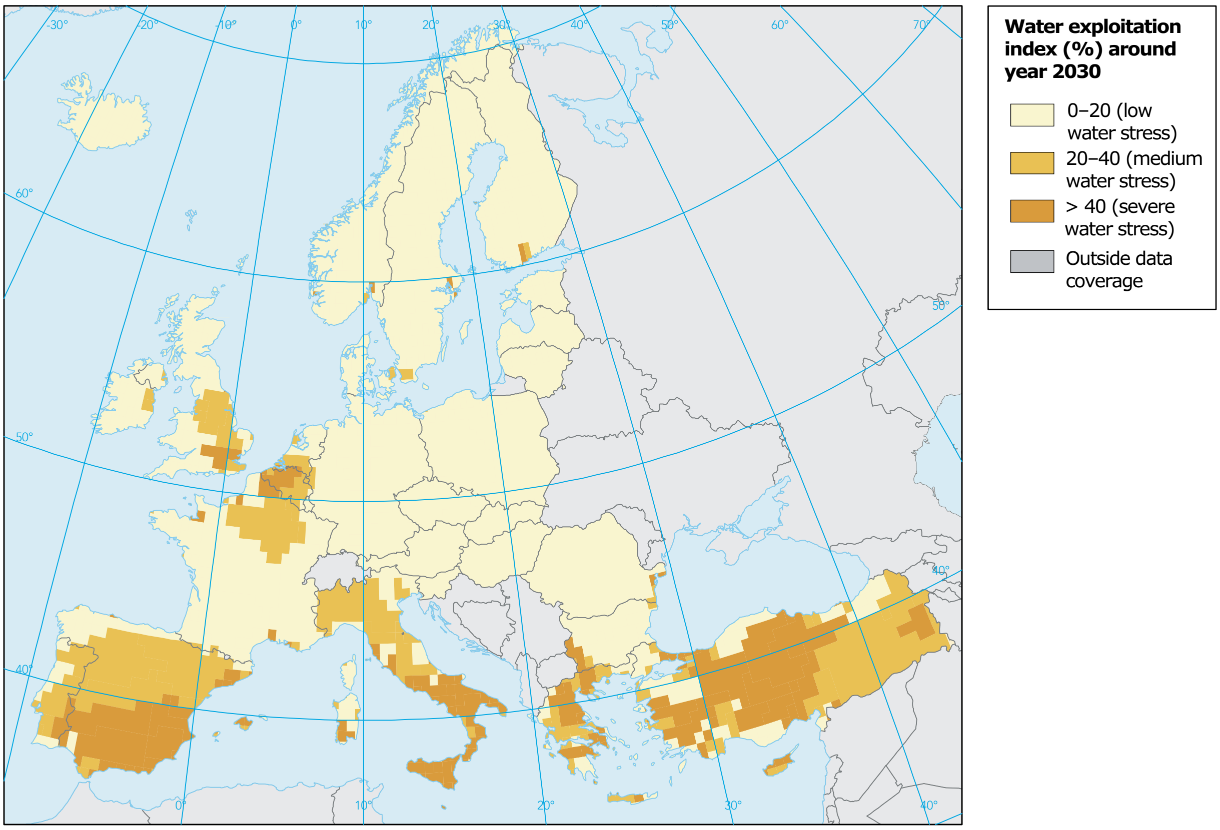
Source: EEA ETC/W, 2005.

with an EU average of 125 cubic metres. It is expected to rise substantially towards the EU average as living standards improve, though by how much is uncertain. The biggest increases in water use in the coming years, however, will probably be in the EU candidate countries, especially Turkey, where growing wealth, industrialisation and increased demand for irrigation will be compounded by continuing population growth.

Not all these expected increases need occur. The potential for greater efficiency in water use may be much greater than currently anticipated. Such improvements may be unlocked by more realistic water pricing, which would make investment in efficiency more attractive, especially in agriculture. Domestic water use could be cut through tougher water-efficiency standards for household appliances such as washing machines, dishwashers and lavatories.

Perhaps the greatest potential for water saving lies in reducing leakage rates in water distribution systems, particularly for domestic use. In some older cities in Europe, losses exceed a third. In some places this leakage is not strictly 'lost', since it recharges groundwaters, from where it can be pumped to the surface again. However, in many places this is impossible because the groundwaters beneath cities are too contaminated to be used.

Map 5.3 Water stress in 2030



Source: EEA, 2005.

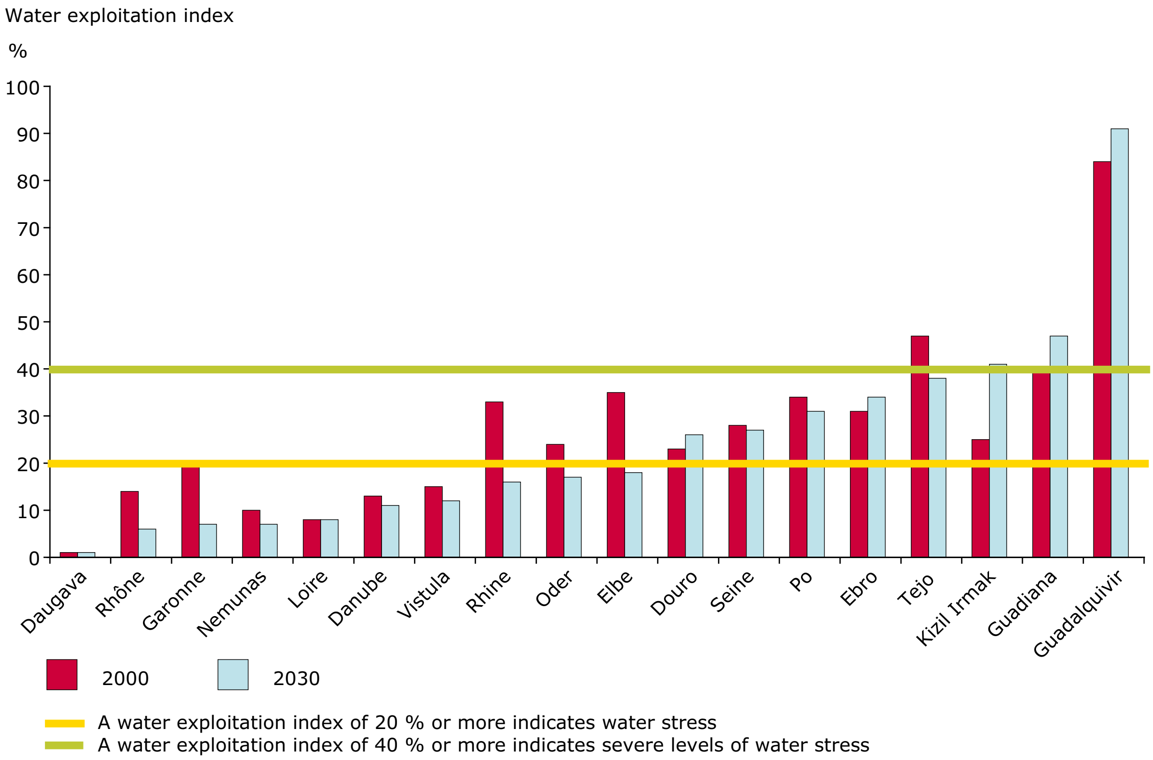
5.4 Climate change and water stress

Substantial changes in precipitation patterns, possibly linked to climate change, are already apparent in Europe. In some northern countries there has been a marked increase in precipitation in recent decades, particularly in winter, while declining rainfall is a recent feature of southern and central Europe, especially in summer. These trends are expected to continue, causing serious water stress in parts of southern Europe in particular (Map 5.3).

In parts of the north, additional rainfall will increase river flow. Water availability may increase by 10 % or more in much of Scandinavia and parts of the United Kingdom by 2030. In southern Europe a combination of reduced rainfall and increased evaporation will cause a reduction of 10 % or more in the run-off in many river basins in Greece, southern Italy and Spain, and parts of Turkey, by the same date. Most of this change is already on course to happen from emissions of greenhouse gases that have already occurred; future emissions will likely accelerate these changes.

In southern Europe, this reduced supply will be made worse by sharply rising demand, particularly from farmers needing more water to irrigate their crops. Water stress in many river basins in this part of Europe can be expected to increase (Figure 5.3). Prominent examples will include the Guadalquivir and Guadiana rivers in Spain (and the latter also in Portugal) and the

Figure 5.3 Water stress in river basins in 2000 and 2030

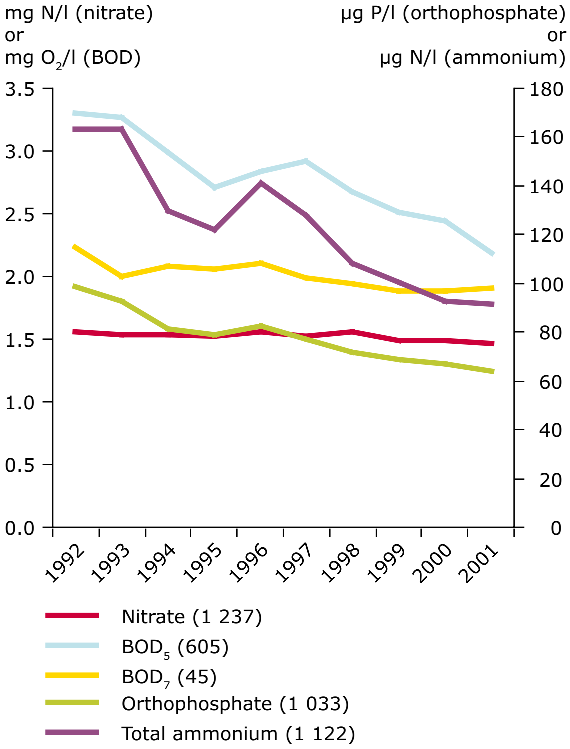


Source: EEA, 2005.

Kizil Irmak in Turkey. The Guadalquivir is expected to see more than 90 % of its flow abstracted by 2030. Spain is already responding to future anticipated shortages with plans for a large network of desalination works in the country and a push to more efficient irrigation systems. The drought conditions already apparent on the Iberian Peninsula in spring/summer 2005 underline the urgency of such measures. Where rivers cross national boundaries the demands of shared extraction add to the complex situation — for example in 2005 the flow of some rivers into Portugal were highly reduced, impacting the generation of hydropower, water available for irrigation and even water for human consumption.

In general, northern Europe is likely to become more flood prone and southern Europe more drought prone as the extra energy in the climate system increases the probability of extremes — not just droughts but also severe storms and floods, such as those in central Europe in recent years.

Figure 5.4 Average pollution concentrations for European rivers



Note: Numbers in brackets refer to the number of rivers used to calculate average concentrations for each pollutant.

Source: EEA-ETC/W, 2004.

5.5 Water quality

River water quality across Europe is generally improving (Figure 5.4). Like water use, water quality can be a complicated concept underlined by the influence of various pressures and multi-cause/multi-effect relationships. A pristine pollution-free river flowing through an unaltered landscape may be easy to recognise, but the manner in which human activity has altered and degraded pristine rivers has taken many forms, and assessing the extent of the damage and progress towards recovery is no easy task.

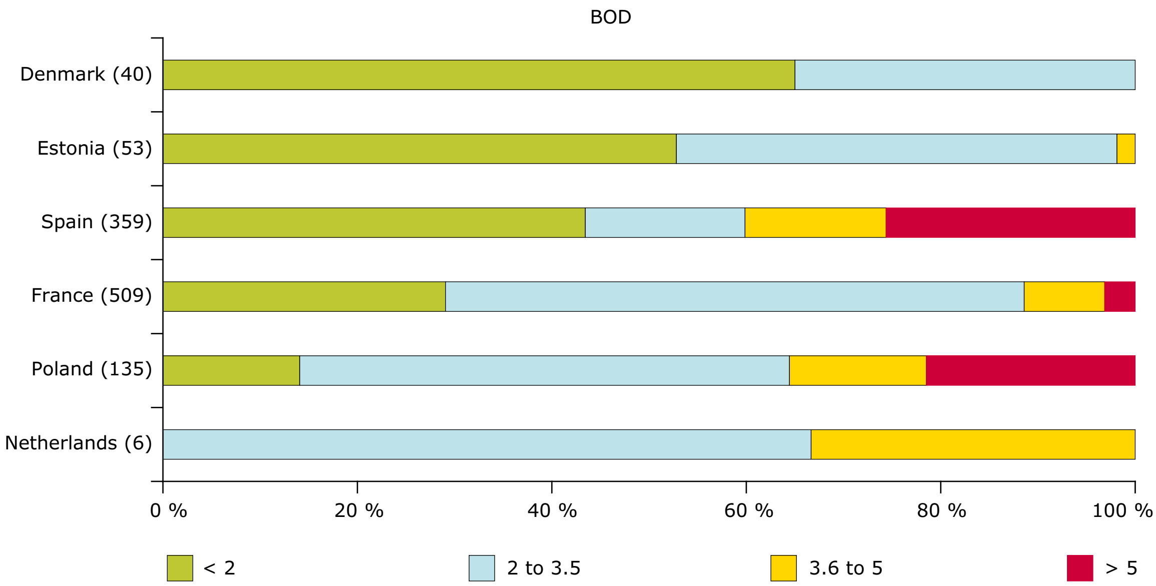
Conventionally, water quality is defined by biological and chemical parameters. For instance, biochemical oxygen demand (BOD) is an index widely used to assess the amount of organic oxygen-consuming pollution in a river. BOD results for six EU Member States show markedly different distributions for water quality in rivers (Figure 5.5). However, simple statistical parameters can be misleading because the baseline natural conditions of rivers can be very different. Hence efforts are being made to conduct wider assessments of biological and ecological health. The water framework directive aims at achieving good ecological and chemical status for all water bodies in Europe by 2015.

Pollution can take many forms. Faecal contamination from sewage makes water aesthetically unpleasant and unsafe for recreational activities such as swimming, boating or fishing. Many organic pollutants, including sewage effluent, and farm and food-processing wastes consume oxygen, suffocating fish and other aquatic life. Nutrients such as nitrates and phosphates, from everything from farm fertilisers to household detergents, can 'overfertilise' the water causing the growth of large mats of algae, some of which are directly toxic. When the algae die, they sink to the water bottom, decomposing, consuming oxygen and damaging ecosystems.

Pesticides and veterinary medicines from farmland, and chemical contaminants including heavy metals and some industrial chemicals can threaten wildlife and human health. Some of these damage the hormonal systems of fish, causing feminisation, even at very low concentrations. Sediment run-off from the land can make water muddy, blocking sunlight and, as a result, killing wildlife. Irrigation, especially when used improperly, can bring flows of salts, nutrients and other pollutants from soils into water. All these pollutants can also make the water unsuitable for abstraction for drinking water, without expensive treatment.

Water quality is also influenced by the physical management of rivers and the wider hydrological environment of a river basin. Canalisation, dam-building, river bank management and other changes to the hydrological flow can disrupt natural habitats such as bank side vegetation and destroy pebble riffles where salmon and other fish spawn. They also change seasonal flow patterns that are vital to many species, as well as the connectivity between habitats, a very important factor for the functioning of aquatic ecosystems and for the development of the different life stages of aquatic organisms. In urban agglomerations, storm water carrying contamination from streets and roofs can contribute to water pollution if it is not collected into the sewage system and delivered to treatment plants, but discharged directly into water bodies.

Figure 5.5 **Percentage of rivers from six EU countries distributed on water quality classes for BOD (mg/O_2/l) in 2001 (1997 for the Netherlands)**



Note: River classification based on annual average concentrations from representative subset of river monitoring stations. Numbers refer to number of river stations.

Source: EEA-ETC/W, 2005.

Most European rivers have been modified. For instance, some 90 % of Danish rivers are canalised, culverted or regulated. In Germany only 10 % of rivers are considered to be largely natural, while in France river engineering has degraded 64 (out of 76) wetlands of national importance, covering more than 11 000 square kilometres.

Groundwaters, too, suffer from the consequences of intensive agriculture and the use of nitrogen fertilisers and pesticides. Nitrates contamination is widespread across Europe, where the EU drinking standard for nitrate is exceeded in many of the groundwater bodies. Other sources of groundwater contamination are heavy metals, oil products and chlorinated hydrocarbons, mainly introduced from point sources of pollution, such as landfills.

Overall, nitrate contamination is the most commonly sited issue. It is often a particular problem in rural water supplies, which are not necessarily well monitored since they often serve only small populations and are not covered by the monitoring requirements of the drinking water directive. However, nitrate contamination should be reduced with the implementation of the nitrates directive (91/676/EEC).

5.6 Water pollution control developments

Today, around 90 % of the population in north-west Europe is connected to sewer and treatment systems. The figure is generally between 50 and 80 % among southern European members of the EU-15, but averages less than 60 % among the 10 new Member States. Most industries also have their effluent discharges connected to sewerage systems or have their own treatment plants. Some large cities, however, including the cities of Bucharest and Milan, still discharge their wastewater almost untreated into rivers.

Treatment of urban wastewater is typically divided into three categories. Primary treatment involves the filtering and physical removal of detritus; secondary treatment is biological, removing or neutralising microbiological contamination and oxygen-consuming organic material. The most advanced, tertiary, treatment involves chemical methods to remove more intractable pollutants, particularly nutrients. More than 70 % of wastewater in Austria, Denmark, Finland, Germany, the Netherlands and Sweden undergoes tertiary treatment, while in southern Europe just around 10 % of discharges receive this treatment.

Under the 1991 urban waste water treatment (UWWT) directive, the standards for collection, treatment and disposal of wastewater required in each location depend on the size of the urban area and whether the receiving waters are classified as sensitive or non-sensitive. For discharges to sensitive waters, the directive required all urban areas with more than 10 000 people to provide primary, secondary and tertiary treatment for their waste by 1998. Meanwhile, for discharges to non-sensitive waters, urban areas with populations greater than 15 000 people should provide primary and secondary treatment for their waste by 2000. For both categories, these rules will apply to all urban areas down to a population of 2 000 inhabitants from the end of 2005. The dates are extended, generally to 2010, for the 10 new Member States.

Many EU-15 countries have not yet complied fully with the directive. Several have failed to monitor water courses and assess their ecological status so they can be designated sensitive areas where appropriate. Many have not yet installed the sewage treatment capacity that the directive required by 1998 and 2000. Others are seeking postponements to requirements to extend sewage treatment to smaller urban areas by 2005.

Countries that have shown that a successful implementation of the UWWT directive is possible, leading to significant improvement in water quality, include Austria, Denmark, Germany and the Netherlands. Those further behind include France, where only 40 % of sewage discharges to sensitive areas meet the required standard. In Spain, supported by substantial subsidies from the EU Cohesion Funds, 55 % of the population is so far connected to public sewage treatment plants.

Some new EU Member States are further advanced than others. In Estonia, 70 % of the population is served by wastewater treatment plants, while in Poland 55 % of the population is connected to sewage plants.

Despite the gaps in compliance, the directive is cutting point sources of pollution to rivers substantially. In both Denmark and the Netherlands, point-source discharges to surface waters have decreased by 90 %. Estonia has also achieved a 90 % reduction in such discharges in a decade.

Assessing the outcomes of investment in the quality of river water is difficult because there is no simple measure. No two rivers are alike; and no single indicator captures all the factors. Also, the quality of water in rivers in some countries is a response to pollution control measures in upstream countries as well as the host. In places, the deposition of pollution onto water from the air may also play a role.

Nonetheless, most rivers have improved across Europe, generally the greatest in formerly badly polluted urban and industrial areas, where point sources of pollution predominated, and where clean-up investment has been concentrated. It has been less good — and in some cases there has been clear deterioration — in rural areas which until recently were near-pristine, where diffuse agricultural sources of pollution predominate, and which have been largely outside the requirements of the UWWT directive.

Most of these are smaller rivers, but there are larger rivers, too, that have not seen improvement in all parameters. These include the Duero in Spain, where BOD and phosphate levels have deteriorated in the past 25 years, and the Wisla in Poland, where ammonium concentrations rose in the 1980s.

Discharges of a wide range of trace amounts of hazardous substances into the aquatic environment — such as heavy metals including cadmium and mercury, as well as pesticides and dioxins — have been in decline in recent years, thanks to a range of EU environmental measures, some related to water and some more general in scope. For instance, loads

History of water pollution control

After the industrial revolution, most of Europe's rivers were treated not so much as natural ecosystems but more as convenient routes for transporting liquid wastes to the sea from thousands of factories and sewerage networks. The discharges often received minimal or even no treatment to reduce their toxicity or aesthetic unpleasantness. Thousands of kilometres of waterways became toxic, devoid of oxygen and often entirely lifeless. Cities turned their backs on them; some were covered over and became little more than large sewer pipes.

In recent decades, largely since the launch of the EU environmental policy at the Paris Summit in 1972, strenuous efforts have been made to clean up discharges of sewage and industrial waste, and turn these rivers into amenities for leisure and corridors for wildlife. In financial terms, it has been Europe's largest environmental endeavour.

Initially, efforts were concentrated on removing gross and offensive pollutants and oxygen-consuming organic wastes, including raw sewage, through filtration and biological treatment. Investment was made first on rivers used for drinking water, and later moved to protecting estuaries and coastal waters, to meet standards set by the bathing waters directive.

Microbiological contamination and oxygen deficiency is now largely under control in many places. During the 1990s, BOD levels in rivers improved by 20–30 %. Efforts have moved to controls on chemical pollutants such as pesticides. Here, there has been considerable success in removing such pollution from point sources, such as industrial discharges and effluent from urban sewage systems.

Phosphate concentrations in European rivers have been reduced by a third and more — with the biggest reductions in countries which had the largest point-source pollution. Eutrophication of lakes and coastal waters has been reduced as a result, but hot spots remain. The number of monitored lakes with phosphorus concentrations below 25 micrograms per litre has increased from 75 % to 82 % in the past 20 years.

There is, however, growing recognition that, in increasing numbers of water bodies, point sources are no longer the main pollution threat. As pipe discharges have been cleaned up, an increasing, and often dominant, source of pollution has been diffuse sources percolating from the land, through soils, in numerous rivulets and trickles from land drains.

of hazardous substances reaching the Baltic Sea have fallen by at least 50 % since the late 1980s. However, not all substances are monitored, and, for many, their toxicity is not clear.

5.7 Costs and benefits of water pollution control

Water pollution control has undoubtedly proved costly for many countries. Several Member States spend around 0.8 % of gross domestic product (GDP) on this, and it has used up more than 50 % of environmental investment across Europe in recent decades. This raises questions about whether it has crowded out action on other, perhaps more immediately important, problems. Nevertheless, lessons can be learned about how to do the job most effectively.

Governance problems often lie behind difficulties with meeting the objectives of the UWWT directive. In particular, sewage treatment is often the responsibility of municipal authorities which lack the financial resources and administrative competence to complete expensive treatment works in good time and to the greatest benefit of a river system. In some countries, for example France and Spain, overlaps of institutional responsibilities, together with bottlenecks in financing, appear to be important reasons for not fully implementing the directive on time.

Comparisons also show that efforts to reduce pollution at source, before it enters the sewerage system, are often cheaper than building new treatment plants. Realistic charging for effluent treatment, for instance, made it easier for the Netherlands to meet its directive requirements (and more cheaply because measures were taken by industry to prevent pollution) than in other countries where governments had to invest heavily in treatment plants.

Across Europe, direct legislative action to reduce certain widely used pollutants in consumer products has also been shown to be highly cost effective. The most dramatic change has been the reduction, by more than 50 % in many countries, of phosphorus in household detergents. Phosphorus discharges per person have typically fallen from 1.5 kilograms per person per year to less than 1 kilogram.

The main reason for delays in implementing the UWWT directive is the costs involved, so eco-efficient approaches that minimise investment deserve more attention. Greater emphasis on eco-efficiency, and economic incentives that promote wastewater reduction at source, are likely to be the keys to more timely and cost-effective implementation of the UWWT directive in Member States.

Under the EU cohesion policy, countries are eligible for considerable EU subsidies, up to 75–85 % of investments. If there are no economic instruments in place to provide industries with incentives, there appears to be a considerable risk that EU subsidies will lead to excess investment in sewage treatment plant capacity. Finding the right balance between incentives to promote eco-efficiency and prevent pollution at source, and adequate sewage treatment capacity, would help, as sewage treatment is one of the most capital-intensive environmental measures.

It is expected that the cohesion policy, through the Cohesion and Structural Funds which are designed to bring about closer economic and social integration by encouraging growth in those regions of the EU most in need, will continue to support sewage treatment plants from its proposed EUR 336 billion budget for 2007–2013 for EU-10. Support is greatly needed as current investments in, for example, Estonia and Poland are at the level of EUR 5–10 per capita (not PPP — purchasing-power parity — adjusted), and will need to be increased to a level of about EUR 40–50 per capita to comply with the agreed deadlines.

These findings suggest that EU funding for pollution control plants — e.g. through the Cohesion Fund — should be spent carefully to avoid over-reliance on large capital projects. Often, the use of economic instruments such as taxing and charges, alongside capital investments, would be more cost-effective.

5.8 Tackling diffuse sources of pollution

While the UWWT directive will continue to reduce the discharge of nutrients from point sources, the new focus for EU activity to protect water bodies from pollution is likely to be diffuse sources, which make up an increasing proportion of emissions to rivers. Where traditional point discharges may all come through a handful of large pipes, diffuse discharges trickle from soils and thousands of field drains over hundreds of square kilometres. The challenge of controlling and policing them will thus be great in both technical and logistical terms.

Recent laws, such as the nitrates directive and the water framework directive, provide the in-country basis for establishing the further regulations, new institutional frameworks and additional monitoring systems that are seen as needed to tackle diffuse pollution and manage water bodies so that their ecological functions and resources are maintained.

The main source of diffuse pollution to water is from the largest land use across most of Europe — agriculture. A particular focus of concern is nutrients, primarily nitrates and phosphates. Nitrates are generally the greatest problem. More than half of the nutrient discharges in Europe now come from diffuse sources. Most nitrate pollution in particular arises from farm fertiliser and manure. Nutrients contribute to eutrophication in lakes, coastal waters and the marine environment. They pollute rivers and groundwaters and contaminate drinking water.

During the past half century, the rising use of commercial inorganic mineral fertilisers and increased concentrations of livestock, with their resulting manure, have resulted in a sharp increase in the application of nutrients to the land over Europe. In the past decade or so, nutrient use on farms in the EU-15 has been stable at around 70 kilograms per hectare per year (surface balance), and is expected to remain stable in the coming decades.

In eastern Europe, agricultural sector activity has dropped substantially as a result of political and economic changes during the 1990s, leading to a sharp decline in fertiliser use, which typically halved from around 70 kilograms per hectare at the start of the 1990s and remained low throughout the decade. As these countries join the EU, fertiliser use is resuming its upward trend. In EU-10, increases of 35–50 % in use of phosphates and nitrates are likely.

While much of the nutrients in fertilisers is, of course, absorbed by crops — the purpose for which they are applied — much is not. Wherever fertiliser and farm manure is not absorbed, nitrates will migrate through soils. Most European soils contain a large nitrogen surplus from constant applications. These are typically around 50–100 kilograms per hectare of farmland. Most of this surplus will eventually find its way to water.

As a result of these changes, coupled with the controls on point sources, agricultural emissions are now the dominant source of pollution in many river basins. In the river catchments that drain into the North Sea, the total nitrogen load averages 14 kilograms per hectare of land per year, of which 65 % comes from diffuse sources associated with human activities, mainly farming. The equivalent figures for phosphorus are 0.9 kilograms and 45 %.

Away from the North Sea, most other catchments, with the exception of the Po basin in northern Italy, have lower absolute levels of nitrate loading, although the proportion from agriculture remains high, above 60 % in all cases. The picture for phosphorus is more varied, because of the continued importance of point sources for this nutrient, which are being dealt with largely through implementation of the UWWT directive.

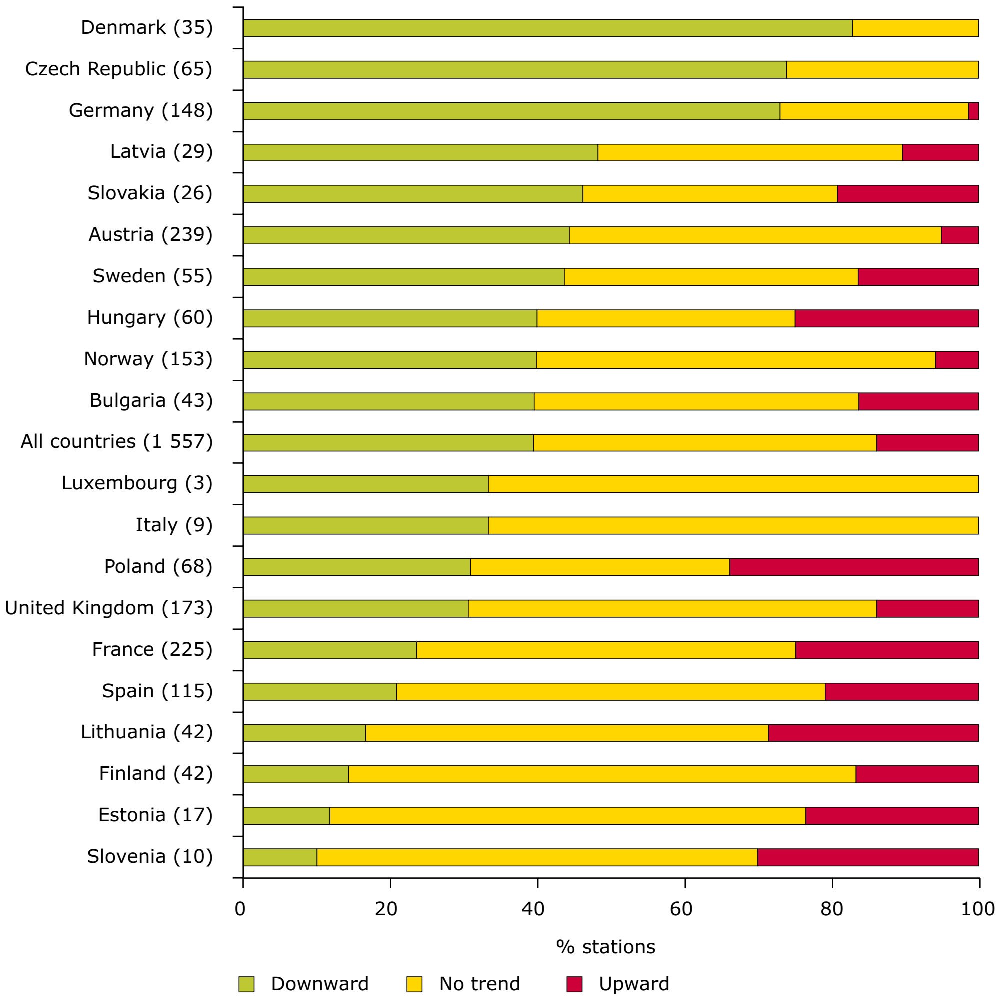
5.9 Nitrates

Fertiliser application for arable farming is the main source of nitrates. In rivers where arable land covers more than half the upstream catchment, nitrate levels are three times higher than in rivers where the upstream arable land cover is less than 10 %. Across the EU, nitrate pollution of rivers is generally lower in the Nordic countries and central Europe, where arable farm intensity is less (Figure 5.6).

In 2000, 14 European countries had rivers whose waters exceeded the nitrate value set in the EU drinking water directive which is designed to keep water in public supplies safe for drinking. Five countries had rivers that exceeded maximum allowable concentrations under the directive.

The situation is even worse for groundwater reserves. In many groundwater bodies in Europe for which data are available, measurements of nitrate concentrations have found levels that exceed the specified values of the drinking water directive.

Figure 5.6 Trends in nitrate concentrations in rivers in European countries



Source: EEA, 2005.

In some parts of Europe, these problems may be expected to get worse before they get better, particularly for groundwater. It can take years or even decades for nitrates to reach zones from which drinking water is taken. As the average age of groundwater used in drinking water is 40 years, much of the surplus nitrogen applied to farms in recent decades has yet to reach the water that it will eventually pollute. Indeed, a nitrate legacy may exist beneath many of Europe's fields that future generations will have to pay to clean up.

Removing nitrates from water to make it fit for drinking is expensive. To make it fit for public supply, water contaminated with nitrates is often diluted with cleaner water from other river or groundwater sources. Denitrification of UK drinking water already costs some EUR 30 million a year, and capital spending in the next two decades to meet European standards could cost the country 10 times as much.

It is generally much cheaper to prevent nitrates from reaching the water in the first place. A review of the possible costs to farmers makes an initial estimate of EUR 50–150 per hectare per year to alter farming methods to comply with nutrient management standards under the EU nitrates directive. This is considerably cheaper than the cost of removing nitrates from polluted water. Moreover, changing farming practices puts the responsibility on the farmers who caused the pollution, rather than on the consumer.

In 1991, the EU introduced a nitrates directive, aimed at stemming the flow of nitrates into the natural environment and drinking water. Member States are required to designate nitrate-vulnerable zones where the risks are highest and to impose strict controls on nitrate use in those areas.

Implementation of the nitrates directive across Europe has been generally poor. However, the synthesis of Member States' reports for 2000 concludes that 'Member States have in the last two years shown a real willingness to improve implementation. They realise that costs induced by drinking water treatment for nitrates excess, or by eutrophication damages in dams or coastal waters will still increase, and that the investments dedicated to urban wastewater treatment will be inefficient regarding nutrients if a parallel effort is not devoted to an effective reduction of agricultural nutrients losses'.

Nitrate pollution can be tackled at source. In Denmark, for instance, a national nitrate management plan began in the 1980s, before the directive came into force. It offered advice to farmers on making efficient use of fertilisers and imposed annual nitrogen 'budgets' on farms. It has substantially stemmed the leakage of nitrate from Danish farming systems.

The patchy implementation of the nitrates directive has been reflected in a patchy pattern of trends in nitrate pollution across Europe. Average nitrate concentrations in European rivers are falling. However, while 25 % of monitoring stations have shown a decline since 1992, 15 % have shown an increase. The most marked reductions have been noted in Denmark, Germany and Latvia, with additional success stories noted in regions, including the Algarve and the east of France, where intense field controls, including soil analysis, have accompanied the dissemination of good-practice advice.

The story for coastal waters is more complex, often because of complicated interactions between the riverine and marine environments. There has been a decrease in measured concentrations of both phosphorus and nitrogen in Dutch coastal waters since 1991, in line with reduced loads in the river Rhine. In Denmark, where reductions in discharges began earliest, there has been a 40 % reduction in the marine nitrogen load around Danish shores since 1989.

5.10 Summary and conclusions

The quality of river water across Europe has improved thanks to a range of EU environmental directives since the 1970s. Water abstractions have also been in decline. However, pressures from agriculture, urbanisation, tourism and climate change suggest that guaranteeing water quality will continue to be a costly issue.

Future demographic and economic trends are likely to increase water consumption by households and for tourism-related use. Northern Europe is likely to see substantial reductions in water withdrawals as power stations switch to new technologies. However, overall use could rise if climate change leads to greater demand for water for irrigation.

In southern Europe, higher temperatures are likely to increase the need for irrigation of crops, so there is a strong case for substantial improvements in the efficiency of irrigation systems. Among new EU Member States and candidate countries, water use is expected to increase, especially in households as living standards improve, suggesting scope for using technologies and market measures to manage demand.

Water quality is most severely affected by pollution from households, industry and agriculture. For the past 15 years, the main focus has been on point sources of water pollution, such as households and factories, with good results. Today, approximately 90 per cent of the population in north-west Europe is connected to sewerage and treatment plants. Nevertheless, many EU-15 countries have not yet complied fully with the UWWT directive and the new EU countries still have many years of effort ahead of them.

Treating wastewater is expensive: the EU-15 has spent around 0.8 per cent of GDP on it. Approaches which combine avoiding pollution at source, through charges, with targeted construction of treatment plants offer a cost-effective solution to implementation. Under the EU cohesion policy, new EU countries are eligible for considerable subsidies over the next decade or so to assist with wastewater treatment. Guidelines would help to steer new member countries towards a policy of charges paid for by polluters linked to EU funding for treatment plants.

As point sources of pollution show a marked improvement in terms of impact on water quality, diffuse sources of water pollution, particularly from agriculture, will dominate future water policy. Diffuse sources of water pollution are by their nature less obvious and harder to police than point sources, and this will have an impact on the success of the required legislation.

Fertiliser application for arable farming is the main source of diffuse pollution to water, with nitrates the greatest problem. Nitrate pollution is higher in the EU-15 than in the new Member States. In some parts of Europe these problems are expected to get worse before they get better, especially in groundwater where it can take decades for nitrates to reach drinking water zones. Cleaning up nitrate pollution is estimated to be around 10 times more expensive than preventing pollution in the first place through changes in farming methods.

Sustainable management will continue to be the dominant theme regarding freshwater resources. Across Europe, rivers have been canalised, culverted or regulated. Wetlands of national importance have been altered by river engineering. In other words, much of Europe's waterways have been 'managed' in ways that are damaging to the long-term condition of the environment.

The water framework directive, launched in October 2000, aims at achieving good ecological status for all water bodies in Europe by 2015, based on wider ecological principles. There is potential for much greater efficiency in water use through the introduction of market-based instruments (such as water charges and pollution taxes) and new technologies, as well as tougher standards to reduce leakage in water distribution systems.

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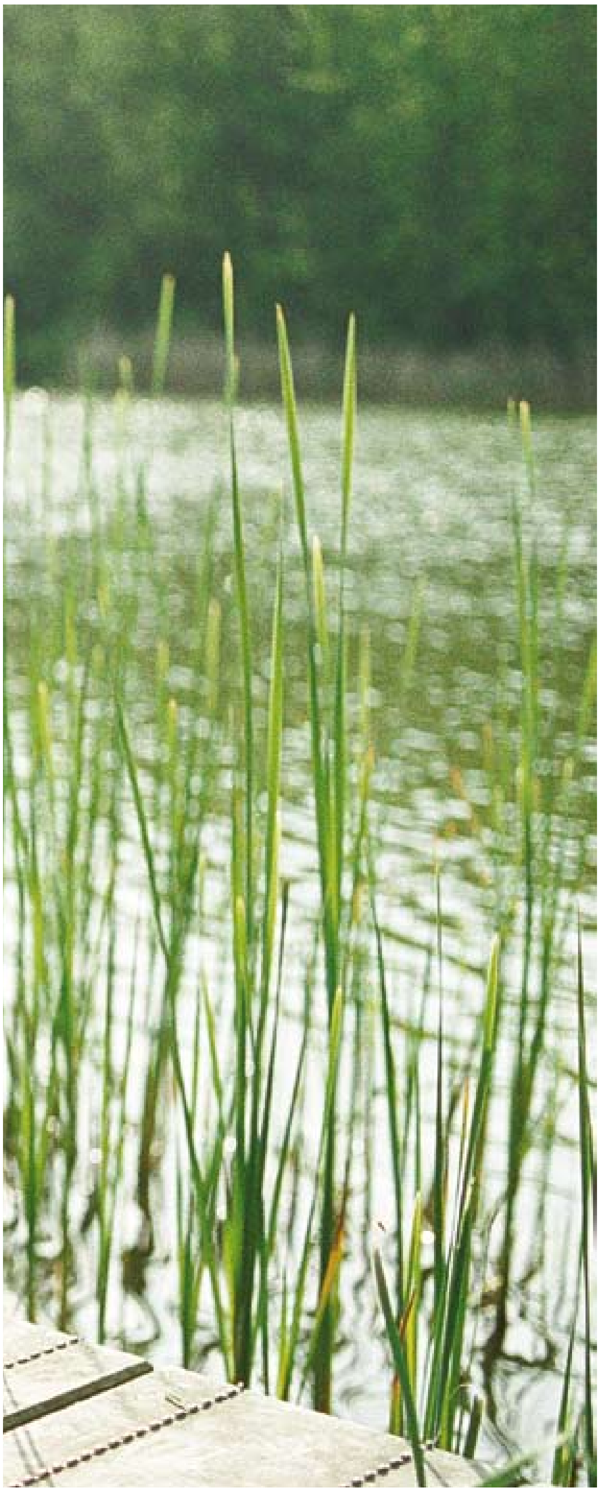


6 Marine and coastal environment

6.1 Introduction

The seas around Europe have been a vital resource over millennia. They provide a wide range of employment and environmental services, including fisheries, shipping and port development, tourism, wastewater cleansing, oil and gas production, aggregate extraction, wind, wave and tidal energy production, and much more. In many coastal regions, fish and marine mammals have been the dominant source of food and their capture the main employment activity. Balanced management of marine and coastal resources can contribute to the objectives of the Lisbon agenda and the longer term aspirations of the EU sustainable development strategy.

Recent results from European scientific programmes such as ELOISE, and from the EEA, have identified a number of key pressures, drivers and impacts affecting Europe's marine environment (Table 6.1). They derive from a variety of land and marine-based activities and the two key global processes of climate change and ocean dynamics.

The pressures arising from these global processes include elevated air and sea surface temperatures, rising sea levels and changing weather conditions. They occur at a pan-European scale but have regionally different outcomes.

The pressures arising from land-based socio-economic activities are of a more regional and local nature. The sources of such pressures include changing farming and forestry practices that alter the contents of run-off water to estuarine and coastal waters. Urbanisation and infrastructure development are changing the natural dynamics of coastal ecosystems as well as increasing pollution from effluents and storm waters. Industrial discharges, mass tourism and maritime trade are other contributors. The extraction of large volumes of aggregates also has a significant effect on coastal systems.

Table 6.1 Major impacts related to main drivers and pressures in the coastal and marine environment

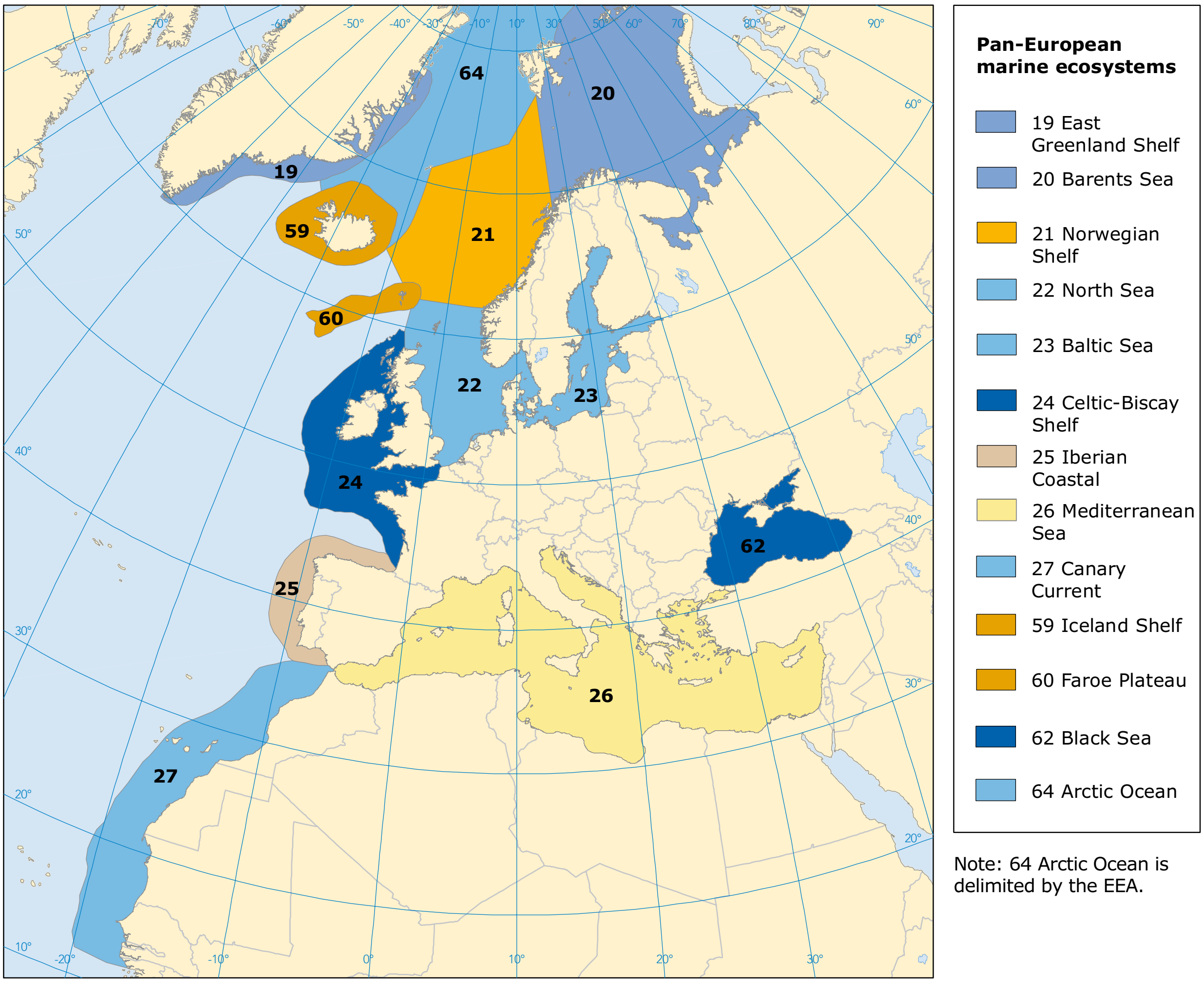
Pressures/drivers	Impacts
Climate change	Erosion, biodiversity loss, increased/changed flood-risk, altered species composition
Agriculture and forestry change	Eutrophication, contamination, biodiversity/habitat loss, subsidence, salinisation, altered sediment/water supply
Urbanisation and infrastructure change	Coastal squeeze, eutrophication, contamination, habitat loss/fragmentation/ human disturbance, subsidence, altered sedimentation, increased flood-risk, salinisation, altered hydrology
Tourism development	Seasonal/local impacts, beach 'management', habitat disruption, loss of species, increased water demand, altered longshore sediment transport, loss of local cultural values
Industry and trade expansion	Contamination, exotic species invasion, dredging, sediment supply/erosion
Fisheries/aquaculture expansion	Species loss/overexploitation of fish stocks, impact on migratory species, habitat loss, species introduction/genetic pollution, contamination, eutrophication
Energy exploitation and distribution	Habitat alteration, altered water temperature, changed landscape/amenity, subsidence, contamination, accident risk, noise/light disturbance

Source: ELOISE, 2004.

Pressures from offshore marine and other coastal activities are equally apparent. Overfishing and aquaculture and the increasing demand for energy are the most pertinent, with relatively new techniques and practices, in particular, threatening marine wildlife populations on an unprecedented scale.

One of the main reasons for the build-up of pressures on the marine and coastal environments stems from

Map 6.1 Pan-European marine ecosystems



Note: 64 Arctic Ocean is delimited by the EEA.

Note: The large marine ecosystems (LMEs) project was created in support of the global objectives of Chapter 17 of Agenda 21, as a follow-up to the 1992 United Nations Conference on Environment and Development (UNCED). Out of the 64 LME defined worldwide, 13 are pertinent to the European environment. Numbering used in the map follows the one used in the LME project.

Source: UN (See www.oceansatlas.org — accessed 12/10/2005).

the fragmented approach to strategic development and management. Without doubt the future health of the marine environment and its living resources now depends upon Europe taking an integrated approach to conservation, management and spatial planning — with the ecosystem at its core (Map 6.1).

6.2 Regional perspectives on the state of the marine environment

The relative strength of the drivers, pressures and impacts varies regionally. This is partly because of the hydrography of Europe's marine ecosystems and surrounding coastal landscapes, and partly because of the socio-economics of the coastal states associated with them.

From both a biophysical and a political perspective, the fact that Europe's ecosystems are so different means that extra efforts must be made to achieve comparable assessments of trends in environmental conditions and policy effectiveness. In particular, existing data and monitoring schemes need to be analysed consistently, in order to be able to detect changes in trends from the various long time series that exist. In this respect the ecosystem approach, proposed in the EU's marine strategy, is vital.

Results are available from a range of analyses of environmental conditions undertaken and variously published by intergovernmental, European, regional and scientific bodies and the EEA. They are presented here in summary for key marine regions: the Baltic Sea, the Barents Sea, the Black Sea, the Celtic-Biscay Shelf Sea, the Iberian Coast Sea, the Mediterranean and the North Seas. Boxes giving further background information for each region can be found across the chapter.

Over the last decade different regions have witnessed significant alterations in coastal morphology, increases in coastal flooding, loss of ice cover, reduced water quality, and declines in biodiversity, living resources and cultural landscapes, as a result of climate change and socio-economic conditions in the coastal zone. There are early signals that Europe's marine and coastal ecosystems are also undergoing structural changes to the food chain, evidenced by the loss of key species, the occurrence of large concentrations of key planktonic species in place of others, and by the spread of invasive species, and caused by widespread human activities.

In the **Baltic Sea** there are continuing problems with eutrophication, anoxic conditions and toxic blooms of algae, overexploitation of both freshwater and marine fisheries, and with alien and accidental introductions of species. To the north, in the **Barents Sea**, ecosystem-wide disturbances have been documented; these have been caused by the decline in capelin due to overfishing and periodic booms in the herring population, and pollution levels from shipping, military activities and oil extraction. Future challenges will arise from the disposal of nuclear submarines and ecosystem changes related to reductions in ice cover and the melting of the permafrost due to global warming.

In the **North Sea** the concerns are those of damage to the food web, threatening globally important populations of seabirds and some commercially important fish species, and the wide range of discharges of pollutants such as nitrogen to water and air from the heavily populated coastal zone and larger rivers. The **Celtic-Biscay Shelf Sea** has extensive fisheries using trawls, gill-nets and long-lines; these together with oil drilling have damaged the rich cold-water coral reefs. The rough sea conditions also mean that coastal ecosystems have been seriously impacted by a series of oil and other discharges, and also make shipwrecks more likely. The **Iberian coastal sea** is heavily influenced by oceanic conditions. As a result, global warming and any alterations to ocean circulation due to climate change will have an effect in the future on the structure of the ecosystem.

The challenges facing the **Mediterranean** are associated with coastal erosion, eutrophication hot spots and toxic algal blooms, low nutrient levels leading to low productivity in the south-east, fisheries by-catches of marine wildlife and invasion of alien species. To the east, the structure of the **Black Sea** ecosystem has been

Baltic Sea

The Baltic is, in essence, a giant brackish fjord 1 500 kilometres long, where freshwater and pollutants from rivers accumulate at the surface, making the waters increasingly anoxic, until they are 'flushed out' every few years by oxygen-rich water from the North Sea.

The Baltic Sea is bordered by Denmark, Estonia, Finland, Germany, Latvia, Lithuania, Poland, Russia and Sweden. Cities on its shores include Gdansk, Helsinki, St Petersburg and Stockholm. The primary human impacts on the sea are overfishing; pollution from the land, including heavy metals, persistent organic pollutants and, particularly, nutrient discharges, arising from agriculture, forestry, urbanisation and industrial developments; changes to the aesthetic landscape and seascape from industrial and energy developments such as wind farms; coastal squeeze and coastal erosion.

The Baltic is particularly vulnerable to eutrophication, partly because it is semi-enclosed and partly because it drains an area of land four times larger than the sea itself. Eutrophication has caused large-scale replacement of coastal sea grasses, important for fish nurseries, with large beds of algae, particularly along the more densely populated shores of the southern Baltic. The associated toxic blooms of algae have caused major losses of fish and disturbed recreational activities.

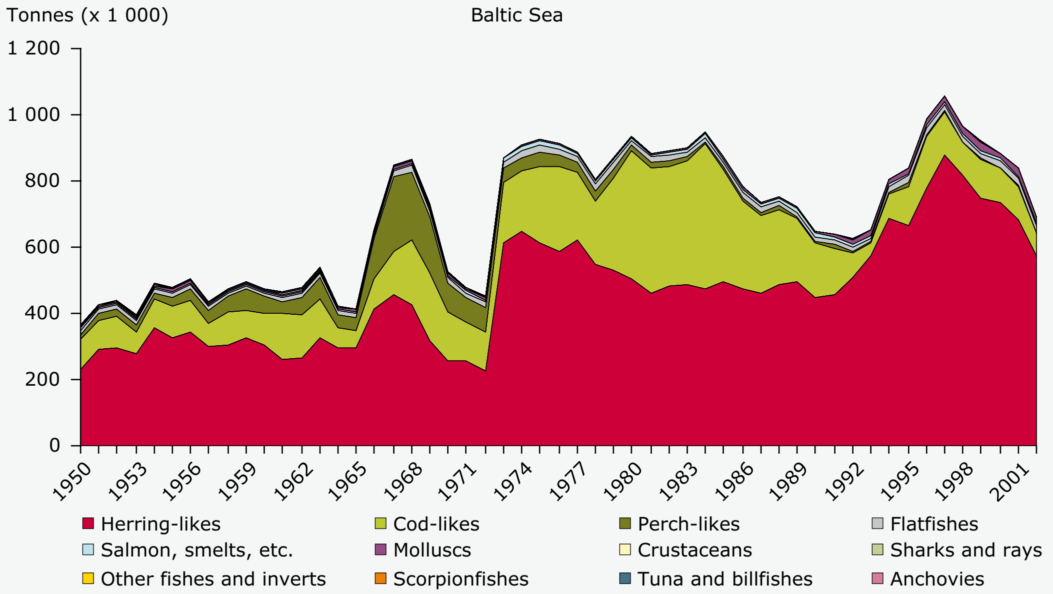
The anoxic conditions on the bottom of the sea seem to be worsening. This is partly due to eutrophication, and partly because of natural variability in weather conditions.

Because of its changing salinity, the Baltic is home to stocks of both freshwater and marine fish. Catches grew through the 1990s, but stocks are now generally overexploited. Most of the catches are small herrings, but there are also significant cod and other marine stocks near the exit to the North Sea and freshwater fish such as salmon in the fresher regions of the Gulf of Bothnia in the north (Figure 6.1).

The ecosystem has been disturbed by hunting for marine mammals, which, along with pollution, has reduced seal populations to low levels. This has left the cod as the main predator in the sea. The cod in turn is now threatened both by overfishing and by episodic events. As predators progressively disappear, other fish species, such as sprat, have grown in importance.

Another problem in the Baltic is invasion by alien species which, together with accidental introductions, is having a direct effect on the viability of native species found only in the Baltic.

Figure 6.1 Landings of main commercial species in the Baltic Sea



Data source: UN Food and Agriculture Organization (FAO): www.seaaroundus.org — accessed 12/10/2005.

Barents Sea

The Barents Sea is a shallow shelf area located between the northern shore of Russia, the southern edge of the Arctic Ocean and the northern tip of the Atlantic Ocean. It includes Svalbard on the far northern edge of the Atlantic and Novaya Zemlya, north of the Urals. The sea receives water from the Pechora and other Russian rivers, and it is strongly influenced by major currents that exchange water between the two oceans. Depending on the season, ice covers between a third and two-thirds of the sea.

The Barents Sea is a highly productive area with strong upwelling and a ready food supply for many commercial species. The food web is dominated by a handful of species: diatoms, krill, capelin, herring and cod. The relationship between these species is highly dynamic. At up to 8 million tonnes, the capelin stock, which feeds on the sea's abundant plankton, is potentially the largest in the world and in the past has supported extensive fishing operations.

The capelin has been in serious decline, partly because of overfishing and partly due to periodic booms in the population of young herring, which eat capelin larvae. The size of capelin and herring populations go up and down like a seesaw. Capelin numbers rocketed after herring stocks collapsed in the late 1960s, but then declined as herring recovered.

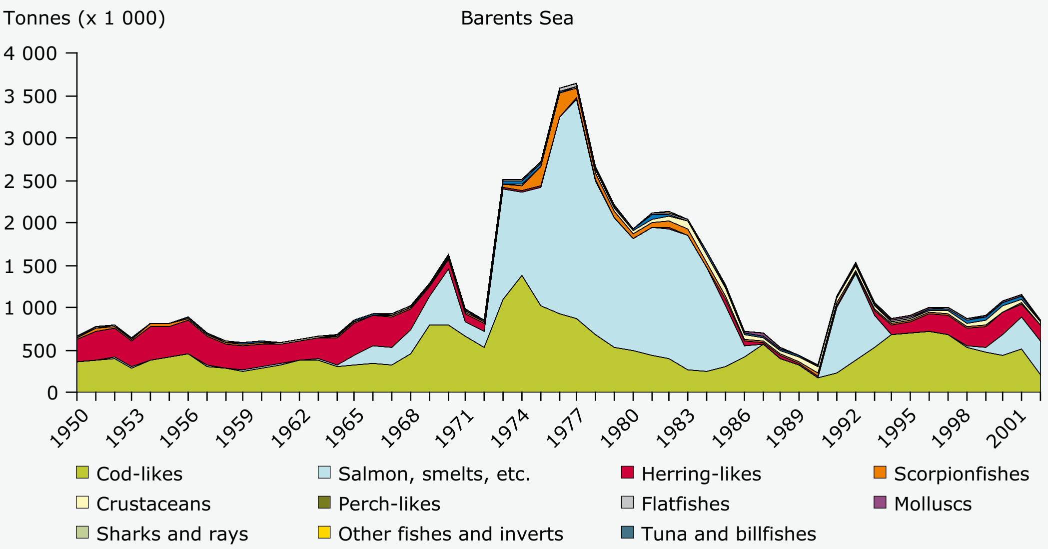
The periodic collapses in the capelin population cause food shortages for other species, including fish such as cod, mammals such as harp seals and birds such as guillemots. When the capelin last disappeared, cod switched to feeding on krill and other species. Seals left the ice and invaded the Norwegian coast looking for food. The birds mostly died.

These switchback changes are a natural phenomenon, probably partly driven by changing inflows of water from the surrounding oceans. They are further affected by fishing, mainly by Norwegian and Russian fleets. Fishing, for instance, caused a crash in the herring population in the 1970s, which saw an overall decline in the sea's fish landings of some 95 % between the late 1970s and mid-1980s. Catches have since partially recovered (Figure 6.2).

In this marine ecosystem and in the deeper waters off east Greenland, Iceland, around the Faeroes, off Norway and Svalbard, large sponge fields with very rich associated fauna exist. So far no detailed records about the impact of fisheries on the benthic community in these areas have been collected, but it is thought very likely that because of their slow growth they take many years to recover after even partial damage.

Pollution levels are not high in the Barents Sea, but there are significant sources present, including onshore oil extraction, shipping and radioactive fallout from nuclear tests and the Chernobyl accident. There is also a lot of military activity, highlighted by the loss of the Kursk nuclear submarine in the eastern Barents Sea in 2000. An expected major increase in oil and gas production in the region is likely to add to pollution risks.

Figure 6.2 Landings of main commercial species in the Barents Sea



Data source: UN Food and Agriculture Organization (FAO): www.seaaroundus.org — accessed 12/10/2005.

North Sea

The North Sea covers some 750 000 square kilometres and, at an average depth of 90 metres, is shallow. From the results of the EU research programme Eurosion, it has been estimated that some 17 million people in nine countries live in the coastal zone under the influence of erosion. The coastline is one of the most diverse in the world, with towering fjords, wide estuaries and deltas, mudflats and marshes, rocky cliffs and sandbanks.

The sea is intensely exploited by European countries for a wide range of resources. These include fish, marine sands and gravels, and the hydrocarbons beneath the seabed, which provide half of the EU's energy needs. It is also a major shipping route, serving world ports like Hamburg and Rotterdam, and oil and gas terminals linked to offshore rigs by pipelines. It provides access to the Baltic Sea, and its narrow southerly exit through the Straits of Dover is one of the most heavily used sea routes in the world.

The ecology of the North Sea has been substantially altered by heavy levels of fishing. Landings are currently at around 2.3 million tonnes a year and include herring, sardine, anchovy, cod, mackerel and haddock for human consumption, along with shellfish and sand eels, which are used as feed for farm animals and aquaculture (Figure 6.3).

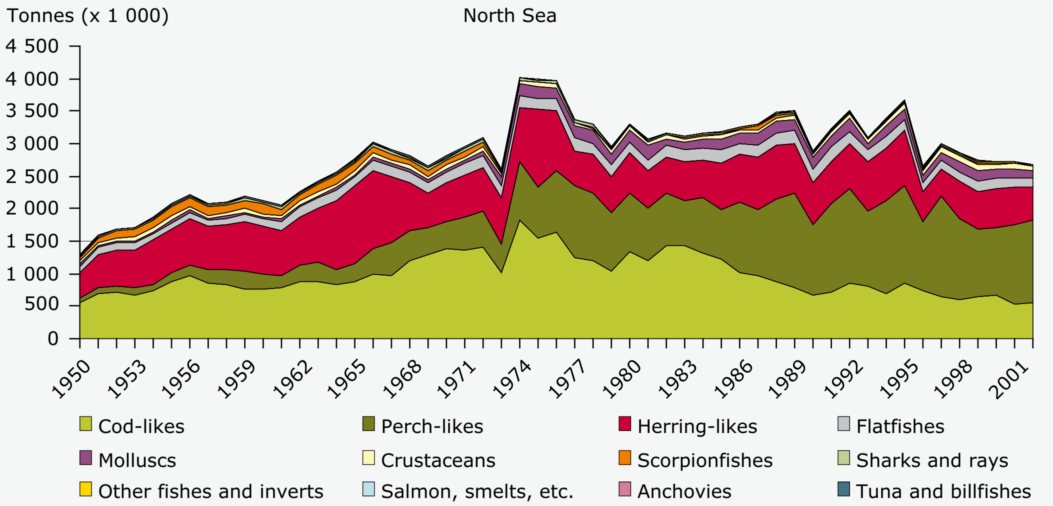
Most fish stocks are overexploited and some are in danger of crashing. As a result of low levels of spawning stocks of North Sea cod, recruitment has fallen from 390 million fish a year in the 1960s and 1970s to less than 250 million in the 1990s. The current low stocks mean that fish are caught younger and smaller, which is economically as well as ecologically bad news. Allowing stock recovery would go hand in hand with bigger profits.

Overexploitation has happened despite progressively tougher restrictions on catches and fishing technology introduced through the common fisheries policy. Overfishing is also damaging the marine food web, reducing its resilience, with sometimes unpredictable consequences for other species.

Those species under threat from the damaged food web include globally important populations of seabirds. A recent crash in stocks of sand eels in the Shetland Islands and elsewhere, principally caused by overfishing, has deprived coastal breeding populations of puffins and other species of a main source of food. More unexpectedly, recent enforced reductions in fishing are also lowering numbers of opportunistic seabirds. This is because some seabird colonies, such as some species of gulls or skua, have grown large by feeding extensively on discards and process waste from fishing vessels. The North Sea's population of skua, for example, has risen 200-fold in the past century.

The sea is a major sink for a wide range of discharges to water and air from the surrounding countries. Pollution to the sea comes from direct discharges from coastal communities and via rivers, drainage from farmland and, to a significant extent, fallout of air pollution. Eutrophication from nitrogen sources in water and air is a major threat. Wildlife also suffers from such pollution as well as from oily wastes and industrial discharges.

Figure 6.3 Landings of main commercial species in the North Sea



Data source: UN Food and Agriculture Organization (FAO): www.seaaroundus.org — accessed 12/10/2005.

Celtic-Biscay Shelf Sea

The Celtic-Biscay Shelf occupies the north-east Atlantic west of Scotland, Ireland, England and France. It includes the Irish Sea, the English Channel and the shallower inshore reaches of the Bay of Biscay off France. It is strongly influenced by currents in the Atlantic itself, including the Atlantic Drift in the north and the Azores Current in the south.

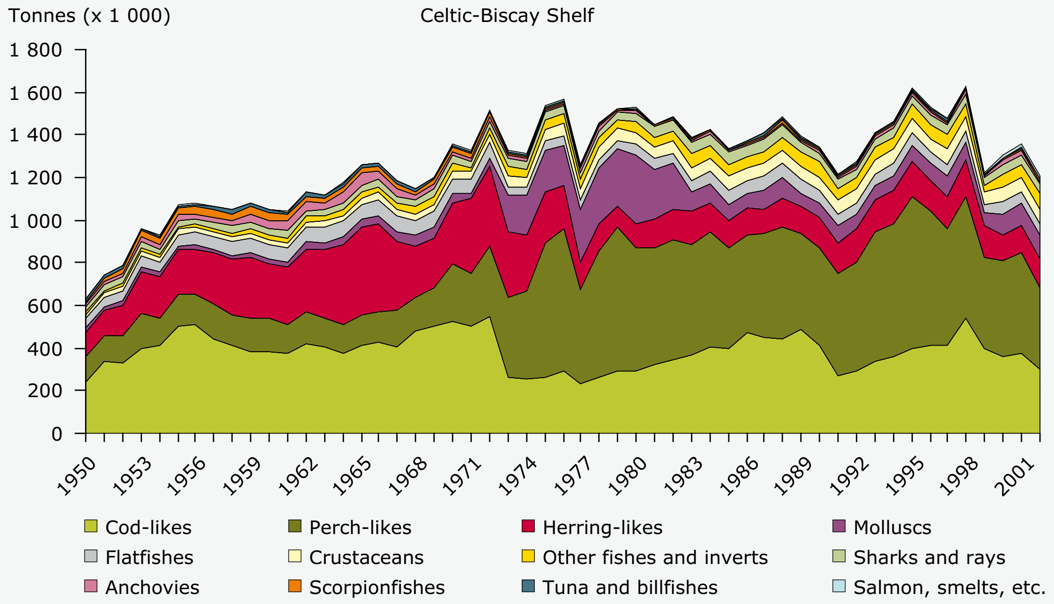
Its conditions are highly seasonal, and it responds strongly to periodic flips in the natural climate system known as the North Atlantic Oscillation. The North Atlantic Oscillation influences sea temperatures, currents and the numbers and distribution of many species of fish, including bluefin tuna and albacore. All this gives the Celtic-Biscay Shelf a high and dynamic biodiversity, much of which is now being actively exploited or has been in the past. Major harvests have included seaweed, whales, molluscs, herring, sand eels and mackerel. Landings of main commercial species have remained fairly constant in recent decades (Figure 6.4).

The shelf includes a number of large sea mounts on which sit rich reefs of cold coral, such as *Lophelia pertusa*. Globally important, cold corals are long lived, slow growing and provide a habitat for other marine species, including commercially valuable fish. The reefs form a chain along the edge of the continental shelf from western France, through high concentrations west of Ireland to a scattering off Scotland.

The waters near the reefs are known to contain unusually large concentrations of flatfish, resulting in their being targeted by fishing boats, often with damaging and counter-productive results. Some reefs have been badly damaged by trawling, as well as by gill-nets and bottom long-lines. The reefs are also at risk from oil drilling.

Pollution is not a great threat out on the shelf, where waves and a strong tide flush away any accidental discharges from ships. Local coastal ecosystems such as estuaries, coastal lagoons and sandy shores, however, can be damaged, and the rough waters make shipwrecks more likely. The shelf has seen a series of oil tanker disasters, including the Torrey Canyon, which ran aground off Cornwall in the United Kingdom in 1967; the Amoco Cadiz, which was shipwrecked off Brittany, France, in 1978; the Sea Empress off Wales in 1992; and the Erika, again off Brittany, in 1999. In each case, the winds and waves brought the oil ashore, and some remains of each of these ecological disasters can still be seen.

Figure 6.4 Landings of main commercial species in the Celtic-Biscay Shelf



Data source: UN Food and Agriculture Organization (FAO): www.seaaroundus.org — accessed 12/10/2005.

Iberian coastal sea

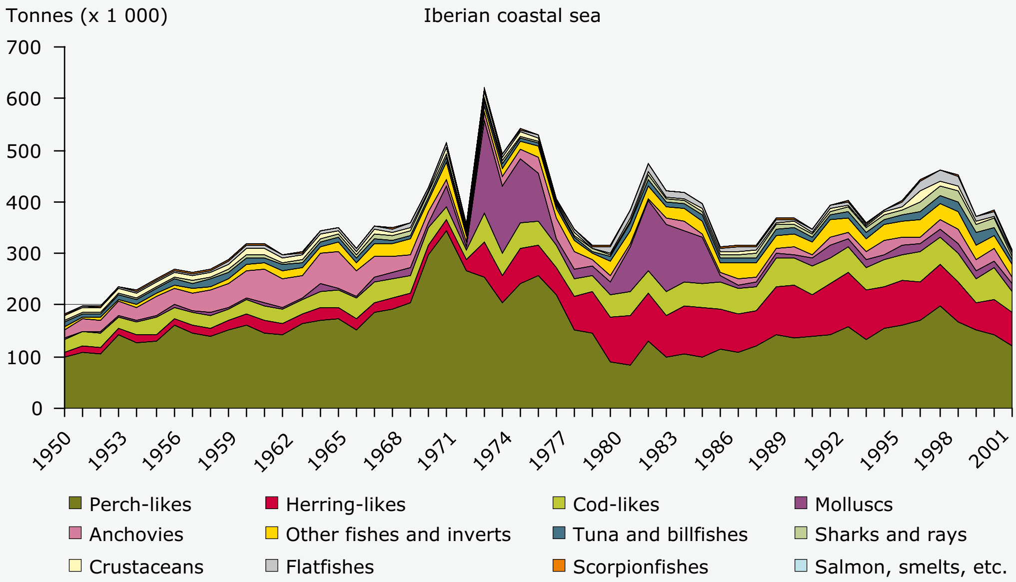
The Iberian shelf region is part of the eastern Atlantic seaboard of western Europe, immediately south of the Celtic-Biscay Shelf. It stretches round the Iberian Peninsula from near the French border to Gibraltar. Much of the coastline is deeply indented with drowned river valleys. The shelf, which varies in width here from 15 to 400 kilometres, experiences intense upwelling of nutrients from the ocean depths in summer, with consequently high biological activity, a rich fishery and abundant marine mammals. This coastline was the original home of the European whaling industry in the Middle Ages.

Like the Celtic-Biscay Shelf, fierce tides and storms make it risky for shipping. The Prestige tanker disaster in 2002 happened in this region, causing massive oil pollution off the Galician coast of north-west Spain.

Commercial fish stocks are dominated by small pelagic fish such as herrings, anchovies and sardines. Landings have remained fairly constant since 1980 (Figure 6.5). Anchovies are a major catch for former whaling ports in the Basque country. The abundance of sardines and other species changes dramatically with the variable ocean conditions, mediated largely through the ocean's influence on the availability of diatoms. Thus the sardine fishery goes through natural periods of boom and bust.

Similarly, in the past, blooms of dinoflagellate algae have been caused by apparently natural variations in oceanic conditions. There is some suggestion that the recent emergence of toxic algal blooms may be a result of eutrophication and the introduction of alien species from discharged ballast water.

Figure 6.5 **Landings of main commercial species in the Iberian coastal sea**



Data source: UN Food and Agriculture Organization (FAO): www.seaaroundus.org — accessed 12/10/2005.

Mediterranean Sea

The Mediterranean has been the transport hub and the fish basket of numerous civilisations; from the time of the Ancient Greeks, through the rise of Venice as the great trading port with Asia, to its modern tourist-based economy. From Spain to Greece, and from Morocco to Turkey, the Mediterranean is bordered by 20 nations. More than 130 million people live permanently along its coastline, a figure that doubles during the summer tourist season. The sea and its shores are the biggest tourist destination on Earth.

Despite covering more than 2.5 million square kilometres, and lapping at the shores of Europe, Asia and Africa, it is largely landlocked. It has a narrow upstream connection through the Bosporus to the Black Sea and almost as narrow an outflow into the Atlantic Ocean through the Straits of Gibraltar. Well-oxygenated Atlantic water flows in at the surface and flows out at depth.

Although in some respects an outsize lake, with virtually no tidal range, the Mediterranean is nonetheless a dynamic sea with wind-driven currents, big seasonal fluctuations in sea temperatures and significant local areas of upwelling that bring nutrients to the surface, especially in the Adriatic.

It also has strong sources of man-made nutrients and other pollutants delivered down rivers such as the Rhône, Po, Ebro and Nile, as well as directly from the numerous large settlements and from the fallout of air pollution over the sea. The combination of nutrient pollution from the Po and local upwelling causes serious eutrophication problems in the north Adriatic in some summers.

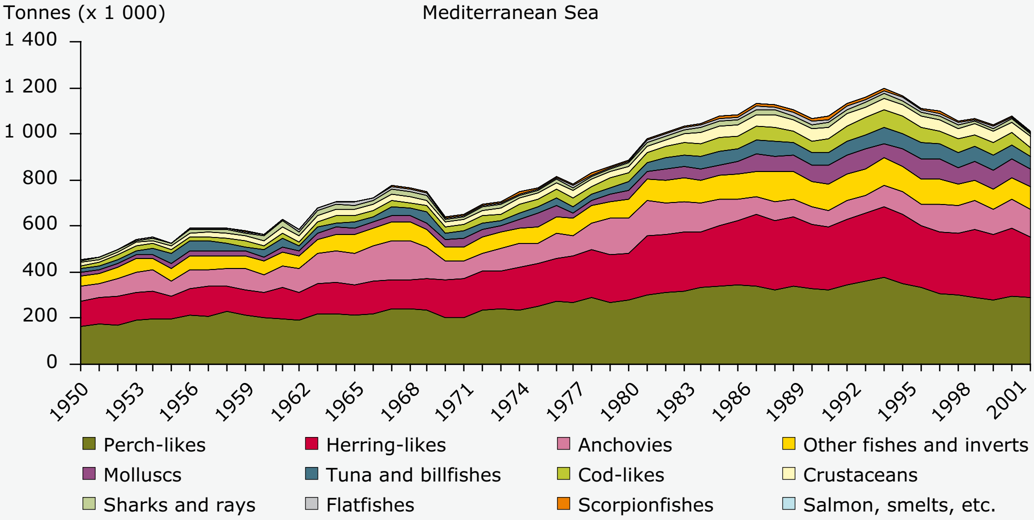
There are other hot spots where nutrients accumulate and cause eutrophication, mostly in estuaries and around coastal population centres. During long periods of summer calm, when the sea becomes stratified and surface water temperatures soar, toxic algal blooms can also form in these areas. In the Adriatic in particular, pollution has damaged fisheries. Toxic algal blooms and de-oxygenation cause occasional fish kills, and from time to time beaches on the Italian Adriatic coast are closed after toxic algae, such as *Ostreopsis ovata*, cause outbreaks of illness among bathers.

Elsewhere, nutrient levels, and consequently biological productivity, are low. This is especially so in the south-east Mediterranean, where natural nutrient sources in silt brought down from East Africa by the River Nile, were cut off following the damming of the river 40 years ago. This has since resulted in the collapse of fisheries in this part of the sea.

Fish catches in the Mediterranean have been fairly stable at around 1 million tonnes for a decade and more, though catches per boat have declined significantly, demonstrating that stocks are under stress (Figure 6.6). Efforts to maintain catches with high-intensity fishing equipment such as drift-nets and long-lines have caused serious problems with by-catches of marine animals such as dolphins and endangered species of turtles. Another major threat to turtles and other marine wildlife is tourism and development activities on nesting beaches.

Human activity and invasions of alien species have also damaged coastal ecosystems on which fisheries depend. A form of algae native to the Red Sea, *Caulerpa taxifolia*, has spread round the Mediterranean from the French Riviera, where it first emerged in the 1980s, obliterating sea grasses and replacing them with largely sterile algal beds.

Figure 6.6 Landings of main commercial species in the Mediterranean Sea



Data source: UN Food and Agriculture Organization (FAO): www.seaaroundus.org — accessed 12/10/2005.

Black Sea

The Black Sea is largely enclosed. It receives two-thirds of its water from the River Danube, and the rest from other major rivers like the Dnieper, Dniester and Don. Together these rivers drain an area of central and eastern Europe 20 times the size of the sea itself. Six countries — Bulgaria, Georgia, Romania, Russia, Turkey and Ukraine — have Black Sea shores, but a further 16 countries form part of the area that drains into the sea. The rivers bring large amounts of pollution into the ill-flushed sea, including nutrients, raw sewage, oil and heavy metals from industry. Beaches are regularly closed because they become unsafe for bathing following the formation of red tides and the build-up of sewage pathogens in coastal waters. Coastal wetlands that once filtered pollution, such as the Danube delta, have been damaged by intensive farming and the construction of navigation channels.

The sea has a low salinity, since its inflows are freshwater, and it exchanges water only slowly with the saline Mediterranean via the Bosporus. The sea is in places more than two kilometres deep, but oxygen is virtually absent below 250 metres. Below this level, comprising some 90 % of the sea's water, is the largest known volume of lifeless, anoxic water on the planet. This is essentially a natural phenomenon.

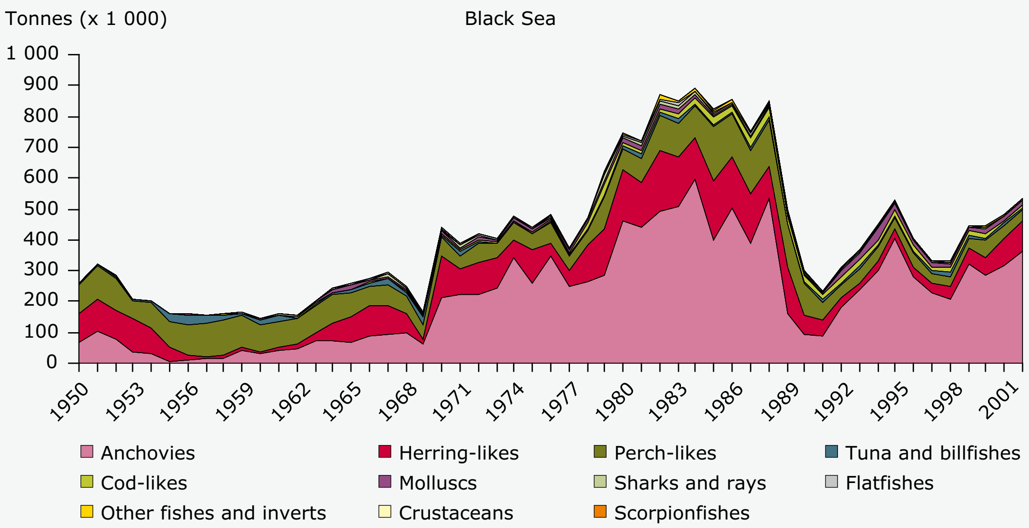
Eutrophication appears to have been a major problem only since the 1970s. Phosphates and nitrates, largely flowing into the sea from the large Danube drainage basin, have reached levels roughly double those of the also-eutrophied Baltic Sea. Eutrophication is thought to have extended the anoxic zone, which now reaches into the shallow north-west of the sea. In turn, the ever larger volume of anoxic water reduces the ability of the sea to purify itself. However, the causal link to nutrient levels may not be so simple. Evidence from a 6 000-year sedimentary record shows that the volume today is the same as then — before extensive human influence.

Combined with overfishing, eutrophication has seriously disrupted the ecosystem. It has increased the amount of plankton in the sea, boosting plankton-eating fish, while decreasing the numbers of species further up the food chain.

These changes have left the ecosystems vulnerable to invasions of alien species. In particular *Mnemiopsis*, a type of jellyfish, saw explosive growth after arriving in ships' ballast water in the late 1980s. It eventually amounted to more than 90 % of the entire biomass of the sea, and caused the collapse of anchovy and chub mackerel stocks, local oyster fisheries and even the indigenous jellyfish. Its spread was only contained with the artificial introduction of a competitor jellyfish; in the past five years there has been a modest revival of anchovy stocks, but not so far of chub mackerel (Figure 6.7).

The sea's most productive area is now the shallow Sea of Azov. However, this too has suffered from a decline in inflows of freshwater as a result of abstractions for irrigation on the River Dnieper. The crisis in fisheries in the sea has had extensive socio-economic consequences with many coastal economies undermined. Fish have also become expensive, with implications for nutrition in communities already impoverished by the collapse of the Soviet system. Meanwhile, the extensive pollution of beaches is undermining intended expansion in tourism.

Figure 6.7 Landings of main commercial species in the Black Sea



Data source: UN Food and Agriculture Organization (FAO): www.seaaroundus.org — accessed 12/10/2005.

disrupted by overfishing which has left it vulnerable to invasions, increased inflows of nutrients and pollution arising from damage to the coastal wetlands, and the extension of the anoxic zone.

6.3 The state of coastal and intertidal areas

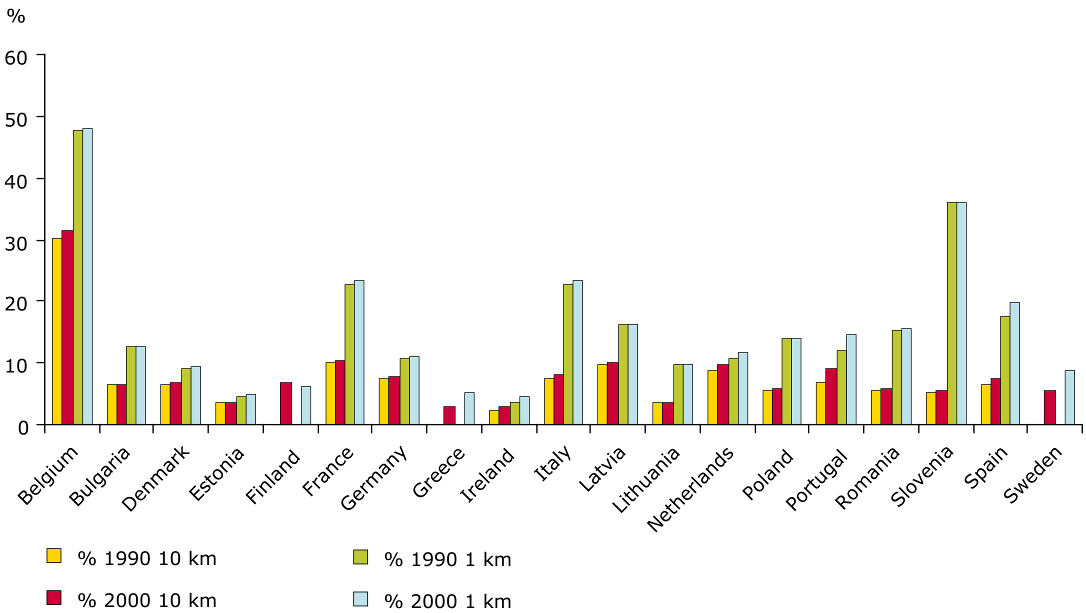
Despite its relatively small geographic size, Europe has a very long coastline, and one that has always proven attractive for settlement. Ports have built up over the ages as centres of trade and industry, and the flat, fertile coastal plains have been the focus of agriculture and convenient land for building and transport infrastructure.

Many of Europe's capital cities are on or close to the coast, including Amsterdam, Athens, Copenhagen, Dublin, Helsinki, Lisbon, London, Oslo, Riga, Rome, Stockholm, Tallinn and Valletta. Altogether there are 280 coastal cities with populations above 50 000. In Belgium, Portugal and Spain, the population density on land within 10 kilometres of the coast is more than 50 % above that further inland. Today, about 70 million of the 455 million citizens of the enlarged EU, i.e. 16 % of the population, live in coastal municipalities, although the coastal zone represents only 11 % of the EU's total area.

In recent decades, the coasts have become a magnet for the tourist industry and for second homes based around fast-growing coastal resorts on the French and Italian Riviera, Greece, southern Spain and elsewhere. The oceans, beaches, dramatic coastlines and clean sea air have emerged as prime environmental assets. As a result, in regions such as Brittany in France, more than 90 % of the entire population lives on the coast.

Figure 6.8 Percentage of artificial coastline length by NUTS3

Percentage of built-up in 10 km and 1 km coastal buffer, by NUTS3 (CLC90 and CLC2000)



Source: Corine Land Cover 1990 and 2000; EEA, 2005.

Today, the coastal strip in many European countries is the fastest growing area, in terms of social and economic development. The Mediterranean coast of Spain, along with Ireland, has the fastest growing population in Europe, with increases of up to 50 % in the past decade. In Spain, 1.7 million houses, mostly sited along the coastal strip, are the secondary residences of Spanish city dwellers or are owned by foreigners, primarily as holiday homes. Other countries with more static populations are seeing considerable migration along the less-populated parts of the coastal zones, such as southern England, the Atlantic coast of France, as well as the coastal areas of Denmark, Sweden and Norway.

This movement of people is being accompanied by extensive development of infrastructure within the 10-kilometre coastal zones of Europe (Figure 6.8). The coastal Mediterranean region, in particular, is now one of the most densely populated regions on Earth, with more than 13 million people from the EU living near the coast. Permanent populations exceed 1 000 people per square kilometre along the French and Italian Riviera.

By one estimate, 22 000 square kilometres of the coastal zones are covered in concrete or asphalt, an increase approaching 10 % since 1990, causing habitat fragmentation and exacerbating the risks of flooding due to soil sealing.

Development is very uneven, however. Land use studies show that the greatest concentration of artificial surfaces in the coastal zone is within just 1 kilometre of the coast itself. In several parts of France, Italy and Spain, such as Andalucia, more than half of this immediate coastal strip is built upon. Two-thirds of this recent increase in artificial surfaces in the coastal zone has occurred in just four countries: France, Italy, Portugal and Spain, with most of the rest in two more — Greece and Ireland.

As a result, natural grasslands and heaths in Greece, Portugal and Spain are disappearing, and Mediterranean coastal forests are under a growing threat from fires originating on adjacent urban land. Wetlands, including marshes, coastal lagoons and estuary mudflats, have also suffered extensively from drainage to create land for development.

Traditionally, many of these intertidal and coastal areas have been regarded as having a low value — almost wasteland. Their environmental services such as nurseries for fishes, crustaceans and birds, salinas, hunting grounds, pollution filters, buffers against coastal erosion, storm surges and saltwater intrusion, absorbers of land-based nutrients and pollutants, and much else, have been ignored by developers and regulators alike. To replace these naturally fulfilled functions would impose an impossible burden on future generations of European citizens.

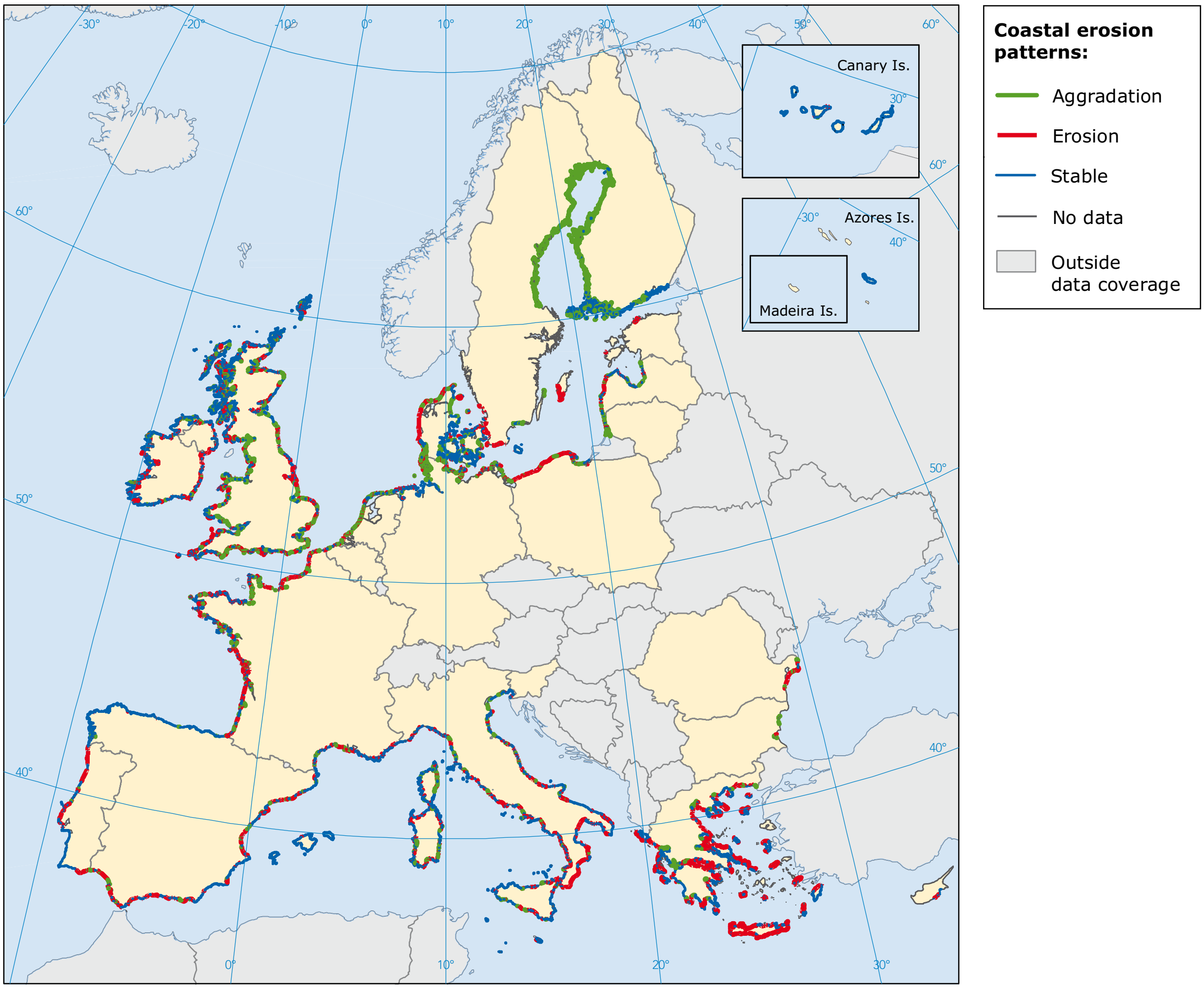
An estimated two-thirds of Europe's coastal wetlands have disappeared in the past century, and the loss continues. There was a net decline in European coastal wetlands of 390 square kilometres during the 1990s. Examples include peat bogs in Ireland and parts of the 200 kilometres of lagoons and salt marshes of the Languedoc-Roussillon coastline of southern France.

Another critical pressure arising from the build-up of socio-economic activities in the coastal zone is the proliferation of engineered frontage, the intensive use of natural shores for recreation and tourism, and the extraction of near-shore sand and gravel for construction purposes, leading in turn to accelerated erosion of the European coastline — one of the most visible consequences of this relentless and silent depletion of the coastal environment.

All European coastal states are to some extent affected by coastal erosion (Map 6.2, Table 6.2). About 20 000 kilometres of coast, corresponding to 20 % of the total, faced serious impacts in 2004. Most of the impacted zones, approximately 15 100 kilometres, are actively retreating, some of them despite coastal protection works along 2 900 kilometres. In addition, another 4 700 kilometres have become artificially stabilised. The area lost or seriously impacted by erosion is estimated to be 15 square kilometres per year. Within the period 1999–2002, between 250 and 300 houses had to be abandoned in Europe as a result of imminent coastal erosion risk and another 3 000 houses saw their market value decrease by at least 10 %. These losses are, however, insignificant compared with the risks of coastal flooding due to the loss of foreshore and the undermining of coastal dunes and sea defences. This threat has the potential to impact on several thousands of square kilometres and millions of people.

Beyond the tideline, Europe's sea grasses have suffered from physical destruction and pollution. Sea grass meadows are vital nurseries for fish and shellfish and provide other important ecological services such as regulating water quality and buffering the coastline from erosion. The pollution threat includes both chemical effects of eutrophication and the physical effect of reducing the penetration of light into surface waters. In addition, alien species can also impact on these habitats: one example is the arrival in the Mediterranean of the algae *Caulerpa taxifolia*, which

Map 6.2 Coastal erosion patterns in Europe



Source: Eurosion, 2004.

has spread round the shoreline, destroying sea grass meadows, since its discovery off Monaco in the 1980s.

6.4 Drivers and pressures affecting marine and coastal areas

Global drivers and pressures

The oceans surrounding Europe play a key role in controlling its climate. Through their immense heat capacity, the oceans effectively act as the 'thermostat' for the planet, moving heat between the equator and the poles; more than 80 % of the heat reaching the Earth's surface from the sun ends up in the oceans.

Chemical and biological activity in the surface waters of the oceans plays a major part in controlling the long-term composition of the Earth's atmosphere, helping to determine the Earth's response to rising levels of greenhouse gases by acting as the largest long-term sink for atmospheric carbon dioxide (CO_2).

It is estimated that gaseous exchange at the sea surface plus biological activity in shallow waters is responsible for about 85 % of the carbon removed from

Table 6.2 Extent of coastal erosion by country

	Total length of the coastline (in km)	Eroding coastline in 2001 (in km)	Artificially protected coastline in 2001 (in km)	Eroding coastline in spite of protection 2001 (in km)	Total coastline impacted by coastal erosion (in km)
Belgium	98	25	46	18	53
Cyprus	66	25	0	0	25
Denmark	4 605	607	201	92	716
Estonia	2 548	51	9	0	60
Finland	14 018	5	7	0	12
France	8 245	2 055	1 360	612	2 803
Germany	3 524	452	772	147	1 077
Greece	13 780	3 945	579	156	4 368
Ireland	4 578	912	349	273	988
Italy	7 468	1 704	1 083	438	2 349
Latvia	534	175	30	4	201
Lithuania	263	64	0	0	64
Malta	173	7	0	0	7
Netherlands	1 276	134	146	50	230
Poland	634	349	138	134	353
Portugal	1 187	338	72	61	349
Slovenia	46	14	38	14	38
Spain	6 584	757	214	147	824
Sweden	13 567	327	85	80	332
United Kingdom	17 381	3 009	2 373	677	4 705
Others (Bulgaria, Romania)	350	156	44	22	178

Source: Eurosion, 2004 (See www.eurosion.org — accessed 17/10/2005).

the atmosphere, with the remainder being taken up by terrestrial plants and soils. Ultimately, this atmospheric CO_2 is captured by the sediments of the deep ocean, but it is a slow process. Removal of the present excess levels of CO_2 in the atmosphere into seabed sediments will take more than 1 000 years.

The oceans are a litmus test of climate change and human-induced changes in the composition of the atmosphere. The effects of climate change on Europe's marine ecosystem can be seen already — in changes to the geographic distribution of species, in local and global species extinctions, through the disruption of critical planetary processes and in the degradation of important flows of goods and services from the more vulnerable ecosystems.

Already the surface waters of the oceans are 30 % more acidic than before fossil-fuel burning began, because of the increase in CO_2, and coastal waters are getting warmer and contain more freshwater as a result of inflows from melting glaciers and ice sheets and increased precipitation at high latitudes. At high latitudes, warmer air temperatures are resulting in significantly reduced sea ice cover in the Barents Sea and Arctic Ocean.

The increase in the acidity of sea water will progressively upset the oceans' chemical balance and possibly eliminate some forms of marine life. The greatest effect will be on organisms with hard shells and skeletons such as molluscs, corals and planktonic coccoliths. Even under the lowest future scenarios for carbon emissions, the cold-water corals in Europe could be virtually gone by 2050.

In European waters there is clear evidence of systematic increases in sea surface temperature, along with the periodic fluctuations associated with major natural climate cycles, such as the North Atlantic Oscillation. The net rise in surface sea water temperature will eventually reduce the oceans' ability to dissolve atmospheric CO_2, and hence the ability of the oceans to act as a sink for increased atmospheric CO_2.

With heat comes expansion, which, together with freshwater inputs from melting glaciers and ice sheets, will mean that sea levels around European coasts will rise, as will the incidence of flooding of some major capitals and cultural centres. Over the last 100 years, sea levels rose by between 0.8 millimetres a year in the western approaches of Brittany in France and Cornwall in the United Kingdom and up to 3 millimetres on the Atlantic coast of Norway. This large range is caused simply by differences in the rise and fall of the land masses.

The rising ocean temperatures also affect the composition, distribution and abundance of marine life, especially in shallow and enclosed seas such as the North Sea. There is evidence from the Sir Alistair Hardy Foundation Continuous Plankton Recorder Surveys that phytoplankton communities, the organisms most responsible for removing CO_2 and nutrients from sea water have shifted their location in relation to temperature changes. The observed changes are greatest in enclosed areas such as the North Sea, where southern species, including sub-tropical fish, have moved northwards by as much as 1 000 kilometres over the past few decades. Warm-water zooplankton such as *Calanus helgolandicus* are now twice as abundant as cold-water species such as *Calanus finmarchicus*. This warming is also believed to be inhibiting the recovery of species such as Atlantic cod, depleted through overfishing.

There is also widespread evidence of an increasing incidence of extreme concentrations of particular phytoplankton — beyond the normally occurring algal blooms— in European coastal waters. These extreme events, which can contaminate food supplies, have been observed in regions such as the Barents Sea, where they were previously unknown.

The Arctic Ocean and surrounding regions are expected to warm the most in response to increases in atmospheric greenhouse gases, with predicted warming of more than double the global mean. The extent of sea ice in the Arctic is dropping at a rate of 3 % of multi-year ice and 8 % of single-year ice per decade, suggesting that the Arctic may become ice free in summer by the end of the century.

The consequences of diminished Arctic sea ice cover for Europe's marine ecosystems are many and are already being observed: key amongst them are changes to the thermohaline circulation in the Arctic and Atlantic Oceans; increases in water temperatures and sunlight leading to significant alterations in primary productivity and potentially fisheries, especially in areas such as the Barents Sea; reductions in habitat for many ice-dependent species, such as polar bears, seals and some marine birds; and impacts on the distribution of marine intertidal species along the circumpolar shores.

Fisheries and aquaculture

European Commission figures show that the EU is the world's third fishing power and the first market for processed fish and aquaculture products. Catches from fisheries in the EU-25 in 2003 were 5.9 million tonnes live weight, representing about one-tenth of the world's fish catch, and from aquaculture 1.4 million tonnes. In 2004, the size of the European fleet was approximately 100 000 fishing boats, with a gross tonnage of 1.8 million.

Europe has taken steps through the common fisheries policy to help some fish stocks, notably cod, recover by reducing the overall number of vessels. However, the high level of employment in fishing — the total for just five European nations, France, Greece, Italy, Portugal and Spain is 190 000 full-time equivalent — means that there are often conflicts between the need to preserve the livelihoods of fishing communities and the recommendations of the scientific advisory bodies.

Successive efforts to rein in fleets have had only modest success in cutting catches of cod and other threatened species, and in reducing by-catches of non-target species. In 2003, the International Council for the Exploration of the Seas (ICES) reported that 61 % of Europe's demersal fish stocks were outside safe biological limits, together with 22 % of pelagic stocks, 31 % of benthic stocks and 41 % of industrial stocks. The situation today has not changed significantly. This is partly because, even though there are fewer vessels, many of them are more powerful, with more efficient fishing practices.

For many years it has been the perception that capture fisheries provide a poorer income than many other industries and occupations. One of the reasons is the peripheral geographical location of many fishing enterprises, and the fluctuations in the size of the landings. However, good returns are available in well-managed fisheries, including those where property rights have been defined in terms of a share of the catch of a species (e.g. individual transferable quotas as in Iceland and the Netherlands) or a limited area of access has been assigned.

Not all fishing enterprises are equally efficient, but the poor returns available from alternative employment in many fishery-dependent areas, and the generally low investment in peripheral local economies, have allowed a longer tail of marginal or unprofitable fishing enterprises to exist than would otherwise be the case.

The fact that the value of the whole production chain — from fishing, aquaculture, processing to marketing — is estimated to be approximately 0.28 % of the EU gross domestic product, and certainly less than 1 % in terms of contribution to the gross national product of Member States, does not reflect its highly significant role as a source of employment in areas where there are few alternatives. The number of fishermen has been declining in recent years, with the loss of 66 000 jobs in the harvesting sector, a decrease of 22 %. There has also been a 14 % decline in employment in the processing sector. In some areas these trends are threatening the viability of small coastal communities in the absence of suitable alternative employment.

The development of aquaculture in isolated coastal communities has had a positive impact on employment. On the west coast of Scotland, for example, aquaculture provides an important source of employment for local people in areas where there are very few alternatives. The EU Aqcess survey has revealed that the main reason individuals began working in fish farming was the lack of alternative employment in the local area: just under 60 % of fish farmers said there were no other job opportunities available to them. This is also the main reason why aquaculture workers stay in the industry despite relatively low pay.

Landings of fish and shellfish from European waters have declined because of the overexploited status of many stocks and tougher controls on overfished zones, especially the fishing grounds in the North Sea and the Atlantic, where stocks of cod, whiting and hake are under threat. The pressures on commercial or targeted stocks also vary considerably across the regions, largely because countries have quite different catching regimes. In Denmark, for instance, an important fraction of landings consists of 'industrial' catches of sand eels and other species for fishmeal and oil; in Spain landings are mainly for human consumption including high-value fish for sale in restaurants.

The reformulation of the common fisheries policy and the development of a European Fisheries Control Agency are intended to rebuild marine fish stocks through enhanced controls, better enforcement, local management and voluntary conservation measures.

In the meantime imbalances between domestic and external demand and domestic supply are largely being met through imports. Improved technologies for low-temperature storage and transport have created new international markets and an increased trade in fish products, with various value-added levels. These developments have also tended to suppress price responsiveness to changes in domestic supply.

The major importers by value are Norway with 21 % of the EU-15 total, Denmark with 16 %, Spain 10 % and the Netherlands and the United Kingdom each with 8 %. The figures are by value rather than quantity, given that the extent of processing varies from none from landings by foreign vessels to the sale of a final product by retailers. The major exporters by value are Spain with 16 %, France 14 %, Italy 12 %, the United Kingdom 10 % and Denmark 8 %.

One of the key drivers in fisheries is, of course, human consumption. The United Nations Food and Agriculture Organization (FAO) has estimated that consumption of fish in Europe is now about 15 % higher than in the mid-1960s. The rate of consumption per capita has remained steady for the EU-15 at 23.7 kg per year. There are wide differences in consumption per capita from country to country, reflecting European demand and widely varying culinary traditions. Overall, total consumption closely follows population size, although there are anomalies. In Turkey, which has the second largest population, consumption was only 8.0 kg per capita in 2000, while in Iceland consumption was 90 kg per capita and in Portugal 60 kg.

Shifts in consumer attitudes and preferences have been an important influence on the demand for fish. Fish is considered a 'healthy' product and has benefited from the trend towards reduced meat consumption as a requirement for a healthy lifestyle. Besides quality and price, consumers are increasingly concerned about how their food is produced. Thus, for example, farmed fish can give rise to the same concerns about the levels of antibiotics in fish products and animal welfare as any intensive livestock production system. The environmental effects of intensive fish farming may also provoke a negative consumer response when chemical additives are used for growth and disease control.

Europe's increasing consumer demand for wild fish means that imports are steadily rising. Imports to Europe increased from 6.8 million tonnes in 1990 to 9.4 million tonnes in 2003.

However, global fish catches have been stalling for some years: declining stocks are defeating the increased investment in fishing. In the longer term the prospect of compensating for the loss of European stocks with stocks from other seas is diminishing.

If European wild marine fish stocks decline, the extra demand for fish will need to be met through marine aquaculture. At present salmon is grown in the Atlantic and Baltic, turbot around Spain, sea bass and sea bream in the Mediterranean and sturgeon in the Black and Caspian Seas. Nearly 8 tonnes of fish are produced annually from aquaculture for every kilometre of coastline in the European Free Trade Agreement (EFTA) countries. Norway is the largest producer with large fish pens moored offshore, mostly holding Atlantic salmon.

Even though aquaculture can take the pressure off wild reserves of high-value fish, it also uses wild fish stocks such as capelin and sand eel to make fishmeal for the caged high-value fish. Marine aquaculture is also a significant source of additional nutrient loading in coastal waters — and disinfectants such as formalin, copper-based anti-foulants and medicines to fight sea lice infestations — and needs to be carefully managed. Average discharges of nitrogen have been calculated at 40 kilograms for every tonne of fish produced. Escapees are also a potential threat to wild populations of fish.

Tourism

The biggest driver of development in the European coastal zone in recent years has been tourism. Europe is the world's largest holiday destination, with 60 % of international tourists, and business continues to grow, by 3.8 % a year. The greatest activity is along the Mediterranean coastal zone, with France, Spain and Italy receiving respectively 75 million, 59 million and 40 million visitors a year. These represent increases of between 40 and 60 % since 1990. France and Spain are the world's top two tourist destinations.

As the big resorts of the western Mediterranean fill up, areas to the east are becoming increasingly popular, including the Greek islands, Cyprus and Malta. Malta receives more than a million tourists a year, three times its permanent population.

Tourism is the largest sector of the economy in many coastal zones, and construction of hotels, apartments and other tourist infrastructure is the dominant form of development. In French coastal regions, tourism provides an estimated 43 % of jobs, generating more revenue than fishing or shipping. This dominance of tourism is reflected in the seasonal changes in population density, with an influx of both tourists and people to work in the tourist industry each summer. Peak population densities on the Mediterranean coasts of France and Spain reach 2 300 people per square kilometre, more than double the winter populations. A further 40 % increase in peak populations is expected in the coming 20 years.

The expansion of tourism extends beyond the Mediterranean, however. The Atlantic coasts of France and Portugal, the southern Baltic coast and parts of the Black Sea coast are all seeing expansion. Other coastal areas, such as either side of the English Channel, remain popular visitor destinations and conference venues. Tourism is expected to continue to grow, though potential brakes on this could emerge from higher temperatures, fires and droughts, and a desire by tourists for emptier and less-developed resorts.

Tourism is now having a major environmental impact on many coastal areas. Besides land-grab, its demand for resources and need for waste disposal facilities cause pressure on water resources and natural coastal habitats and structures such as wetlands and sand dunes. Demand for water in Malta doubles during the tourist season; on the Greek island of Patmos, it increases sevenfold. Many regions, including Spanish resorts and Malta, are running out of water and are resorting to investment in desalination of sea water.

Tourism can, however, sometimes have a positive influence. Increasingly, tourists demand high aesthetic standards, including clean beaches, scenic beauty and amelioration of urban areas. They also provide the income for investment in clean-ups and other environmental measures.

Nature conservation

Nature conservation is an important and growing element in the coastal and marine environment. Significant areas of coastal wildlife habitat have been given protection through the EU Natura 2000 network (Figure 6.9) and there is much discussion about the efficacy of marine reserves as a tool for helping overexploited fisheries to recover.

Some countries have significantly more land designated as Natura 2000 sites in coastal zones than in the interior. They include Poland, with four times more, and Germany, Lithuania and the Netherlands, and Belgium, France and Ireland, all with at least twice as much. Habitats protected include lagoons and deltas, sandbanks and dune systems, mudflats, estuaries, reefs, sea grass meadows and small islands, as well as coastal grasslands and forests. Countries with markedly less protected land in coastal areas than elsewhere include Greece, Italy and Spain.

As evidenced in the EU Biomare project, which documents marine sites around Europe suitable for long-term monitoring and observation, ecotourism and nature conservation are providing protection for some of Europe's more pristine areas.

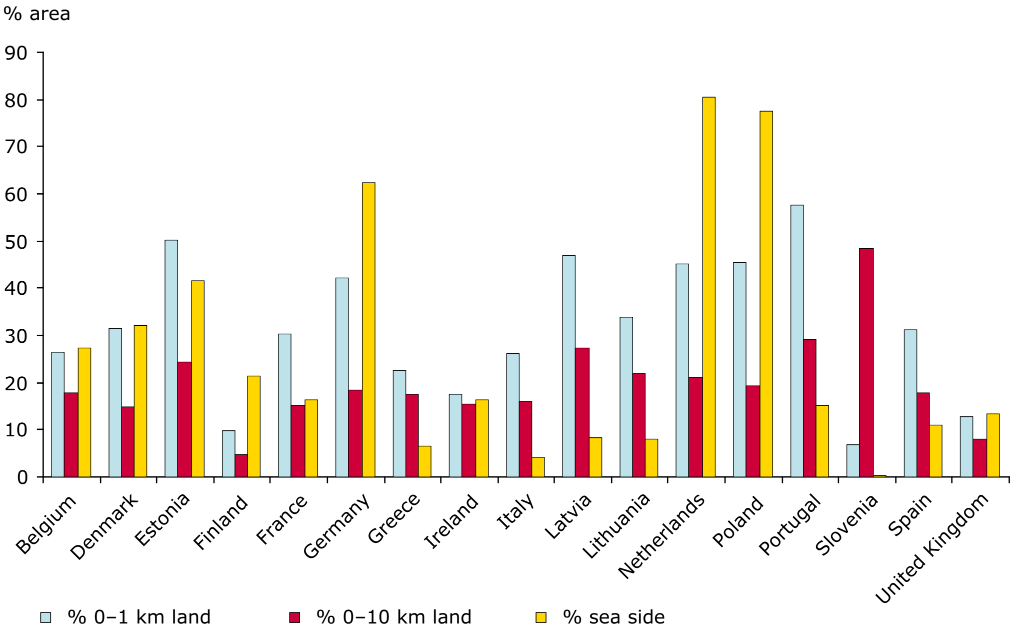
Industry, energy and transport

Many industries are located on the coast, close to port facilities, with access to transport routes for supplies of raw materials, shipping of products and often large land areas. Currently, almost one in five European industrial facilities is on the coastal strip, with a third of the total clustered round the North Sea in Denmark, Germany, the Netherlands and the United Kingdom. Often these industrial complexes are built on 'reclaimed' mudflats in estuaries, replacing ecosystems of value for birdlife and other intertidal species.

Coastal zones also attract industries connected directly with marine activities, such as dredging of sand and gravel, cable laying and offshore exploration and construction. Energy facilities are also concentrated in the coastal strip. These include oil terminals, plant and pipelines connected with offshore oil installations in the North Sea, the Adriatic and elsewhere; large fossil-fuel and nuclear power plants supplied with fuel from ships or pipelines and taking advantage of sea water to provide cooling; and coastal energy plants using wave and wind power.

The conflict between visually intrusive facilities and the demand for high aesthetic standards and healthy coastal environments is growing. Some evidence of this can be seen in the demand to exploit offshore locations

Figure 6.9 Percentage of coastal surface covered by Natura 2000 designated areas



Note: Refers to 10 km zone for terrestrial and for marine side, respectively.

Source: EEA, 2005.

for wind farms, particularly in north-west Europe, where wind turbines can take advantage of shallow seas.

Although shipping is often ignored in national statistics and has recently been overshadowed by the growth in international air transport, during the 1990s the volume of freight moved by ship between European destinations increased by a third to about 1 270 billion tonne-kilometres, a figure similar to road freight transport. The busiest receiving ports are in Italy, the Netherlands and the United Kingdom. Passenger transport has also increased on many routes. Concerns over high-speed ferries, designed to compete with other forms of transport, are now being raised, especially in the North Sea. The European Maritime Safety Agency has been established recently to deal with this type of issue.

Despite an increase in the marine transport of oil, pollution from oil spills on a worldwide scale has been reduced by 60 % since the 1970s. The worldwide average number of accidental oil spills above 7 tonnes was estimated by the International Maritime Organization (IMO) to be 24.1 per year for the decade 1970–1979, 8.8 per year for the decade 1980–1989 and 7.3 per year for the decade 1990–1999. Nevertheless, major accidental oil tanker spills (i.e. those greater than 20 000 tonnes) still occur from time to time in European waters. In 2000 there was one spill of 250 tonnes (Germany) and in 2001 three spills totalling 2 628 tonnes, including one (Denmark) of 2 400 tonnes.

Agriculture is the sector that, whilst placing significant pressures on the coastal zone, has at the same time suffered most from coastal urbanisation and the spread of tourism. Recent EEA studies have shown that, during the 1990s, some 2 000 square kilometres of high-value farmland was lost in European coastal zones. The process has been most pronounced in Belgium, Ireland, Italy, the Netherlands and Portugal. The greatest loss has been pasture, notably in Ireland and Portugal. Nonetheless, agriculture remains a major user of (sometimes constrained) natural resources and a source of pollution in many coastal areas. In the Mediterranean coastal region, for example, where water is scarce, irrigation remains the dominant use of water, and is one of the reasons why Spain has the largest per capita use of water in Europe.

6.5 Trends in ecosystem health

One of the major difficulties in making progress in the area of coastal and marine ecosystem management and sustainable development is that indicators, targets and assessments for marine ecosystem health are currently very restricted. The European marine monitoring and assessment (EMMA) working group for the European Commission's marine strategy has recognised this. It has identified a number of issues for which a pan-European approach and set of baseline indicators and assessments need to be adopted urgently, either because of the scale of the policies involved (e.g. the common fisheries policies and the water framework directive) or because of the regional and transboundary character of the problems (e.g. invasive species and hazardous pollutants), or both. The issues include: eutrophication, hazardous substances and persistent organic pollutants, problems arising from shipping and oil discharges, overexploitation of fisheries, decline of biodiversity and habitat degradation, emergence of invasive species and threats from climate change, and extensive shoreline and coastal development.

Even without a harmonised set of baseline indicators, it is still possible to detect the early signs of trends which, by their very nature, hint at changes within the marine environment that should not be ignored.

Water quality

European efforts to clean up its surface waters have generally had a beneficial effect on coastal waters. Under the urban waste water directive, river clean-up programmes have been extended to curb discharges to estuaries. This, combined with the controls under the bathing waters directive and others to protect shellfish grounds, has reduced discharges of pathogens, organic material and nitrogen and phosphorus to coastal waters, sometimes 10-fold or more. Compliance with mandatory standards under the bathing waters directive stand at more than 95 % most years, and the more stringent guideline values have compliance greater than 85 % (Figure 6.10).

Bathing water quality is a prime example of how environmental regulation, when combined with effective monitoring and public information, has had a beneficial effect on economies. Failure to comply with the directive has demonstrably influenced tourists' choices of destination, while nominations such as the Blue Flag awards have shown clear benefits.

Concerted efforts since the 1980s have also brought about reductions in oil discharges from tankers, refineries and offshore installations. During the 1990s, Europe's refinery discharges decreased by 70 %. Nevertheless, accidents continue to happen. The break-up of the Prestige tanker off north-west Spain was a major pollution disaster that will have an impact on coastal ecosystems for years. In addition, there are indications of continuing large numbers of illegal discharges of oil from shipping in the Mediterranean and Black Seas, with consequent harm to coastal waters and shorelines.

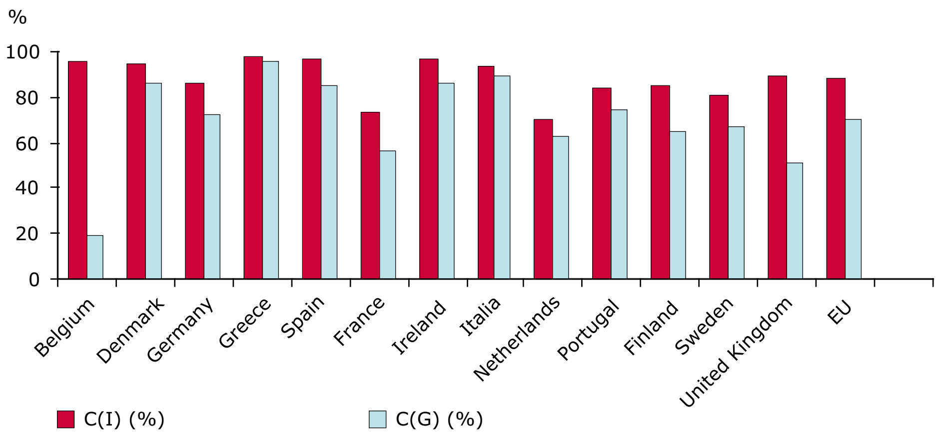
Overall, improvements in the quality of coastal waters have been most marked in north-west Europe and least in the Mediterranean, though here the warm waters naturally destroy pathogens and hydrocarbons more quickly, and the risks of eutrophication are less compared with other badly affected areas in Europe.

Nutrient enrichment is a widespread pollution problem in coastal waters, particularly in enclosed bays and estuaries. It is predominantly the result of nitrogen pollution, and arises from a mixture of run-off of fertilisers from agricultural land, releases from coastal fish farms, air pollution fallout and sewage discharges.

Eutrophication causes changes in marine populations, with diatoms being replaced by blooms of green or blue-green algae. Intense pollution can result in the creation of 'dead zones' in which all the oxygen is removed from the water by bacteria processing the vast quantities of dead algae. Dead zones are normally seasonal, but can have major impacts on fish stocks.

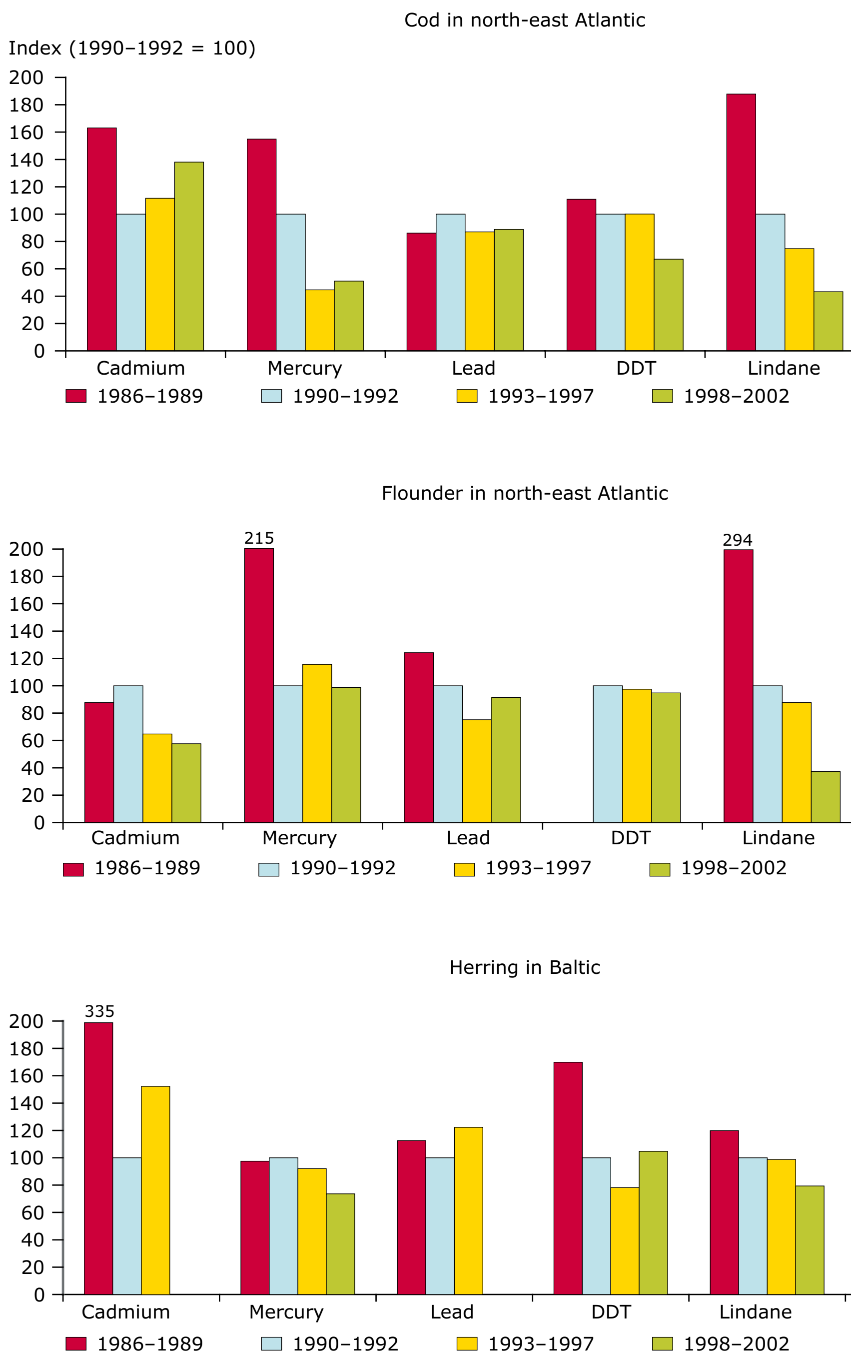
There are long-standing eutrophication hot spots in the Mediterranean, for instance in the Venice area at the head of the Adriatic Sea, and the Gulf of Lion. Others occur in the Baltic Sea, Black Sea, Belt Seas, Kattegat, in the Norwegian fjords and the North Sea's Wadden Sea.

Figure 6.10 **Percentage of bathing water sample points complying with Guide values (C(G)) or complying with Mandatory values (C(I)) — 2003**



Source: European Commission-Bathing water quality database, 2005.

Figure 6.11 Concentrations of hazardous substances in fish from the north-east Atlantic and Baltic regions



Source: EEA, 2003.

More widely, eutrophication of coastal waters also reduces the transparency of the water and causes a decline or shift in life on the seabed. Thus red algae beds disappeared from wide areas of the Black Sea, and sea grass beds from the Baltic. Eutrophication can shift the species balance, favouring shellfish that enjoy sediments rich in organic matter; filter feeders such as mussels and oysters gain over sponges and red coral that prefer clearer water.

Problems appear in most cases to be directly related to the volume of fertiliser use on land. Thus eutrophication in the Black Sea reduced during the 1990s when the economic downturn led to less fertiliser being applied. Reductions were also observed in the Baltic and North Seas following constraints on direct discharges into the Rhine.

Worsening nutrient pollution in the Mediterranean is apparently causing a deterioration in the sea grass beds that once fringed almost the entire sea, much as in the Baltic. The decline is worst around urban areas, such as Alicante, Marseilles and Venice, that discharge nutrient-rich effluents into the sea. Many fish species that use the sea grasses as nurseries are also declining. This ecological disruption has allowed an aggressive exotic weed, *Caulerpa taxifolia*, to spread, apparently after having escaped from aquaria in Monaco.

Industrial pollution

Marine transport has a direct impact on the marine environment through illegal discharges of oil and oily and other waste; the introduction of 'alien' species carried from one marine area to another in ballast water and on ship hulls; accidents resulting in oil spills or spills of dangerous chemicals; the effects of anti-fouling paints on the environment; and disturbance of sediments in coastal or shallow areas.

Environmental issues in relation to maritime transport are considered at both a global level by the International Maritime Organization and on a regional level by several of the regional marine conventions. In the Baltic there is an active programme to minimise the environmental effects of shipping, and maps of the locations of oil spillages observed by aerial surveillance are compiled annually. For the Arctic, a comprehensive assessment of Arctic marine shipping is now to be undertaken, following concerns about the opening up of the Barents Sea. Matters concerning the introduction of alien species via shipping are also reviewed annually.

Heavy metals, pesticides and hydrocarbons are entering the marine environment from air and water run-off and accumulating in marine waters and in the bodies of marine animals — especially those at the top of the food web, such as large fish, marine mammals and some bird species. Typically these substances do not kill but they have subtle effects on fertility, growth rates and health. Enclosed seas such as the Baltic and Black Seas tend to suffer most, because the pollution is not readily flushed to the open ocean. Recent studies by the EEA and the Arctic Council have shown that the problem is being amplified throughout the Arctic food chain amongst both animal and now human populations.

In most cases concentrations of these pollutants in the tissue of fish caught off Europe has fallen in the past 15 years. Cod and flounder in the north-east Atlantic, for instance, have half as much mercury, only a quarter as much lindane and marginally less cadmium than in the late 1980s (Figure 6.11). Trends for lead, the insecticide DDT (dichlorodiphenyl trichloroethane) and PCBs (polychlorinated biphenyls), however, are less clear. Some persistent organic pollutants, though often banned in Europe, continue to be widely used elsewhere and are accumulating in Arctic organisms as a result of global distillation processes.

The Helsinki Commission (Helcom) has reported that high concentrations of pollutants such as dioxins in the tissues of Baltic fish have led to intake restrictions.

Marine sediment balance

The artificial land surfaces proliferating along Europe's coastlines often extend to sea walls, harbours and other structures along the coastline itself. Around 10 % of Europe's coastline is now artificial; in Belgium, the Netherlands and Slovenia, the figure exceeds 50 %. These structures are often necessary to prevent flooding during storms, and to curb local erosion. By stopping erosion in this way, however, the sediment balance in coastal waters is disrupted at the expense of beaches and sand spits elsewhere. Preventing coastal damage in one area can increase damage elsewhere.

Other causes of overall sediment loss in coastal waters include development of upstream dams, which trap sediments as well as water, canalisation of rivers, which reduces bank erosion, and offshore dredging of sands and gravels. For example, the Ebro delta on the Mediterranean coast of France is retreating because dams upstream on the river prevent sediment reaching the delta to maintain it against coastal erosion.

Taken together, these changes to the sediment balance have resulted in an annual loss to Europe's coastal systems of an estimated 100 million tonnes of material. In combination with rising sea levels, this has resulted in around a fifth of Europe's coastline suffering significant erosion, with coastlines retreating by an average of between 0.5 metres and 15 metres a year.

Any future rise in sea levels will dramatically increase the future risk of lost coastal land. The only solution may be to attempt to reinstate natural systems for protecting shorelines. Modern methods of 'soft' coastal engineering attempt to do this by reinforcing natural buffers against the rising tides, such as sand dunes and salt marshes, and protecting key sources of sediment and natural coastal dynamics, such as eroding cliffs, to maintain the coastal sediment balance. In some areas, for instance in parts of eastern England, coastal engineers are deliberately sacrificing land to allow 'managed' coastal retreat.

Fisheries

Overfishing in Europe's waters and the deep ocean has proved hard to tackle. Some fish stocks that have high reproductive rates, in conjunction with reduced fishing pressure, have successfully recovered from past overfishing. Most notable are the herring around Iceland and Norway and in the North Sea. Other stocks are also unlikely to recover. Sharks, skate and rays, in particular, are vulnerable because they produce few young and breed only slowly. Their recent sharp decline in the north-east Atlantic and Mediterranean is unlikely to be reversed quickly. As well as being a commercially targeted fish, these species also suffer from accidental capture, especially in drift-nets and on long-lines.

By-catches and unreported and misreported landings are all major issues that can lead to distortions in fisheries data trends. In many fisheries, between 20 and 60 % (in some even 80–90 %) of the catch is undersized or of non-targeted, non-commercial species. The average discard rate in the North Sea is 22 % of landings. Some of the highest discard rates are for crustaceans and some shrimp fisheries. Off the Portuguese coast there is a discard issue with 'verdinho' — blue whiting — that in Portugal has no commercial value; in contrast, the same fish is being landed in Spanish ports where it has a high commercial value.

Marine ecosystem structure

Fishing rarely makes species extinct, but it can easily eliminate species as significant elements in the marine ecosystem, sometimes with widespread implications for the whole structure. For example, over the past two decades the number of fish species regularly caught in nets in the Black Sea has fallen from 27 to 6.

Large fish at the top of the marine food chain are generally the most valued by consumers; and they are the first to disappear. Thus in the Black Sea the largest, top-predator species such as the swordfish, tuna and mackerel disappeared first. In the North Atlantic, the biomass of these top predators has decreased by two-thirds in 50 years.

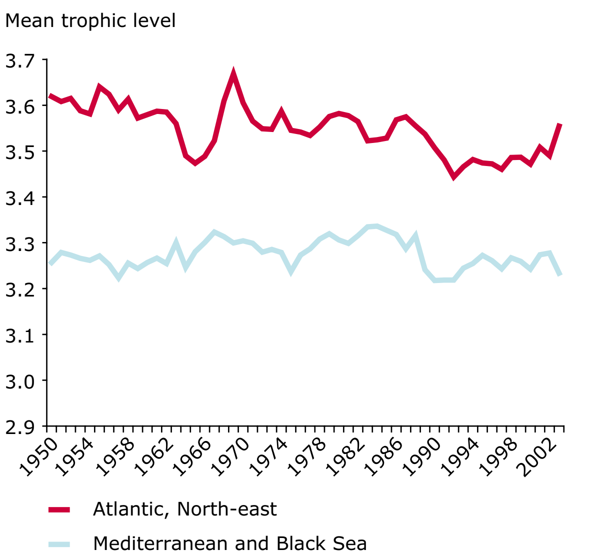
As the big fish at the top of the food web disappear, their places in the ecosystem are taken by smaller species on which they once preyed, such as the anchovy in the Black Sea and the sprat in the Baltic. These in turn become the next target for fisheries, leading to a phenomenon known as 'fishing down the food chain'. One aspect of this is that a growing proportion of fish catches are now of plankton-eaters rather than fish eaters, a trend seen in the Atlantic, and the Mediterranean and Black Seas.

The place of fish in the food chain is measured by its 'trophic level', with the species at the top of the chain having the highest number. Research has shown a steady drop in the average trophic level of landed fish in European waters (Figure 6.12).

As fishing moves to catch second-tier species, other predatory species may emerge, such as jellyfish. These changes have knock-on effects, and can lead to entire marine systems being destabilised. Sometimes, fishing and other environmental damage provides ecological 'space' for new invasive species. The emergence of the *Mnemiopsis* jellyfish in the Black Sea is just one such case.

Other cascade effects reported in recent years by scientists include the impact of fishing pressure on sand eels in the north-east Atlantic. Sand eels are caught primarily for industrial purposes. Their disappearance deprived puffins of their main food item, causing their populations to crash in turn. In the Arctic, a decline in capelin stocks followed a revival of herring, which ate capelin larvae. The loss of capelin in turn left guillemots and several species of toothed whales hungry, causing a 50 % decline in guillemot numbers.

Figure 6.12 Decline in mean trophic level of fisheries landings



Note: The decline in mean trophic levels results in shortened food chains, leaving ecosystems less able to cope with natural or human-induced change. The long-term sustainability of fisheries is, in turn, directly linked to human livelihoods and well-being.

Source: Adapted from Pauly *et al.*, 1998 and updated using Fishbase.

By-catches in fisheries are also a major threat to the survival of some endangered non-fish species round Europe's shores, including turtles and the Mediterranean monk seal. There are fewer than 500 Mediterranean monk seals left, and static fishing gear and abandoned nets are a major threat to their survival. Also in the Mediterranean, more than 50 000 turtles — including the endangered loggerhead, green and leatherback turtles — are caught in nets and by long-lines each year, with death rates in some areas as high as 50 %. Long-lines are also a major cause of seabird deaths in the Mediterranean when birds are hooked as they try to eat bait on hundreds of lines trailing from factory ships. The list of birds includes several endangered species.

Small marine mammals such as dolphins and porpoises are also caught in large numbers. Between a fifth and a half of all the cetacean strandings on the shores of England and Wales are attributed to injury during fishing. The FAO has suggested that the loss may be even greater in the Mediterranean where EU bans on drift-nets are being evaded by fishers switching to similar equipment known as anchored floating gill-nets.

By-catches of dolphins in the western Mediterranean may still exceed 3 000 animals a year, but the true extent of these by-catches and their ecological importance is often hard to establish because of a lack of data. The same applies to so-called 'ghost-fishing', in which discarded fishing gears cause fish mortality.

As catches diminish on the continental shelf round Europe, trawlers are heading into the deep waters of the Atlantic and the western Mediterranean. Here, the problems of species sustainability may be even greater. Deep-sea fish often live in fragile ecosystems where they grow and reproduce only slowly. Any recovery of depleted stocks will thus take much longer, often decades.

Another problem that is clearly underestimated is the by-catch of seabirds diving for food, and becoming entangled and drowning in setnets in the Baltic Sea in shallow waters of 25–30 metres. Helcom calculates this loss of seabirds to be serious, and to amount to several tens of thousands.

Biodiversity and habitats

The percentage of area protected by different conservation measures, such as marine protected areas, varies widely among the marine ecosystems of Europe. The lowest values occur in the Celtic-Biscay Shelf Sea and the Mediterranean Sea, whilst the highest are in the Baltic and the Arctic.

To establish what this means in relation to the progress that Europe is making towards meeting its 2010 target to halt biodiversity loss, an overall indicator of the trends in marine species populations has been calculated in a study for the EEA using the same approach as the WWF Living Planet Index. The indicator integrates trends in different species groups, and can be aggregated across habitats, countries and large marine ecosystems. The analysis uses more than 480 historical trends of populations of fish, marine mammals and reptiles for a total of 112 species. The results show that overall, whilst fish populations have declined, bird populations have generally improved.

Fishing technology can reduce biodiversity not only through altering the trophic dynamics, but also through damage to habitats. One major instance is trawling amongst cold-water corals in the north-east Atlantic and Arctic Oceans. Cold-water corals live around sea mounds, sometimes more than 1 000 metres down. The largest reefs, such as those in the Rockall Trough, Darwin Mounds and Porcupine Seabight areas, can cover some 100 square kilometres. They have been threatened by a move among trawling fleets since the mid-1980s to deeper waters along the edge of the continental shelf, where they catch often uncontrolled fish stocks such as orange roughy, blue ling and roundnose grenadier. Recent research has found extensive damage to cold-water coral off Ireland, Norway and Scotland. Trawling kills the coral polyps and breaks up the vital reef structures that are believed to be important fish habitat and nurseries.

The Norwegian government was the first to protect sea mounds with cold coral, and the EU introduced its own protection regime for key sites in 2003 and a Council regulation in 2004 protecting deep-water coral reefs from the effects of trawling in the area off Scotland. The Darwin Mounds are to become a special area of conservation under the habitats directive.

6.6 Future perspectives

The intense pressure on coastal ecosystems and habitats is being met with strong regulatory responses in areas such as pollution control, but far less action in others, such as curbs on inappropriate development in the coastal zone. A number of studies have shown that poor governance is often linked to a vulnerability towards ecosystem degradation and an incapacity to monitor and regulate. Good governance and harmonised, integrated policy approaches are the only solution: without these, and clear institutional arrangements and coherent management targets, the future of Europe's marine and coastal resources looks highly insecure.

Individual actions at the national level are emerging. For example, recognising that coastal development has cut citizens' access to the shoreline, the Spanish government in mid-2005 announced a plan to buy back buildings that blocked access to the coastline. However, national actions will not be sufficient to match the powerful pan-European drivers and pressures at play around Europe's coastlines and seas.

One of the major difficulties in making progress in the area of coastal and marine ecosystem management has been the general lack of coherent strategic planning at a pan-European level and no political targets, beyond those in the fisheries sector, to conserve or rebuild the health of Europe's marine ecosystems.

The significant impacts of land-based activities on the seas and coasts, and the large number of institutions and organisations involved in looking at only specific aspects of the marine system, has also meant that there has been no agreed set of baseline indicators with which to undertake an overarching integrated assessment of the health of Europe's marine environment.

Now, however, there is widespread agreement amongst all the key organisations and institutions that an ecosystem-based approach needs to be adopted to safeguard and ensure the future sustainability of the marine and coastal environments of Europe. This underpins the proposed European marine strategy, supported through the work of its working group on European marine monitoring and assessment (EMMA).

The ecosystem boundaries, indicators and future targets will be defined according to a range of criteria, including the status of the biological resources, oceanography, integrity of the adjacent catchments and land use patterns, coastal demography, goods and services, governance and political boundaries, monitoring schemes and consistency with international norms.

If approved, the marine strategy will enable Europe to develop an integrated response to the major drivers and pressures — such as coastal development, fisheries, industry, shipping, aggregates, oil and gas extraction — that act regionally and globally and are without question transboundary in nature. It will also form the natural underpinning for maritime policies, currently under preparation within the European Commission. So what are the problems that must be overcome?

Most of Europe's marine ecosystems are shared by more than one state. It is therefore essential that there are strong linkages and good governance amongst the states and amongst all the institutions, both formal and informal, which conduct or influence the management, control and regulation of the marine environment.

Over the past century, many different organisations have been established that have undertaken sectoral assessments, monitoring for the protection of the marine environment and scientific analyses of different marine resources. In many cases, the organisations have used different spatial classifications or have developed their own for data collection and assessments. For European seas alone, classifications include the economic exclusive zones (EEZs) of national territories, fisheries zones and ecological regions used by regional fisheries bodies such as the International Council for the Exploration of the Seas (ICES), the North-East Atlantic Fisheries Commission (NEAFC) and the North Atlantic Salmon Commission (NASCO), the 13 Regional Seas programmes of the United Nations Environment Programme (UNEP), and the large marine ecosystems of the Global Environment Facility, the areas applied by the Helsinki Commission (Helcom) and the Oslo and Paris Convention (OSPAR), covering other marine activities such as shipping, oil, gas and aggregate extraction and marine pollution.

Different models of assessment have also been employed, ranging from the maximum sustainable yield and spawning stock biomass models in fisheries, to indicator- and risk-based approaches for sectoral and environmental assessments.

Legally, the main treaty that deals with the management of marine resources around Europe is the UN Convention on the Law of the Sea (UNCLOS). This embodies the jurisdiction of coastal states in their EEZs and provides for broader ecosystem management in Article 192 through a general duty to protect and preserve the marine environment from pollution of all sources. UNCLOS also stipulates the duty of interested states to cooperate in the management and conservation of high seas resources.

Equally important as legally binding instruments are the UN Framework Convention on Climate Change, the Convention on Biological Diversity and the Convention on Wetlands of International Importance (Ramsar).

UNEP's Regional Seas programmes are also of significance for Europe because most have a legal framework for cooperation including conventions and appropriate protocols. So, for example, the Mediterranean Regional Seas programme adopted a protocol to the Barcelona Convention on protected areas. Other regional arrangements of this nature include OSPAR and Helcom for the north-east Atlantic and Baltic respectively.

The 1995 UN Agreement on Straddling and Highly Migratory Fish Stocks explicitly calls on states to adopt measures for species belonging to the same ecosystem or associated with target stocks. The FAO Code of Conduct for Responsible Fisheries calls upon states to use responsible technologies and methods with the aim of maintaining biodiversity and conserving population structures, ecosystems and fish quality.

Over and above these, there is a wide range of ministerial, sectoral and non-governmental organisations that collate and produce information on the marine environment. Examples include the North Sea Ministerial Conference, the European Science Foundation, the Joint European Ocean Drilling Initiative, the Arctic Marine Assessment Programme and the UK Offshore Operators Association. Many of these bodies also produce periodic assessments of particular aspects of the marine environment.

It is clear from the reports of all these bodies that Europe's marine ecosystems are facing increasing pressures from an enormous range of land and marine-based activities. Yet despite the fact that at the international level there are many global and regional strategies, recommendations, binding agreements and guidelines, there is little articulation between them at the European level. In Europe there are a number of policies affecting the marine environment, such as the common fisheries policy, marine transport policy, chemicals policy, common agricultural policy, air policy and water policy, but to date none is specifically designed to protect the marine environment. There is no harmonised legislation on marine protection across the Member States. Gaps in knowledge exist because assessment and monitoring programmes are not integrated or complete, and the links between research needs and priorities remain weak.

For Europe's marine and coastal environments to continue to provide real economic benefits to its populations, remain healthy and provide food, resources and cultural support in the longer term, it is critical that a more integrated approach to management and conservation, such as the marine and maritime strategies, be adopted — one that recognises regional differences and vulnerabilities, but applies common principles and measures of progress.

6.7 Summary and conclusions

The seas and coasts around Europe are a vital resource upon which many millions of people depend, both economically and culturally. They also provide a wide range of ecosystem services that are essential to the health of Europe's environment. During the last four decades there has been a significant increase in local and regional pressures on the coastal and marine environments from urban settlement, tourism and industrial development, with the result that many of the improvements in environmental protection and clean-up are being undermined.

There are early signals that Europe's marine and coastal ecosystems are undergoing structural changes to the food chain, evidenced by the loss of key species, occurrence of large concentrations of key planktonic species in place of others and by the spread of invasive species. These are happening as a result of climate change and widespread human activities.

Different seas face both common and unique interconnected challenges, highlighting the value of integrated approaches to solutions. In the **Baltic Sea** there are continuing problems with eutrophication, overexploitation of fisheries and invasive species. In the **Barents Sea**, ecosystem-wide disturbances have been caused by overfishing and pollution from shipping, military activities and oil extraction. In the **North Sea** ecosystem damage threatens important populations of seabirds and some fish species, as a result of a wide range of pollution discharges.

In the **Celtic-Biscay Shelf Sea**, overfishing and oil drilling have damaged rich cold-water coral reefs. In the **Iberian Coast Sea** future alterations to ocean circulation due to climate change are expected to most affect future ecosystem structure. The challenges facing the **Mediterranean Sea** include coastal erosion, eutrophication, fisheries by-catches and invasive species. To the east, the structure of the **Black Sea** ecosystem has been disrupted by overfishing and by damage to coastal wetlands.

The long coastline of Europe is the site of many capital cities and internationally important ports. It is also a magnet for tourism. This has led to the coastal strip being the fastest growing area in economic and social terms. The downside is that intertidal communities of sea grass meadows and coastal wetlands, forests and heathlands have been stripped away by development and intensive foreshore construction.

On a more positive note, discharges to estuaries and coastal areas, including vital shellfish grounds, have improved with high levels of compliance under the urban waste water directive and controls under the bathing waters directive. Nevertheless, eutrophication hot spots and dead zones still remain, and worsening nutrient pollution in some areas has caused a significant deterioration in key habitats such as sea grass beds.

Looking to the future it is clear that the impacts of global warming and climate change will become widespread. They will be exacerbated by coastal development and foreshore engineering. Europe's fisheries will continue to face difficulties in balancing fishing capacity with available resources, given the modest success of common fisheries policy reforms — reducing fleet sizes, modernising vessels and deploying fishing vessels into other areas. Aquaculture, on the other hand, is having a positive impact on incomes as well as helping people to remain in rural coastal areas. Imbalances between consumer demand for fish and Europe's capacity to meet it will continue to create a 'fishy footprint' across the world as demand is met from outside the region.

The largest growing pressure on the coast and intertidal areas is coming from industrial development, tourism and coastal urbanisation. Many highly intensive industrial developments, with associated port and energy developments, are expected in the coming decades. At the same time the coasts of France, Italy and Spain receive nearly 200 million visitors per year and the number of tourists is also expected to rise. Tourism has a significant effect on foreshore development, drainage patterns and movement of sediment, with the consequence that many special conservation sites around the coast will need special attention if they are to be protected.

Often the aesthetic beauty of the sea and coast is an important aspect of tourism, so the expansion of industry along the coastal strip and into the marine area is likely to lead to many conflicts between users. The need for coherent planning is considered by many to be essential in the future development of the marine and coastal environment.

In Europe, there are a number of policies affecting the marine environment, but none is specifically designed to protect the health of its ecosystems. There is no harmonised legislation on marine protection across the Member States. Gaps in knowledge exist because assessment and monitoring programmes are not integrated or complete, and the links between research needs and priorities remain weak. The proposed ecosystem-based approach to management and sustainable development of the EU's marine strategy will enable these issues and others such as eutrophication, hazardous substances and persistent organic pollutants, discharges from shipping, the effects of fisheries, declines in biodiversity and habitat integrity, and impacts of climate change to be properly assessed.

For Europe's marine and coastal environments to continue to provide real economic benefits to its populations, remain healthy and provide food, resources and cultural support in the longer term, it is critical that a pan-European approach to management and conservation now be adopted — one that recognises regional differences and vulnerabilities, but applies common principles and measures of progress towards meeting the Lisbon agenda and other policy targets.

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7 Soil

7.1 Introduction

Soils are as essential to human society as air and water. They are the basis for the production of 90 % of our food, fibre and livestock food. They capture and filter rainfall, delivering it to geological formations on which millions rely for their water supplies. Properly managed soils can also absorb a significant proportion of the carbon dioxide released into the atmosphere from human activity, contributing to the moderation of climate change. A recent study, however, has suggested that rising temperatures are causing soils to unlock larger quantities of carbon dioxide than previously thought, offsetting the reductions achieved in carbon dioxide emissions from other sources.

In many parts of the continent, soils and the environmental services they provide are under threat. Human activity is triggering unsustainable levels of erosion, often combined with chemical contamination and biological degradation. Additionally, good quality agricultural soils are being sealed by the concrete and asphalt of urban and infrastructural development — indeed in some regions, such as the Mediterranean coast, soil sealing may affect large portions of the total land area.

From acid deposition to farming, from landfill seepage to mining, from highway construction to reservoir flooding, and from irrigation to overgrazing, the threats to soils are numerous. Their very resilience often means we do not perceive the damage until it is far advanced. The implications are profound for the habitability of the continent, for, while air or water pollution may disperse in a matter of days, contamination and erosion of soils can take centuries to put right.

Europe already has strategies for managing air and water quality. In line with the general recognition that soil degradation is also a serious and widespread problem, the Commission, as part of the sixth environment action programme (6EAP), established in 2002 a process towards a thematic strategy for soil protection. The soil thematic strategy (STS) identifies eight threats: contamination, erosion, decline in organic matter, compaction, salinisation, landslides, sealing, and loss of soil biodiversity. The first three are considered priorities. Five wide-ranging technical working groups were set up to examine issues of erosion, organic matter, contamination, monitoring, research and sealing, and other cross-cutting issues.

Subsidiarity and flexibility are key words for the new soil directive, which is likely to include common principles and definitions. Different 'working units' (or levels of aggregation) are proposed for different threats. For more local soil threats such as erosion, decline of organic matter, compaction and land slides, the focus of EU policy is likely to fall on the so-called 'risk-areas', to be identified by the EU Member States on the basis of common criteria. For sealing and contamination, the working unit is likely to be defined at the national and regional scale. This is because there is a need for more subsidiarity to handle these threats, due to their stronger links with the national and regional policies.

Work carried out by the technical working groups has brought into focus the paucity of available information on the geographical distribution and extent of soil-related problems, which is complicated by soils' innate heterogeneity. This chapter reflects that reality. The value of soils for sustaining many ecological functions relevant to Europe's economy, and hence competitiveness, in the face of threats such as climate change and extreme weather events is increasingly better understood. This, in turn, underlines the importance of making substantial progress on soils research, monitoring and analysis to provide a better basis for policy actions.

7.2 Erosion

Erosion of topsoil is one of the most widespread threats to the continent's soils, but there is only sparse quantitative information on actual rates and the extent of soil erosion at the European scale.

Soil erosion in Europe is primarily caused by water. It is the result of the physical impact of raindrops on exposed surfaces, combined with the ability of the subsequent run-off to dissolve nutrients and wash away soil particles. In drier areas high wind can be a threat, whipping up dust storms, particularly in finer soils.

According to a recent study called PESERA, undertaken as part of the European Commission's fifth framework programme for research, as much as a quarter of Europe's land is thought to be at some risk of erosion, with the greatest problems occurring around the Mediterranean and Black Seas, in the Balkan Peninsula and in Iceland, which has one of the highest soil erosion rates in Europe. Furthermore, the same study estimates that more than another 10 million hectares of Europe's lands are subject to high or very high risk from erosion with a further 27 million hectares under moderate risk. Countries with the largest areas at risk include Greece, Hungary, Italy, Moldova and Portugal. The PESERA results should be considered with some care. Erosion risk is overestimated in some countries (e.g. Denmark) or underestimated in some others (e.g. Spain) owing to shortcomings either for input data or modelling algorithms. Nonetheless, the results are a useful starting point and there is an opportunity to develop the methodology further so that it can provide a basis on which to build better quality results in future years.

Erosion is a natural phenomenon, of course. Indeed, it is a vital part of the functioning of the biosphere. Sediment and nutrients removed from soils by wind and rain feed life in rivers and the oceans and play an essential role in the natural carbon cycle. In the natural environment, however, those soil losses are counteracted by the formation of fresh soil as rocks beneath the soil are themselves weathered and transformed by groundwaters and the action of soil microbes. Natural factors determining the erosion potential of soil include climate, topography, vegetation and the characteristics of soil, such as how light and friable it is.

The challenge today is that human activity has dramatically accelerated the rate of soil loss. The primary causes of this escalation are the clearance of forests and dense natural vegetation, and unsustainable agriculture, including intensive arable farming and overgrazing of pastures, all of which leave soils exposed to the elements.

Erosion poses serious questions in particular about the sustainability of certain agricultural practices. Since erosion removes organic material from the soil, reducing fertility and productivity, farmers tend to apply more artificial fertilisers to maintain output. However, erosion is a process that feeds on itself as degraded soils become more vulnerable to further erosion.

Eroded soils are less efficient at filtering pollution and capturing water to replenish underground water reserves. Erosion also reduces the ability of soils to capture and store atmospheric carbon. Globally, soil loss over the centuries has reduced the amount of carbon retained by soils by about 100 billion tonnes, equivalent to some 15 years of current emissions from fossil-fuel burning.

In many areas of Europe where soils have been cultivated for long periods, organic carbon content is currently low or very low. Even modest changes in its organic carbon content can cause rapid decreases in the quality of soil structure and biodiversity. The problem is most pronounced in southern Europe, where more than 100 million hectares have an organic carbon content of less than 1 %. Across the whole of Europe nearly 230 million hectares are defined as having this low or very low content of organic carbon in the topsoil.

Soil erosion also causes impacts 'off-site'. Whilst historically deposition of eroded soil material has contributed considerably to the fertility of flood plains, in the absence of expensive dredging, it can silt up river courses and lakes, causing flooding and damaging biodiversity. When reservoirs accumulate silt, they lose water storage capacity and the potential for hydroelectricity generation. The presence of eroded soil in suspension in river systems can also significantly impact aquatic flora and fauna, with serious implications for valuable fish stocks. Erosion may also undermine man-made physical structures such as roads and bridges.

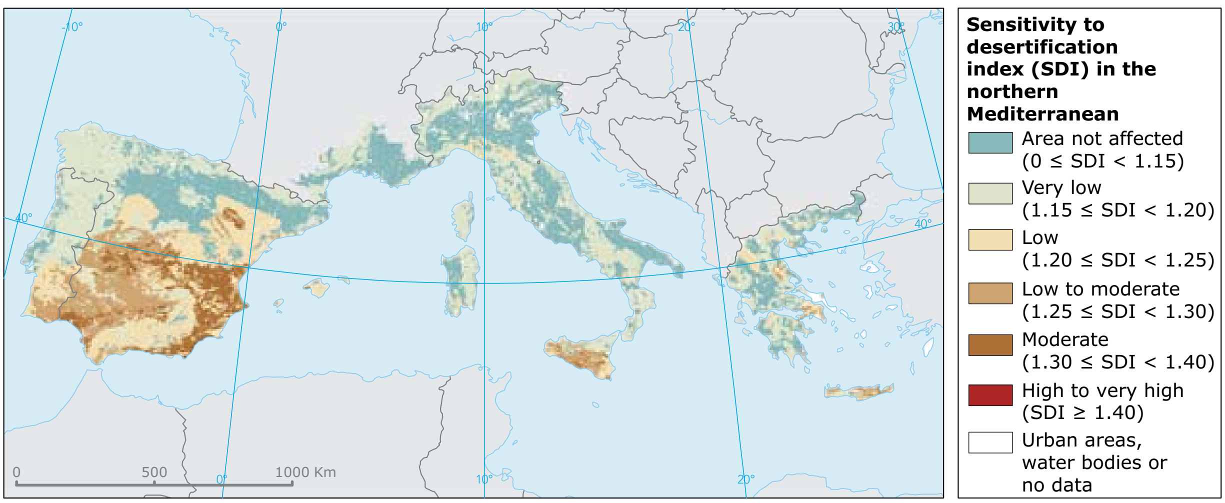
Chemically, soil erosion delivers nutrients that cause eutrophication of rivers and lakes. As improved wastewater treatment across Europe has reduced the releases of nutrients from that source, the contribution of run-off and soil erosion to eutrophication has grown. This is evident, for instance, in two UK lakes, Lough Neagh and Lough Erne, where concentrations of phosphorus have increased in spite of reduced loads from wastewater. These high concentrations were caused by a steady build-up of a surplus and continued re-application of phosphorus (arising from manures and fertilisers) in the soils in the upstream catchments.

Erosion is often seen as a process confined largely to the dry lands of southern Europe, where in extreme cases, in combination with other factors such as climate, the unsustainable use of water and a lack of vegetation, it can lead to 'desertification'. Certainly the problems are intense there. Long, dry periods leave soils vulnerable to erosion. Droughts are often broken by intense storms that can wash away large amounts of soil. Individual storms in the region have been known to remove 100 tonnes from a hectare of land, and more frequently remove 20 to 40 tonnes.

According to the desertification information system for the Mediterranean (DISMED), sensitivity to desertification is not high in Europe in comparison with its neighbouring countries. However, in the areas of the northern Mediterranean for which quantitative data are available, one-third of the territory, approximately 37 million hectares, currently shows a moderate or low sensitivity (Map 7.1). The affected areas increase to more than 70 million hectares if very low sensitivities are taken into account. Southern Portugal, southern Spain, Sicily, and parts of Greece are most seriously affected, where areas with moderate or low sensitivities range from approximately 65 % to more than 85 % of the region concerned.

In addition, the fast pace of current development in southern Europe often results in building on steep slopes that are most vulnerable to erosion when vegetation is removed. For example, this has resulted in a sharp rise in instances of landslides in Italy in the past 20 years, affecting more than 70 000 people and causing economic damage approaching EUR 11 000 million.

Map 7.1 Sensitivity to desertification in the northern Mediterranean



Source: DISMED project (Desertification Information System for the Mediterranean) and EEA, 2005.

Soil erosion is far from being confined to the south of the continent. In northern Europe there are wide areas of light, easily eroded soils, such as in the northern loess zone, stretching from northern France through Germany and southern Poland, and in some parts of the United Kingdom. The most obvious effects are off-site, through eutrophication and siltation of water courses.

Erosion right across the continent is expected to worsen, partly as a result of climate change, which will intensify both droughts and rainstorms. The water erosion risk is expected to increase as a result of climate change in four-fifths of Europe's agricultural areas by 2050, with the deterioration generally greatest in places that already have serious erosion problems.

All this carries major economic consequences, both on- and off-site. On-site impacts are mainly related to the loss of long-term net farm income and the cost of both restoring damage to soil structure and reversing the decline of organic matter. Off-site costs include cleaning roads and dredging eroded sediments from reservoirs used for water supply and the generation of electricity. Further costs could be incurred in restoring the aquatic environment from the effects of eutrophication and in improving the quality of water which has been damaged by eroded sediments.

The European Commission is currently preparing a quantification of the economic impacts of soil degradation. Some estimates have already been attempted which provide an indication of the magnitude of the problem across the continent. However, these do not include costs that are not related to current uses of soil or costs which may result from soil erosion but cannot be described in monetary terms, such as the loss of biodiversity or the deterioration of ecosystem health.

One such estimate suggests that the yearly economic losses in agricultural areas are in the region of EUR 53 per hectare, while the cost of off-site effects on the surrounding infrastructure, such as destruction of roads and siltation of dams, could reach EUR 32 per hectare. Data on economic losses due to soil erosion are also available for some countries and regions. In Armenia, for example, the costs of the damage from soil erosion in the past 20 years amounted to 7.5 % of national gross agricultural product.

Older, more limited studies have estimated that fertilisers needed to compensate for the loss of nutrients caused by a single wind erosion storm cost up to EUR 300 per hectare, and estimate the annual cost of short-term wind erosion damage in the Netherlands at about EUR 9 million. Other information is available on economic losses due to off-site impacts — for example, the external cost of water-induced soil erosion in Bavaria, Germany, was estimated in 1991 to be up to EUR 15 million per year.

7.3 Contamination

Soil contamination is widespread across Europe. It occurs both through localised sources of pollution, such as industrial sites, and through 'diffuse' pollution from atmospheric fallout such as acid rain, leaching of farm chemicals and even soil erosion which, as already mentioned, can liberate nutrients.

Local sources

According to the latest estimates there might be more than two million sites across Europe potentially contaminated from localised pollution sources, with an estimated 100 000 considered as needing remediation. The largest concentrations of sites are estimated to be around the old industrialised heartlands of north-west Europe, from southern United Kingdom through north-east France, Belgium and the Netherlands to the Rhine-Ruhr region of Germany. Other places with serious hot spots include the Po valley around Milan in Italy, and the old eastern European heartland of heavy industry known as the 'black triangle', which includes the Czech Republic, Slovakia, eastern Germany and parts of Poland.

Major contaminants include heavy metals, both from factory point sources, spills of mineral oil and from chlorinated hydrocarbons, and the tailings of mining and minerals processing. Cyanide leaks from metalrefining processes are a frequent problem, as are the chemical cocktails left behind by old gasworks.

The tanks of petrol filling stations are one of the most numerous and ubiquitous sources of contaminated soils. Leakage from landfills is also widespread. During the past 30 years a huge range of hazardous chemicals has been variously dumped into landfills without adequate precautions to prevent the chemicals migrating into surrounding soils, groundwaters and surface waters.

Mine drainage waters can contaminate large areas if not properly controlled. Recent examples include the Aznalcóllar mine disaster in Spain in 1998, which affected soils and the water course for 60 kilometres downstream, and the cyanide spill from a tailing treatment plant at the Baia Mare gold mine in Romania in 2000.

As former industrial land may be abandoned, problems are often hidden. The soil beneath former transport depots and railway sidings sometimes harbour a

Table 7.1 Remediation actions for soil contamination in some European countries

Country	Year	Policy or technical target
Austria	2030–2040	Essential part of the contaminated sites problem should be managed.
Belgium (Flanders)	2006	Remediation of the most urgent historical contamination. New contamination to be remediated immediately.
	2021	Remediation of urgent historical contamination.
	2036	Remediation of other historical contamination causing risk.
Bulgaria	2003–2009	Plan for implementation of Directive 1999/31/EC on landfill of waste.
Czech Republic	2010	Eliminate the majority of old ecological damage.
France	2005	Establish information system on polluted soil (BASIAS) to provide a complete scope of the sites where soil pollution could be suspected.
Hungary	2050	Handling of all sites. Government Decision No 2205/1996 (VIII.24.) adopted National Environmental Remediation Programme (OKKP).
Lithuania	2009	Waste disposal to all landfills not fulfilling special requirements should be stopped. All waste landfills not fulfilling special requirements should be closed according to approved regulations.
Malta	2004	Closure of Maghtab and il-Qortin waste disposal sites.
Netherlands	2030	All historical contaminated sites investigated and under control and remediated when necessary.
Norway	2005	Environmental problems on sites with contaminated soil, where investigation and remediation is needed, to be solved. On sites where further investigation is needed, the environmental state will be clarified.
Sweden	2020	Environmental quality objective: a non-toxic environment.
Switzerland	2025	The 'dirty' heritage of the past should be dealt with in a sustainable way within one generation.
United Kingdom (England and Wales)	2007	At a political level, the Environment Agency aims to substantially remediate and/or investigate 80 Special Sites identified under Part IIA Regime (Environmental Protection Act 1990).

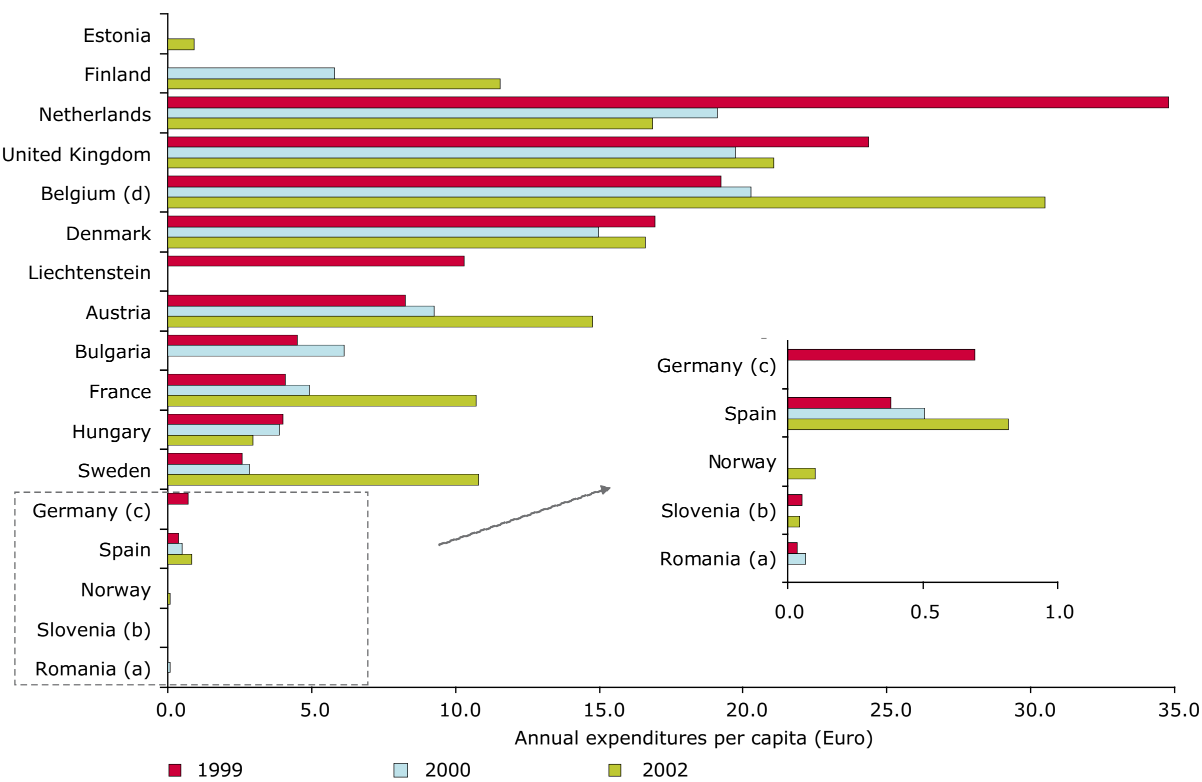
Source: EEA, Eionet priority data flows, 2003.

variety of contaminants that may be hard to predict. Military installations have also often dealt with many hazardous materials, including radioactive materials, without keeping public records. The worst problems on military sites are likely to be in central and eastern Europe. In Estonia, almost 2 % of the land comprises abandoned military land operated in the past by the forces of the former Soviet Union.

In the Balkans, land has been recently contaminated by warfare, including as a result of North Atlantic Treaty Organisation (NATO) bombing during the Kosovo conflict of 1999. This left behind depleted uranium and released toxic chemicals, including mercury and dioxins, from bombed factories. However, it has often proved difficult to distinguish between pollution caused by the bombing and pre-conflict contamination. To make matters worse, large, mainly agricultural areas will remain unusable until the de-mining process has been completed.

Some national assessments have found the major sources of local soil contamination to be municipal waste landfills, industrial plants and handling losses at

Figure 7.1 Annual expenditure on contaminated site remediation by country



a) Romania: data from 1997 and 2000.
b) Slovenia: data from 1999 and 2001.
c) Germany: projection from estimates of expenditures from some of the 'Länder'.
d) Data for Belgium refer to Flanders.

Source: EEA, 2005.

current and former industrial facilities and distribution centres. Frequently the scale of contamination only emerges when old sites are zoned for redevelopment.

Recent EU legislation, based on the application of preventive measures, should avoid new contamination. Waste disposal is more strictly controlled, accidents and handling losses should be greatly reduced, and, in the event of mistakes, records and the chains of public accountability will be much clearer.

Nonetheless, there is a huge legacy of past contamination which is likely to extend its reach with time, as the flow of water through soils can spread the contamination both laterally beyond the site boundaries and vertically into groundwaters. Some of these contaminants are effectively permanent, though others — such as some organic pollutants and radioactive wastes — will degrade with the passage of time.

Remediation remains patchy and European targets are yet to be developed, although the majority of European countries have established national actions to deal with the problems (Table 7.1). Some have taken a proactive stance, mapping former industrial and waste sites and investing large amounts in cleaning up or containing leakage — often linked to policies of redeveloping 'brownfield' former industrial sites in preference to annexing farmland. National annual expenditure on remediation also varies, with national expenditures ranging from a low of EUR 2 to a high of EUR 35 per capita (Figure 7.1).

Most countries have now also put in place legislative instruments which apply the 'polluter pays' principle to cleaning up contamination. However, in many cases the polluters have long since disappeared, so in practice a considerable share of remediation is paid for with public money, on average about 25 % of total costs. Still, the amount of money spent on remediation is relatively small (8 %) compared with the estimated overall costs. New techniques for remediation, such as 'bioremediation' — in which micro-organisms are used to biodegrade organic compounds or hyper-accumulating plants are used to reduce the heavy metal content of soils — hold out the prospect of reducing costs. Nevertheless, the applicability of these techniques is expected to be limited and so the legacy of contaminated sites will remain dauntingly large for some time to come.

Diffuse sources

Diffuse pollution of soils, although probably not as critically widespread as local contamination, presents an even larger problem of accountability and clean-up. Nonetheless, few densely populated areas are without their contamination hot spots. In Lithuania, a country of 6.5 million hectares, almost half the land is contaminated by heavy metals.

Acidification

The most widespread form of diffuse contamination in Europe arises from acid deposition, especially in northern and central Europe (see Chapter 4). Some soils can neutralise the acidity, but many, particularly the thinner and naturally acid soils of northern Europe, cannot. Acid rain leaches vital soil ingredients such as calcium and magnesium from soils and can liberate toxic metals such as aluminium which can then build up elsewhere to toxic levels.

Overall, acid deposition has been reduced in recent years by more than 50 % across Europe. Although sulphur emissions may be much reduced, those of nitrogen remain high, not only increasing acidification in places but also adding to the ecological damage from 'over-fertilisation' of soils, often resulting in the eutrophication of water courses. Soil erosion and run-off from fertilisers often intensify this effect.

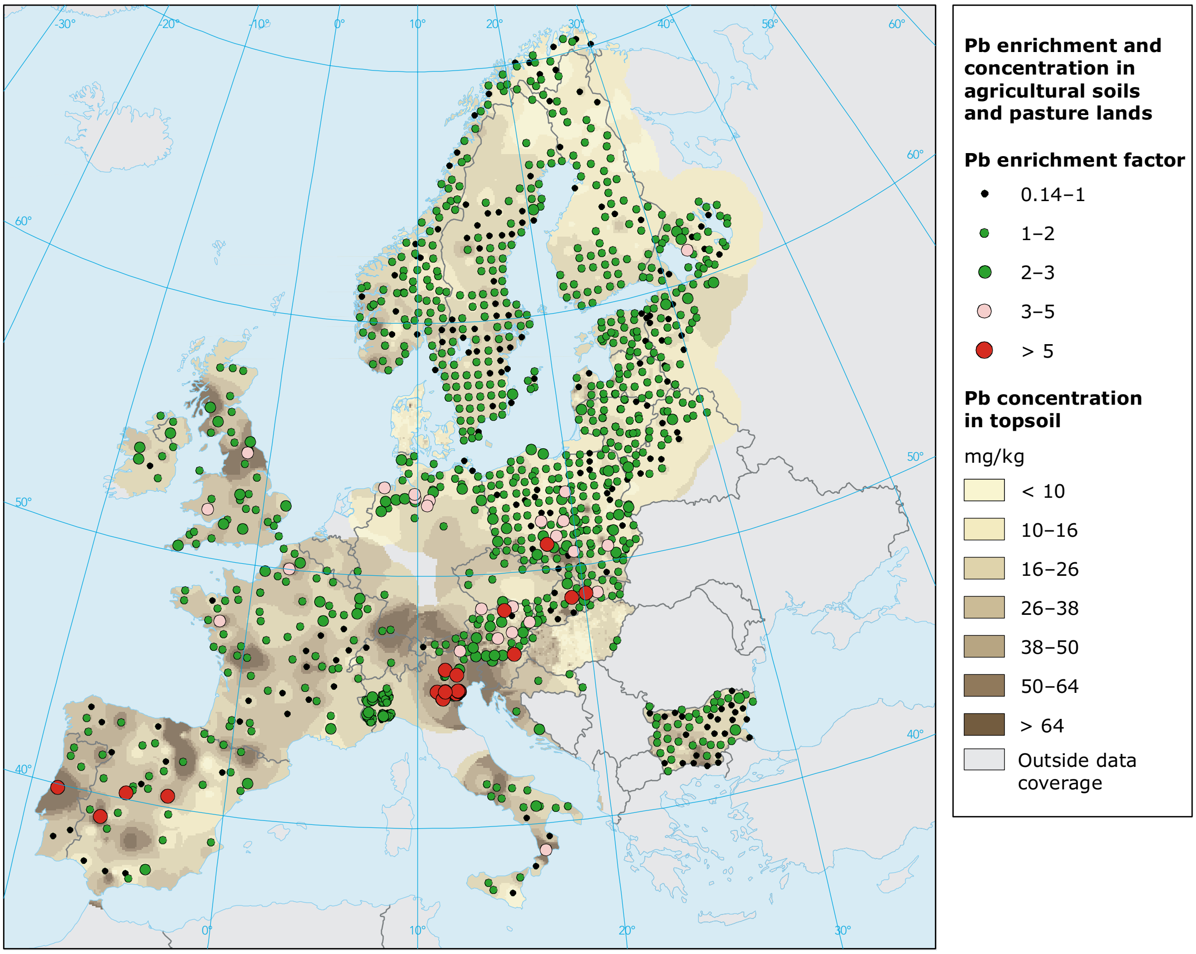
Critical loads for acidification and eutrophication are exceeded across the Benelux countries, the Czech Republic, Germany, Hungary, Poland and Slovakia, as well as in northern France, southern Scandinavia and parts of the United Kingdom. Acidified soils are often all but impossible to rehabilitate. Application of lime will reduce acidity, but the wider geochemical damage will remain. Natural recovery can take hundreds or even thousands of years. Hence, the decline of acid deposition will have only a limited impact in those areas already heavily affected.

Farmland

In parts of Europe such as Belgium, Denmark, the Netherlands and northern France, contamination from aerial spraying of farm chemicals such as pesticides is also a problem, particularly if they percolate through soils into groundwaters.

A study produced for the European Commission as part of the process to develop a thematic strategy on the sustainable use of pesticides identifies the current legal situation on aerial spraying in Europe as very heterogeneous, ranging from a total ban in some countries (e.g. Slovenia and Estonia) and a ban with few exceptions (e.g. Italy) to comparatively weak restrictions (e.g. Spain) and no regulation (e.g. Malta). The study proposes strict minimum requirements for the application of certain pesticides to reduce drift problems, which can affect the health of operators and

Map 7.2 Soil contamination by heavy metals



Note: Only randomly selected enrichment value dots shown for Austria, Bulgaria and Slovakia.

Source: Baltic Soil Survey (BSS), the Foregs Geochemical Baseline Mapping Programme and Eionet,2003.

bystanders, and reduce water contamination, with no significant socio-economic impacts expected.

This proposed measure together with others such as mandatory checking of spraying equipment, integrated pest management and pesticide-free (or pesticide-reduced) zones on land such as Natura 2000 sites, could deliver a reduction of up to 16 % in pesticides use in the mid to long term with consequent reductions in the risks of environment and human health impacts. Farmers would also be expected to benefit economically from these measures with savings on pesticide use more than offsetting the additional costs of maintaining spraying equipment.

Heavy metals from industrial plants are sometimes applied to soils in sewage sludge taken from wastewater treatment works handling effluent from factories. The nutrients in this sludge can improve soil fertility in the short term where nutrients are in short supply, but the heavy metals may accumulate, potentially damaging long-term fertility (Map 7.2). The precise impacts will generally depend on the extent of heavy metal contamination of the sludge. This is limited by the EU sewage sludge directive which prohibits the use of untreated sludge on agricultural land. The directive also limits the rates and longevity of application of treated sludge in areas where fruit and vegetable crops are grown and where animals are grazing.

Less than 5 % of EU farmland is currently treated with sewage sludge, and most sludge contains only tiny amounts of heavy metals. However, the requirements of EU legislation such as the urban waste water treatment directive and the landfill directive, which limit other disposal options for sewage sludge, may tend to increase their application to land. Currently the heavy metal content of sewage sludge tends to be higher in southern Europe.

Other threats

In parts of the Balkans a new form of land contamination has emerged in recent years: landmines. By one estimate, a quarter of Bosnia's ploughed land is mined as a result of the recent conflict. Meanwhile, nuclear power stations, research facilities and weapons manufacturing plants have caused some contamination of European soils with radionuclides.

Most cases are highly localised and a result of spills. The major exception is the fallout from the Chernobyl disaster in 1986, which rained large quantities of radioactive isotopes on to parts of Belarus and the Ukraine. As a result, human habitation is still banned from a 30-kilometre-radius exclusion zone around the accident site because of extensive contamination of soils and ecosystems. It will be many decades before people can return.

Smaller amounts of fallout also fell in rain on Poland, north-east Scandinavia and the United Kingdom, where — 20 years later and more than 2 000 kilometres from the scene of the accident — livestock reared on some hillsides are still checked before sale for radioactivity picked up by the animals from grass grown on soils that remain contaminated.

7.4 Sealing

As soils are sealed off, compacted and deprived of air and water, so most biological activity ceases. There are no precise figures but, across the EU-15, as much as a fifth of the land is used for settlements, industry and infrastructure. In the Ruhr region of Germany that proportion rises to 80 %. Often it is the continent's best soils that are sealed: most population centres and infrastructure in Europe are built on fertile valley soils and around estuaries, typically taking the soils most productive for either agriculture or natural vegetation. Yet soil sealing by infrastructures and urban development is increasing at a faster rate than population, mostly at the expense of arable land and permanent crops, a clear indication of development which is not sustainable.

Between 1990 and 2000 about 50 000 hectares a year were used for housing services and recreation. Overall this represents around half the land area sealed across Europe. This rate of uptake of land for residential purposes varies from more than 70 % in Ireland and

Luxembourg to 16 % in Greece and 22 % in Poland, where urban development is mainly driven by the expansion of economic activities.

Sealing soils increases run-off by eliminating percolation of rainwater underground. It thus contributes to the widely recognised problem of increased storm run-off and flood risks, including mudflows and landslides. It also reduces recharge rates for groundwaters. Furthermore, by reducing the amount of time that moisture spends at the surface before being diverted into drains, soil sealing can also reduce evaporation, thereby influencing local climates.

Some countries have sought to limit the rate of sealing of soils by policies to redevelop existing abandoned sites such as old factories, so-called 'brownfield' development. This can, however, lead to increased localised problems within urban areas as the new developments often result in greater areas of sealed soil than the facilities or derelict land they replace.

Despite such initiatives, soil sealing continues. Typically this is due to changes in human lifestyles, such as suburbanisation and the development of tourist activity, rather than growing populations. Between 1990 and 2000, the built-up area of Europe expanded by about 12 %, while population increased by just 2 % (Figure 7.2). While not all urban land is sealed, it seems likely that more land is sealed for each European inhabitant than ever before. Delving deeper, we can see that the vast majority of this land uptake that results in soil sealing is for housing and recreation, with transport networks also making a contribution.

In Germany, for instance, an average of around an extra 100 hectares of land is converted to settlements and infrastructure each day. Settlements make up 80 % of this, and roads and other transport infrastructure most of the rest. While some of the land remains open — being converted from fields into suburban gardens or roadside verges — around half is permanently sealed. The German Government, mindful of this loss, has set a target to reduce the land lost to settlements and infrastructure to 30 hectares a day by 2020.

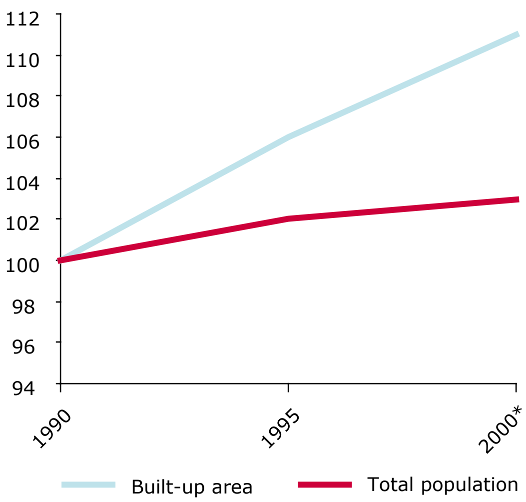
Rates of urbanisation have been greatest in recent times around the Mediterranean coast, including France, Italy, Spain and the islands, and on the French Atlantic coast. Often this is linked to expansion of tourism. High rates of future urbanisation are also expected in Finland, Ireland and Portugal.

Urbanisation and transport infrastructure are not the only causes of the sealing of soils. Others include reservoirs, which flood land, and even mechanised agriculture, which can so compact the soil surface that it becomes impermeable, effectively sealing off what lies beneath.

Recent research from Slovakia has highlighted compaction as the most widespread source of physical soil degradation in central and eastern Europe, affecting more than 60 million hectares. Most prevalent in areas where heavy machinery is used in agriculture

Figure 7.2 **Built-up land and population trends**

Built-up area and population
Index (1990 = 100)



* Data for 2000 or latest available year

Source: EEA, 2004.

and forestry, compaction reduces the air-filled porosity and permeability of soils, increases its strength and partly destroys soil structure. The area affected by compaction is growing as wheel loads in agriculture continue to increase.

7.5 Salinisation

Salinisation of soils is another common diffuse contamination problem. It is caused by the accumulation of salts on or near the surface of the soil and may result in completely unproductive soils.

Evaporation of saline groundwater, groundwater extraction itself and industrial activities can contribute, but salinisation is most frequently the result of poor irrigation practice. Poor drainage and evaporation concentrate salts on irrigated land — even good quality irrigation water contains some dissolved salt and can leave behind tonnes of salt per hectare per year. Additionally, irrigation can raise groundwater to within a metre of the surface, bringing up more dissolved salts from the aquifer, subsoil and the root zone. Unless the salts are washed away below root level, soil salinity stunts growth and eventually kills off all but the most resistant plants. Salinisation has a strong impact on a range of physico-chemical properties of soil and, above certain thresholds, restoration is very expensive if not impossible to carry out. In extreme cases, salinisation becomes a perverse form of desertification brought about through the application of water.

Estimates of the extent and severity of salinisation are not easy to make due to the progressive nature of the process and the difficulty of detecting it in its early stages. However, as much as 16 million hectares or 25 % of irrigated cropland in the Mediterranean may be affected.

7.6 Summary and conclusions

Europe's soil is uniquely varied — more than 300 major soil types have been identified across the continent. Lost soil may eventually be replaced through natural processes of weathering rocks, a process that can take as little as 50 years to produce a few centimetres of new soil in areas with ample rain and organic inputs but thousands of years in mountainous areas such as the Alps. Soil is thus, on the timescales of normal environmental interest, a non-renewable resource.

There are many threats to soil — erosion, sealing, contamination, salinisation. These have proven difficult to tackle up to now and are expected to continue to be a challenge in line with expected future developments in Europe on urbanisation, intensive agriculture and industrialisation/deindustrialisation.

Countries have been taking more and more action, especially on the issue of contaminated sites. Many of the threats to soil, however, are interlinked through the main socio-economic developments (e.g. erosion, compaction, diffuse contamination and salinisation all result from agriculture), and so more integrated and coordinated actions in the future would deliver many positive effects, in a cost-effective way.

There are no overall estimates of the cost of soil erosion, contamination and sealing in Europe. One estimate puts the annual loss to farmers alone at EUR 53 per hectare from erosion, with another EUR 32 per hectare from off-site impacts of erosion, such as damage to infrastructure and siltation of reservoirs. That suggests a cost to non-Russian Europe of around EUR 15 billion a year.

These cost estimates are not insubstantial. In addition, the ecological services provided by soil are under further threat from climate change — desertification, extreme weather events — so the costs can be expected to get higher in the future. This could, in time, have implications for Europe's food security as recognised through the Global Monitoring of Environment and Security initiative established by the European Commission and Member States in 2003.

What is being done? Directives on nitrates, sewage sludge and others will help, as will recent reforms to the common agricultural policy that remove most subsidies from production and move them to other services, including protection of biodiversity and soils. Further, it is expected that the thematic strategy for soil protection and the soil framework directive will facilitate the coordination and implementation of existing but different policies related to soil.

Many data on soil have already been collected by the wide range of organisations which support the numerous different 'users' of soil. Nonetheless, there remain important gaps in the data, and access to them is difficult — few can be directly used for policy purposes and most of them cover small geographical areas.

Progress is being made towards closing these gaps and producing better information to support policy-making, for example by the collaboration on the development of the European data centre, led by the Joint Research Centre in collaboration with the EEA and its Eionet partners, and with the support of other parts of the European Commission. Recognition of the importance of a coherent framework for the monitoring and assessment of Europe's soils, and the streamlining of existing activities, is a significant step towards the success of the thematic strategy and framework directive.

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8 Biodiversity

8.1 Europe's biodiversity: the background

'Biological diversity' is defined by the United Nations Convention on Biological Diversity as the variability among living organisms from all sources including, among others, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems (Article 2 of the United Nations Convention on Biological Diversity, 1992).

The countries of the European Union are home to a wide range of biomes (the basis for ecosystem services) that host around 1 000 species of vertebrate animals, some 10 000 plant species and maybe 100 000 different invertebrates, not including marine species. These are significant levels of species diversity, and yet, in comparison to many other parts of the world, the numbers are relatively small.

This is mostly a reflection of the geological history of Europe. Repeatedly over the past 2 million years, great ice sheets have spread across northern and central Europe, removing soil and vegetation and sanitising the land. Every time, life has had to start again, colonised from warmer areas to the south. The last of these glaciations only ended around 10 000 years ago.

While the glaciations stripped Europe of many of its species, the continent has nonetheless developed a variety of ecosystems. Extending from the Arctic Circle to the Mediterranean and from the Caucasus to the Canary Islands, it is home to permafrost and deserts, dry forests and alpine mountains, semi-tropical lagoons and Arctic fjords, steppe and peat bog. This variety in itself is an important resource and a buffer against climate change, geological disturbances and human disruption of the landscape.

There is a substantial variety of wildlife habitats in Europe. Some habitats harbour endemic species, that is, species that can be found nowhere else on Earth. Some mountain regions of southern Europe, in particular, as well as islands under the macaronesian bio-geographic region (Azores, Madeira and Canary Islands), are rich in endemic plants. Amid the natural conifer forests of the Baetic and sub-Baetic Mountains in southern Spain, for instance, there are more than 3 000 plant species — one of the richest troves in Europe. In parts of the mountains, 80 % of the plants are unique to the area. Almost as rich are the Gudar and Javalambre mountains near Valencia.

Other biodiversity rich spots with more than 1 000 plant species, many of them endemic, include the Pyrenees and the Alps. The highest number of plant and animal species in Europe is hosted in the Mediterranean basin, which has been identified by Conservation International as one of the world's 34 biodiversity hot spots. Particularly rich are the mountains of the Balkans and southern Greece, as well as 5 000 or so Mediterranean islands. These last include the Greek island of Crete, and Cyprus where the Troodos Mountains are particularly rich, with 62 unique species of plants. At a smaller scale, a large number of areas have been identified in Europe as of special importance for particular groups of species such as birds, butterflies and plants.

Most of Europe's land surface has been used for centuries to produce food and timber or provide space for living. Less than a fifth can be regarded as not directly managed at present. Much of that is under pressure.

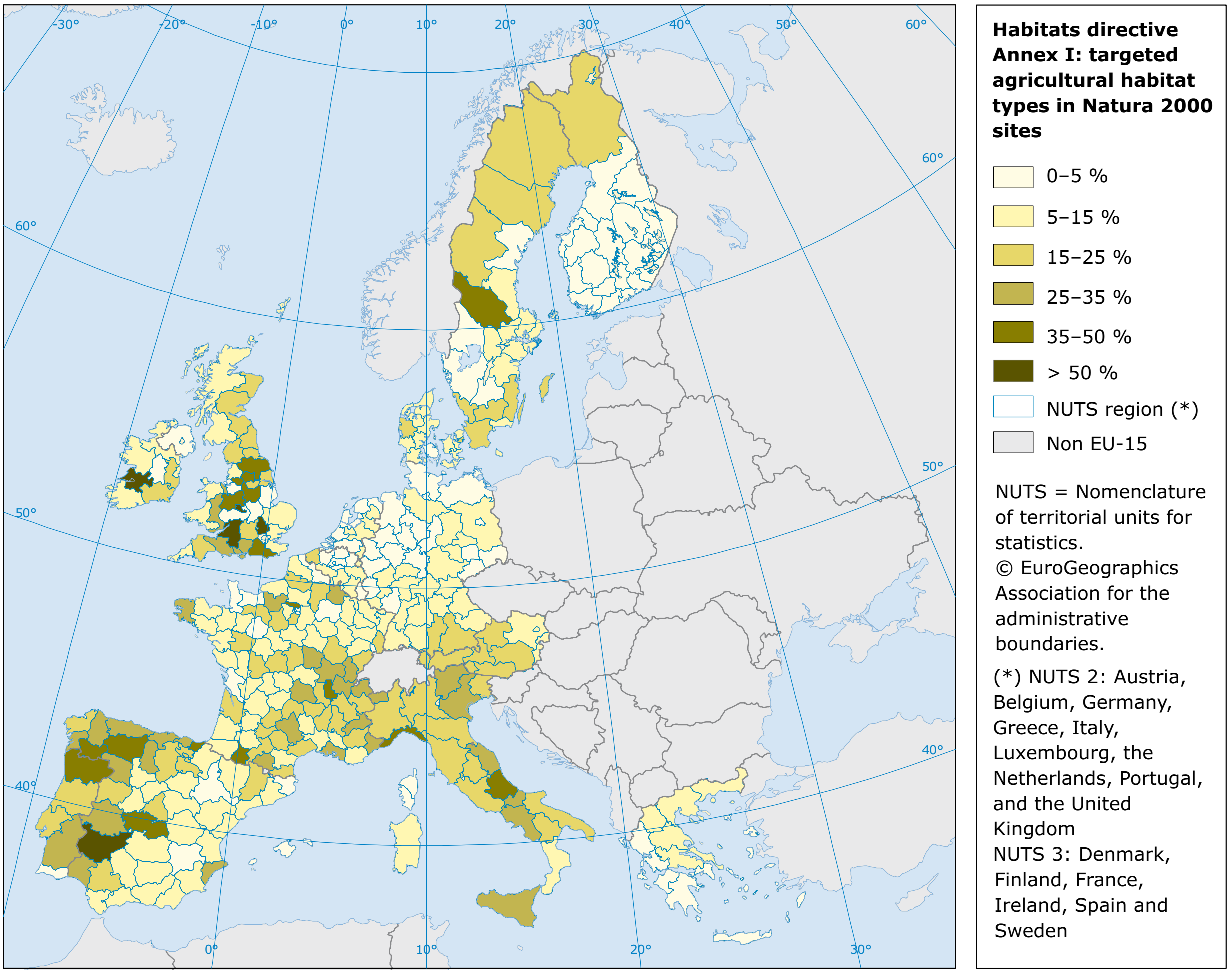
The most habitat-relevant changes in land across the continent during the 1990s were the increases in artificial habitats (5 %) and in inland surface water (some 2.5 %), due to the creation of dams. Losses were identified for heath, scrub and tundra (some 2 %), and wetland mires, bogs and fens, which diminished by 3.5 %. Many of these wetlands have been lost to coastal development, mountain reservoirs and river engineering works. These changes have in some cases caused dramatic changes in landscape character and biodiversity richness.

8.2 The changing countryside: intensive farmland and urban expansion

Europe is unique in global terms because the diversity of its species is to a large extent dependent upon landscapes created by human influence. More than on any other continent, Europe's biodiversity has been shaped by agriculture since the last glaciations. Remarkably few areas of even the highest conservation value are truly natural. A continuation of traditional methods of land management is essential to species survival in these areas.

Europe has some of the oldest and most enduring agricultural landscapes, from the woodlands and olive groves of the south to the reindeer pastures of Scandinavia. Areas defined by ecologists as 'semi-natural' farmland, forest and grassland habitats are home to many of Europe's most valued species.

Map 8.1 Share of targeted agricultural habitat types (dependent on extensive farming practices) within Natura 2000 sites



Source: EEA, 2004.

The largest semi-natural areas are in eastern and southern Europe. They include semi-natural pastures, steppe and dehesas (grasslands with scattered oak trees, typical in parts of Iberia), and mountain pastures. Many of these are under threat and have been given protected status. Central to this protection is the network of Natura 2000 areas designated for conservation under the EU birds and habitats directives. The network is designed to ensure the long-term conservation of the most typical and most threatened species and habitat types and now covers almost 18 % of the EU-15 and is being extended to the new Member States. According to current estimates, 17 % of the sites on the adopted lists are 'agri-ecological' landscapes that depend on the continuation of existing, usually extensive, farming practices to survive (Map 8.1).

The structure and functions of the European countryside are in many places also under threat from a range of developments. The urbanisation of Europe and the intensification of its agriculture, as well as forest management over the past half-century, have caused profound changes to the traditional agri-ecological landscapes and the species that live in them. Emerging new threats include the spread of transport networks and tourism infrastructure, the abandonment of agriculture and climate change.

Urbanisation remains a major threat to habitats across Europe. Suburban sprawl, highways, minerals extraction and industry are spreading across former rural areas. Some 800 000 hectares of Europe's land, an area more than three times the size of Luxembourg, was covered by concrete and asphalt during the 1990s, an increase in built-up area of 5 %.

One feature of this trend is that the traditional sharp divide between urban and rural areas is progressively breaking down. Urban areas are becoming less densely populated as people prefer living in semi-rural and suburban areas — an aspiration more easy to fulfil when households have one, two or even more private cars. The spread of transport infrastructure, as well as directly taking land, has also fragmented the natural and semi-natural areas through which it passes, disrupting migration routes and spreading air pollution and noise.

As suburban zones expand, they become greener, with parks and gardens and golf courses. Equally, in many rural areas, farming ceases to become the dominant economic activity as tourist accommodation, horse stabling, market gardening, theme parks and other land-hungry activities move in. Many farm labourers' houses are taken over by city dwellers as second homes. Even farming areas look very different, with large tracts of soil under glass and plastic.

Coastal areas are being subject to especially intense development, partly as a result of mass tourism. The coastal zones and islands of the Mediterranean, which are especially rich in species diversity, are under particular pressure. Urban sprawl is growing in all countries but most intensively in the Benelux countries, northern Italy, much of Germany, Portugal and Ireland, and around Paris and Madrid. In some cases this process has been stimulated by EU regional development policies.

This process is likely to continue as prosperity grows. The more prosperous EU countries have a larger built-up area per inhabitant than poorer countries. Demographic and social changes are generating a decrease in average household size. Unless development policies change, new EU Member States, which generally have less suburban sprawl, can be expected to develop similarly, consuming large areas of natural and agro-ecological landscapes as they do.

Meanwhile, planned extensions of the motorway network, especially in new Member States, will see more than 12 000 kilometres of new motorways built within the next decade.

In some European countries where intensification of farming is most pronounced ecologists are attaching an increased importance to conserving wildlife in urban areas. Even mammals such as foxes invade urban areas to take advantage of the abundant food available, much of it food thrown away by humans. Cities, especially those with old industrial areas, often provide a variety of unique wildlife habitats — some polluted and some simply abandoned — where unusual species of plants and insects congregate. Many such urban 'brownfield' sites contain more species than intensively managed farms in the countryside nearby.

Clearly the requirements of conservation are changing, and the maintenance of Europe's biodiversity will depend on action on a wide range of policy areas from agriculture and forestry through regional development, tourism and energy to land use and transportation.

The development of policies to ensure the preservation of ecosystems and habitats in Europe requires different approaches than in other parts of the world where nature is more pristine. In Europe, classical conservation methods, such as the creation of national parks, can protect only a fraction of the continent's biodiversity. Protecting Europe's species, habitats and ecosystems therefore requires broader support for the social and economic systems that developed and sustain them.

8.3 Major ecosystems across Europe

This section addresses major terrestrial and freshwater ecosystems; marine ecosystems are addressed in Chapter 6 and landscapes are assessed more comprehensively in Chapter 2.

European landscapes can be described in terms of the species and habitat types present in them. Their richness is essential when considering present and future ecosystem services, in particular in relation to potential adaptations to climate change. Maintaining the variety inherent in landscapes in terms of their health and connectivity is no longer a stand-alone target of nature conservation but a main challenge for society. Across Europe, landscapes differ, but most are under pressure and experiencing rapid changes which give cause for concern.

Farmland

Farmland, including arable land and permanent grassland, is one of the dominant land uses in Europe, covering more than 45 % (180 million hectares) of the EU-25. It has been estimated that 50 % of all species in Europe depend on agricultural habitats. Consequently, some of the most critical conservation issues today relate to changes from traditional to modern farming practices on habitats such as hay meadows, lowland wet grasslands, heathlands, chalk and dry grasslands, blanket bogs, moorlands and arable land.

The most significant pressures currently affecting farmland biodiversity are the loss and fragmentation of semi-natural habitats, the introduction of invasive species, the direct effects of pesticide or mechanical treatments and water consumption for irrigation, as well as the loss of crop varieties and livestock breeds.

There are two key trends leading to the loss and fragmentation of semi-natural habitats in agriculture in Europe today. One is the intensification of agriculture. The other is the abandonment of farmland. The latter happens when intensification is not possible or is uneconomic and when farmers and their families move out of farming. Both changes often cause a decline in biodiversity.

The intensification and mechanisation of agriculture is the most obvious threat. It results in numerous physical, chemical and biological changes to the landscape. Stone and earth terraces on steep hillsides are abandoned; hedgerows are degraded; small irregular fields with different crops are converted into large monoculture fields; pastures, ponds and other wet areas are drained; rivers are canalised and numerous small streams disappear; cattle are kept indoors while their pastures are turned over to growing fodder; crop rotations are lost; pastures are converted to arable land; farm woodlands, including coppiced and pollarded trees, are converted to agriculture.

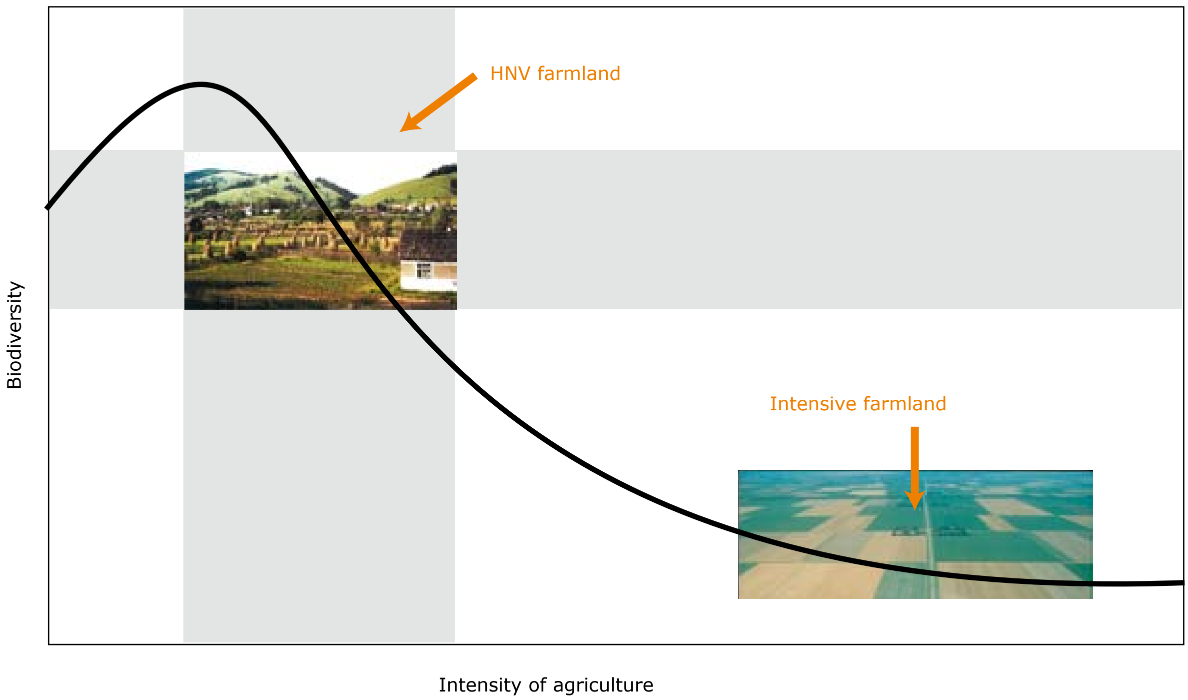
At the same time, more intensive use of fertilisers, pesticides and water, coupled with the use of modern machinery, are all changing landscapes by reducing plant diversity and sometimes poisoning wildlife. Pesticides reduce the abundance of many insects and invertebrates and can poison the birds and mammals that feed on them. Nitrate fertilisers impact widely on soils and aquatic ecosystems. An example is provided within the experimental project Biodepth which covers a variety of grasslands across Europe: it shows that crop productivity, as expressed by hay yield, declines in line with reductions in plant diversity.

There are still areas of Europe, however, where soil and climatic constraints have meant that it has not been possible to intensify farming practices to the same extent as elsewhere. Such areas not only generally contain more of a patchwork of semi-natural and natural habitats but also the farmland is more varied and subject to a greater range of management intensities.

Although such high nature value (HNV) farmland occurs in association with traditional cropping systems in southern Europe, the majority of remaining HNV farmland is now largely associated with livestock grazing systems on semi-natural habitats in the mountains and other remote areas of this and other parts of Europe. These areas host habitats of relatively high biodiversity value (Figure 8.1). Approximately 15–25 % of the European countryside can be categorised as HNV farmland.

Due to the relatively small remaining area of undisturbed natural habitats, the so-called 'semi-natural farmland habitats' and in particular semi-natural grasslands, have become relatively more important for European biodiversity. Depending on biogeographic contexts or local situations, these habitat types often have higher levels of biodiversity than undisturbed areas, as is the case for vascular plants in semi-natural grasslands in Sweden.

Figure 8.1 General relationship between agricultural intensity and biodiversity



Source: After Hoogeveen *et al.*, 2001.
Photos: Peter Veen (left); Vincent Wigbels (right).

Often the cessation of farming is scarcely better for biodiversity than intensification. Farmers give up their land because the soils are poor, because it is too remote from markets or labour, or simply because it is surplus to requirements. Mountain regions have suffered especially from abandonment. Traditional transhumance pastoral systems are almost gone in many areas. Mediterranean areas at risk of drought and forest fires are also being abandoned on a large scale, as are parts of eastern and central Europe, where economic conditions no longer make farming viable. About 30 % of Estonia's farmland is currently out of production.

In places, other economic activities take over. Alpine shepherds and their flocks give way to skiers and hikers, for instance. Tourist resorts take over around the Mediterranean coast and islands. Often, however, the land is simply abandoned.

On the face of it, abandoning farmland to nature sounds good for biodiversity. But in practice this tends not to be true, or is double edged. In Latvia, where large farms growing cereals and sown grasslands were abandoned in the 1990s, bird species such as white storks and corncrakes increased their numbers on abandoned land, but grassland plants such as the marsh gentian and marsh dandelion that depend on grazing to create their ideal habitat have declined.

Abandonment often leaves behind a simplified and transient ecosystem, populated by fast-growing, opportunistic and invasive species. This results from the loss of land management practices that have boosted biodiversity, often for many hundreds of years. These practices include the mowing of meadows and the grazing of chalk grasslands, and the maintenance of micro-features such as walls, hedges and ponds.

So abandonment generally reduces the diverse patchwork of extensive agricultural habitats. Many species of plants and animals disappear. In Estonia it is the most biologically valuable farmland that is being lost. More than 50 % of permanent grasslands that are rich in plant species and need mowing or grazing to survive have been abandoned.

Intensification and abandonment can take place in the same region. Where abandonment dominates, the result can be a cycle of depopulation and further land abandonment, as young people leave in search of work. The situation is particularly worrying in central and eastern Europe, where economic changes in the past 15 years have already impoverished rural areas, and where privatisation of collective farms has reduced job opportunities.

The problem is likely to become even more severe in the coming years among the new EU nations, which currently have the largest share of extensively used farming areas. In future, economic restructuring may increase the magnet of urban areas as centres of economic regeneration. Economic pressures

Biodiversity and biotechnology

Developments in technology pose opportunities as well as challenges for biodiversity policy and the chances of achieving the 2010 targets. New biotechnology techniques have the potential to deliver improved food quality and environmental benefits through agronomically enhanced crops, leading to more sustainable agricultural practices in both the developed and developing worlds.

However, the development of biotechnology, and genetically modified organisms (GMOs) in particular, has also raised concerns about the possible impacts on human health and the environment, including biodiversity. The European Community is a signatory party to the Cartagena Protocol on Biosafety, which seeks to protect biological diversity from the potential risks posed by living modified organisms resulting from modern biotechnology.

The EU has been legislating on GMOs since the 1990s and has the toughest adoption procedures in the world. Only GMOs that have been positively assessed through strict authorisation procedures can be placed on the market in the European Union. Directive 2001/18/EC is concerned with the experimental release of GMOs into the environment, for example in connection with field tests, and the cultivation, import and transformation of GMOs in industrial products.

on the farming sector for either intensification or abandonment will probably become more intense.

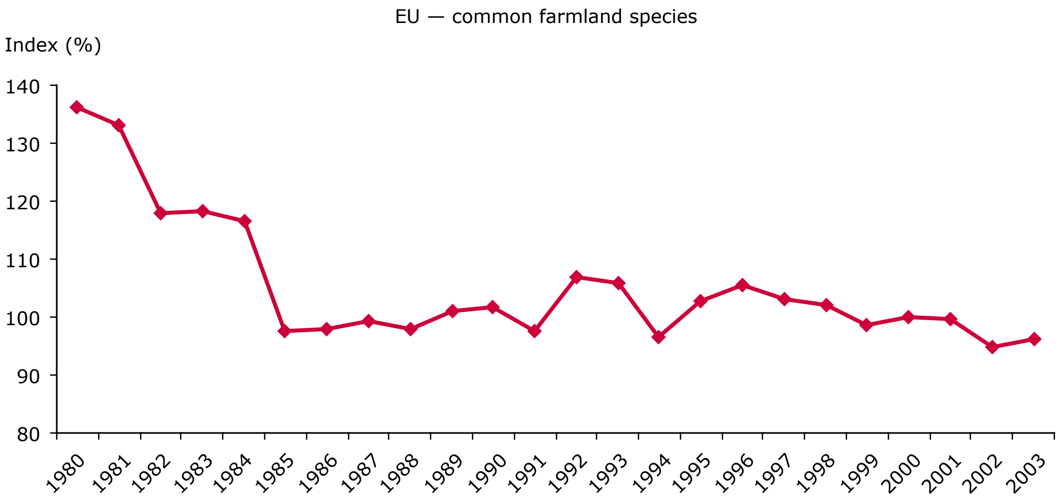
The mid-term review of the EU common agricultural policy in 2003 placed environmental concerns at the heart of the debate. Consequently, from 2005 farmers are receiving a single farm payment based on their historic level of support, provided they undertake to comply with a suite of EU directives (including the birds and habitats directives) and keep their land in good agricultural and environmental condition.

Although a wide array of measures can be funded under the rural development heading, it is anticipated that this modification of the policy will release funds to encourage more farmers to join agri-environment schemes, thereby helping to strengthen the preservation of ecologically valuable agricultural land. However, much will depend on the total budget available for rural development, and on the manner in which Member States apply agri-environment and other instruments under the CAP.

Biological diversity is fundamental to agriculture and food production. A rich variety of cultivated plants and domesticated animals serves as the foundation for agricultural biodiversity. Yet people depend on a mere 14 mammal and bird species for 90 % of their food supply from animals. Just four species — wheat, maize, rice and potato — provide half of our energy from plants. When food producers focus on this limited range, however, less-commercial species, varieties and breeds may die out, along with their specialised traits.

A wide range of species dependent upon farmland habitats has been affected by the increasing intensification of farming practices, thus becoming threatened. For example, more than 400 species of vascular plants in Germany have declined because of habitat loss or fragmentation due to agricultural intensification, while in the United Kingdom there has been a greater decrease in recent decades in plant diversity in arable habitats than in any other habitat. Farmland invertebrates have also suffered, with total insect abundance, including moths, butterflies, sawflies,

Figure 8.2 Trends in EU farmland bird populations in some EU countries between 1980 and 2003 based on 24 characteristic bird species



Source: EEA, 2005 based on data from BirdLife International.

parasitoid wasps and aphids, decreasing in both numbers and range.

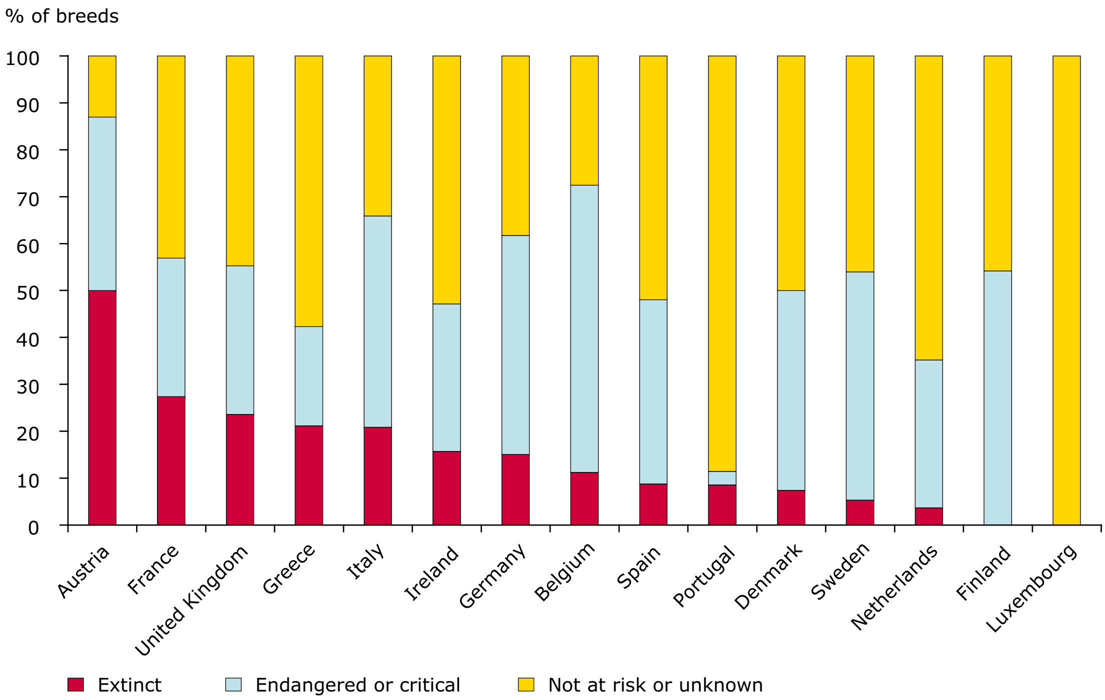
Changes in the populations of individual farmland bird species have been particularly well documented (Figure 8.2). For example, the red-backed shrike (*Lanius collurio*) has shown a widespread decline in Europe. It is thought that the application of inorganic nitrogen fertiliser and the use of insecticides has reduced the abundance of food for this species.

The marsh fritillary butterfly (*Euphydryas aurinia*) is declining in almost every European country. The United Kingdom (and Ireland) are believed to be the major remaining strongholds for the species, but even here it has declined substantially over the last 150 years. The main factors contributing to the decline are agricultural improvement of marshy and chalk/limestone grasslands, afforestation and changes in livestock grazing practices.

Europe is home to a large proportion of the world's domestic livestock diversity, with more than 2 500 breeds registered in the United Nations Food and Agriculture Organization (FAO) breeds database. A large number of European breeds are threatened because of their perceived lack of economic competitiveness. In nearly all EU-15 countries about 50 % of all livestock breeds have been categorised as extinct, or of endangered or critical status (Figure 8.3).

Europe's HNV pastoral grazing systems depend on hardy old livestock breeds adapted to natural conditions and to practices such as transhumance. For

Figure 8.3 Distribution of the endangered risk status of national main livestock breeds (cattle, pig, sheep, goat and poultry) in EU-15



Source: EEA, 2005. Prepared by IRENA from data within FAO's Domestic Animal Diversity Information System.

example, Avileña negra cattle in central Spain can walk 20–40 kilometres a day on the journey to their summer mountain pastures. Modern breeds — which can produce a lot of milk and meat — need large quantities of rich grass and supplementary feeds, and cannot cope with the same conditions. This switch of breeds has therefore led to the abandonment of remote pastures in many areas, and the loss of biodiversity that depends on grazing impacts.

Forests

Despite Europe's high population density, roughly 30 % of the continent's land area is still covered by forest, which remains a key ecosystem for biodiversity. Most of these forests are semi-natural. During the 20th century concern at the sustainable supply of timber and pulp encouraged most governments to pass laws on enhancing the productive function of the forests.

Recent estimates show a slight overall increase in the extent of European forests, by about 0.5 % per year. Most of this has taken place on abandoned farmland, in equal measure through spontaneous regrowth and deliberate plantation — the latter often with funding support from the European Union. Afforestation has been highest in Ireland, Iceland and the Mediterranean countries, in particular Spain, France, Portugal, Turkey, Greece and Italy.

Most forests in Europe are, to some extent, economically productive and about 25 % of the forest area is subject to more or less extensive protection. These forests cover some 37 million hectares and are designated for the protection of biodiversity, soil or water supply. In the Natura 2000 network, forests currently cover almost half of the total number of designated areas.

The bulk of Europe's surviving 'natural' forests, unaffected by humans, are concentrated in a few, mainly northern, boreal regions. Scattered relicts of undisturbed forests also occur in the mountainous areas of the Balkan, Alpine and Carpathian regions. Natural forests often contain a diverse range of tree species, usually accompanied by a wide range of non-tree species. However, all forests, even monoculture plantations, are reservoirs of biodiversity.

Tree species composition is a key factor to consider when assessing the development of biodiversity conditions in forests. Unfortunately it is not possible to present European-level data on the long-term development of the overall tree species composition in the main types of European forest. Data reported by countries on forest-related vascular plants (including the trees) provide an insight into the situation of threatened species of this group in European countries (Map 8.2).

Agriculture and biodiversity management issues

The main policy instruments for site protection at EU level are the birds and habitats directives (79/409/EEC, 92/43/EEC). Annex I of the habitats directive lists 198 natural and semi-natural habitat types that must be maintained in a favourable conservation status. Of these, 65 have been shown to be threatened by the intensification of agriculture practices, whilst 26 grazed pasture habitats and 6 mown grassland habitats are threatened by the abandonment of pastoral management practices. The Natura 2000 network is building on special protection areas (SPAs) and proposed sites of Community interest (pSCIs) that will safeguard these habitats. Despite the importance of farmland across Europe for biodiversity, agricultural habitats only form about 35 % of the total area listed as pSCIs in the EU-15. Only Greece, Portugal and Spain have a higher proportion of such habitats within the pSCIs they have listed.

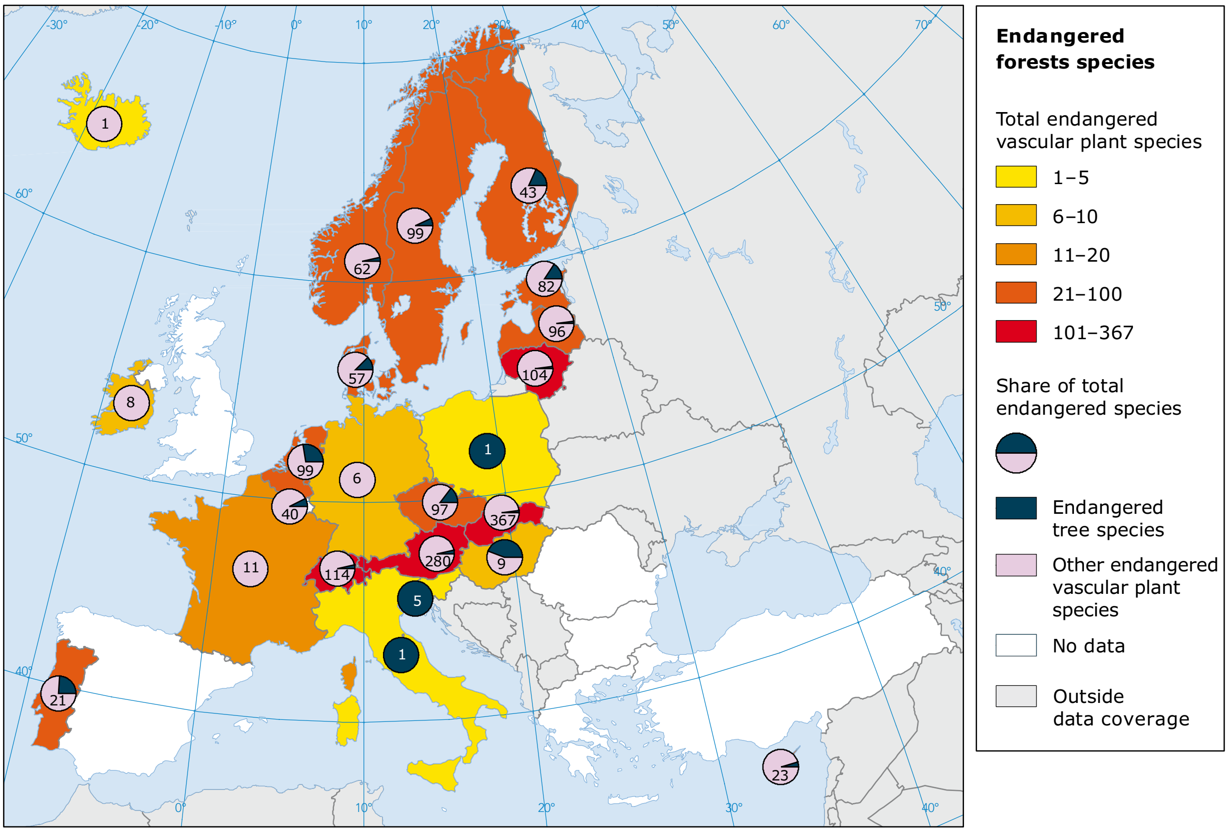
The current reform of the EU agricultural policy represents a radical change in the system of farm support provided within the EU, by decoupling support payments from production. The subsequent effects on farming practices and land use patterns are largely unknown. The likely impacts on farmland biodiversity are also currently unclear.

The increased use of agri-environment schemes in rural development measures is good in principle. However, the reforms to date have done little to address the question as to whether or not the programmes themselves have been effective in achieving their biodiversity objectives to protect biological features that have evolved as integral functional components of farming systems.

In contrast to much of the rest of the world, forestry in Europe today extracts timber at a rate slower than or equal to the rate of regrowth. For the EEA member countries as a whole, average rates of felling are only two-thirds of the amount of regrowth. Afforestation can be achieved either naturally, by seeds from remaining or neighbouring trees, or by planting. Natural regeneration conserves the genetic diversity and, if the original stand is suitable, maintains the natural species composition of the forest. In practice, however, planting is often preferred because it creates homogeneous stands and can be tailored to need, often with the use of 'improved' genetic material.

In other respects forestry practice in Europe is developing in a way that can be considered good for biodiversity. For instance, with felling rates lower than growth rates, Europe's forests of all sorts are growing older. Bigger, older trees are typically of greater value for moss and other plants that grow on the trees themselves, and they may contain dead and hollow parts that are important for a number of plants, fungi, animals and insects. Nowadays, in many European countries, forestry practices aim at increasing the amount of dead wood in the forests.

Map 8.2 Total number of endangered vascular plant species and the share of endangered tree species and other endangered vascular plant species in forests



Source: UN-ECE/FAO, 2000 and updates.

Forest fires, especially in the Mediterranean region, pose a threat to the productive potential of forests and to surrounding land. At the same time, they are also a natural feature of most forests and a vital part of their dynamics, creating clearings and new habitats. From a biodiversity perspective, therefore, fire suppression may threaten species dependent on habitats formed by fire, especially in boreal forest. Moreover, fire suppression runs the risk of increasing the standing stock of timber ready to be burned in future, thus 'priming' the forest for a future, larger conflagration.

On the other hand, many fires are far from natural, since they are caused by people. They also cause significant economic, social and ecological losses. Thus forest fire management needs an integrated approach, taking account of ecosystem needs and long-term fire suppression strategies rather than simply operating short-term fire prevention regimes.

Freshwater ecosystems

Few of Europe's large freshwater systems are close to what can be considered their natural ecological state. Many have lost numerous species because of pollution and alterations to natural flow and flood regimes. Nevertheless, a marked improvement in the water quality of many rivers and lakes in recent decades has made water suitable again for the return of some lost species.

Pollution clean-up has contributed to this improved prospect and is discussed in Chapter 5. Better management practices, such as the construction of ponds and the provision of fish ladders through dams and weirs, have also contributed to this improvement. Still, much remains to be done to restore the quality of water, riverine habitats and biological communities in many areas. In addition, new threats are emerging. Climate change will change water temperatures, quantity and flow characteristics; while invasive non-native species represent a growing threat to freshwater biodiversity.

Europe has approximately 1.2 million kilometres of rivers. Most are, by global standards, small. Only about 70 of Europe's rivers have a catchment area exceeding 10 000 square kilometres. Along these rivers are around 600 000 lakes larger than 0.01 square kilometres, mostly in Finland and Sweden. As with rivers, there are many more small lakes than larger ones. Size matters: small lake and river water bodies are rich in biodiversity but often extremely sensitive to anthropogenic pressures, such as agricultural activities.

The EU water framework directive (WFD) is now the prime legislative instrument for the protection of the water environment of Europe. It covers all surface and groundwater bodies. One of its principal objectives is to achieve good chemical and biological water status

Regulation of the Danube — Europe's largest river

There have been major modifications to the Danube's flow since the 19th century, as communities along the river sought to control floods and improve navigation. This involved the construction of dykes along the river that reduced inundation of the floodplains. In Hungary in the Middle Danube, for instance, the area of floodplain that is seasonally inundated has fallen by 93 % from 22 000 square kilometres to 1 800 square kilometres.

Other changes have reduced river length, which has accelerated the passage of flood peaks. As a result, river flows have became more extreme, with higher floods and worse fluvial droughts. The straightening and dredging of the river bed has also increased channel erosion, deepening river beds, lowering water levels and breaking the river's contact with its backwaters. This in turn has led to falling water tables in surrounding aquifers and extensive siltation of surviving water bodies on the floodplain.

The annual inundation of the Danube floodplains has historically been a crucial event for maintaining the reproduction and productivity of fish populations, especially in the middle reaches. Dykes along the River Tisza, one of the largest tributaries of the Middle Danube, have caused an enormous loss of fish-spawning habitat, and a 99 % reduction in fish catches.

by 2015. The only exception should apply to water bodies designated by their governments as 'heavily modified', and where over-riding socio-economic reasons prevent the necessary improvements. The WFD is directly relevant to the management of Natura 2000 sites, for the conservation of those habitats and species dependent on water.

Most rivers in Europe have been subject to extensive damming for hydroelectric power, channelisation to facilitate transport and drainage of riparian habitats to provide agricultural land. Such modifications have led to widespread losses of aquatic habitats and biodiversity, with thousands of small lakes, ponds and streams lost entirely to drainage for agricultural land. Today, very few unregulated waters remain.

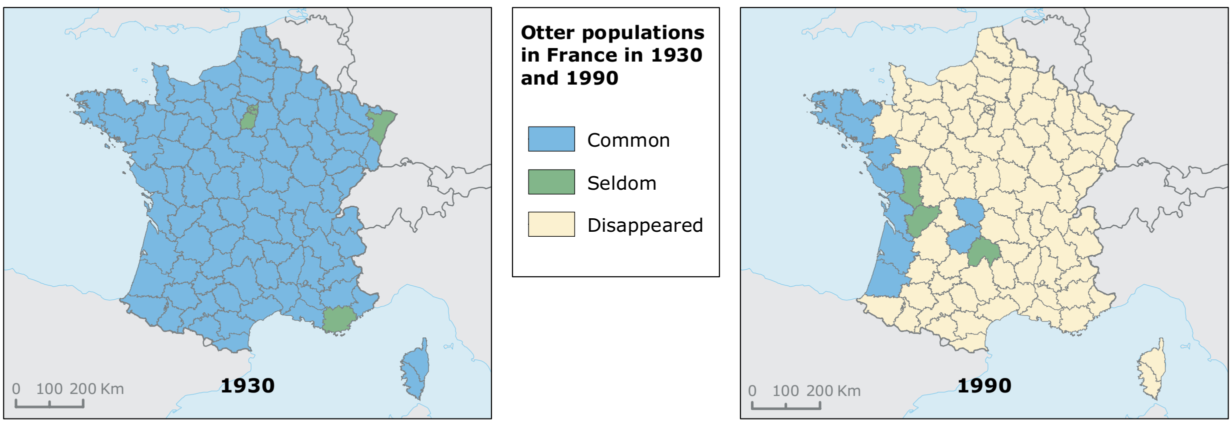
There is an increased awareness of the conservation importance of riverine and wetland habitats, and their role in buffering dry land against floods. In traditional farming systems, riverine and lake-shore habitats were often grazed or mowed, but allowed to flood. These areas offered valuable habitats for many rare species. Recreating and restoring these habitats is one of the greatest challenges for current and future actions on nature conservation.

The common otter, *Lutra lutra*, is found in European rivers, lakes and marshes, as well as in coastal waters. The species was once widespread, but the inland water populations in particular decreased dramatically during last century in countries such as France, although the otter still thrives in Ireland (Map 8.3). Destruction of habitat, pollution of watercourses and trapping have all contributed to its decline. There are now signs of recovery in, for instance, Denmark and the United Kingdom. Nevertheless, otters are still absent or sparse in many other countries, for example France.

Salmon, *Salmo salar*, is widely seen as an indicator of the health of rivers. Once widespread in northern and middle Europe, salmon requires good water quality and natural riffles and other features to support breeding and maintain stocks. Furthermore, the fish must be able to swim from the sea to upstream river spawning areas. Since the 1970s there has been a general decline in Europe's salmon.

There have been similar declines in other fish stock, such as eels and sturgeon, in many European rivers in response to dams, other river modifications and pollution. Many European countries have also seen declines in a wide range of species of freshwater plants,

Map 8.3 Otter populations in France in 1930 and 1990



Source: www.cigogne-loutre.com/html/dispaloutre.html — accessed 13/10/2005.

animals and invertebrates such as mayflies, dragonflies, stoneflies and caddis flies, with hardy generalists and some new invasive species surviving, while local specialist species disappear.

Wetlands

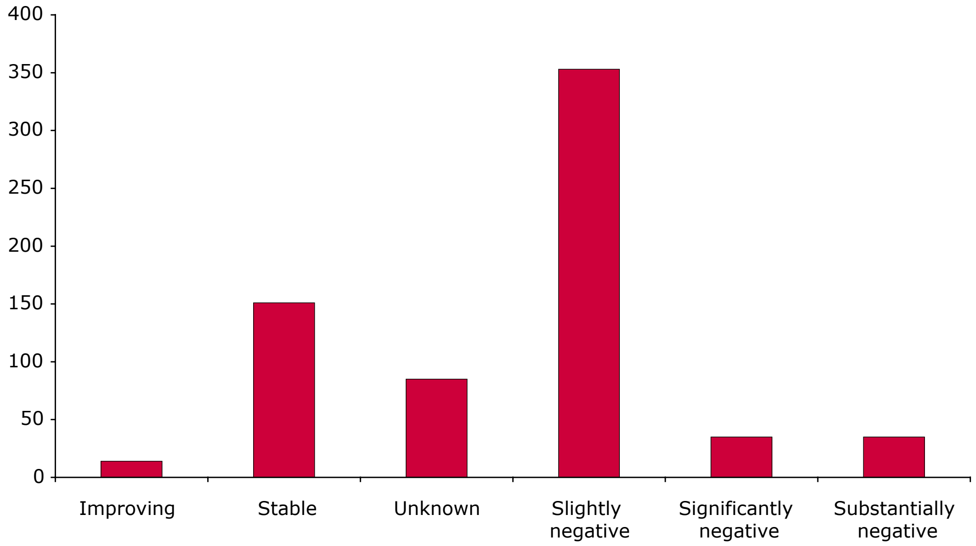
Freshwater ecosystems are more than just rivers and lakes. Among the most biologically productive freshwater areas are wetlands, including lagoons, estuaries, riparian forests, grazed wet meadows and farm ponds. Although varying in size, often only seasonally wet and rarely focused on, wetlands are vital for a wide range of biodiversity.

Modifications to rivers, combined with intensified agriculture, urban development and changes to agricultural drainage and run-off and water abstraction have caused a massive decline in these ecosystems. In north and western Europe, for instance, 60 % of wetlands disappeared during the 20th century, and that decline continues. The EEA countries have seen a 3.5 % loss of large wetland areas since 1993; estimates of loss would rise to 10 % if changes in small wetlands were included. Traditional uses of wetlands are being abandoned throughout Europe.

This continued decline has happened at the same time as a growing concern to protect surviving wetlands, and serious efforts at conservation management. All EEA countries are parties to the Ramsar Convention on Wetlands, and have designated about 19 % of their total wetland area. According to national reports, there has been an overall negative change in ecological status of Ramsar sites (Figure 8.4).

Additionally, in the EU Member States, important wetlands are given strong protection through the birds and habitats directives. Other positive features include

Figure 8.4 Ecological change status of Ramsar sites within the EEA member countries according to national reports to the Ramsar Convention



Note: There is no objective measure in place for countries to report changes in actual wetland area or ecological status. The data behind this figure are uncertain, for example Nivet and Frazier (2002, 2004) concluded that only 16 countries have adequate national wetland inventory information available.

Source: Ramsar Sites Database, 2004.

reformed agricultural policy, which now aims to avoid adverse effects on wetlands. There is also increased public and local community awareness of the value of wetlands, including their value for local traditions and culture. Wetland ecotourism activities are of growing significance.

In an independent report by the World Bank with WWF, Ramsar site designation was considered to be a significant factor in increasing conservation success. While conservation success was considered to be relatively high in the Ramsar Europe region generally over a period from 1993–1995 to 1999, eastern Europe reported a slight downturn.

The outlook for wetlands of international importance, such as those included in the Natura 2000 network, those with Ramsar designation and those with potential for ecotourism, appears to be quite good, at least in the medium term, thus contributing to the 2010 target of halting the loss of biodiversity in Europe. Nevertheless, for the majority of wetlands without protection or recognition, the outlook remains at best mixed.

Mountainous areas

Mountain environments in Europe are among the continent's most valuable natural areas, rich in biodiversity. They are also among the most vulnerable. European mountains host many endemic species, attracted by their isolation and special climate conditions. For example, more than 2 500 out of Europe's 11 500 vascular plant species are found mainly above the tree line.

Though often apparently stable, mountain regions are experiencing unprecedented change. Large-scale industrial projects, such as damming for hydroelectric power, mining and development of transport infrastructure, invade the mountains, often with drastic consequences for nature and biodiversity. Many European mountain areas are also important tourist areas, with an increased pressure especially from ski resorts. Meanwhile, the abandonment of farming and livestock grazing is influencing mountain vegetation as well as species diversity.

Despite the increasing pressure, some successful measures have been taken to bolster biodiversity in Europe's mountains. There has been widespread designation of mountain areas for Natura 2000 protection. A number of other EU programmes and directives recognise mountain areas in need of special attention, for example the common agricultural policy, the European Regional Development Fund, the directive on less favoured areas and the water framework directive.

The populations of several large herbivores have increased in the Alps in recent years, partly as a result of direct human actions such as reintroductions. The southern chamois, *Rupicapra pyrenaica*, nearly became extinct because of intensive hunting and poaching. In the past 40 years, regulation of hunting has led to an increase in numbers from a few thousand to 50 000 individuals in the Pyrenees, the Cantabrian Mountains and the Apennines.

Other large mammals are experiencing difficulties or are in decline. The wolverine, *Gulo gulo*, is the only large mammal predator in Europe that is naturally confined to mountains, where it lives on semi-domesticated reindeer. Long-term hunting and persecution has reduced wolverine populations and the total population in northern Europe is now less than 1 000 individuals, but apparently steady.

The brown bear, *Ursus arctos*, originally a widespread species in Europe, is today largely confined to mountains, and is now among the rarest large mammals in Europe. Like the wolf, it is seldom appreciated by local people, because it induces fear and attacks farm animals. The western European populations in the Pyrenees, the Cantabrian Mountains, the Trentino Alps and the Apennines are very small and fragmented. Nonetheless, the bear lives on in Finland and Sweden, where around 2 000 survive, in the Carpathian Mountains of Romania and Slovakia, and in the mountain ranges of the Balkan Peninsula, where a substantial number of bears can still be found.

The Pyrenean ibex, *Capra pyrenaica pyrenaica*, has for centuries been in decline due to hunting. The small

Spanish residual population recently faced new threats from habitat destruction, human disturbance, poaching and its own faltering genetic diversity. These led to a serious decline in numbers, and eventually to extinction when the last individual succumbed to a falling tree in 2000.

8.4 Invasive alien species

Invasive alien species are species introduced outside their natural habitats where they have the ability to out-compete native species. They are widespread in the world and found in all types of ecosystems: plants, insects and other animals comprise the most common types in terrestrial environments. Their threat to biodiversity is considered second only to habitat loss. Invasions are expected to increase because of the growing globalisation of trade, tourism and business travel.

Alien species also threaten our economic and societal well-being. Weeds reduce crop yields, increase control costs and decrease water supply, thereby degrading freshwater ecosystems. Pests destroy plants and increase control costs; and dangerous bugs continue to kill or disable millions of people every year.

Considerable uncertainties surround the economic costs of invasive species, but estimates of the impact of particular species on different sectors indicate the magnitude of the problem. The international trade in birds, for instance, in which the EU is an important actor, exposes populations to infectious diseases such as Asian bird influenza. The recent avian flu outbreaks in Belgium and the Netherlands resulted in 30 million poultry being killed, and cost industry and taxpayers hundreds of millions of euro.

The majority of non-native species in inland waters have been introduced accidentally, for aquaculture or for angling purposes. For many species the ecological effects are unknown but where the impact is known, the effects on the ecosystem have mainly been adverse, i.e. the species are invasive.

Despite decades of research, knowledge of the ecological and human dimensions of invasive species remains incomplete. Only some 20 % of the world's species have been scientifically described, so we are unable to predict either which species are likely to become invasive or the economic and social impacts they may have. This would suggest taking a precautionary approach to mitigate the occurrence of invasions through increasing globalisation of markets.

8.5 Climate change and biodiversity

Large uncertainties remain about the capacity of ecosystems to resist, accommodate or even sometimes benefit from climate change. Nevertheless, there is a strong probability that climate change will become the dominant force in changes to the continent's biodiversity, overwhelming the forces of habitat destruction, pollution and overharvesting, whether for good or ill.

Climate change will impact almost every aspect of Europe's biological life. Growing seasons and flowering times will alter; so will migration times and destinations. Species unable to move will decline or die out; others will take advantage of climatic space that opens up. Pests will change their domains. Carbon dioxide in the atmosphere will fertilise some plants, while drought will undermine others.

Often ecosystems are shaped less by average conditions and more by large natural disturbances such as fires, floods, high winds and droughts. Climatologists suggest that the probability and intensity of such extreme events may change even more than average conditions.

The one certainty is that a changing climate will put pressure on many species and ecosystems. It is thus of paramount importance to protect as much as possible of the natural landscape to improve the chances of a smooth transition to new climatic conditions. As climate zones shift, species will need to move. For some, this may be easy enough but for others it could be very hard. Species need habitats in which to live, and if the habitat as a whole cannot move, then the migrant may be left homeless.

Some regions of Europe have been identified as probably more vulnerable to climate change. In the Arctic, higher temperatures have already brought a greater variety of plants to Arctic lakes, and new niches may open up as permafrost thaws, glaciers retreat and temperatures warm. However, some endemic Arctic plants will be lost. Moreover, as sea ice conditions change, there will be threats to marine mammals, particularly polar bears which need sea ice from which to hunt in the cold Arctic waters.

Mountain species are able to cope with extreme conditions and may handle moderate warming quite well. Migrating up hillsides to keep pace with moving climate zones will involve much smaller distances than migrating on flatter lands. On the other hand, many plants in mountain areas occupy small niches with very localised climatic conditions; if these conditions change there may be nowhere suitable for them to grow.

The most extreme case will be near mountain summits. As temperature zones move up mountainsides, cold-loving species, having retreated to even higher altitudes, may find nowhere left to go. Plants, insects and mammals alike could be stranded. At the same time, other species, including trees, will be migrating from lower slopes, creating a botanical gridlock in which the delicate specialist endemic species will be most at risk. So, for instance, around the summits in the Alps, there could be a profusion of species but also the significant disappearance of local endemics.

One study suggests that a 1 °C warming in the Alps will result in the loss of 40 % of local endemic plants, while a 5 °C warming would produce a 97 % loss. Another study confirms the trend, suggesting a 90 % loss with a warming of 3 °C. Specific mountain plant species under threat include the mountain bladder fern (*Crysopteris montana*).

Coastal zones will suffer complex changes as rising sea waters invade freshwater ecosystems, storms become more intense, water quality changes in the warm

Projected impacts of climate change on European flora

Following earlier Euromove surveys, a study by the advanced terrestrial ecosystem analysis and modelling (Ateam) project of projected changes in the late 21st century distribution of 1 350 European plant species under seven climate change scenarios came up with the following conclusions:

- Even under the least severe scenario (mean European temperature increase of 2.7 °C), the risks to biodiversity appear to be considerable.
- More than half the species studied could be vulnerable or threatened by 2080.
- Different regions are expected to respond differently to climate change, with the greatest vulnerability in mountain regions (approximately 60 % species loss, including many endemic species) and the least in the southern Mediterranean and Pannonian regions.
- The boreal region is projected to lose few species, although gaining many others from immigration.
- The greatest changes, with both loss of species and a large turnover of species, are expected in the transition between the Mediterranean and Euro-Siberian regions.

The results of the study cannot be taken as precise forecasts given the uncertainties in climate change scenarios, the coarse spatial resolution of the analysis and uncertainties in the modelling techniques used. In particular the relatively crude grid scale of the study may hide potential refuges for species and environmental heterogeneity that could enhance species survival, especially in mountain areas where the risk of extinctions could be overestimated. On the other hand, impacts of land use change, which were not taken into consideration, could increase the vulnerability of these refuges to fire or other disturbances, which, in combination with the lack of propagule flow, could compromise the survival of remnant populations.

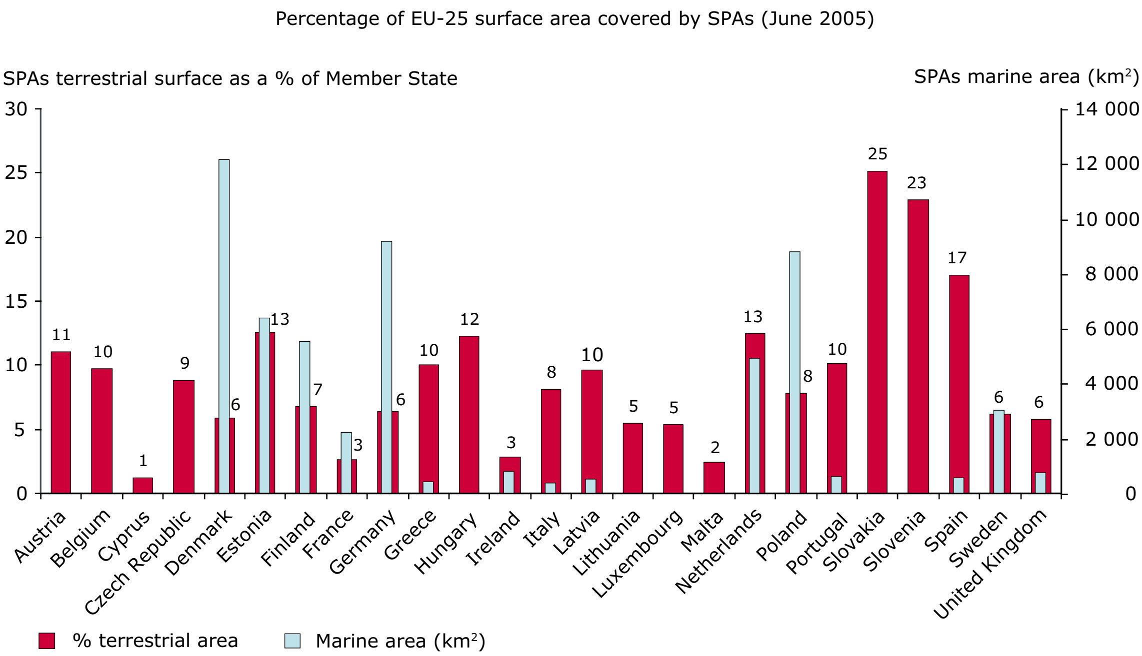
temperatures, and flows of sediments and freshwater down rivers change. Wetlands, already under grave threat from development, will suffer further damage from climate change.

Some Atlantic coastal wetlands may cope well with sea inundations because they are adapted to a wide tidal range. They have evolved protective features such as sand spits. Both the Mediterranean and Baltic Seas, however, are virtually tideless and thus have no coping strategies for inundation. Several predictions put the likely loss of coastal wetland habitat in these two seas, under a 2–3 °C warming, at greater than 50 %. Several large river deltas in the Mediterranean, such as those of the Ebro and Po rivers and the lagoons within them, are thought to be particularly at risk.

The Mediterranean region as a whole, while prone to coastal changes, is also likely to face more droughts and fires, land degradation due to desertification and spreading salinity in newly irrigated areas, and loss of wetlands.

Several studies have concluded that the Mediterranean is probably the part of Europe most vulnerable to climate change. Much of the region's biodiversity is already close to its climatic limit, and particularly vulnerable to the droughts that climate models suggest will become ever more frequent. Even small changes in temperatures and rainfall could have severe consequences for some tree species most typical of the Mediterranean landscape. In practice, increased fire risk may become the most serious threat. Fire is already

Figure 8.5 Special protection areas (SPAs) established under the EU birds directive (EU-25)



Note: Although there is no agreed percentage of terrestrial or marine areas that require SPA designation by individual Member States, it is clear that some countries need to conserve larger areas if the intended network is to be realised.

Source: EEA, 2005.

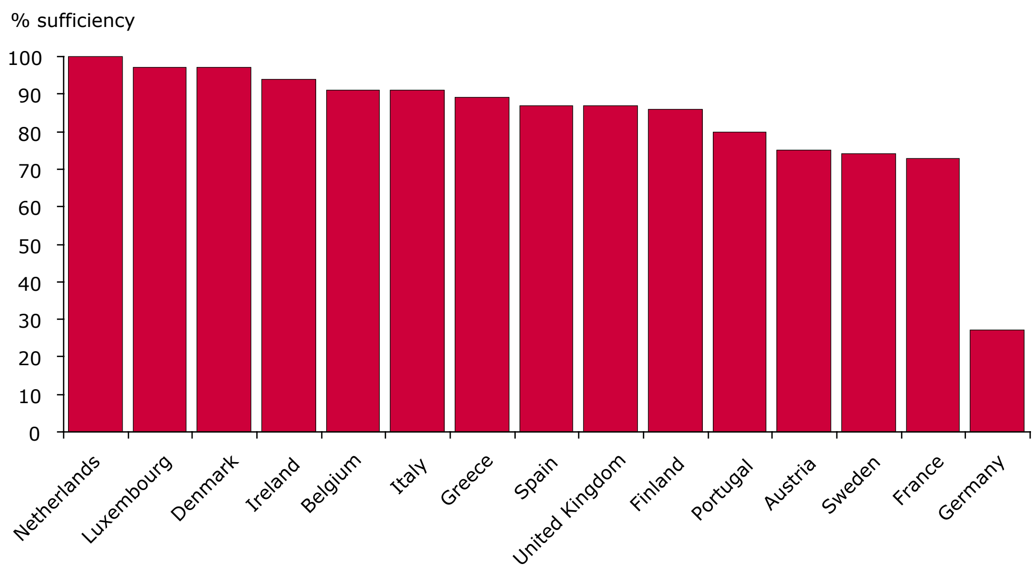
the crucial survival determinant for a number of tree and shrub species in the region as, each year, an area the size of Corsica is scorched.

8.6 Main biodiversity policy responses

European countries have long made commitments to protect their nature through joining international conventions, including the Ramsar Convention on the Conservation of Wetlands of International Importance (1971); the Helsinki Convention on the Baltic Sea (1974); the Barcelona Convention on the Mediterranean (1976); the Bonn Convention on Migratory Species (1979); the Bern Convention on European Wildlife and Natural Habitats (1979); and the Convention on the Protection of the Alps (1991). At the same time, the EU has been developing its own strategy for protecting its critical wildlife habitats, the wider landscape and the biosphere.

EU action began with protected area programmes under the 1979 birds directive and the 1992 habitats directive. In 1998, the Community adopted a biodiversity strategy, which was developed in accordance with the United Nations Convention on Biodiversity (CBD) signed at the Earth Summit in 1992. Under the strategy, a series of biodiversity action plans on natural resources, agriculture, fisheries, and development and economic cooperation followed in 2001. Additionally, commitments under the CBD have been carried forward into the EU sixth environment action programme and its thematic strategies, which

Figure 8.6 EU habitats directive: sufficiency of Member State proposals for designated sites (EU-15, September 2004)



Note: As shown in the 'sufficiency' indicator, some countries need to strengthen their contribution to Natura 2000 under the habitats directive. Bars show the degree to which Member States have proposed sites that are considered sufficient to protect the habitats and species mentioned on the habitats directive Annex I and II (situation of September 2004). Marine species and habitats are not considered.

Source: Natura 2000 database.

cover such issues as the marine environment, soil protection, air pollution, the sustainable use of pesticides, and the urban environment, all of which touch upon biodiversity concerns.

At the centre of the EU biodiversity strategy is the creation of a coherent ecological network of protected areas, Natura 2000, made up of special protection areas (SPAs) to conserve 194 bird species and sub-species, as well as migratory birds, and special areas of conservation (SACs) to conserve the 273 habitat types, 200 animal species and 724 plant species listed under the habitats directive.

By February 2005, 4 169 SPAs, covering nearly 382 000 square kilometres, had been classified across the EU-25, of which 325 000 square kilometres are terrestrial (approximately 8 % of the Community's land area) and 56 000 square kilometres are marine (Figure 8.5).

The establishment of a list of sites of Community interest (SCIs), as a prelude to selecting special areas of conservation, has not been as rapid as initially hoped. Nonetheless, 19 516 sites covering nearly 523 000 square kilometres have been proposed as SCIs across the whole of the EU-25, covering almost 14 % of its land area as well as 65 000 square kilometres of marine area. These sites cover four of the six biogeographic regions identified by the habitats directive — Alpine, Atlantic, Continental and Macaronesian. The sufficiency of EU-15 Member State proposals for designated sites under the EU habitats directive is quite high with the exception of Germany (Figure 8.6).

Member States have six years following the adoption of the lists of SCIs to establish the measures necessary to protect and manage designated sites, and in doing so designate them as special areas of conservation.

The Natura 2000 network must be ecologically coherent both within individual Member States and between Member States and neighbouring countries in order to provide species and habitats the best possible chances of survival in the face of climate change.

The habitats directive also recognises the need to tackle conservation of species and habitats within and beyond designated protected areas, and to integrate management plans into broader landscapes and seascapes, contributing to the practical implementation of the 'ecosystem approach' promoted by the CBD.

Progress is being made towards the implementation of the Natura 2000 network. Almost 18 % of the EU's land area is protected, and a significant part is a net addition to the total area of nationally designated sites in Europe. Because many SPAs and SCIs overlap, the total protected area is less than the summed area of SPAs and SCIs.

Some findings of the 2003–2004 EU biodiversity policy review

At the World Summit on Sustainable Development in Johannesburg, South Africa, in 2002, nations agreed to significantly reduce the rate of loss of biodiversity in the EU by 2010. The EU had already gone further, committing itself to halting biodiversity decline by 2010. To plan its approach to meeting these ambitious targets, the EU began a review of its biodiversity strategy in 2003. Some of the findings are presented here.

Many species remain threatened in Europe: 43 % of European avifauna has an unfavourable conservation status; 12 % of the 576 butterfly species are very rare or declining seriously on the continent; up to 600 European plant species are considered extinct in the wild or critically rare; 45 % of reptiles and 52 % of freshwater fish are threatened. Some species such as the Iberian lynx, the slender-billed curlew and the Mediterranean monk seal are on the verge of extinction in the wild. Even once-common species such as skylarks have seen their populations drop dramatically in recent years.

These trends are not surprising given the generally low rate of implementation of both the strategy and the action plans in Member States, and the extent of natural habitat loss outside protected areas. The strategy itself underlined, however, that much of Europe's wildlife is to be found outside protected areas. Wider efforts are therefore needed to protect landscapes, especially traditional extensive farming systems, as suitable for wildlife.

More recently, and in response to the development of the strategic plan of the CBD, the countries of the EU endorsed the 'Malahide Message' in 2004. The message contains 18 concrete targets on how to work towards reaching the EU goal to stop the loss of biodiversity by 2010.

Meanwhile market forces are encouraging farmers to produce more organic crops. Although organic production may not necessarily lead to a reduction in intensity, it will mean fewer inputs, including no artificial pesticides and fertilisers. The reliance on animal manure and crop rotation to maintain soil fertility and combat pests and diseases reduces the risk of eutrophication of freshwaters and, by removing direct toxins, generally promotes more wildlife. In 2003 organic farming represented 4 % of the total farmed area in the EU-15, a doubling in just five years. In the 10 new Member States, where consumer demand and state help for organic farming are both lower, the proportion remains below 1 %.

Besides the organic movement, certification, also often market-led, is helping to promote both quality products and awareness of biodiversity issues. Two EU regulations associated with the origin and processing of agricultural and food products have played a role in this development.

Nonetheless it is recognised that additional efforts are needed, particularly to conserve HNV farmland and improve the biodiversity value of intensively managed farmland.

The EU forestry strategy, adopted in 1998, considers biodiversity as an element of sustainable forest management. Most European countries have made significant efforts to reduce the threats to, and enhance forest biological diversity within protected forest areas and through more environmentally sustainable and close-to-nature management practices in the countryside. This includes the increasing reintroduction in the last 10 years of native tree species in forest areas, the diversity of which had been affected by monospecific plantations of exotic species.

The development of certification initiatives, such as that of the Forest Stewardship Council, which define and encourage sustainable forestry regimes, is expected to have a positive effect. So, too, is the emergence of consumer-led demand through buyers' groups within the retail industry for sustainably produced wood and wood products, even though this is not directly targeted at the preservation of biodiversity.

However, action is still needed to mitigate threats to the forest ecosystems by long-range pollution and alien invasive species, to ensure the long-term survival of threatened species, and to establish an ecologically adapted fire regime. Additionally, consideration should be given to how forest management for carbon dioxide sequestration may affect biodiversity.

A range of general issues is in need of further consideration to help steer future action:

- the long-range damage to biodiversity from transboundary pollution such as acid rain and climate change;
- the failure to break the common perception that conservation and economic development are incompatible;
- the continued abandonment of traditional wildlife-friendly extensive farming methods; and
- gaps between theory and practice in Europe's management of forests and fisheries.

The broad objectives, set at the Community level, to protect nature and manage natural resources according to principles of sustainability could benefit from getting closer to local practice. In part this points to opportunities to improve the coherence of governance between different levels of administration in countries and at the EU level. The implementation of policies, strategies and directives has been relatively slow, with the Natura 2000 process already 15 years in development. Subsidies remain that encourage landowners to undermine ecological goods and services, though recent reforms to the common agricultural policy point the way forward. Nevertheless, the external costs to biodiversity have not yet been fully internalised in the sectors that have most impact.

The EU's biodiversity policy review culminated in a conference on 'Biodiversity and the EU' held under the Irish Presidency at Malahide in May 2004. The resulting 'Message from Malahide' achieved a broad degree of consensus on priorities towards meeting the 2010 targets. The Message contains 18 objectives with a set of targets relating to each. The Commission is now developing a new communication on biodiversity which will provide its response to Malahide. It is expected to provide a road-map of priority measures for the EU to 2010.

8.7 The global picture: how biodiversity underpins society

Healthy ecosystems deliver an abundance of life-sustaining services, often at no cost (Figure 8.7). Some we instantly recognise for their economic value. Ecosystems provide wild crops such as timber, fruit, nuts and medicinal herbs. In more heavily managed landscapes, soils and the microbial populations within them maintain a life-support system for arable crops, grazing animals and managed forests, from which modern societies gain most of their food, fibre and timber.

Other ecological services of biodiversity are more indirect and often less well recognised. Natural vegetation maintains insects that pollinate crops and control pests. Soils and vegetation store and filter water, watering crops, filling underground water reserves and protecting against floods. Evapotranspiration from vegetation and soils creates rain and cools the land, while gas exchanges between the atmosphere and vegetation maintain atmospheric chemistry. Among the services so provided is the moderation of climate change by trapping carbon dioxide that would otherwise remain in the atmosphere. Ecosystems also act as sinks for waste products, absorbing and oxidising them. They also contribute to landscapes that are valued for tourism and their cultural and psychological value.

Nature still provides direct genetic resources. A quarter of all modern medicines, though mostly synthesised, have their origins in traditional plant remedies. Drug companies are among the most assiduous corporate 'bio-prospectors' in rainforests and elsewhere, seeking out the active ingredients developed by nature and often already discovered and used by local communities.

Every lost forest is a risk to such enterprises. In 1987, a crucial chemical for fighting HIV was discovered in leaves and twigs sampled from a tree called *Calophyllum langierum*. Unfortunately, when scientists returned to find more material, they found that the original tree was gone and no more could be found. A similar gene has since been identified in a related tree, but it is not as active as the original. Meanwhile, the genetic variety present in wild precursors of major food crops remains a valuable resource for plant breeding to fight pests and increase yields. Most of these services are simply impossible for humanity to replicate. Therefore future well-being is dependent on the maintenance of the planet's ecological services, through protecting its biodiversity.

Biological and ecological systems are in a constant state of natural flux, so conservation need not be about preserving every habitat intact or keeping every endangered species untouched. Species are constantly becoming extinct — probably about one in every million each year.

However, conservation works best when it is about preserving those basic life-support systems on which we depend. What is worrying about the current situation is the scale of change triggered by human activity — a scale that undermines the ecosystems and the services they provide. Whether market instruments can be used to protect biodiversity and the ecosystem services that it underpins remains an open question.

Figure 8.7 Ecosystem services and their links to human well-being

Ecosystem services

Supporting services

Services necessary for the production of all other ecosystem services

- Soil formation
- Nutrient cycling
- Primary production

Provisioning services

Products obtained from ecosystems

- Food
- Freshwater
- Fuelwood
- Fiber
- Biochemicals
- Genetic resources

Regulating services

Benefits obtained from regulation of ecosystem processes

- Climate regulation
- Disease regulation
- Water regulation
- Water purification

Cultural services

Non-material benefits obtained from ecosystems

- Spiritual and religious
- Recreation and ecotourism
- Aesthetic
- Inspirational
- Educational
- Sense of place
- Cultural heritage

Determinants and constituents of well-being

Security

- Ability to live in an environmentally clean and safe shelter
- Ability to reduce vulnerability to ecological shocks and stress

Basic material for a good life

- Ability to access resources to earn income and gain a livelihood

Health

- Ability to be adequately nourished
- Ability to be free from avoidable disease
- Ability to have adequate and clean drinking water
- Ability to have clean air
- Ability to have energy to keep warm and cool

Good social relations

- Opportunity to express aesthetic and recratinal values associated with ecosystems
- Opportunity to express cultural and spiritual values associated with ecosystems
- Opportunity to observe, study, and learn about ecosystems

Freedoms and choice

Source: Millennium Ecosystem Assessment, 2005.

It may be that legal instruments will, as now, remain the main method of protection. What is clear is that many new instruments of all kinds are likely to be needed if the huge task of maintaining ecosystems and biodiversity is to be achieved.

The current rate of species extinctions is around a thousand times higher than the natural rate. Between 10 and 30 % of all mammal and bird species are currently threatened with extinction, and the geographical extent of human transformation of the planet's landscape is unprecedented. A study by the Wilderness Conservation Society defined areas of the Earth's land surface as being influenced by humans if:

- human population density was above 1 person per square kilometre;
- there was a road or major river within 15 kilometres;
- the land was used for agriculture or was within two kilometres of a settlement or railway; and
- it produced enough light to be visible to a space satellite at night.

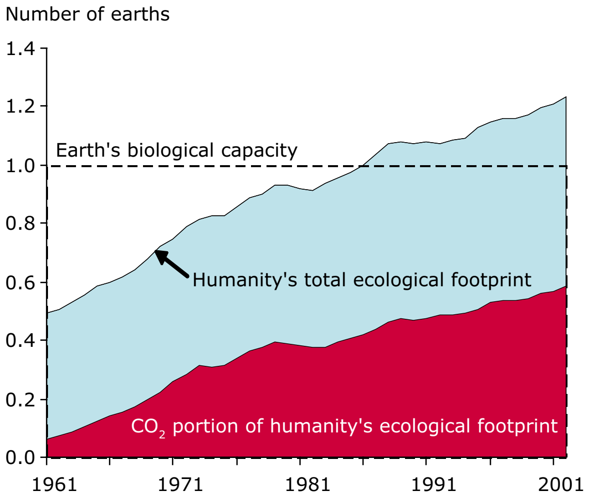
By that measure, 83 % of the Earth's land surface is under human influence. The Millennium Ecosystem Assessment (MEA) have attempted to capture the extent to which we have degraded natural ecosystems and the price we are paying for it. It found that more land has been converted to agricultural use in the last 50 years than in the 18th and 19th centuries combined. More than half of all the synthetic nitrogen fertilisers ever used on the planet have been applied since 1985.

Overall the MEA concluded that 60 % of ecosystem services that support life on Earth — the services that purify and regulate water, deliver fisheries, regulate air quality, climate and pests — are being degraded or used unsustainably. As most of that damage has been done in the last 50 years, it may be too soon to be sure of the lasting impacts of our abuse.

It is far from clear that natural systems can cope with this without widespread collapse of those ecological services. Many of the systems and services are in evident decline — including ocean fisheries and freshwater supply, regulation of air quality and climate, protection against soil erosion and timber production. Meanwhile, ecosystem loss such as deforestation is causing epidemics of diseases such as malaria, a disease that came close to elimination 35 years ago but now kills three million people a year, mostly children. It may also be related to the spread from the natural world to humans of viruses such as Ebola and HIV.

Ecosystem damage is increasing human vulnerability to a range of natural disasters. Storms, tsunamis and high tides rip through coastal communities because mangroves and coral reefs have been destroyed. Floods engulf communities inland because deforestation has destabilised soils and reduced their ability to absorb heavy rains. Elsewhere the loss of forests allows wildfires to spread across the landscape.

Figure 8.8 Ecological overshoot 1961–2002



Source: Global Footprint Network, 2004.

Human influence does not necessarily lead to degradation. People can thrive in a landscape while maintaining its rich biodiversity. Nature can cope with a certain level of human pressure. Surviving agri-ecological landscapes, even in densely populated Europe, illustrate this.

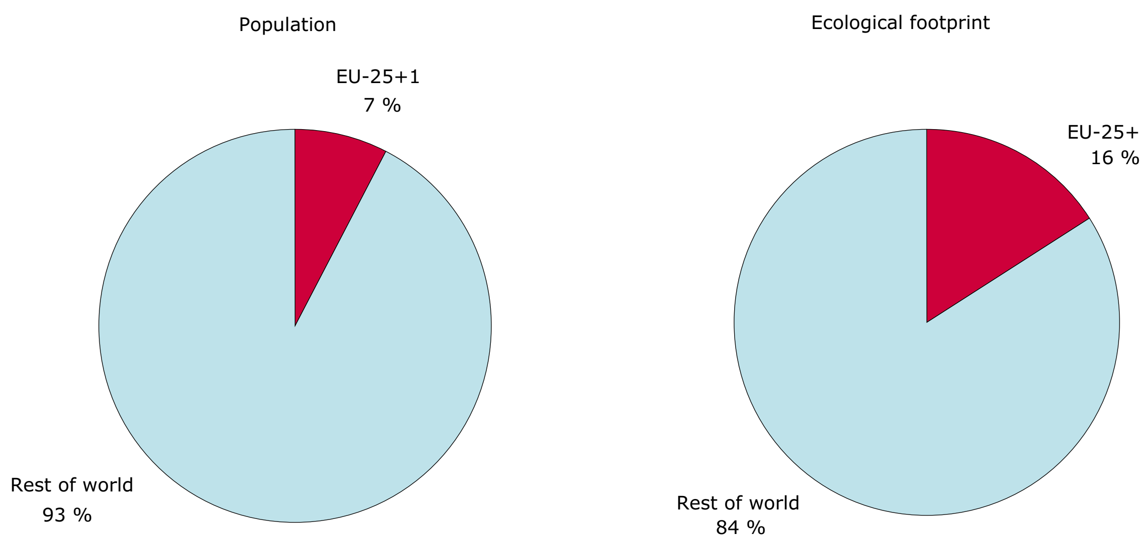
Nevertheless, it is clear that the world is too populous for us to return to a relationship with nature based on hunter-gatherer economies, or even on traditional agricultural economies. However, developing technologies for living in very large numbers at a high standard does not mean we can forgo the natural resources on which all our wealth and health depends. We need to conserve and nurture the planet's ecosystems to ensure our own survival.

8.8 Tracking Europe's ecological footprint

Europe's impact on biodiversity extends far beyond its own shores. We use materials from across the globe to feed, clothe, house and transport ourselves. And our waste is spread around the world — on the winds and via ocean currents. Europe's high per capita consumption and waste production means that its impact on ecosystems is felt well beyond its own borders.

One attempt to capture that is the 'ecological footprint' — a measure of how much of the ecological capacity of the Earth we use up to grow our food and fibre, dispose of our waste, create room for our cities and infrastructure, and provide other ecological services such as sequestration of our carbon dioxide pollution. It has been developed by WWF, the global conservation organisation, and the Global Footprint Network, among others.

Figure 8.9 EU-25 and Switzerland — footprint versus population



Source: Global Footprint Network, 2004.

By these measures the global footprint of humanity was 2.5 times greater in 2002 than it was in 1961. We are now overusing the planet's resources by about 20 % (Figure 8.8).

The ecological footprint is normally measured in terms of hectares of land and productive ocean take-up to provide the goods and ecological services of a country's citizens. This can then be compared with the actual area available, the planet's biocapacity. According to these calculations, the planet's available biocapacity is between 1.5 and 2 hectares per person, though less than half the world lives at this level. North Americans require around 9 hectares to maintain their lifestyles, western Europeans 5 hectares, central and eastern Europeans 3.5 hectares and Latin Americans 3 hectares. The EU share of the world's footprint is more than twice its share of the global population (Figure 8.9).

Such calculations are inevitably crude, and not without controversy. Nonetheless, they can act as a warning about how we manage and share the planetary resources and ecological services on which we all depend.

Some countries, because they have low population densities, can reasonably claim that, while they consume more than their share of the planet's resources, they also contribute more. Not so for Europe, however. The continent is running up a large ecological deficit with the rest of the world. The difference between its footprint and its domestic biologically productive capacity is large and growing.

In 1961, the EU-25's global footprint was around 3 hectares per person, which was virtually the same as the continent's biocapacity. By 2001, Europe's global ecological footprint had risen to more than twice its internal biocapacity. Effectively it requires two continents with the size and fecundity of modern-day Europe to maintain the continent in the style to which it has become accustomed.

Europe achieves that by using its wealth to import the biocapacity of others. In effect, Europe exports many of its environmental problems, by buying products that are created through the depletion of natural capital elsewhere, including the poor, developing world.

Europe's footprint across the globe

So how has Europe's footprint grown, and what impact does it have on the rest of the planet? Europe's demand for fish is a potent case. Fish is the last wild source of animal protein available to Europe in and around its territory. Demand is increasing, while most of the fisheries of Europe are seriously overexploited. Despite growing production of fish from aquaculture, Europe has increasingly turned to foreign waters to maintain supplies. In 1990, the EU-15 imported some 6.8 million tonnes of fish products; by 2003, that had increased by almost 40 % to 9.4 million tonnes.

Analysing Europe's footprint

The list of the global 'top 20' countries with the biggest per capita ecological footprints is headed by the United Arab Emirates, USA, Kuwait and Australia. But European countries feature strongly. The European countries with the highest ecological footprint, as calculated by WWF, are Sweden and Finland, at around 7 hectares per person each. They occupy fifth and sixth places. Overall, European countries occupy more than half of the top 20 places.

Europe's footprint in other countries is created in part by its imports of a range of crops such as coffee, tea, bananas and other fruit, soy and palm oil, wood and fish. However, carbon dioxide emissions from burning fossil fuels are alone responsible for half Europe's total footprint.

Some countries have begun to decouple economic growth from their ecological footprint. One is Germany, which has not increased its footprint since about 1980 — even though it remains more than twice the country's biocapacity. Much of this has been achieved by reducing coal-burning, and reducing its footprint from both acid rain and carbon dioxide emissions. Poland's footprint fell dramatically after the collapse of the former Soviet Union, but it has not grown as its economy has recovered, probably as a result of the closure of much heavy industry. By contrast, the ecological footprints of France and Greece have continued to grow.

EU fleets work in the territorial waters of 26 foreign countries where the EU has negotiated access. Half of these are in Africa. While the deals are open and legal and contain clauses on sustainable harvesting, there are criticisms that, particularly in Africa, some EU fleets are depleting fish stocks and depriving local artisan fishers of their traditional catches.

Europe also imports large quantities of shrimp. Most shrimps in international trade are the products of aquaculture, so there is little direct loss to wild shrimp populations. However, particularly in Asia, shrimp farmers create their ponds by clearing coastal mangrove forests. The increase in shrimp farming over the past two decades has been a major cause of the destruction of around a quarter of the world surviving mangroves.

Mangroves are one of the most biodiverse tropical forest ecosystems. They provide other ecological services, too. The tsunami in Asia in 2004 showed how they protect against storms and tidal waves. Areas of India and neighbouring countries that had cleared their mangroves for shrimp farms generally suffered more from the tsunami than those that still had their mangroves, because the mangroves provided a buffer against the lethal tidal wave.

Timber is another critical natural resource widely exported to Europe, often from poor developing countries where the sustainability of the trade has been widely questioned.

While European countries produce enough timber to supply much of our needs for wood, paper and board, a large part of the remainder comes from tropical countries where illegal logging is often rampant, and ecologists warn of the ecological and social effects of deforestation. Half of Belgium's plywood imports come from the tropics, along with 30 % of French log imports, 50 % of Portuguese sawn wood imports and 30 % of UK veneer imports.

Forest resources are critical in most developing countries, both for national economies and for the subsistence lifestyles of inhabitants of the forests themselves. The World Bank estimates that more than a billion of the world's poorest inhabitants are in some measure dependent on forest resources for their livelihoods. Sustainably managed and harvested, the forests should benefit the people.

The volume of timber imported by the EU is less than by some other continents. Europe is responsible for about 4 % of world trade in timber, but the trade is concentrated in certain areas. European companies dominate the trade in timber from the countries of Central Africa, for instance, taking 64 % of timber exports from the region. Timber makes up a fifth of the EU's total trade with Central Africa. Within the EU, France is the largest importer, followed by Spain, Italy and Portugal.

It is often not easy to establish if imported timber comes from legal or illegal sources, especially when the supply chains are complex and the imported products have been processed along the way. In Asia, there are strong indications that large volumes of wood are harvested illegally in countries such as Cambodia, Indonesia and Myanmar, with some of this undoubtedly reaching Europe.

The World Bank estimates that around a half of all logging in Indonesia may be illegal. This means loggers are removing timber from someone else's land — often that of native forest inhabitants — or at an ecological or social cost unacceptable to the government. Among species threatened by this destruction are the last orang-utans of Borneo and Sumatra. Besides the environmental destruction and the loss of livelihoods for forest dwellers, the Bank calculates that the illegal trade results in a loss of revenue to the government of more than EUR 500 million a year.

Europe is also a major importer of vegetable oil products, especially soybean oil and meal and palm oil that are produced in the tropics on forest land cleared for the purpose. Soybean products come primarily from South America, and palm oil from South-East Asia.

Globally, the EU is the second biggest importer of soy products and, after efforts were stepped up to eliminate animal protein in animal feed, it has become the world's largest importer of soybean meal.

Europe's biggest source of soybean products is Brazil; in 2004 Europe imported almost half of Brazil's 19 million tonnes of exported soy products. This comes at a major ecological cost. Soybean is now probably the largest cause of the destruction of natural habitats in Brazil. Besides rainforests, large areas of dry savannah, known in Brazil as *cerrado*, are being cleared for soybean plantations. The *cerrado*, mostly in the Mato Grosso region of the country, receives much less protection than rainforests, but it is home to more than 4 000 endemic plant species as well as endangered animals such as the giant armadillo and the giant anteater. Seeing Brazil's success in selling to Europe, both Argentina and Paraguay have ambitious plans to expand soybean production in their own Chaco and Atlantic forests.

Palm oil exports to Europe come primarily from South-East Asia. Palm oil finds its way into a huge number of food products, from margarine and cooking oils to confectionery, ice cream, noodles and bakery products. The EU is one of the world's top importers, with 17 % of world trade. The two largest producers are Malaysia and Indonesia: combined, they have 85 % of global production. Expanded production, much of it to meet growing markets in Europe, is a main driver for forest clearance in both countries, as well as exacerbating social conflicts over the ownership of forest resources.

Europe's global ecological footprint also extends to water. While Europe does not directly import water, it does import large volumes of crops that have been grown using scarce irrigation water in other lands. Economists have characterised this as 'virtual water'. Three commodities — wheat, rice and soybean products — make up almost two-thirds of the world trade in virtual water.

The volumes of water involved are huge. It takes between 2 000 and 5 000 litres of water to grow 1 kilogram of rice and 7 500 litres to grow the 250 grams of cotton needed to make a single t-shirt. More and more countries come under water stress, and as the cost of providing water for irrigation grows, there is increasing discussion of how sustainable such trade in virtual water is.

European countries are among the world's largest importers of virtual water, with annual imports estimated at around 400 billion cubic metres. Typical imports of virtual water come in the form of tomatoes and oranges from Israel, cotton from Egypt and Australia and rice from South-East Asia. The Netherlands alone imports some 150 billion cubic metres of virtual water. Germany, Italy and Spain are also in the world top ten importers, with more than 60 billion cubic metres each.

The EU also has a large footprint in the live animal trade. The EU imports 92 % of all internationally traded wild birds, for instance. The leading importers are Italy, the Netherlands and Spain. Many of the birds are listed as endangered by the Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES). A study by non-governmental organisations found that over the past four years the EU imported three million birds listed under CITES. The trade could have been the route of introduction of Asian bird influenza to Europe in 2003.

8.9 Giving biodiversity a cash value

We live in a world where value is usually measured in cash terms. The problem for protecting biodiversity is that, however much we sense its worth or comprehend its importance in maintaining ecological services, that worth is hard to put a price on. Often, economic enterprises do not pay the cost of the damage they do to ecosystems. Equally, there is often no benefit or incentive for those who take the trouble to preserve those assets. The world economic system has yet to find a satisfactory way to internalise these losses of natural capital on which the system itself ultimately depends.

A new generation of economists is attempting to put a price on biodiversity and to evaluate the benefits of the services that ecosystems provide. They believe that the process of evaluation will help policy-makers appreciate the value of natural assets. It will allow society to assess better who wins and who loses when natural forests are logged out, wetlands drained and coral reefs wrecked, and to consider alternative economic strategies and whether they provide a better return in protecting ecosystem services. Ultimately the new economists hope that the value of ecosystem services can be routinely incorporated into mainstream market mechanisms.

Biodiversity can appear to many a rather abstract concept. So what specifically are the economists trying to value? There are four categories:

- Direct use values. These include things we harvest, such as timber, food and plant medicines, together with features of nature that we use without consuming, such as landscapes we visit.
- Indirect values. These are the ecological services provided by nature. Wetlands, for instance, purify water; forests maintain wildlife and capture and store carbon, so moderating climate change; mangroves protect coastlines from storms and tsunamis.
- Option values. These are both direct and indirect values that are not used now, but might be in future. Thus mangroves might be worth protecting because they will in future provide a barrier against a rise in sea levels. A forest may be kept because one day it might yield a cure for a disease.
- Existence values. These are largely cultural or spiritual. Europeans might see a value in a rainforest even if we never expect to use or visit it, or gain any services from it. We just like to know that it is there.

The first two of these values can, in theory at least, be measured. Directly used resources have a cash value in the market place. We can measure, for instance, the value of a harvest that would be lost if a rainforest were clear-felled. Indirect values can be indirectly measured, too, by assessing the cost of a replacement for the ecological service, whether purifying water, cooling the air or preventing floods.

Option and existence values may be no less important to society, but they are harder to assess. Conventionally, economists would 'discount' future value, thus giving little credence to option value, but is that acceptable when, through the United Nations, governments have agreed to the proposition that we should maintain the planet's ecosystems in a state fit for the use of future generations?

The trouble is that the cash value of a rainforest may be most readily realised by harvesting things of direct value with little regard to things of indirect value or to option or existence values, by clear-felling the forest for timber, for instance. If, however, these other values are included, it would be more economic to harvest the forest it a way that allows it to regenerate, and maintain the value of its asset for other uses. Similarly coral reefs might best be protected from destructive fishing, and mangroves from conversion to shrimp farms.

That is the theory; turning it into practice is harder. A private owner of land will generally only be able to 'harvest' the direct value of the resource. The indirect value has a wider constituency of beneficiaries who do not in legal terms have any ownership or control over the resource. Governments may have to intervene, either to establish economic instruments to allow the owner to benefit from the indirect value of the resource, or to enact laws on behalf of the wider community to prevent loss of those indirect values.

How market instruments can be used to protect biodiversity and the ecosystem services that it underpins remains an open question. It may be that legal instruments will, as now, remain the main method of protection. What is clear is that many new instruments of all kinds are likely to be needed if the huge task of maintaining ecosystems and biodiversity is to be achieved.

8.10 Summary and conclusions

Europe is home to around 1 000 species of animals, birds and fish, some 10 000 plant species and maybe 100 000 different invertebrates. This richness of European biodiversity and ecosystems is essential when considering present and future ecosystem services, in particular in relation to potential adaptations to climate change. Maintaining the variety of ecosystems in terms of their abundance, health and connectivity is not a stand-alone target of nature conservation but a main challenge for society. Across Europe, most large ecosystems exhibit worrying signs of rapid changes.

Most of Europe's land surface is in productive use — less than a fifth can be regarded as unproductive, and most of that is just formerly productive land that has, possibly temporarily, been abandoned. The largest losses of habitats and ecosystems for biodiversity across the continent during the 1990s were in heath, scrub and tundra, and wetland mires, bogs and fens. Many wetlands have been lost to coastal development, mountain reservoirs and river engineering works. Similarly, although more of Europe is covered by trees today than in the recent past, many forests are harvested more intensively than before.

These losses are impacting individual species. Although almost 18 % of the Community's land area is protected as part of the European strategy to conserve its critical wildlife habitats, many species remain threatened, including 42 % of native mammals, 15 % of birds, 45 % of butterflies, 30 % of amphibians, 45 % of reptiles and 52 % of freshwater fish.

Europe's high rates of consumption and waste production impact biodiversity far beyond its own borders and shores. We use materials from across the global to feed, clothe, house and transport ourselves. Our waste, too, is spread around the world — on the winds and via ocean currents. In 1961, the EU-25's global footprint was around three hectares per person, which was virtually the same as the continent's biocapacity. By 2001, Europe's footprint had risen to more than twice its internal biocapacity.

While uncertainties remain about the capacity of ecosystems to resist, accommodate or possibly even benefit from it, climate change will affect almost every aspect of Europe's biological life. Growing seasons and flowering times will alter; so will migration times and destinations. Species unable to move will decline or die out; others will take advantage of the climatic space that opens up. Pests will change their domains. Carbon dioxide in the atmosphere will fertilise some plants, while drought or floods will undermine others.

The European Union and its Member States have agreed an ambitious target to halt biodiversity loss by 2010, recognising the seriousness of the threat to the planet's ecological resources and our well-being. Progress, albeit slow, is being made on several fronts, and awareness is being raised among key stakeholders. This is despite the complexities surrounding biodiversity and our limited understanding of the interplay between genes, species, habitats, ecosystems, biomes and landscapes.

Conservation is not just about preserving special habitats and threatened species. It is about preserving those basic life-support systems on which life on Earth depends. Whether market instruments can be used to protect biodiversity and the ecosystem services or whether legal instruments will, as now, remain the main method of protection is an open question. What is clear is that much more effort is needed to implement to best effect the policy instruments already available for the benefit of biodiversity, and that new instruments of various kinds are likely to be needed if the huge task of maintaining ecosystems and biodiversity, on which our standards of living depend, is to be achieved.

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9 Environment and economic sectors

9.1 Introduction

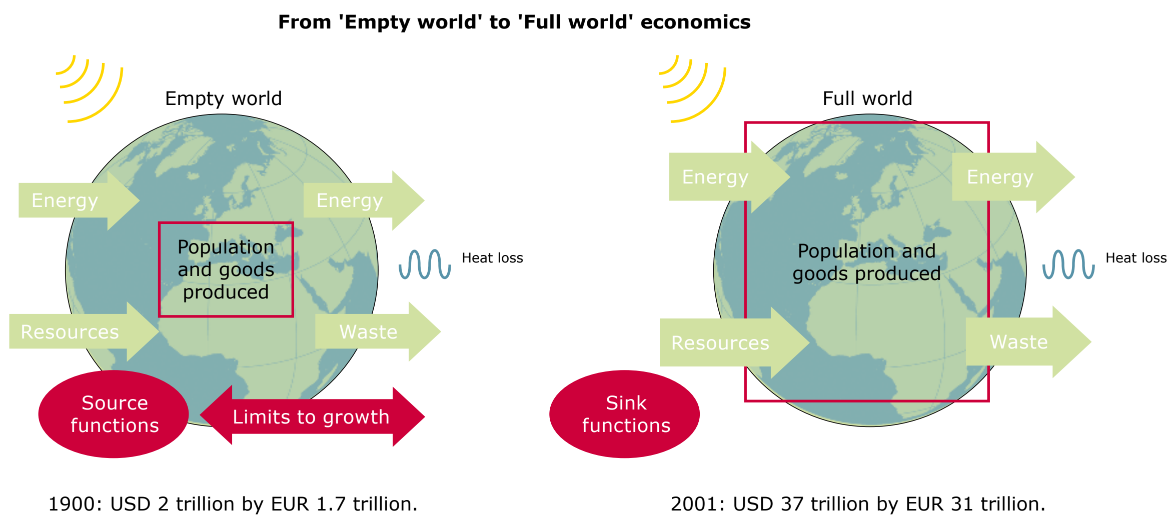
The economy depends on the environment. The natural environment provides invaluable ecological services, including forests that moderate local climate, wetlands that absorb floods, and soils that purify water and buffer pollution. It also provides sources of materials, water, medicines and energy, as well as sinks for our wastes and pollution, recycling toxic materials into benign and sometimes useful forms. Finally, it offers space for people's homes and their leisure pursuits, and room for other species. Particularly in the developed world, economic prosperity is needed to deliver effective environmental management.

The assessment of realistic values for ecological services — values that reflect their true place within modern economies — is still in its infancy. This is, perhaps, one reason why we are still eroding the planet's natural resources faster than may be viable. As the World Business Council for Sustainable Development said in the Millennium Ecosystem Assessment: 'Business cannot function if ecosystems and the services they deliver — like water, biodiversity, fibre, food and climate — are degraded or out of balance…'.

It took the whole of human history to the year 1900 for the world economy to grow to a gross domestic product (GDP) of EUR 1.7 trillion (USD 2 trillion) at 1990 prices. Fifty years later this had grown to EUR 4.1 trillion (USD 5 trillion) and by 2001 to EUR 31 trillion (USD 37 trillion), more than seven times the 1950 amount. It is the speed and scale of this economic development that threatens the integrity of the ecological services which underpin economic activity. It is now generally accepted that there are physical limits to continuing economic growth based on resource use (Figure 9.1).

The current rates of change in economic growth and population make it more difficult than before for ecosystems and their associated services to adapt.

Figure 9.1 World economic growth 1900–2001 and links to the use of environmental services



Source: EEA based on data from OECD.

Together with rapidly rising personal consumption patterns, demographic changes and economic transformation, the increasing economic use of environmental assets allows relatively little time for ecological adaptation. Worryingly, analyses of trends suggest that we should expect the intensity of use of ecological services to increase in the future.

9.2 The changing state of Europe's environment

The overall picture of the state of Europe's environment remains complex. On the plus side, there have been substantial reductions in emissions of substances that deplete the ozone layer, reductions in air emissions that cause acidification and air pollution, and cleaner water as a result of reductions in point source pollution. Protection of biodiversity, through the designation and protection of habitats, has provided some improvements in maintaining ecosystem productivity and landscape amenity. Such progress, overall, has been brought about mainly through 'traditional' measures such as regulating products and production processes, and protecting important nature sites. These policy areas are supported through well-established European Union legislation and in many cases are also directly or indirectly framed within international conventions.

Trends in other environmental pressures such as greenhouse gases and waste generation have been upward, in line with broader socio-economic developments. Short-term targets for reducing greenhouse gas emissions are expected to be met by 2008–2012 provided all planned polices and measures are implemented. As part of its effort to reach its target, the EU has in 2005 introduced an emissions trading system for greenhouse gases. The aim is to stimulate innovation and give reductions in emissions a market value. Long-term targets for emissions reductions, though, established to prevent harmful climate change, are not expected to be reached without substantial changes to the energy mix. Many countries are already developing adaptation strategies in recognition of the need to act on expected future long-term impacts.

Climate change is already visible. Increasing temperatures across Europe, changing precipitation patterns in different regions, melting glaciers and ice sheets, increased frequency of extreme weather events, rising sea levels and increasing stress on terrestrial and marine ecosystems are among the most visible impacts on the environment.

The EU has made substantial progress in reducing the environmental impacts of waste disposal and will make further progress as recently adopted legislation on landfill and incineration is implemented. Nevertheless, the volume of most waste streams continues to rise in step with growth in GDP — by 2020 we can expect to be producing nearly twice as much waste as today if current trends continue.

At the same time, air quality in urban areas continues to have adverse effects on people's health, and in rural areas on ecosystems. The impacts in rural areas are expected to decline substantially on the basis of existing policies and measures; however, negative impacts are expected to remain significant in highly populated areas up to 2020.

Much remains to be done on point source emissions to water especially in the EU-10, whilst there has been relatively little progress in reducing nitrates in water across the EU-25. Implementation of the urban waste water treatment directive should reduce point source emissions substantially in the EU-10, but nutrient discharges from rural populations and agriculture are expected to remain a major water pollution problem in coming decades. Future prospects suggest that eutrophication of Europe's freshwater and marine waters will remain a challenge.

Biodiversity loss is continuing, especially on farmland. Gains and losses of plant species are expected in the future in some countries as a consequence of climate change. Soil remains a resource under pressure with sealing and contamination of soils in and around urban areas being of particular concern. Exceedances of critical loads for soils from nitrogen deposition are expected to decline for most areas of Europe in the coming decades.

Table 9.1 The sixth environment action programme (6EAP) — Are we on track?

Action on tackling climate change

Target	Outlook	Region
Kyoto Protocol commitment of an 8 % reduction in GHG emissions in the EU as a whole by 2008–2012 compared with 1990 levels (Art. 5.1)	-> With existing domestic policies and measures alone (as of mid-2004), a reduction in emissions of less than 3 % is expected in the EU	EU-25
	-> However, taking into account the latest policy developments and all the additional policies, measures and third-country projects planned so far, the EU-15 is likely to meet its target	EU-15
Long-term objective of a maximum global temperature increase of 2 °C over pre-industrial levels (Art. 2)	-> Global temperature to increase by more than 3 °C by 2100	EU-25
	-> Potential to reach target by a long-term deep reductions of global and EU GHG emissions	EU-25
Use of renewable energy sources […] meeting the indicative target of 12 % of total energy use by 2010 (Art. 5.2 (ii (c)))	-> Renewable energy sources in total energy use expected to be about 7.5 % by 2010	EU-25
Doubling the overall share of combined heat and power to 18 % of total gross electricity production (Art. 5.2 (ii (d)))	-> Combined Heat and Power in total gross electricity production is expected to be about 16 % by 2030	EU-25
Promote the development and use of alternative fuels in the transport sector (Art. 5.2 (iii (f)))	-> Biofuels in transport final energy demand are expected to be 1 %, 2 % and 4.5 % by 2005, 2010 and 2030	EU-25
Decoupling economic growth and the demand for transport (Art. 5.2 (iii (h)))	-> Relative decoupling from GDP is expected over the next 30 years for both passenger and freight transport demand	EU-25

Action on nature and biodiversity

Target	Outlook	Region
Halting biodiversity decline with the aim of reaching this objective by 2010 (Art. 6.1)	-> Losses in the number of plant species are expected as a consequence of climate change in some European countries	EU-25
Protection and appropriate restoration of nature and biodiversity from damaging pollution (Art. 6.1)	-> On the basis of existing policies and measures, air pollution and its impacts on health and ecosystems are expected to decline significantly up to 2030	EU-25
Encouraging more environment-responsible farming, such as extensive, integrated, and organic farming (Art. 6.2 (f))	-> Moderate expansion of good farming practices expected	EU-25

Action on environment and health and quality of life

Target	Outlook	Region
Ensure that the rates of extraction from water resources are sustainable over the long term (Art. 7.1)	-> Total water withdrawals are expected to decrease by 2030, but water stress may remain in southern Europe	EU-25
Achieve levels of air quality that do not give rise to significant negative impacts on and risks to human health and the environment (Art. 7.1)	-> On the basis of existing policies and measures, all emissions of land-based air pollutants (except ammonia) are expected to decline significantly up to 2030	EU-25
	-> The EU as a whole is expected to comply with the 2010 targets of the NEC directive	EU-25
	-> Impacts on human health and ecosystems are expected to diminish substantially, although large differences across Europe persist	EU-25
Sustainable use and high quality of water, ensuring a high level of protection of surface and groundwater, preventing pollution (Art. 7.2 (e))	-> The urban waste water directive is expected to significantly reduce the overall discharge of nutrients	EU-25
	-> Agricultural nutrient surpluses are expected to be moderately reduced in 2020	EU-15
	-> Pressures are expected to increase significantly in the New-10, due to mineral fertiliser use	New-10

Action on the sustainable use and management of natural resources and waste

Target	Outlook	Region
Indicative target to achieve 22 % of electricity production from renewable energies by 2010 (Art. 8.1)	-> Electricity production from renewable energy expected to be about 15 % in 2010	EU-25
Significant overall reduction in the volumes of waste generated (Art. 8.1)	-> Waste generation continues to grow across Europe. In the New-10 relative decoupling from GDP growth is expected (but not in the EU-15)	EU-25
Establishment of goals and targets for resource efficiency and the diminished use of resources (Art. 8.2 (i (c)))	-> Resource productivity in the New-10 is expected to remain about 4 times lower than in the EU-15	EU-25

Although anti-pollution measures taken over the past half-century have dramatically reduced the presence of many known toxins, the number of toxic substances in consumer products, pharmaceuticals and the wider environment has grown. Individual chemicals, such as endocrine disrupters, are likely to be detrimental to human health and reproduction, while there is growing scientific concern about the effects of the cocktail of chemicals each of us is exposed to every day.

Many of Europe's commercial fish stocks are overharvested and some are in danger of collapse. As a result, an increasing proportion of fish for European consumption is caught outside European waters, by either foreign or licensed European vessels. Europe's environmental footprint on the world's fisheries is unsustainably large and, besides questions of equity, forms part of a threat to the survival of the resource itself.

There has been a decline in the health of Europe's forests, attributable at different times to air pollution and drought, with a quarter of the continent's trees currently rated as damaged. This damage has particularly serious implications in Europe's remaining old-growth forests, where biodiversity is at its richest.

As indicated in Chapter 1, the EU's sixth environment action programme provides the main framework for action to 2012. The programme identifies key environmental problems within which are embedded various objectives and targets relevant to these priorities and the economic sectors that have most impacts. Outlooks for the future suggest that full implementation of existing environmental policies would deliver significant improvements in the coming years in several fields and help the EU meet its targets in a number of areas. Nevertheless, progress is expected to be limited towards targets for greenhouse gases, renewable energies and transport (Table 9.1).

New and more integrated actions are therefore needed that reflect the strong relationship between environmental problems and socio-economic developments, over space and over time. What Europe is now facing is a series of mainly diffuse source issues that require both actions across a number of well-established sectors, whether agriculture, transport, manufacturing or energy production, and actions which engage with social factors such as urbanisation, personal consumption and waste production.

A look at recent developments and prospects in four of the main sectors — transport, agriculture, energy and households — and their impacts on the environment helps to provide some clues as to where the focus for such future integrated actions could lie. A fifth sector, industry, which has major environmental impacts, directly influences trends in the other four: for example, the metals and materials industries in transport, the chemicals industry in agriculture, the minerals industry in the energy supply sector and the construction industry in households. This sector, especially the manufacturing part, is addressed further in the section on eco-innovation in the next chapter.

9.3 Developments in four socio-economic sectors

Transport

An efficient and flexible transport system is essential for our economy and our quality of life. The current European system poses significant and growing threats to the environment, to human health, and to the economy, through, for example, increasing congestion. Passenger and freight transport, by road, air and sea, are either growing at the same rate as or faster than the economy overall, implying that the eco-efficiency of transport in the EU economy, and the decoupling of growth in transported passenger or tonne from growth in GDP, are not improving. Trends to 2020 suggest that decoupling will continue to be a challenge overall (Figure 9.2).

Transport volumes in the EU-25 have increased steadily over the past decade: about 30 % for freight transport and almost 20 % for passenger transport. This growth is strongly linked to infrastructural development that, in turn, contributes to air pollution, the sealing of soil and the fragmentation of habitats across many parts of Europe, as well as exposing a significant proportion of the population to high noise levels. Freight transport has increased as a result of changed procurement and distribution strategies of companies (outsourcing, just-in-time delivery) and the development of the internal market as companies exploit the competitive advantages of different European regions.

Causes of the growth in passenger transport include an increase in the number of households and in the number of cars per household, as well as a lengthening of the average journey. This last trend is influenced by such factors as urban sprawl, together with the location of services including schools, shops and medical facilities; the availability and pricing of public transport; and changes in lifestyle fuelled by two incomes per household and a wider choice of leisure activities.

Unsurprisingly, transport is the fastest growing consumer of energy, currently accounting for 31 % of Europe's final energy consumption. Greenhouse gas emissions are also growing rapidly — by more than

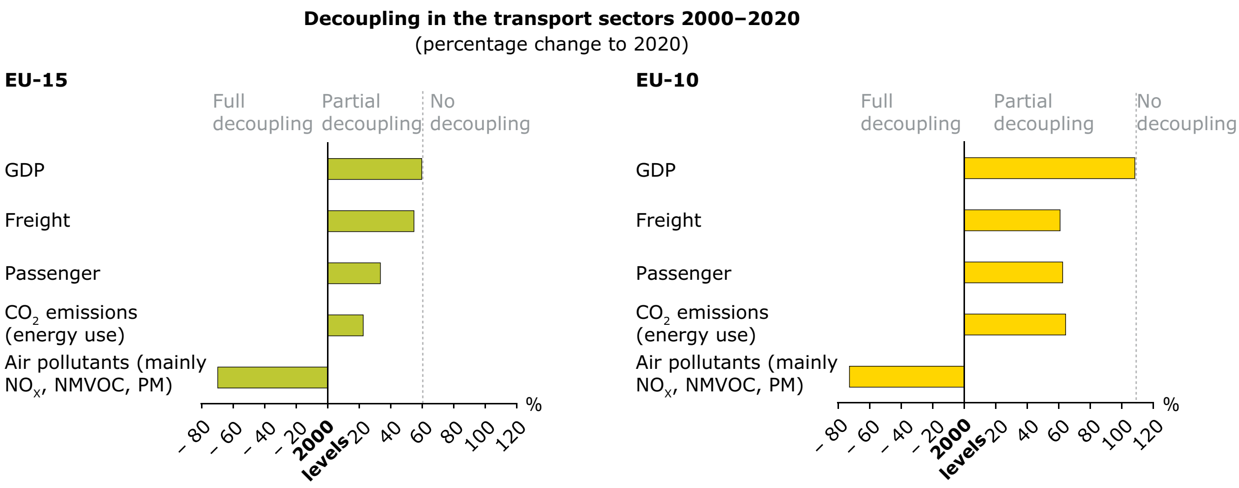
20 % between 1990 and 2003 — and they are expected to be 50 % higher by 2030 than they were in 1990. Aviation, as the fastest growing mode of transport, and marine transport account for an increasing share of these emissions while remaining outside the coverage of environmental policies such as the Kyoto Protocol and fuel taxation. On the road, increasing traffic volumes and a rising number of larger, heavier and more powerful vehicles travelling ever further has more than offset progress in improving energy efficiency, stimulated by the industry's voluntary commitments to reduce average CO_2 emissions from new passenger cars to 140 grams/kilometre by 2008/2009.

The rapid increase in passenger and freight demand projected over the next 30 years, together with the difficulties in replacing oil as the fuel on which the sector depends, suggests that transport will be one of the most difficult sectors in which to reduce carbon dioxide (CO_2) emissions. Even increases in fuel prices, possibly through such measures as the introduction of carbon permits, seem unlikely to substantially alter this picture, unless appropriate policies for new fuels are developed alongside such measures.

Technological developments, including catalytic converters and other technical abatement measures on road vehicles, have resulted in marked decreases of some other pollutants such as ozone precursors and acidifying substances. Emissions of these regulated pollutants fell by about a third between 1990 and 2002 across EEA countries, with further improvements expected as stricter limits come into force and the vehicle fleet is renewed.

Developments in vehicle technology go hand in hand with improved fuel quality standards. Lead has been banned in the EU-25 and new standards for sulphur content have been set at 50 parts per million (ppm) by 2005, falling to 10 ppm by 2009. There is, however, increasing evidence that standardised test cycles used for the type approval of road vehicles do not necessarily represent 'real world' driving conditions. The issue of 'chip-tuning' of diesel vehicles to boost power at the expense of fuel efficiency and low emissions is a further cause for concern.

Figure 9.2 Transport — decoupling outlooks to 2020 for key environmental resources and pressures



Source: EEA, 2005.

Technical improvements in vehicles and fuels can be supported by economic incentives such as taxation tied to CO_2 performance, road pricing policies or environmental zoning. The introduction of mandatory CO_2 emission limits might be considered, too. There is also a need to raise public awareness about how much car parameters such as size, weight and engine power, and energy-consuming equipment such as air conditioning, influence CO_2 emissions.

Any emission control policy needs to be complemented by other measures aimed at controlling road transport volumes. If the forecast growth in road transport is not to undermine current and expected achievements, focus needs to be put on user behaviour. Options include improving spatial planning to reduce distances to and between key services and providing settlements with improved access to better public transport. Given the slow rate of change in housing and infrastructure stock, and the fact that decisions are seldom based on considerations of what is best for the environment, these measures would inevitably take some time to produce benefits. Investment in public transport and pricing mechanisms could, however, also strengthen a shift to more environmentally sound transport and improve incentives to higher load factors.

Thus, a sustainable road transport policy that guarantees social inclusion and economic development with a high level of environmental quality and safety has to combine a number of different approaches, instruments and strategies that aim to:

- improve efficiency by reducing the number and average distance of journeys;
- shift transport to more environmentally benign modes;
- use existing vehicle capacity and infrastructure more effectively; and
- improve the environmental performance of vehicles.

Some instruments, such as road user charges or fuel taxes, can contribute to several or all strategies simultaneously, while others — for example setting emission standards for vehicles or the provision of public transport — basically influence one or two approaches.

Emissions of air pollutants from aviation and marine transport, which are not subject to international regulation, and from rail and inland shipping have not reduced substantially. In the case of aviation and marine transport, they have grown significantly due to increasing volumes allied to a lack of strict and mandatory standards. It is expected that emissions of sulphur dioxide and nitrogen oxides from maritime activities will surpass land-based emissions within the next 20 to 30 years.

Agriculture

Across Europe, highly developed agricultural land patterns and their functions have evolved over centuries to ensure that the population is fed and rural landscapes are maintained. Current agricultural activity has substantial environmental impacts in terms of greenhouse gas and air pollutant emissions, contributing to climate change and acidification; pollution of water by nitrates, phosphorus, pesticides and pathogens; habitat degradation and species loss; and the over-abstraction of water for irrigation. Looking ahead to 2020, in the EU-15, a partial decoupling of water and mineral fertilizers uses is expected, and full decoupling for nutrients surpluses and greenhouse gas emissions. Partial and full decoupling are also expected in the EU-10 for water use and greenhouse gas emissions, but no decoupling might characterise the development of mineral fertilizers use and nutrients surpluses (Figure 9.3).

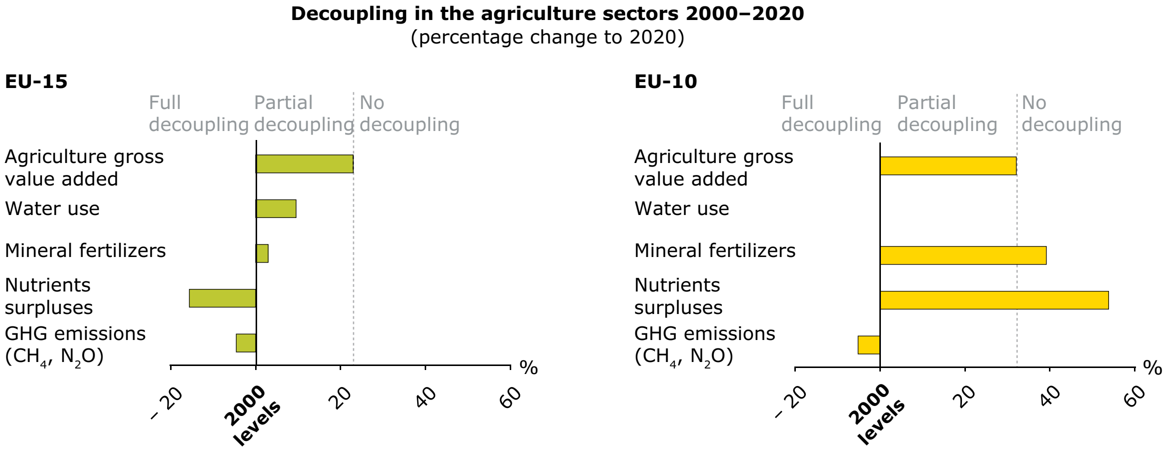
Farmland boasts a wide range of habitats and species that depend to a large extent on continued (extensive) agricultural use. However, depopulation is occurring in many rural areas, profoundly affecting the countryside and the environment. Low and variable incomes, hard working conditions and a lack of social services and leisure activities in many areas make traditional farming a less attractive option for young people living in a predominantly urban Europe — the proportion of the elderly is already very high amongst Europe's farmers. Depopulation is a phenomenon all over Europe, whether from hill farms in the Alps or traditional small farms from Poland to Portugal. The trend is particularly worrying in central and eastern Europe, where recent political and economic changes during the 1990s negatively affected the conditions for farming. As a result, further land abandonment is to be expected.

Agriculture's share of the total national land area ranges from 30–60 % in the new Member States. Here many private farmers, with limited formal agricultural training, rely on relatively outdated machinery and buildings. Economic restructuring and lack of capital caused a sudden drop in agricultural investment in the 1990s. This resulted in lower pesticide and fertiliser inputs, with a consequent reduction of pollution, and, in most EU-10 countries, the abandonment of biodiversity-rich grassland systems.

The reduced investment in erosion mitigation and in manure storage facilities poses significant environmental risks if, as expected, agriculture in these countries intensifies in the future. Indeed, fertiliser use in the new Member States is expected to increase by up to 50 % by 2020, while in the EU-15 fertiliser use is expected to remain stable. The increased use of inputs will be a key factor behind the expected increased yields and agricultural production in the EU-10, and brings with it risks of environmental pollution requiring careful management.

Over many decades, in response to greater demand driven by improved standards of living, population growth and urbanisation, large-scale rationalisation and industrialisation of agricultural production has taken place. This has led, amongst many outcomes, to pastures and semi-natural grasslands being converted to intensive farmland, with the consequent destruction of habitats such as hedgerows and ponds that have supplied, over at least the past 250 years, niches for a wide range of species. Moreover, conversion of marginal land to agriculture has taken place in parts of Portugal and Spain and to a smaller extent in the south-west of France. Withdrawal of farming has occurred in some mountain areas in southern Europe, as well as in many new Member States.

Figure 9.3 Agriculture — decoupling outlooks to 2020 for key environmental resources and pressures



Source: EEA, 2005.

Agricultural intensification has brought about a rapid decline in semi-natural vegetation such as hedgerows and field borders. Wild-living species of both fauna and flora rely for their survival on habitats and the corridors that connect them — for example, roughly two-thirds of the currently endangered bird species depend on agricultural habitats. These have become increasingly fragmented, making the maintenance of viable species populations more difficult. As a result, over the last few decades, biodiversity on farmland has declined. Farmland species of particular conservation concern occur throughout Europe, but many of them are associated with high nature value (HNV) farmland, particularly in southern Europe.

A realisation that the regional identity of European landscapes — testimony of the continent's combined natural and cultural heritage — is at risk has placed the conservation of biodiversity on agricultural land high on the political agenda. Of the many relevant conservation efforts at European level, the most important are the habitats and birds directives and the biodiversity action plan for agriculture. In the sixth environment action programme, the EU has committed itself to halting the decline of biodiversity by 2010.

Conserving HNV farmland is essential to achieving this target. Under the EU common agricultural policy (CAP), agri-environment schemes are being used as a tool to give farmers compensation for taking specific environmental measures that can support HNV areas. However, the rate of uptake varies greatly: it is particularly low in southern European countries, including Portugal and Spain, where the share of HNV farmland is relatively high. Thus, the challenge for agri-environment schemes is specifically to target those areas that could benefit most from conservation.

Nitrates from agriculture continue to damage the environment, contributing to eutrophication of coastal and marine waters and pollution of drinking water, especially where groundwaters have become contaminated. Problematically, substantial time lags can occur before changes in agricultural practices are reflected in groundwater quality. The length of these lags, which may be measured in decades, varies according to soil type and the specific hydro-geological conditions of the groundwater body and overlying substrate.

It is generally cheaper to prevent nitrates reaching the water in the first place. A review of the possible costs to farmers comes to an initial estimate of EUR 50–150 per hectare per year to alter farming methods to comply with standards set by the EU nitrates directive. This is considerably cheaper than the estimated costs of removing nitrates from polluted waters. Moreover, changing farming practices puts the responsibility on the farmers who have caused the pollution, rather than on the consumer.

The nitrogen (N) surplus in the farmland soils of the EU-15 declined from 65 to 55 kilograms N/hectare between 1990 and 2000. In some European hot spots, surpluses as high as 200 kilograms/hectare can be found. These surpluses are the overriding contributor to continuing high nitrate levels in Europe's rivers. Looking forward, the good news is that such surpluses are expected to decouple completely from agricultural production growth in the EU-15 and partially decouple in the EU-10. Nonetheless, forecasts suggest they will continue to increase in absolute terms.

Currently nitrate levels in surface and groundwaters are lower in the EU-10 than in the EU-15. However, if agriculture intensifies in the EU-10, as expected, good implementation of the EU nitrates directive, supported by the CAP cross-compliance rules that tie funding to legislation and other measures, will be essential to avoid creating extensive, expensive and long-lived water pollution problems in the coming years.

Withdrawal for agricultural irrigation is the largest source of water abstraction in southern Europe and will continue to be so in the future. Technological developments have led to some improvements in efficiency — and there is scope for much greater uptake of these new technologies — but these have been more than offset by increases in the area of irrigated land. The hotter drier summers predicted as a result of future climate change will further increase pressures on water use in the next 20–30 years. In northern Europe, abstractions for irrigation are relatively small, and may decrease further in future as a result both of improved technologies and of the expected wetter conditions. For the EU-10, as well as for southern Europe, savings in the future from more efficient irrigation systems are likely to be cancelled out by increases in the need to irrigate as a result of anticipated climate change.

Changing climatic conditions will, in all likelihood, have a range of favourable and unfavourable impacts on agriculture. For example, the annual growing season for plants, including agricultural crops, lengthened by an average of 10 days between 1962 and 1995 and is projected to continue getting longer. In most parts of Europe, particularly the middle and northern Europe, agriculture could also potentially benefit from a limited temperature rise. However, while Europe's cultivated area could expand northwards, agricultural productivity in some parts of southern Europe may be threatened by water shortages. More frequent extreme weather, especially heatwaves, could bring more bad harvests. Agriculture's capacity to adapt will be a key factor in response to expected climate change in Europe.

Energy

Energy services provide all of us with comfort and mobility, and underpin economic competitiveness and security. Despite reductions of some air emissions, the energy supply sector (including electricity and heat production, refineries, etc.) is a prime contributor to environmental concerns such as climate change, air pollution and water stress. In particular, it continues to be the major source of greenhouse gas emissions (around one-third of total emissions) and emissions of acidifying substances such as sulphur dioxide and nitrogen oxides (about 30 % of total emissions). Future developments thus depend to a large extent on progress in decoupling environmental pressures from production and consumption.

Energy consumption is expected to continue increasing over the coming decades but to partially decouple from GDP, consolidating past reductions in energy intensity (Figure 9.4). At the same time, the policy targets for increasing sources of renewable energy are not expected to be met across the EU-25 without additional policies and measures. As a consequence, the energy sector is expected to contribute to increasing greenhouse gases and climate change in coming decades, while reductions in emissions of acidifying substances are expected to continue.

Past measures to reduce air emissions from power stations have been hugely successful. In the EU-15, between 1990 and 2002, emissions of sulphur dioxide and nitrogen oxide from public electricity and heat production fell by 64 % and 37 % respectively, despite a 28 % increase in the amount of electricity and heat produced. This success has been attained through strict regulations setting clear emission standards based on available technological abatement measures.

The introduction of flue gas desulphurisation and the use of lower sulphur coal and oil contributed some two-thirds of the sulphur dioxide reductions; another major contributor was the switch in the fuel mix away from coal and oil towards lower sulphur fuels such as natural gas, prompted by the liberalisation of energy markets and, to a lesser extent, improvements in the efficiency of the conversion process. Some of these developments produced one-off benefits, however, and will not contribute to any further decoupling of environmental pressures from production and consumption.

The development of the electricity sector over the 1990s demonstrates that new technologies can be introduced. Electricity produced from gas doubled in both the EU-15 and the new Member States between 1995 and 2002 as competition favoured gas use due to the high efficiencies and low capital costs associated with some gas-based technologies, in particular combined cycle gas turbines (CCGT).

Overall, the CO_2 emissions intensity of power production fell by about a fourth between 1990 and 2002 in the EU-25, but increases in demand meant that CO_2 emissions from power production declined only slightly, by around 5 %. For CO_2 emissions, end-of-pipe abatement technologies are not yet available. This may change in the future with the planned use of CO_2 capture and storage. This technology separates CO_2

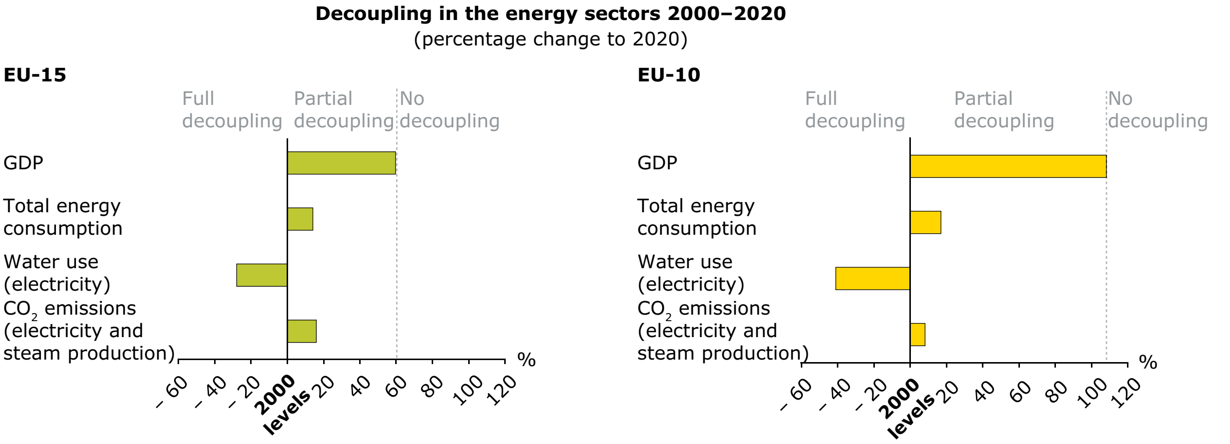
from the flue gas or a process gas before burning. It can substantially reduce CO_2 emissions from the burning of fossil fuels. However, the process is expensive and requires a substantial extra amount of energy; the long-term safe storage potential, and even feasibility, is not yet fully known.

With CO_2 capture and storage not yet being commercially available, reducing CO_2 emissions requires a lower consumption of fossil fuels (coal, oil, gas). Since the majority of electricity — and over three-quarters of total energy consumption — is produced from fossil fuels, this requires deeper changes in electricity generation. Technologies are available to reduce the CO_2 emissions of electricity. These include the increased use of non-fossil fuels such as renewable and nuclear energy, improving the efficiency of the conversion process, or using less carbon-intensive fossil fuels such as natural gas. The use of combined heat and power plants, which produce not only electricity but also make use of the heat that would otherwise be lost, can also contribute to substantial CO_2 emissions reductions.

Many of these measures imply investing in new plants and infrastructure as opposed to applying abatement technologies in existing plants. Combined heat and power plants need a heat distribution infrastructure to the end-user, while some renewable technologies — such as wind energy — face the problem of fluctuating electricity production. Nevertheless, the difficulties in achieving such structural changes are primarily due to socio-economic barriers, not the lack of technical solutions. If long-term targets and appropriate incentives are set, such changes can be realised within the ongoing renewal of the European power system.

The importance of further penetration of new, less carbon-intensive technologies and fuels in electricity generation can be demonstrated by the results of scenarios which have been developed for the EEA. If no additional policies and measures were implemented to mitigate expected climate change, the share of coal in electricity production would decrease in the short term but increase after 2015, before returning to its current level in 2030. Despite a further penetration of gas-fuelled technologies in the short term, their rate

Figure 9.4 Energy — decoupling outlooks to 2020 for key environmental resources and pressures



Source: EEA, 2005.

of growth is expected to decline as a result of higher natural gas import prices, enhanced by concerns about security of supply. The share of electricity from technologies such as renewable energy sources and combined heat and power plants would increase by only a few percentage points until 2030. This would lead to CO_2 emissions from electricity and steam production being some 15 % above 1990 levels in 2030.

The scenarios also highlight the important emissions reduction potential of low-carbon technologies that already exist but have yet to be fully mobilised. The scenarios suggest that the introduction of a carbon price alone would not be sufficient to reach high shares of renewable energies but would have to be complemented by specific policies and measures. These include direct price support, subsidies and loans or market-based mechanisms — for example, calls for tender for electricity from renewable sources, trading of 'green certificates' or voluntary payments of premium rates for renewable electricity by consumers.

Large reductions in water withdrawal for electricity production are expected in coming decades as newer power plants operating with tower cooling systems replace older plants using once-through systems (Figure 9.4). Tower cooling systems commonly require only a twentieth of the water per MWh for cooling purposes. These reductions can be achieved despite an expected near doubling of electricity production in Europe by 2030.

The future of nuclear power remains unclear across the Community apart from in, for example, Finland and France. Some believe that, as the current generation of nuclear power stations reaches the end of its useful life, so the share of electricity generated in this way will dwindle. Others suggest that to mitigate the effects of climate change and avoid possible future shortages or massive price increases, nuclear power must remain a significant option. The debate is likely to continue.

Households and demography

Important drivers of Europe's changing environmental pressures are demographics and increasingly affluent lifestyles. The environmental pressures of personal consumption are generally lower than those of the production they drive, but are expected, as in the recent past, to grow substantially faster than overall GDP and in line with increased house building, transport use and tourism.

Europe's population has stabilised for now. Over the next 30 years, the overall population of the EU-25 is expected to remain broadly at around 455 million. Current projections suggest there will be 7 % fewer people in the EU-10 by 2030, with declines particularly concentrated in rural areas. Furthermore, in line with trends throughout the developed world, the Europe of 2030 is likely to have a substantially higher proportion of older people.

Assuming a continuance of current working lives and retirement patterns, which is far from certain, this ageing of the population means that the proportion of Europe's population that is economically active is set to drop substantially, placing a greater importance on each of those working to generate more wealth. Leaving aside issues of immigration policy which are beyond the scope of this report, this calls for innovative thinking about the structure of taxation and benefits, including the possibility of moving some of the tax burden away from labour and on to resource use and pollution.

An older Europe may also bring about changes in consumption patterns. More old people will mean an increasing proportion of the national income being spent on health. It is also conceivable that, as the number of old people unable or unwilling to drive increases, demand for public transport will also increase. Additionally it has been suggested that, as the number of reasonably healthy and relatively wealthy older people grows, so too will the demand for tourism and second homes. However, with the exception of the increasing demand for health services, these are as yet uncharted territories.

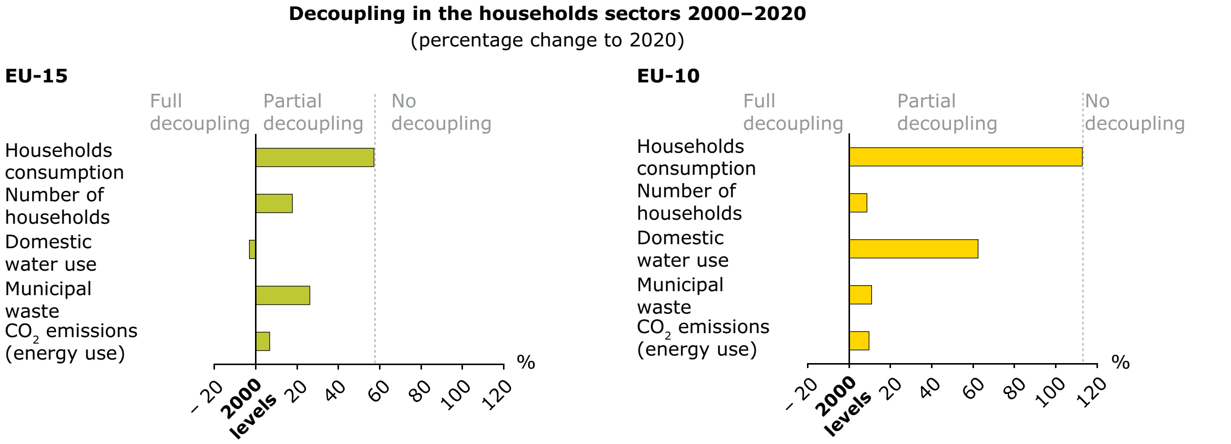
Europe, again in concert with much of the developed world, is also experiencing a reduction in the size of the average household. By 2030 this will have fallen from more than 3 in 1990, through the current figure of around 2.75, to around 2.4. Driven by a variety of factors, led by increasing personal wealth but including the ageing population, high divorce rates, and the increasing number of adults who choose either to live alone or not to marry, the number of households in Europe is expected to rise by approaching one-fifth. In general, more households result in net increases in demand for energy and water and generate greater volumes of waste.

More goods, including computers, stereo systems, mobile phones, household appliances and air-conditioning systems, are being bought. Although new equipment is sometimes less wasteful of resources, this is not always the case. For example, many electronic goods run on stand-by mode when not in use, and so use substantially more electricity than their predecessors. The recent Green Paper on Energy Efficiency states that according to available studies as much as 20 % of energy savings could be realised in a cost-effective way by 2020. Demand-side improvements in efficiency will probably be more dependent on awareness-raising among end-use consumers and on providing incentives to change behaviour as well as on regulations that foster higher technical standards.

Within the EU-25, water withdrawals for household consumption are expected to increase at a rate less than expected household expenditure growth up to 2020 (Figure 9.5). Demand-side measures such as more efficient homes and appliances linked to taxes and charges explain this trend. Nevertheless, household water withdrawals are expected to increase substantially in the EU-10 as these countries approach average consumption levels in the EU-15 in the coming decades.

In the 1990s the EU set a target of reducing the municipal waste stream to below 300 kilograms per person per year by 2000. Unfortunately this has not been achieved and waste production continues to rise. Landfill remains the most common route for its disposal but the implementation of the EU landfill directive is cutting the use of this method for biodegradable municipal waste. The directive was intended to reduce the generation of carbon dioxide, methane and nitrous oxide, all of which are greenhouse gases controlled under the Kyoto Protocol, and it is adding pressure on manufacturers, retailers and local authorities to find new and innovative ways of reducing the waste stream — for example, by using biodegradable waste for all sorts of energy production.

Figure 9.5 Households — decoupling outlooks to 2020 for key environmental resources and pressures



Source: EEA, 2005.

Experiences for packaging waste show both the extent to which Europe has tackled the problem — and the distance it has to go. Consumers and industry seem happy to recycle their waste packaging, but extremely reluctant to take steps to avoid producing it in the first place. Most packaging waste policies relate to recycling and recovery, rather than reduction.

In most EU countries packaging waste production still increases in line with GDP. Absolute rates range from 217 kilograms per person per year in Ireland to 87 kilograms in Finland, but the trend everywhere is continuing upwards. Analysts expect paper and cardboard waste generation within the EU-15 to grow by more than 60 % between 2000 and 2020, roughly in line with growth in GDP — dreams of a paperless office induced by changes in information technology have proved false.

In contrast, most countries have easily exceeded their targets for recycling packaging waste. Although the EU target was to recycle 25 % by 2001, the overall recycling rate of packaging in the EU-15 is now above 50 %. This reflects the relative ease of adopting 'end-of-pipe' solutions rather than effecting structural changes that reduce materials or energy flows. It is also an example of the management dictum that what gets measured gets done. In this case, specific targets concern recovery and recycling, while the real challenge — that of waste reduction — remains an aspirational objective.

Looking ahead, municipal waste volumes are expected to decouple partially from GDP growth up to 2020, with most progress expected in the EU-10 where economic recovery is expected to provide opportunities for adopting better, more up-to-date technologies (Figure 9.5).

Most Europeans live in urban areas, which are generally connected to sewerage systems. In northern Europe the majority of housing is connected to the most efficient treatment facilities for removing pollutants from wastewater, while in western European countries only around half of the wastewater is treated in this way. In southern European countries and the EU-10, just 50–60 % of the population is connected to wastewater treatment plants of any kind. There remains, still, substantial scope for wider application of tertiary treatment facilities in many parts of Europe. There also remains substantial scope for combining investments in treatment plants with charging levies to reduce pollution at source and hence treatment costs; currently countries focus primarily on investment in treatment plants.

At the same time, increasing wealth enables many Europeans to invest their savings in second homes. These will often increase development pressures in environmentally vulnerable areas already subject to tourism pressures, such as the Mediterranean coastal areas. The arrival of second-home owners, including significant numbers of retirees, from northern Europe is already the largest cause of construction in parts of Spain. Such investors may, however, help rural economies, particularly in more remote, marginal or mountain areas. They may also allow the continuation of low-intensity agro-ecosystems as part-time activities.

Personal car travel has risen by more than 3 % a year for the past three decades. During 2001, the average European travelled 14 000 kilometres across all transport modes. On current trends, each of us is expected to travel 7 000 kilometres further in 2030. This puts pressure on the land and inevitably has a deleterious effect on urban air quality. During the 1990s, although Europe's motorway network grew by a quarter, extra traffic filled the new roads as fast as governments could build them. This 'generated traffic' generally fills 50 % to 90 % of available road capacity within a year or so. This is, in part, consumer choice, but studies now indicate that the development of out-of-town shopping centres and the spatial pattern of medical and educational facilities also play significant roles.

Air travel's share of the total distance travelled is expected to double to more than 10 % by 2030. Recent changes such as cheap flights and on-line booking are making it more attractive to travel by plane across Europe, rather than by car or train. This considerable growth in air travel is driven by rising demand both from Europeans and from foreign travellers wishing to come to Europe. The travel and tourism industry is now a major economic force, producing 11 % of the continent's GDP and accounting for 12 % of its employment, a major consumer of goods, water and land, and significant producer of waste and emissions of greenhouse gases.

Europe's growing demand for housing, food, consumer goods, transport, tourism and waste disposal are putting pressure on its land, water and air quality, as well as causing the loss and fragmentation of its wildlife habitats. In the coming years, these pressures are expected to be particularly strong along the Mediterranean and Atlantic coasts of southern Europe, and may be widely felt across rural Europe, as more people travel beyond their urban existence into the countryside to improve their quality of life and relax.

9.4 Summary and conclusions

The regulatory regime developed in Europe over the past 30 years has delivered an impressive list of achievements. It has provided the stable basis for the development of technologies that have decoupled some environmental pressures from economic growth, especially pressures from point sources. Nevertheless, it is recognised that environmental regulation of this kind can only achieve so much. The sectoral activities that lie behind many of today's ongoing environmental problems have multiple sources which often require behavioural change and therefore cannot be addressed through command and control regulations alone. Rather, a combination of regulatory standards, technological changes, financial measures, economic instruments, voluntary agreements and information provision provide a more effective mix of actions. Different combinations are appropriate for different problems and sectors.

For the transport sector, regulation and voluntary agreements have provided the stable basis for the auto industry to innovate, and economic instruments, especially taxes and charges, have contributed to making explicit the hidden costs of pollution and changing consumer behaviour to some degree.

For the energy supply sector, regulation has also provided a stable basis for innovation. In the area of renewables, recent policies have provided the basis for increases in venture capital to fund company start-ups. Economic instruments and financial measures have been dominated by subsidies for fossil fuels. More recently, tradeable permits have been used to encourage cost-efficient reductions in emissions of air pollutants.

The agriculture sector is shaped by financial measures taken under the CAP. There have been substantial reforms in recent years shifting from environmentally damaging subsidies for production to incentives that protect the environment and promote economic growth and social cohesion. The cross-compliance measures linking CAP payments to action by farmers on reducing nitrates is an innovative example of integrated action that could be applied more widely, for example the use of Cohesion Funds and recycled charges for building wastewater treatment plants and reducing pollution at source. Innovation has been dominated by production rather than eco-efficiency objectives so there remains substantial scope to increase the use, for example, of more efficient irrigation technologies.

The household sector is different; it is not as homogeneous as the other sectors, nor is it backed by well-defined policy objectives and measures. Changing public behaviour is difficult and often more politically sensitive. Economic instruments, especially taxes and charges, are used extensively in countries to internalise the costs of environmental services such as water provision, sewerage treatment and waste collection. There is huge scope to increase the use of already developed eco-efficient technologies, but financial incentives and awareness-raising activities are relatively absent.

As some major environmental problems are interlinked, and with many sectoral activities contributing to the same environmental problems, there is substantial potential through more integrated approaches to deliver benefits beyond those which could be achieved through unilateral approaches. Examples include reductions in emissions of sulphur dioxide to deal with acidification that at the same time deliver secondary benefits for climate change; the switch from subsidies in agriculture, transport and energy that contribute to environmental degradation towards incentives that change behaviour; and investments in new technologies that reduce diffuse environmental pressures such as hydrogen and carbon sequestration, and at the same time create jobs and contribute to improving Europe's overall competitiveness. The concluding chapter looks ahead by assessing three interlinked approaches that could form the basis for making progress on integration in the future.

References and further reading

All of the core set of indicators found in Part B of this report are relevant to this chapter. The most relevant are: CSI 11, CSI 14, CSI 16, CSI 17, CSI 18, CSI 20, CSI 24, CSI 27, CSI 28, CSI 29, CSI 30, CSI 31, CSI 32, CSI 35 and CSI 36.

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10 Looking ahead

10.1 Introduction

Europe faces several interconnected challenges in coming decades. These include greater global competition for natural resources and markets; pressures on social and territorial cohesion from an ageing population and from a decreasing size of families; and environmental problems from climate change, biodiversity loss, use of land and water resources, over-fishing and marine ecosystem impacts, soil loss, and air pollution and health impacts from day-to-day living, and the widespread use and generation of chemical substances.

Europe is well placed to meet these challenges. It has some of the world's most competitive companies, a quality of life that is one of the best in the world, a long history of industrial and institutional innovation, and a wide range of people and cultures that can stimulate a diversity of economic and social activities. It also has a rich and varied environment that, if nurtured, can maintain and sustain a high quality of life in the face of rapid change.

Both the challenges that Europe faces and its capacities to manage them are interlinked by webs of ecological, economic and social networks. Cost effective measures need to be similarly interlinked via more coherent and integrated responses.

The integration of environmental policies into economic activities is one key response. In addition, environmental measures should be designed to achieve high environmental standards whilst contributing to or at least not inhibiting, innovation, social integration and the reform of markets and governance. Recent debates on environmental policies have shown that unless such policies are seen to contribute to these wider issues they can easily be relegated to 'luxury' items that must await some future prosperity.

Three main interlinked approaches could help Europe to make further environmental and economic progress. Firstly, stronger and more coherent environmental policy *integration* to ensure that environmental issues are fully reflected in all policy-making. This is particularly needed in the economic sectors that contribute most to environmental problems i.e. transport, agriculture and energy. Secondly, the *internalisation* of the environmental costs of energy and resource use into more realistic market prices via environment taxes, charges, tradeable permits and tax and subsidy reform. And thirdly, more efficient use of renewable and non-renewable resources, via measures that stimulate **eco-innovation**.

10.2 Integration

Institutional and financial integration

Article 6 of the EU Treaty states that 'environmental protection requirements must be integrated into the definition and implementation of the Community policies and activities, … in particular with a view to promoting sustainable development'.

Two types of institutional integration are necessary: the horizontal level, that makes links across government between ministries, and Parliamentary committees, at Member State and EU level; and the vertical integration between regional, national, city and local governments.

Environmental policy integration is a feature of the EC Treaty, the sixth environment action programme, the Cardiff integration process and the EU sustainable development strategy. It is promoted, indirectly, in the White Paper on European governance. Environmental objectives are, in principle, also embedded in the Lisbon process, which is the ten-year strategy to make the EU the world's most dynamic and competitive economy.

The role of governments in establishing goals, regulatory frameworks, incentives and information flows whilst encouraging more environmentally responsible activities by corporations, investors, consumers and citizens is an overall feature of these various initiatives.

Progress in sectoral integration has been slow over the last five years due in part to the failure to adequately address institutional integration. However, a closer look reveals some signs of positive change. The Cardiff process, initiated in 1998 to stimulate sectoral integration at the EU level, has encouraged a gradual breakdown of some administrative walls between sector and environment departments; the establishment of environmental units in sector directorates-general of the Commission; and a reorientation of some departments to address more integrated issues, e.g. rural development.

The development of the thematic strategies under the sixth environment action programme further supports new cross-departmental and multi-stakeholder engagement. Increasing the institutional capacity to support environmental policy integration in terms of human and financial resources could offer additional rewards.

Meanwhile, there has been a quiet revolution in the strategic management and coordination of the European Commission and Council activities. The potential of the EU's move towards multiannual and annual planning offers the potential for putting environmental integration into practice. This is also applicable to budgetary planning cycles and auditing, both of which could be used to promote environmental integration.

The European Parliament has used its budgetary role to advance the integration of environment into other policy areas, such as the Structural and Cohesion Funds. This process of greening the EU's budget could be further encouraged by regular and comprehensive reporting on the environmental impacts of EU spending programmes and on progress with environmental policy integration.

New forms of governance are also emerging, such as the 'open method of coordination', aiming at better linking countries and stakeholders in policy processes. In the new EU Member States, environment ministries have used the high priority that the EU has given to environment protection as a means to raise their profile in government. In some of the old Member States, the shift of environmental responsibilities to other ministries has increased opportunities for better policy integration.

National governments have made good progress in terms of developing and agreeing high-level political commitments to environmental policy integration and sustainable development. Most of the 25 EU Member States (EU-25) have established national sustainable development strategies. There is, however, little evidence so far of these strategies being implemented, and considerable opportunities exist for greater cross-country learning.

Since the early 1990s, many countries have developed committees to address environmental integration. Germany's committee of state secretaries for sustainable development is one such example. Other countries, such as Austria and Belgium, have established inter-ministerial commissions to support the implementation of sustainable development commitments. A large number of countries now have environment or sustainable development advisory councils, with councils in Finland, Latvia and Lithuania also serving inter-ministerial coordination functions.

Few countries have exploited opportunities to link their regular strategic planning, budgeting and auditing with the delivery of overarching environmental or sustainable development commitments, although some useful examples are emerging in the Netherlands, Sweden and the United Kingdom. Few countries have explicitly allocated responsibilities for environmental policy integration throughout all key departments, although some countries have established environmental units in some sectoral ministries.

In the new Member States, the transposition and implementation of EU legislation is improving the quality of the environment and decreasing transboundary pollution. There is an opportunity to reorganise governance structures in many countries to bring together policy decision processes (e.g. under IPPC directive) and strengthen cooperation in international networks (e.g. IMPEL).

However, the priority given to economic development has been seen to put at risk the implementation of necessary environmental protection measures. There is therefore a need to ensure sufficient financial resources for implementation of EU legislation. There is also a unique opportunity to decouple environmental from economic pressures especially for the energy, transport and industry sectors. Funds from the EU could be better targeted to local, more sustainable solutions in this respect. The new Member States' extensive spatial planning experience could also be utilised to strengthen further transboundary and cooperative planning initiatives, e.g. for new roads that have already demonstrated the ability to deliver improved environmental outcomes.

The importance of vertical integration is illustrated by the EEA studies into the effectiveness of urban wastewater treatment systems and packaging waste systems in selected EU countries. Packaging waste management is complex, including industry, retailers, consumers, and local and national governments. Institutional arrangements, incentives and governance become every bit as important as the policy itself. Pre-existing institutional arrangements can make effective implementations easier — or more difficult — to achieve.

For urban wastewater, clear lines of responsibility and financing were important in Denmark and the Netherlands for achieving full or near-full compliance through implementation of the urban wastewater treatment directive. In contrast, the overlap of responsibilities in France and Spain between authorities at the national, regional and local levels, together with large investment needs and bottlenecks in financing, appear to have been important reasons for greater implementation difficulties.

The corporate social responsibility movement is bringing additional pressure to bear on the environmental performance of companies, particularly when their performance can be monitored by common approaches to indicators, as with the global reporting initiative. At sector level, corporate initiatives within the chemicals, food, fisheries and forests industries are encouraging more responsible environmental activity, including certification schemes that encourage informed consumer choice.

Investors are increasingly looking towards the environmental performance of their funds and of the corporations within them. Initiatives such as the Green Fund system in the Netherlands, which includes tax incentives for green investments and a partnership with the financial sector, illustrates the potential of such market-based instruments to influence flows of capital towards more sustainable activities, and in doing so help promote over the long term the internalisation of environmental costs into the prices of goods and services.

Evaluating progress

Building on previous work by the Organisation for Economic Co-operation and Development (OECD) and others, and reflecting the national and EU practice summarised here, a possible framework for evaluating progress with environmental policy integration has been developed by EEA (Figure 10.1).

The framework focuses on the following six main areas: political commitment, vision and leadership; administrative culture and practices; assessments and information for decision-making; policy instruments such as market-based instruments that promote internalisation; monitoring progress towards objectives and targets; and eco-efficiency. The evaluation of progress in these six areas is supported by a checklist of relevant criteria.

The framework serves two purposes: firstly, it helps to show how integration can be promoted; and secondly, it provides a single framework for evaluating progress towards environmental policy integration in a consistent manner and across very different economic sectors. It can also be used at all levels of governance, from EU institutions to national, regional and local governments, and even within large companies.

10.3 Internalisation using market-based instruments

Purpose and progress

Market-based instruments can help to realise environmental and economic policy objectives simultaneously in a cost-effective way by taking account of the hidden costs of production and consumption to our health and the environment.

Currently, the prices of goods and services do not fully reflect the environmental costs of their provision, use and disposal — so-called 'environmental externalities'. The greater reflection of the costs of environmental replacement, recovery and reparation in market prices is becoming increasingly urgent.

For example, the price of coal, oil and natural gas does not fully include the costs that will be incurred by climate change and other environmental degradation created by burning them; the price of a hardwood table does not fully include the cost of the lost biodiversity in the forests from which its timber was taken or the increased risk of flooding from logged land; water bills do not always include a tariff for depleted and polluted aquifers; the price of food in supermarkets does not fully include the environmental impacts of the

Figure 10.1 Framework for evaluating integration of environment into sector policies

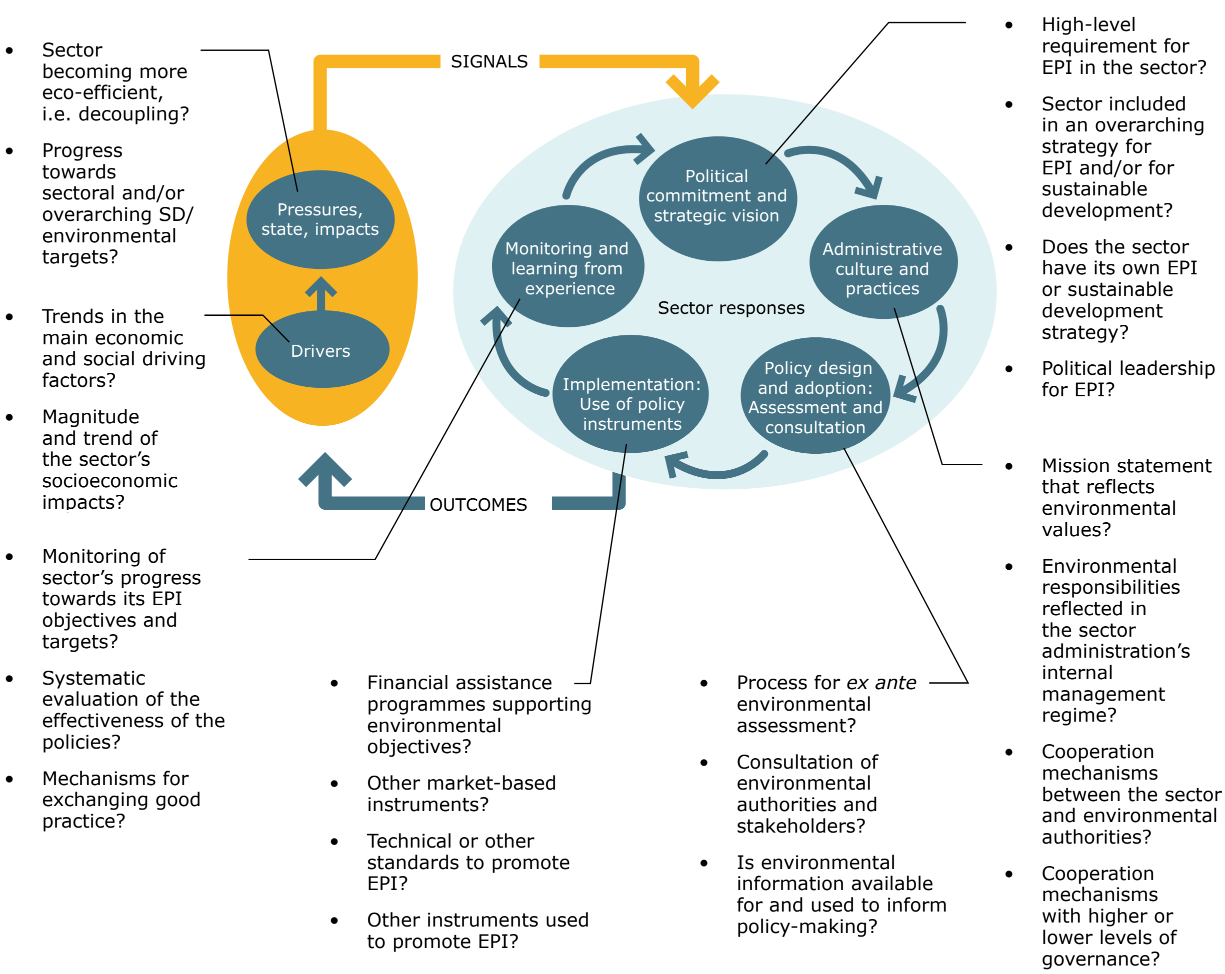
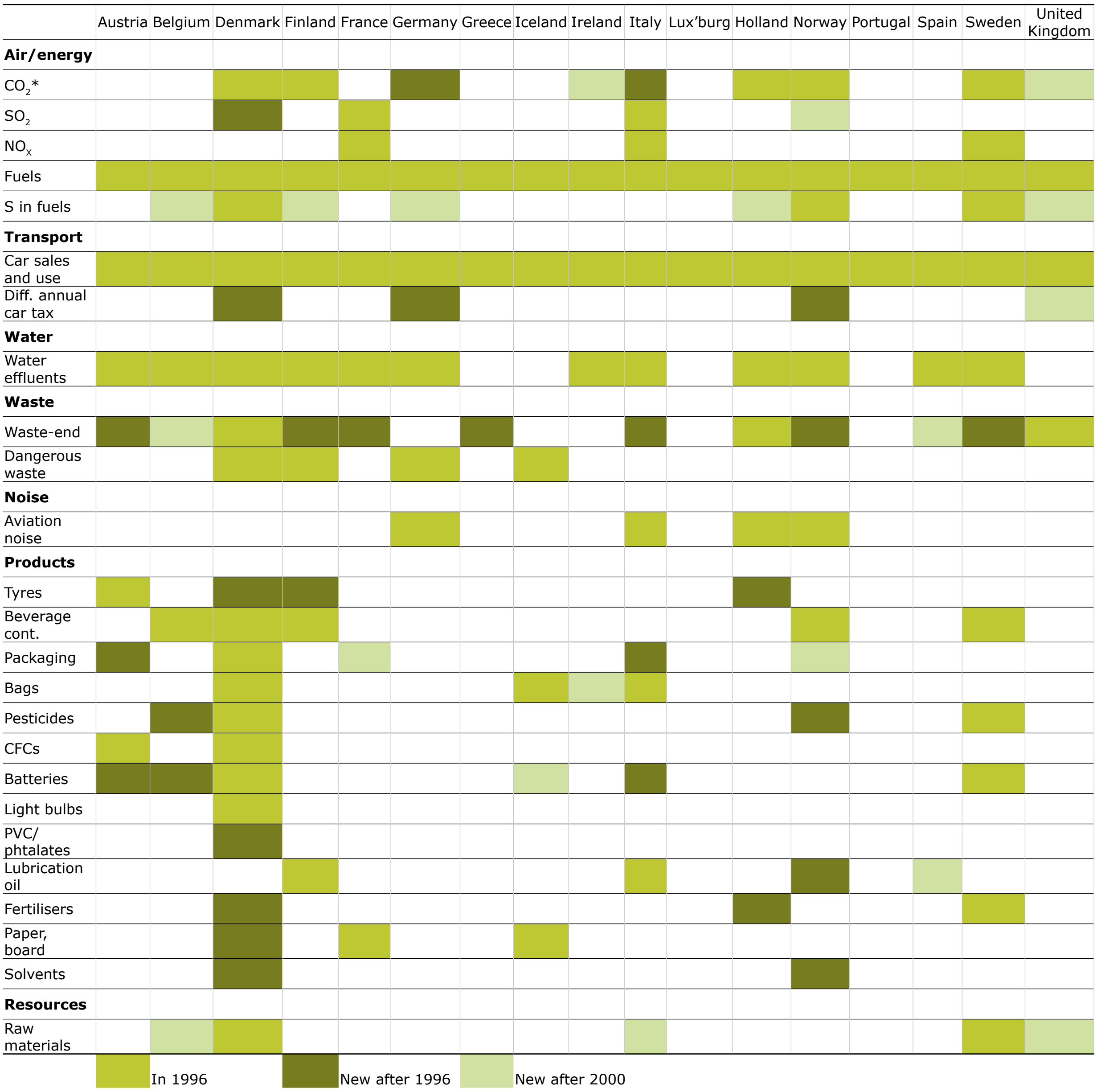


Figure 10.2 Development of environmental tax bases in EU-15, Iceland and Norway since 1996



Source: EEA, 2005.

agricultural systems that produced it, nor the health effects and noise of traffic fumes from the trucks that brought the food to the store.

All environmental policy tools can help to internalise environmental costs by encouraging companies and consumers to pay for their pollution by meeting environmental standards. However, once environmental targets are reached under regulation, for example, there is often no continuing incentive to go further.

Figure 10.3 Overview of environmental tax bases in EU-10 and other countries, 2004

	Cyprus	Czech Republic	Estonia	Hungary	Latvia	Lithuania	Malta	Poland	Slovenia	Slovakia	Bulgaria	Croatia	Romania	Turkey
Air/energy														
CO_2*			■						■					
SO_2		■	■	■	■	■		■	■	■		■		
NO_x		■	■	■	■	■		■	■	■		■		
Other air pollutants		■	■	■	■	■		■	■	■		■		
Fuels	■	■	■	■	■	■	■	■	■	■	■	■	■	■
S in fuels													■	
Transport														
Car sales				■	■	■	■	■		■	■		■	■
Annual circuation tax	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Water														
Water effluents		■	■	■	■	■		■	■	■	■		■	
Waste														
Waste taxes		■	■		■			■		■		■	■	
Noise														
Aviation noise		■												
Products														
Tyres				■	■	■				■	■			
Beverage cont.		■		■										
Packaging			■	■	■	■		■		■				
Bags														
Pesticides														
CFCs		■		■	■					■			■	
Batteries				■	■					■	■			
Light bulbs					■	■				■				
PVC/phtalates										■				
Lubrication oil		■		■						■				
Fertilisers														
Paper, board					■	■				■				
Solvents														
Resources														
Raw materials			■	■	■	■					■	■		

Source: EEA, 2005.

Market-based instruments, on the other hand, use the more realistic pricing of goods and services to provide continuous incentives for European producers and consumers to reduce tax by producing and using more eco-efficient innovations. In addition, such instruments also provide more flexibility for companies with different technologies and cost structures to respond to the need for environmental improvements. However, the net impacts of such instruments are not as predictable as direct regulations, and a mix of policy tools may be required for the sake of environmental effectiveness and equity.

There are several forms of market-based instruments. These include taxes and charges on products and processes regarded as environmentally damaging; deposit schemes that provide a refund when the product or packaging is returned for recycling; and tradeable permits for pollution or some other activity such as fishing that needs to be limited. Permits are growing in popularity because they combine flexibility of response with the reasonable certainty that targets will be met.

A number of more recent EU environmental legislation includes specific provisions to allow governments to use these instruments to meet the targets, including the water framework and packaging waste directives. The 2005 EU emissions trading scheme for greenhouse gases aims at helping the EU to meet its shared commitment to the Kyoto Protocol targets and is the first major market-based instrument to be implemented at the EU level.

Market-based instruments in the Member States have mostly taken the form of environmental taxes and charges — for instance as a differential on fuel tax to encourage certain fuels such as low-sulphur diesel or lead-free petrol, or alternative fuels such as ethanol. Market-based instruments have also been widely used by the new EU Member States, particularly to mitigate air pollution. A number of European countries have also introduced taxes on non-renewable raw materials such as sand, gravel and limestone, or on products such as plastic bags. Many are aimed at encouraging the recycling of materials.

In the EU-15, the development of environmental taxes between 1996 and 2004 shows that progress has been made in the application of taxes across a wide range of areas (Figure 10.2). Interestingly, the new EU-10 Member States have made substantial progress on putting in place environmental taxes over a relatively short period of time, in particular, with regard to air pollutants, products and raw materials (Figure 10.3).

The effectiveness of market-based instruments

Evidence suggests that instruments work better if they are well-designed in themselves for the long term and as part of a wider package of instruments, if the reasons for having them and the way revenues will be used are clearly communicated to the public and if the levels at which 'prices' are set reflect both an incentive to producers and consumers to change behaviour and a realistic analysis of affordability.

Europe has a long tradition of imposing high taxes on motor fuels. Taxes, excluding VAT, make up more than half of the pump price of petrol in almost all of the EU-15. Partly as a result of the tax, the European car fleet is much more fuel efficient than that of USA, and has much lower emissions of carbon dioxide for every kilometre driven. New passenger cars in the EU need on average 6–7 litres per 100 kilometres; this figure is 10–11 litres per 100 kilometres for USA.

Several countries have introduced CO_2 taxes as an additional tool to achieve the objectives of climate change policy. In Denmark, industry reduced its CO_2 intensity by 25 % in seven years from 1993–2000; analysis has shown that at least 10 percentage points resulted from the CO_2 tax. The impact came about through both fuel switches and energy efficiency, each accounting for about half the CO_2 reduction.

A variety of other pay-as-you-go charging systems for road transport have been variously introduced in Europe. Traditionally powered cars have to pay a congestion charge for driving in the central London area. It imposes a flat rate for travelling in the city during daytime and has cut traffic volume by 15 %; it speeds traffic flow and generates revenue to improve the city's public transport system. Switzerland has had an environmental standard-dependent, kilometre-based charge for heavy vehicles since 2001. Austria and Germany have introduced similar charges for the use of road infrastructure, but these do not internalise environmental costs.

Per kilometre road pricing is likely to emerge more widely now that efficient satellite-based and computerised systems for monitoring and charging vehicles are becoming available. Increasingly, economy-damaging congestion is a main driver, but the environment will benefit too. Such systems would, advocates argue, be transparent, equitable, economically efficient and environmentally effective. Similar thinking is happening in other fields. Many European countries are switching from conventional fixed rates for water supply, or those based on the value of the property, to water metering. The evidence is that metering cuts general water use, typically by around 10 %.

The pragmatic mixing of market-based instruments with other measures is well illustrated by the water sector. It has rarely proved possible to introduce full market pricing for water where it might have had most effect, e.g. for agricultural irrigation. For example, during the drought in the summer of 2005 in southern Europe, where irrigation is generally the largest user of water, its use was primarily controlled through bans rather than charges. Paying more for a previously 'free' or cheap product or service was deemed to be too unpopular to be practicable. However, realistic waste water charges in the Netherlands, and their use to help companies reduce their polluted wastewater, was more cost-effective in complying with the urban waste water treatment directive than in countries that only built wastewater treatment plants.

Some market-based instruments raise revenues. The revenues from environmental taxes commonly go into the public coffers and can be used to offset other taxes, or to help finance government programmes and other actions that are beneficial for the environment. The revenues from environmental charges are usually meant to finance collective services from which the charge-payer benefits. Emissions trading systems raise revenue if the credits are auctioned, although giving them away without cost is the favoured option in practice. Finally, the reform of harmful subsidies may yield savings in the government budget, or provide revenues to finance incentives that can support more environmentally friendly technologies such as organic farming or renewable energy.

European and national subsidies to agriculture, fisheries, transport and energy production do not efficiently balance economic needs with long-term environmental integrity. Local subsidies can also encourage less environmentally friendly options. For example, when German cities such as Bremen, Dresden and Stuttgart investigated the size of the subsidies associated with the free use of their infrastructure given to car transport, they found that this averaged EUR 128 per citizen, much higher than the municipal subsidies for more environmentally sustainable public transport.

Anomalies in the tax system can accentuate environmental damage. For instance, aviation fuel and fuel for shipping are free from the heavy taxes that make up most of the cost of fuelling European road transport and, in some cases, trains. This international subsidy has, among other things, helped stimulate the boom in aviation. If taxes on all fuels were introduced, their impacts on the environment would be more transparent and, in time, reduced.

In some countries, the revenue from environmental taxes is used to lower other taxes, primarily those on labour. The Swedish programme over the period 2001–2010 will switch EUR 3.3 billion from labour taxes to environmental taxes. This environmental tax reform focuses on shifting the tax burden from the welfare-negative taxes on labour, capital and consumption to welfare-positive taxes on environmental externalities.

At the EU-15 level, energy tax revenues that make up almost 80 % of all environmental tax revenues have risen, and the average effective tax rate on labour (measured by implicit tax rate (ITR) which equals social security contributions of employers and wage earners plus other non-wage personal taxes on wages and salaries, divided by total pre-tax labour income) has dropped, indicating a small shift of the tax burden from labour to energy. Moreover, the overall energy efficiency in the EU has improved in parallel with increased energy taxation.

Equity, competitiveness and innovation concerns

Nevertheless, the energy-tax burden is unevenly spread over target groups, with the bulk resting on consumers. In the Nordic countries, for example, households consume about 20 % of all energy, but pay about 60 % of all energy taxes. By far the biggest contribution comes from taxes on motor fuels (petrol and diesel). Energy carriers such as coal, and heavy and light oil, typically used in manufacturing, are taxed at a much lower level.

This potential tax shift would not be large in the short term as long as energy taxes, which tend to impact the consumer more highly than other sectors, were not raised considerably. Options that might be more equitable include transport taxes that have a share of slightly more than 1 % in total tax revenues, and pollution and resource taxes which make up only 0.2 % of the total tax take in the EU-15. In considering these options, however, it should be remembered that revenue-raising, market-based instruments are primarily a tool of environmental policy; other tools are available to implement labour market policy.

Some environmental taxes can be socially inequitable, since the poorer members of society generally spend a greater proportion of their income on basic needs such as food, water and energy. Denmark, which has the largest range of environmental taxes in Europe, raising 10 % of government revenues this way, has found that energy taxes, and particularly the tax on electricity, impact the poor harder, although less than existing taxes on alcohol and tobacco, and VAT. On the other hand, transport taxes are relatively benign for the poor, and pollution taxes are neutral in their distributional impact.

The latest and most innovative form of market-based incentive is the tradeable 'pollution permit' aimed at limiting resource use and emissions. The EU greenhouse gas emissions trading scheme allocates permits for major companies in certain sectors to emit greenhouse gases. By limiting the allocation of permits to less than projected emissions, it creates a market in the permits. Companies that fall short of permits needed to cover their emissions can either reduce their emissions themselves, or, if that would be cheaper, buy from those who have permits to spare, perhaps because of investment in clean technologies. The scheme provides the auction option to Member States to a limited extent, but, currently, very little use is made of it.

The initial allocation of permits, for the period 2005–2007 and covering carbon dioxide only, is seen as a dress rehearsal for the next five years when Europe must meet its legally binding emissions targets under the Kyoto Protocol. It was introduced relatively seamlessly — in marked contrast to past efforts to introduce an EU-wide carbon dioxide and energy tax, which were abandoned after concerted opposition from several quarters.

There is no evidence that market-based instruments damage the competitiveness of the economy or of specific sectors. This is due to the design of the instruments; to exemption possibilities that avoid unacceptable cost impacts; and to measures that compensate those affected by recycling revenues. Such instruments can maintain or improve competitiveness by encouraging cost-effective and innovative responses to environmental demands.

There is evidence that the venture capital needed to connect technology development with market penetration is lacking for environmental innovations. Environmental technology is seen as more risky, and less of a niche market than biotechnology, computer software and telecommunications. Incentives may therefore be needed to stimulate the design and marketing of innovative and more eco-efficient technologies.

Most of the barriers to implementation of market-based instruments can be overcome by: progressive removal of subsides and regulations that contribute to environmental damage; recycling of saved revenues to provide incentives for eco-innovation; better design of instruments and mitigation measures to deal with inequities; progressive implementation to build up trust and confidence in the measures over time; and integration of market-based instruments for environmental policy into those for economic and social policy so that revenues can be used to support broader tax reforms.

10.4 Resource productivity and eco-innovation

Different resources require different approaches

Some 75–90 % of resources currently used are non-renewable, at least within timescales that are relevant to humans and many ecosystems. This compares with 50 % at the beginning of the last century. A better overall balance between using the stocks of non–renewables and the flows of renewable resources — mainly from bio-based and recycled sources — is essential for maintaining ecosystem services and can provide a strong incentive for eco-innovations.

There are several reasons to focus on improving non-renewable resource productivity over the coming decades. Some of the main ones are the changing nature of environmental pressures; a growing disparity in global non-renewable resource use; rising prices and competition for raw materials; increasing international security risks; and the need to boost EU competitiveness.

One example of a better balance towards renewable resources is the increased use of biomass to produce electricity, heating and transport fuels. This can provide both environmental benefits and an alternative source of income for those living in rural areas. However, biomass production might create additional pressures on biodiversity, soil and water resources, as well as taking land that could be used for food or other production. Bio-energy crops therefore need to be developed that can reduce soil erosion and compaction, minimise nutrient inputs into ground and surface waters, and use fewer pesticides and less water.

If these crops are then to be converted into biofuels for transport, new conversion technologies will have to be used, such as the biomass-to-liquids technology. The increased use of biomass and other renewable energies can also contribute to the reduction of Europe's dependence on energy imports, which otherwise is forecast to grow from 50 % in 2005 to 70 % in 2030.

Improving non-renewable and renewable resource productivity can help strengthen the synergies between environmental protection and growth. The 'clean, clever and competitive' initiative of the Dutch government in 2004 identified many ways in which European companies could achieve significant increases in resource productivity and at the same time reduce environmental pressures. Other studies in many Member States and at EU level have demonstrated that large potential economic and environmental gains can be made at the sector, company and household levels by reducing resource use.

Nevertheless, too much focus on reducing the overall use of resources can hide 'hot' flows of particularly damaging materials which require different approaches than for other materials. For example, the extraction of some metals or the handling of hazardous substances requires specific regulatory attention, although the complexities of estimating and regulating the environmental impacts of a single substance at different stages of its life-cycle are formidable. More research of the life cycle of such small resource volumes that have high environmental impacts would help improve understanding of how innovation can help mitigate these impacts.

Non-renewable resource productivity gains — a mixed picture

Trends in global non-renewable resource use suggest that the current European economic model cannot be followed by emerging economies since this would increase global consumption by between two and five times. Reports such as the Millennium Ecosystem Assessment suggest this would be simply unsustainable given the Earth's finite ecological capacity.

Effectively, amongst other measures, Europe, along with other parts of the developed world, needs to reduce its overall resource consumption by increasing its resource productivity, if it is to be better placed to adapt to future changes.

The average material productivity — raw materials consumed per unit of gross domestic product (GDP) — in the EU-25 is 1 kg/EUR , slightly less than in USA but twice as high as in Japan. The picture is similar for energy productivity, where the difference in the efficiency of the Japanese economy is even more pronounced, suggesting there is room for learning from this country's experiences in particular and others in general.

Over the past decades in Europe, there has been less focus on materials and energy productivity than on labour productivity. For example, between 1960 and 2002 labour productivity in Europe rose by 270 %, compared with 100 % for materials and just 20 % for energy. These trends are largely the result of a shift towards automated production (leading to more energy use and so offsetting energy productivity gains) and to structural changes in the economy. Earlier and full internalisation of environmental costs could have helped to further improve energy and resource productivities.

The cost structure of manufacturing in Germany, and probably throughout the larger economies of the EU, shows that materials and energy costs more than double labour costs. In this respect, the European economy could also be seen as over-consuming natural resources and under-consuming labour. Adjusting this imbalance could also reduce the degradation of the global environment, whilst contributing to Europe's long-term competitiveness and employment.

During the past decade Europe has achieved a relative decoupling of materials and energy use from GDP, but absolute resource use has remained steady. There are large differences between EU countries — in part depending on the modernity, type and level of the predominant industries — with material intensity varying from 11.1 kg/EUR of GDP in Estonia to 0.7 kg/EUR in France. Nonetheless, resource and energy productivity in western Europe is, on average, four times higher than in the EU Member States of central and eastern Europe. This indicates substantial opportunities to achieve greater parity in resource use between the EU-15 and EU-10 through technology transfer and other measures.

Outlooks to 2020 show a partial decoupling of water use, material flows, and waste from economic growth in the industry sector (Figure 10.4). This is expected to be achieved in part by continuing structural changes in the European economy away from resource intensive industries and towards the services sector. These structural changes will, however, allow Europe to continue exporting its environmental pressures by shifting the production of the goods we consume to developing countries.

These countries will also suffer from being the source of increasing greenhouse gas emissions resulting from the transport of goods back to Europe for our consumption. This makes it more difficult for developing countries to meet their emissions reductions targets while allowing Europe to meet some of its targets without having to significantly change its current consumption and productions patterns.

Developments in European manufacturing industry demonstrate the potential for reducing energy use at the same time as increasing economic output. Between 1990 and 2002, the sector's final energy consumption fell by almost 8 % while its added value rose by 17 %. Projections suggest that substantial improvements in industrial energy intensity could continue both under baseline assumptions and in a climate-mitigation scenario. Under these, the energy needed to produce one unit of economic added value in 2030 would be almost half 1990 levels.

The decrease in energy intensity can be explained partly by structural changes to the economy. But it is also the result of improvements in energy efficiency, influenced by technological innovation. Looking ahead, a recent Commission green paper outlines how energy efficiency measures could, by 2020, improve the energy consumption in EU-25 by more than 20 %, saving EUR 60 billion and creating, directly or indirectly, a million new jobs. This would translate into citizens each saving EUR 200–1 000 per year.

Some of the savings would be achieved if the EU directive on energy performance of buildings (2002/91/EC) were fully implemented. If the energy certification provisions of the directive were improved and extended to the renovation of older buildings, the savings could be almost doubled and some 250 000 skilled jobs created. In turn, this could stimulate innovation in the development of new and sustainably produced products and materials.

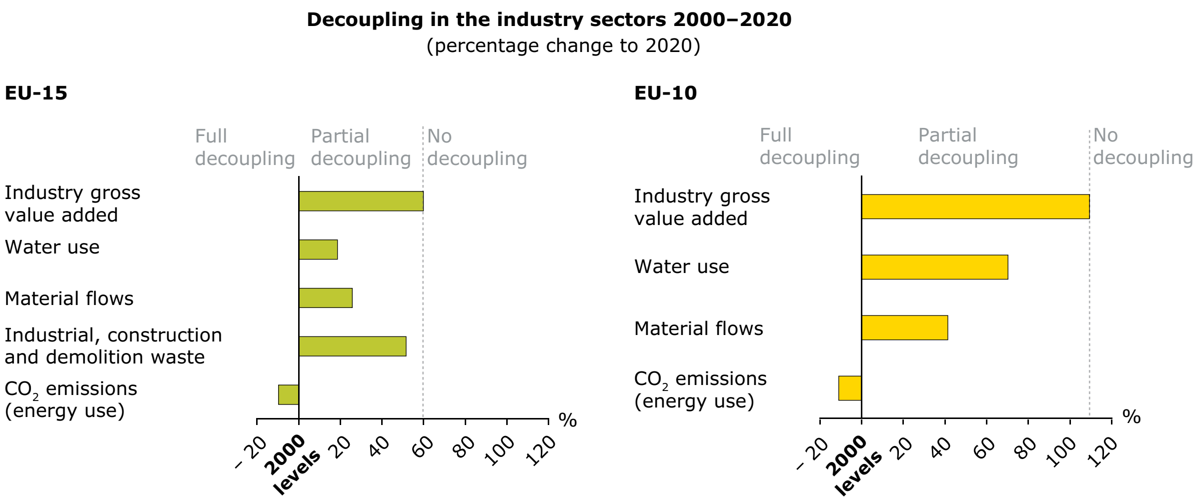
Recent studies also indicate that the adoption of energy efficiency policies have accelerated gains in efficiency, by fostering new, energy-efficient technologies. For example, refrigerators significantly improved after the introduction of energy efficiency labels and standards. Additionally, it has been observed that countries which introduce strict regulatory standards bring new technologies to world markets faster than their competitors.

The data are less robust for gains in materials efficiency because of the relative lack of interest in resource productivity compared with labour and energy productivity. However, a recent German study shows the potential for savings of EUR 5–10 billion on material input costs in small- and medium-sized companies across just four sectors — metals manufacturing, construction, electricity generation and distribution, chemicals and synthetic products.

Furthermore, a UK study shows that waste minimisation in manufacturing produced savings in annual operating costs of EUR 3–5 billion. Other studies indicate that once the process of identifying materials and energy savings begins, other, often large, eco-efficiency gains are also identified and implemented, providing a stream of unintended secondary benefits that are rarely captured by initial estimates of cost savings.

In general, a lack of awareness of the real costs of obtaining, using and disposing of materials and energy is a significant barrier to the wider implementation of many eco-innovations. Both the internal costs to companies and the external costs to societies of energy and materials consumption are generally hidden from the minds of decision-makers. For example, at a company level, savings as a result of waste minimisation are usually identified as reductions in waste disposal costs. However, the total savings available include the reduced purchasing and processing costs of not handling 'unnecessary'

Figure 10.4 Industry — decoupling outlooks to 2020 for key environmental resources and pressures



Source: EEA, 2005.

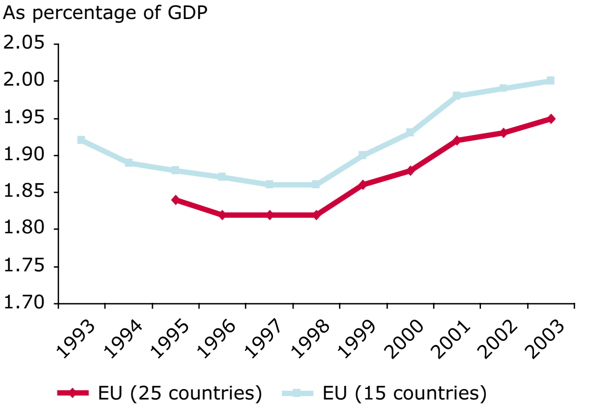
materials, which can be more than double the waste disposal costs.

Creating the conditions for future eco-innovations

The EU can move towards a more balanced economic development that is underpinned by eco-innovation and the recognition of the economy's dependence on the environment. Under the relaunched Lisbon agenda, the contribution that eco-innovation can make to economic growth and employment is fully recognised. Already the EU's eco-industries, which employ more than two million people and are growing by around 5 % a year, account for about one-third of the global market. Exports grew by around 8 % in 2004, producing a trade surplus for the EU of some EUR 600 million.

Equally important to the encouragement of eco-innovation is the promotion of a culture favourable to research and development. There is a proportionally lower number of annual patent applications in the EU. In 2002, research and development expenditure as a proportion of GDP in the EU-25 (at 1.93 %) lagged behind both Japan (3.12 %) and USA (2.76 %). Within the EU-25, research and development expenditure in the EU-15 outstrips that in the EU-10 (Figure 10.5).

Figure 10.5 Public and private sector expenditure on research and development in EU-25



Source: Eurostat, 2005.

The strategic importance of investment in research and development under both the Lisbon and the Sustainable Development strategies was recognised at the 2002 Barcelona European Council, where it was agreed that overall EU spending on research and development should gradually increase and reach 3 % of GDP by 2010.

At the same time, the Commission has proposed the development of an action plan to tackle obstacles to the development, take-up and use of environmental technologies, and the Parliament agreed to this proposal. This has resulted in the EU environmental technologies action plan (ETAP) which also provides a framework for action by Member States. The EU's new research framework programme (FP7) for the period 2007–2013 includes some EUR 2.5 billion for the environment, an increase of nearly 60 % over FP6. In addition, the European Commission has proposed a competitiveness and innovation framework programme for 2007–2013 totaling EUR 4.2 billion, of which some EUR 500 million will be dedicated to supporting eco-innovation initiatives.

There are also benefits to be realised by recycling savings realised from resource productivity improvements towards investment in innovation. A recent German study that modelled the effects of dematerialisation on economic growth and the state budget concluded that if materials and energy savings were reinvested in research and development and engineering strategies, it would lead to 2.3 % GDP growth, the creation of an additional 750 000 jobs, and decreased public spending on social welfare.

Public authorities can also encourage more eco-efficient procurement policies. The World Summit on Sustainable Development in Johannesburg in 2002 called on 'authorities at all levels to promote public procurement policies that encourage [the] development and diffusion of environmentally sound goods and services'.

Public authorities in the EU spend an estimated EUR 2 trillion on goods, works and services every year providing significant opportunities for encouraging a large and stable market for eco-innovations. For example, public administrations could contribute to 18 % of Europe's Kyoto obligations by switching to renewable energy sources. A survey carried out in the EU in 2003 found that almost a fifth of public authorities claimed to have adopted environmental procurement policies in one or more areas, whether buying organic produce for their canteens or using environmentally certified timber for construction. Many said they would do more if they were provided with better advice on best practice.

Many municipal authorities have adopted policies for renewing their vehicle fleets with cars that use low-emissions fuels, and for reducing their own greenhouse gas emissions by investing in renewable energy generation or combined heat- and powerplants for their buildings, including authority-owned housing stock. Some have joined global networks of cities, such as ICLEI (International Council for Local Environment Initiatives), formed under Article 28 of Agenda 21 agreed at the Earth Summit in Rio de Janeiro, Brazil, in 1992. European cities also joined hundreds of others in San Francisco in USA on World Environment Day 2005 to sign 'urban environmental accords' covering energy, waste production, urban design and other goals.

Awareness and information campaigns specifically targeted at individual sectors can help overcome the lack of information on the real costs of both wastes and pollution, and on how to reduce them at source. For example, Europe's chemical industries, particularly those concerned with the production and use of fertilisers and pesticides, are working with farmers to achieve more eco-efficient use of their products. At the same time they are developing such innovations as biocleaning plants, which can replace septic tanks, and the use of living cells from moulds, yeasts and bacteria, that can be used as 'cell factories' to produce enzymes for industry, as well as to make antibiotics, vitamins, vaccines and proteins for medical use. In this they have sometimes been encouraged by regulations and taxes on the overuse of their products as well as by incentives to develop less environmentally damaging chemicals.

Environmental labelling and other consumer initiatives are part of the policy focus on information to the public. Labelling schemes related to energy efficiency have been particularly successful. Given the choice, consumers will often buy energy- and water-efficient white goods, perceiving a benefit both in their fuel bills and to the environment. Initiatives, such as the forest and marine stewardship councils that guide consumers on sustainable products, also help in this respect.

Policies to enhance eco-innovation could also usefully address the financial, institutional and behavioural factors that 'lock in' current patterns of consumption and production. Innovation studies show that a stable policy framework, guided by long-term overall targets and stimulated by flexible policy packages which address interrelated economic realities, are needed to interact with the dynamics of many actors and stakeholders. The Dutch transition approach illustrates one way of tackling this.

Making progress in eco-innovation will be a complex process. However, it could be greatly helped by an increasing involvement of the public in establishing the acceptable risks of innovation balanced against the dangers of inertia in the face of climate change and other environmental threats. Eurobarometer confirms that citizens are concerned about the environment, and understand that environmental protection is often an incentive to innovation rather than an obstacle to economic performance. This provides support for increased, transparent, innovation and contributes more and better jobs to a sustainable future.

10.5 Summary and conclusions

The United Nations Millennium Ecosystem Assessment defines the natural environment in terms of the services, sources, sinks and spaces it provides. There is a growing body of influential opinion, expressed by business leaders, scientists and opinion-formers that environmental concerns and economic growth are far from mutually exclusive; rather they are intrinsically linked. However, the recognition of the real economic value of the natural world, and of our dependence on it for our continued prosperity, is still poorly understood, largely because the connections are relatively invisible.

Environmental policy measures have served the European society, its economy and its environment well over the last 30 years. Much has been achieved across Europe in the past decades to improve the quality of the air we breathe and the water we drink, and to dispose of many of the wastes that we generate. Policies have so far mainly addressed environmental deterioration from easily visible point sources of pollution. In doing so, Europe has encouraged technological advances and developed internationally recognised expertise in several eco-technologies and in environmental policy-making.

Current environmental challenges are more complex, diffuse and less visible than in the past, and increasingly robust science has demonstrated that environmental deterioration is continuing. Our consumption patterns are driving a rapidly rising use of natural resources in Europe and globally. As a result, our health continues to be damaged, the pollution of our waters continues, our biodiversity is still in decline, and our emissions of greenhouse gases have not fallen sufficiently to avoid climate change.

Our analyses of these issues suggest that we now have to consider tackling diffuse sources of pollution, whether, for example, from the cars we drive or from the way farmers respond to the increasing demand for cheap and plentiful foods. Taking action to address these diffuse sources will require integrated measures across economic sectors — agriculture, transport, manufacturing and energy production — and actions that engage with socio-economic factors such as household size, urbanisation, personal consumption and waste production.

Three interlinked approaches could help to realise the benefits available to Europe from tackling these recent or emerging realities: stronger and more coherent environmental policy integration, particularly through institutional and financial reform; the internalisation of the real costs of our use of the natural world into market prices which will contribute to the more efficient use of renewable resources, energy and materials; and the more efficient use of renewable and non-renewable resources via measures that stimulate eco-innovation.

There are sometimes trade-offs between economic and environmental priorities but they can be exaggerated. Many costs are short term (from two to five years), and can be eliminated through dynamic efficiency gains from innovation. EU citizens and businesses recognise that well designed environmental regulations can encourage innovation, particularly when they are predictably phased in over the longer term. Recent, more integrated policy approaches, especially using market-based instruments supplemented with regulations and information campaigns, are more cost-effective and can stimulate innovation better than most policy measures of the 1970s and 1980s.

There are great opportunities in Europe to make better use of the latest technologies in energy, transport and materials use. These can help achieve the eco-efficiency gains needed to avoid breaching environmental thresholds and to provide emerging economies with the ecological space to expand. However, substantial barriers to the exploitation of these opportunities remain, especially environmentally damaging subsidies and the absence of financial incentives to eco-innovate.

Ecological tax reform, alongside a shift to eco-friendly incentives, can help protect the environment, boost innovation and employment, and help deal with problems posed by an ageing population. Such reforms could include a gradual shift over 20–30 years of much of the tax-base away from income (which is at risk due to a dwindling workforce) and from capital (which often discourages investment and innovation), towards taxes on consumption, pollution and inefficient use of energy and materials — thus providing a wider tax-base from an ageing population and lifetime consumption.

The timescale to put in place effective policy measures can be 5–20 years, whilst the harmful impacts, and the time to reverse them, can take up to 100 years or more. Policy actions taken now to prevent the costly consequences of inaction later. Past examples show that inaction can be both very costly and long-term as the histories of asbestos, acid rain, the ozone hole, polychlorinated biphenyls (PCBs), and diminished fish stocks illustrate. In contrast, where action has been taken, all evidence indicates that the costs are usually overestimated while the benefits are underestimated.

The EU has already taken action towards greater coherence and integration of environmental and economic considerations. For instance, the development of the thematic strategies under the sixth environment action programme supports new cross-departmental and multi-stakeholder engagement. Meanwhile there has been a quiet revolution in the strategic management and coordination of the European Commission and Council activities. The potential of the EU's move towards multiannual and annual planning offers the potential for putting environmental integration into practice. Furthermore, Member States are individually taking their own action in support of such integration and internalisation.

The concepts of institutional and financial reforms are, of themselves, significant drivers of innovation. Some of the resulting changes may be painful, such as the reform of possibly outdated and environmentally harmful systems of subsidies. Nonetheless, there are proven cases and studies to indicate that environmental care and management creates economic opportunities and jobs — confirming that by being clever and clean, Europe can also be competitive, as eco-efficient innovations contribute to the broader social and economic goals of the Lisbon agenda.

This assessment of the state of the European environment demonstrates that the current and future challenges to our environment and the services it provides are long-term and strongly linked. They can best be managed by using similarly interlinked policy measures. These solutions often require behavioural changes from social and economic agents that are encouraged and facilitated by government actions. Progress will often be gradual and over several decades. This timeframe can provide space for policy learning and for attracting the broad support of both economic activities and citizens.

Eurobarometer polls show that citizens understand the importance of the environment for Europe's future welfare and are willing to take action, but only if others do. This provides an opportunity to engage with the public on how to tackle together the long-term environmental challenges we face. Their support is essential for the success of more integrated and innovative policy measures. Actions are needed now. The health, social and economic costs of inaction can be very large as experiences illustrate. And Europe is well placed to lead the way by creating smarter, cleaner, more competitive and more secure European societies.

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