Chapter

4

Nitrogen in current European policies

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Executive summary

Nature of the problem

- Europe, and especially the European Union (EU), has many governmental policy measures aimed at decreasing unwanted reactive nitrogen (N_r) emissions from combustion, agriculture and urban wastes. Many of these policy measures have an 'effects-based approach', and focus on single N_r compounds, single sectors and either on air or waters.
- This chapter addresses the origin, objectives and targets of EU policy measures related to N_r emissions, considers which instruments are being used to implement the policies and briefly discusses the effects of the policy measures.

Approaches

- The chapter starts with a brief description of the basic elements of governmental policy measures.
- A review of the main international conventions and EU policies related to emissions of N_r to air and water is then provided.
- Finally the chapter provides a semi-quantitative assessment of the effectiveness and efficiency of European policy measures.

Key findings/state of knowledge

- International conventions and other treaties have played a key role in raising awareness and establishing policy measures for N_r emissions abatement in EU through so-called Directives and Regulations.
- There are many different EU Directives, often addressing individual N_r compounds from individual sectors (e.g. NO_x emissions from combustion; NH_3 emissions from agriculture, pollution of groundwater and surface water by nitrates from agriculture, discharge of total nitrogen from urban sewage to surface waters).
- Many EU Directives have been revised following review and evaluation. There are increasing efforts to cluster single EU Directives into larger Framework Directives.
- Compliance with, and effectiveness of, the Directives differs between sectors; it decreases in the order (i) reducing NO_x emissions from combustion sources, (ii) reducing nitrogen (and especially Phosphorus) discharges to waters from industries and households, and (iii) reducing NH_3 emissions and NO_3 leaching from agriculture.
- There is not much literature on the differences in the effectiveness and efficiencies of Directives; a number of factors seem to be involved in effectiveness and efficiency, but these have not yet been analysed in a coherent manner.

Major uncertainties/challenges

- There is a huge diversity in N_r emission sources and pathways, while the number of policy instruments is limited. There is need to find the optimal mix of policy instruments targeted to the emission sources as well as the stakeholders involved.
- It has been indicated that some EU Directives addressing emissions of nitrogen compounds from specific sources have antagonistic effects. The magnitude of these effects is not yet well known.
- There is a delay in the environmental and ecological responses following the introduction of Directives; these are due to legislative delays, lack of enforcement and control, constraints in practice and because of biogeochemical hysteresis effects; these effects are not yet well understood quantitatively.
- In general, only modest reductions in N_r emissions from agriculture have been achieved to date; this reflects the need for more effective and efficient policy measures and/or greater enforcement of current policies.

Recommendations

- To examine further the differences between sectors of the factors that contribute to the effectiveness and efficiency of policy measures for the abatement of N_r emissions.
- To explore further the effectiveness and efficiency of more integrated N management and integrated policy measures for the abatement of adverse impacts of N_r emissions.

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4.1 Introduction

This chapter discusses the nature and effects of governmental policies in Europe aimed at decreasing the unwanted emissions of reactive nitrogen (N_r) compounds into the wider environment. Policy is commonly defined as 'a plan of actions to guide decisions'. Governmental policy is usually a response to unwanted developments or problems in society. Such policy is thus intended to change the developments in a desired direction and/or to solve problems, in this case related to excess N_r in the environment. Governmental policies are based on the premise that humans as individuals and/or as organizations change their behaviour and activities in response to such policies. This premise originates from the fact that humans prefer to live in communities (families, bands, tribes, chiefdoms, states), and that they accept vertical hierarchy (Diamond, 1997; Patterson, 2001). They are expected to follow rules from the top (in this case government) in return for services provided by government.

The historian Fernard Braudel (1979, pp. 458–599) insightfully described the development of modern states in Europe and the main tasks of their governments: (i) to secure obedience, (ii) to exert control over the market, which serves as a mechanism of exchange between the supply and demand of goods and services, and (iii) to strengthen the culture of the society. Evidently, governmental policies are directed to achieving the main tasks of the governments. Key governmental policies usually relate to national defence, food security, economic development, education, health care, spatial planning, infrastructure, traffic, etc. Environmental policy is a relatively new branch of governmental policy, with the theory borrowed initially from economic policy (Tinbergen, 1952). The general aim of environmental policy is to contribute to social welfare by protecting the environment through correcting societal failures, decreasing pollution, halting biodiversity loss and maintaining natural resources.

The United Nations Conference on the Human Environment in Stockholm in 1972 is generally seen as having been a key step for increased political awareness in Europe about environmental problems created in part by N (UNEP, 1972), and subsequently for the establishment of environmental policies by governments. One of the main aims of the Conference was to put the issue of acid rain on the international agenda. Nitrogen oxides (NO_x) and sulphur dioxide (SO_2) are the main contributors to acid rain (Finlayson-Pitts and Pitts, 2000). They are formed during combustion processes and were linked initially to the acidification of Scandinavian lakes and streams. The 1972 Conference ultimately led to the establishment, in 1979, of the UNECE Convention on Long-range Transboundary Air Pollution (CLRTAP) (UNECE, 2010), which has been ratified by most countries in Europe.

International treaties and conferences also played major roles in the establishment of water-related environmental policies. The first Convention on the Protection of the Marine Environment of the Baltic Sea was signed in Helsinki in 1974 (HELCOM, 2010). In 1992, a new convention was signed, aimed at protecting the Baltic Sea from all sources of pollution derived from land, shipping and atmospheric deposition (HELCOM, 2010). The OSPAR Convention on the Protection of the Marine Environment of the North-East Atlantic was also signed in 1992 (OSPAR, 2010). One of the recommendations was the 'substantial reduction (about 50%) of inputs of N and P into marine areas of the North-East Atlantic where these inputs are likely, directly or indirectly, to cause pollution', between 1985 and 1995, using N (and P) balances as monitoring tools. The HELCOM and OSPAR Conventions have resulted in various national and EU policies on the protection of groundwater and surface waters, as discussed below.

Justification of governmental policy to decrease N_r emissions is mainly based on the significant human health effects and biodiversity losses associated with increased amounts of various reactive N compounds in air, surface waters and groundwaters, and terrestrial ecosystems sensitive to eutrophication and acidification (Erisman *et al.* 2011, Chapter 2 this volume). Hence, the ultimate objective of governmental policy is 'to decrease N_r emissions to a level where the value of marginal damages to human health and biodiversity is (approximately) equal to the marginal cost of achieving further reductions' when considered from a cost–benefit point of view. An alternative formulation is 'the ultimate objective of policies is to decrease N_r emission to levels that do not give rise to significant negative impacts on, and risks to human health and environment'. However, defining the objective of governmental policy is value-laden and often the subject of fierce political debate (Hajer, 1995; Baker *et al.*, 1997). This debate is further complicated by the complexity of the cause–effect relationships of N compounds emissions and the multi-dimensional outcome of governmental policy, which affects different stakeholders, often with opposite interests, in different ways. This in turn often leads to compromises and delays in the implementation of governmental policy (Bressers and Huitema, 2001; Driessen and Leroy, 2007).

The main sources of reactive N compound emissions distinguished by current governmental policy are:

(i) combustion (mainly NO_x by industry, power plants and traffic);
(ii) waste waters (mainly dissolved and particulate N in discharges by industry and households); and
(iii) agriculture (mainly NH_3 and N_2O to air, NO_3 to groundwater and dissolved and particulate N to surface waters).

The lack of full understanding of different emission sources, N_r compounds and loss pathways, and of different receptors with different sensitivities to N_r compounds (Hatfield and Follett, 2008) has led to a strong compartmentalization and (regional) differentiation of governmental policies. There are thus policies for specific sectors (energy, industry, households, waste waters and agriculture), N compounds (NO_x, NO_3, NH_3, etc.), regions (countries, sensitive areas, vulnerable zones, etc.), and compartments or receptors (atmosphere, nature conservation areas, forests, groundwater, surface waters, soil, etc.).

These complexities in part also reflect the compromises of fierce debates and diverging interests between stakeholders, for example, between industry and nature conservation organizations, and between the Departments of Economic

Table 4.1 Possible policy instruments, with some examples

Regulatory instruments	Economic instruments	Communicative instruments
– public land use planning (zoning/spatial planning) – pollution standards and ceilings – fertilization limits – best available technique requirement	– taxes – subsidies (including price support) – import/export tariffs – tradable emission rights and quotas	– extension services – education and persuasion – co-operative approaches

Development, Traffic and Agriculture on the one hand and the Departments for Environment and Nature Conservation on the other (Driessen and Leroy, 2007).

The purpose of this chapter is to provide (i) some concepts of governmental policies, (ii) an overview of governmental policies in Europe (mainly EU) that influence N flows and emissions, and (iii) a preliminary assessment of the various policies, with the aim of identifying interactions between policies and critical success factors.

4.2 Concepts of governmental policy

Basically, there are four principle drivers in organizing and governing societies, namely:

- culture (human values, traditions, fashion and cultural habits);
- market power and expertise (the 'invisible hand' of the free market);
- public policy measures (state coercion, i.e. regulation pressure by governments); and
- civic society pressure (pressure from non-governmental organizations (NGOs) and societal pressure and lobby groups).

Public or governmental policy is a response to the identification of a societal problem, where culture, markets and civic society pressure collectively fail to solve that problem. Governmental policy aims at modifying human individual behaviour so as to achieve societal (public) objectives, i.e. to contribute to the total welfare of society (Tinbergen, 1952; Baumol and Oates, 1988). The fact that 'public policy' addresses societal objectives does not mean that everybody in the society equally accepts this policy and its consequences. There is often a strong divide in societies between those who believe in the cleansing mechanism of the market and in the ability of humans to act responsibly, and who therefore prefer a minimum of governmental policy, and those who emphasize the failures of markets and the need to help the less endowed in society, and therefore favour more extensive governmental policy.

Policy instruments are the tools to implement the policy in practice. There are different type of instruments, the choices of which depend on the nature of the problem, the objectives of the policy and the competences and characteristics of the addressees (Baumol and Oates, 1988; Gunningham and Grabosky, 1998). Instruments can be divided into three categories: (i) regulatory or command-and-control instruments, (ii) economic or market-based instruments and (iii) communicative or persuasive instruments (Table 4.1).

Regulatory instruments (regulation) involve a restriction on the choice of agents, methods and actions. Regulations are compulsory measures imposing requirements on producers to achieve specific levels and standards of environmental quality, including environmental restrictions, bans, permit requirements, maximum rights or minimum obligations. They are the most common policy instrument used in EU environmental policy (e.g. Nitrates Directive).

Economic instruments (stimulation) are meant to stimulate preferred production pathways. They are common in agricultural policy, for example, in the EU Common Agricultural Policy (CAP). Environmental taxes and tradable rights/quotas have only been implemented in a few countries. Subsidies are increasingly used as a policy instrument to promote environmentally friendly practices and the introduction of new technology.

Communicative instruments (persuasion) include public projects to address environmental issues and measures to improve information flows to promote good practices and environmental objectives. This information can be provided to both producers, in the form of technical assistance and extension, and to consumers, e.g. via labelling. Technical assistance and extension are meant to provide users with information and technical assistance to implement environmentally friendly practices. This category also includes so-called voluntary approaches, e.g. codes of good agricultural practice (Sutton *et al*., 2007).

Whether those addressed by policy then change their behaviour and contribute to achieving the objectives depends on the instrument and the decision environment of those addressed. A decision environment can be defined as '*the collection of information, alternatives, values, and preferences available at the time of the decision*'. An ideal decision environment would include all possible information, all of it accurate, and every possible alternative at the time. This is usually not the case and explains why the implementation of a policy in practice is far from complete. In short, compliance with a policy will depend on the knowledge and information held by the addressee ('capability'), the availability of the appropriate tools and means ('ability') and on the persuasion ('willingness') of the addressee to implement the policy (Figure 4.1).

The theoretical and empirical bases of governmental policy measures are still relatively small. This holds also for policy measures related to the abatement of unwanted N_r emissions. The relationships between 'policy objectives – policy instruments – change in human behaviour – human health, ecological impacts and possible side-effects' are complex, and to

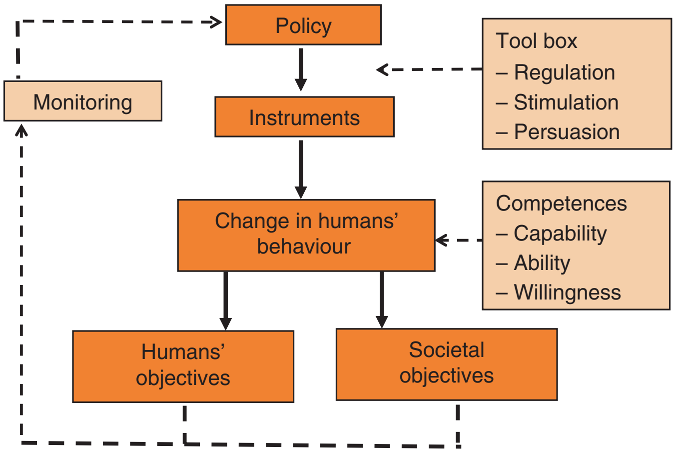

Figure 4.1 Simple representation of the intended working of governmental policy.

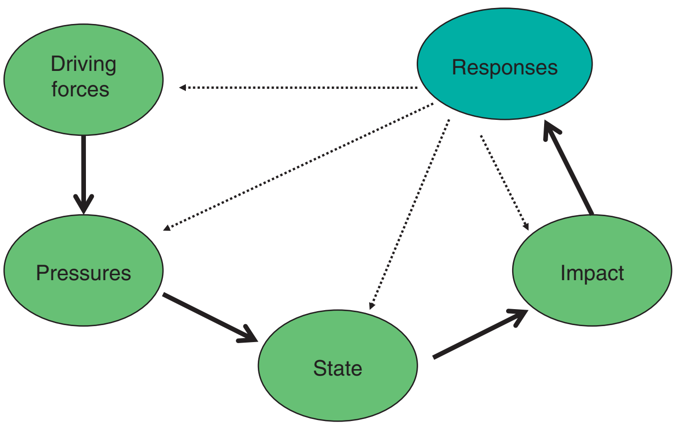

Figure 4.2 The Driving forces – Pressures – State – Impact – Responses framework (DPSIR) for assessing cause–effect relationships and for developing a policy response (*Source*: EEA, 1995.)

some extent based on trial and error. Further, the toolbox for implementing governmental policy measures is relatively small; choices have to be made between regulatory instruments, economic instruments and communicative/voluntary instruments, or a mix of these three. The available theoretical and empirical bases often do not help indicate, *a priori*, which combination of instruments will be most effective and efficient.

The development of the so-called DPSIR framework (see Figure 4.2) and related frameworks by the Organisation for Economic Co-operation and Development (OECD) and the European Environmental Agency (EEA) in the 1990s has improved the understanding of the cause–effect relationships of environmental pollution (see, for example, OECD, 1991; EEA, 1995). It has also provided a framework for responding to environmental problems via policy measures. According to the DPSIR framework, there is a chain of causal links starting with '*driving forces*' (economic sectors, human activities) through '*pressures*' (emissions, waste) to '*states*' (physical, chemical and biological) and '*impacts*' on ecosystems, human health and functions, eventually leading to political '*responses*' (policy definition, prioritization, target setting, indicators).

4.3 International conventions and intergovernmental organizations

International conventions have played major roles in the establishment of governmental policies aimed at decreasing emissions of N_r to, and N_r concentrations in, the environment. Conventions and their protocols relevant to this chapter are summarized in Table 4.2 and further discussed in the supplementary information (Section 4.4).

Intergovernmental organizations (IGOs), whilst not specifically legislative bodies, influence policy internationally (see Table 4.3). They are distinguished from treaties by virtue of their 'international legal personality'.

Further discussion on the inter-relationships of international conventions and IGOs and their interests in N control may be found in Bull *et al.* (2011, Chapter 25, this volume).

4.4 Policy measures affecting nitrogen in European Union

In the following sections, current EU policy measures dealing with N are briefly summarized. Policies related to air and water are discussed first, followed by policies related to agriculture, biofuel and nature conservation. The final section (Section 4.4.6) provides a comprehensive overview. To facilitate access to the various EU policies documents, reference is made to the most recent websites (all policies are referenced as EC, 2010a–y).

EU environmental policy is mostly established by means of Directives, imposing environmental objectives to be achieved by the Member States. EU Directives fix the framework in which Member States must create national legislation directed to industries/civilians in order to attain the environmental quality objectives laid down in the Directives. In contrast, EU agricultural policy is mostly established through so-called Regulations. These Regulations are directly binding for Member States and, depending on the issue, producers/stakeholders/industries. Hence, EU Directives provide more flexibility than EU Regulations for Member States' implementation. Note that EU Directives are commonly based on 'regulatory instruments' (Table 4.1) and that EU Regulations are often based on a mixture of 'economic instruments' and 'regulatory instruments'.

Understanding EU policy measures dealing with N emissions abatement requires insight into the understanding and perception by scientists and policy makers of the cause–effect relationships of these emissions. Many current policy measures dealing with N emissions reflect a simple 'source – receptor/effect' model of understanding. Combustion (mainly NO_x by industry, power plants and traffic), waste waters (mainly dissolved and particulate N in discharges by industry and households) and agriculture (diffuse emissions of NH_3 and N_2O to air and NO_3^- to waters) are seen as the main N sources, while atmosphere, surface waters and groundwater are seen as the direct receptors. Thus, many policy measures focus on decreasing N compound emissions from specific sources and/or on decreasing N compound concentrations in receiving bodies (receptors) to below critical concentration levels.

Table 4.2 Conventions and protocols addressing nitrogen emissions

1974 Helsinki Convention (HELCOM) on the Protection of the Baltic Sea in Helsinki
1974 OSPAR Convention (PARCOM) on the Protection of the North-East Atlantic
1976 Barcelona Convention on the Protection of the Mediterranean Sea
1979 UNECE Convention on Long-range Transboundary Air Pollution (CLRTAP)
1988 Sofia protocol on Nitrogen oxide (NO_x) emissions
1992 Bucharest Convention on the Protection of the Black Sea
1992 Convention on Biological Diversity
1992 Convention on Transboundary Waters and International Lakes
1994 United Nations Framework Convention on Climate Change (UNFCCC)
1997 Kyoto Protocol
1999 Gothenburg Protocol on acidification, eutrophication and ground-level ozone

Table 4.3 IGOs with linkages to nitrogen

1945 Food and Agriculture Organization (FAO)
1948 World Health Organization (WHO)
1950 World Meteorological Organization (WMO)
1972 United Nations Environment Programme (UNEP)
1988 Intergovernmental Panel on Climate Change (IPCC)
1996 Arctic Council

4.4.1 EU policy measures related to atmospheric N_r

Table 4.4 provides an overview of the three main EU Directives on nitrogen in the atmosphere. Following extensive reviews, the 1988 Directive on Large Combustion Plants (LCP; EC, 2010a), the 1996 Directive on Integrated Pollution Prevention and Control (IPPC; EC, 2010b), the 2000 Waste Incineration Directive (WID; EC, 2010c) and the 2005 Directive on Emission from Ignition Engines in Heavy-duty Vehicles (HDV; EC, 2010d), were incorporated into the 2008 Directive on Industrial Emissions concerning Integrated Pollution Prevention and Control (IPPC) (EC, 2010b). This 2008 IPCC Directive is now one of the cornerstones of EU Directives dealing with atmospheric N_r, and sets requirements and standards for NO_x emissions from all kinds of combustion sources (Table 4.4). The IPPC Directive employs an integrated approach to the management of all types of pollution from industrial installations, including those for the intensive rearing of poultry or pigs. It requires these installations to have a permit and to minimize all kinds of pollution (including reactive N compounds emissions) by using Best Available Techniques (BAT). An essential part of the IPPC Directive is that the listed activities require a permit to operate, the approval and renewal of which is subject to cross-compliance with other European Community legislation.

The second cornerstone of EU Directives dealing with atmospheric N_r is the 2001 National Emission Ceilings Directive (NEC; EC, 2010e). This Directive sets upper limits (ceilings) for each Member State for the total emissions in 2010 and 2020 of the four pollutants responsible for acidification, eutrophication and ground-level ozone pollution (SO_2, NO_x, VOCs and NH_3), but leaves it largely to the Member States to decide which measures to take in order to comply (Table 4.4). The Directive aims at achieving the long-term objectives of not exceeding critical levels and loads by establishing national emission ceilings, taking the years 2010 and 2020 as benchmarks. This Directive is currently (2010) under revision.

The 1996 Framework Directive on Ambient Air addresses ambient air quality assessment and management (EC, 2010f). It includes a series of daughter directives, which set the numerical limit values for atmospheric pollutants. For example, the 1999 Air Quality Directive relates to limit values for, among others, nitrogen oxides (NO_x), ozone (O_3) and particulate matter (PM_{10}) in ambient air. The main emphasis is human health in urban areas and on air pollutants from combustion sources. The most recent version of the Ambient Air Quality Directive was approved in 2008. It contains limit values for NO_x, O_3 and $PM_{2.5}$, but not for NH_3. Ozone is included as nitrogen oxides (NO and NO_2) are important O_3 precursor substances, and because of adverse effects of high O_3 concentration on human health and crop growth. Particulate matter is included because of its close link to the N cycle (see Hertel *et al.*, 2011; Chapter 9 this volume), being formed as a result of the processing of ammonia, nitrogen oxide and other N-containing substances, and its effects on human health. The 2008 Ambient Air Quality Directive is now one of the three cornerstone Directives dealing with atmospheric N_r in the EU-27 (EC, 2010f).

4.4.2 EU policy measures related to N in water bodies

A number of EU policy measures exist which address the issue of N_r emissions and concentrations in water bodies, these are detailed below and summarized in Table 4.5.

The 2000 Water Framework Directive (EC, 2010h) embraces all EU legislation for the protection of inland surface waters, transitional waters, coastal waters and groundwater. The Water Framework Directive (WFD) requires all waters to reach 'good ecological status' by 2015. It will do this by establishing a river-basin district structure within which demanding environmental objectives will be set, including ecological targets for surface waters and good chemical and quantitative status for groundwater bodies. It requires the implementation of measures from 11 other EU Directives, including the 1976 Bathing Water Directive (EC, 2010i), the 1990 Urban Waste-water Treatment Directive (EC, 2010j), the 1985 Environmental Impact Assessment Directive (EC, 2010k), the 1991 Nitrates Directive (EC, 2010l), the 1996 IPPC Directive (EC 2010b), the 1998 Drinking Water Directive (EC, 2010m) and the 2006 Groundwater Directive (EC, 2010n). The WFD includes an indicative list of main pollutant substances, including substances

Table 4.4 Overview of main EU Directives related to N emissions to, and concentrations in, the atmosphere (see also EC, 2010g)

Directive	Description / objectives	Limit values
2008/50/EC	**Ambient air quality:** definitions, threshold values, targets and assessment, in relation to sulphur dioxide, nitrogen dioxide, particulate matter, lead, benzene and carbon monoxide.	• Critical level for NO_x for vegetation (average over 1 year): 30 µg m^{-3} • Limit values for NO_x for human health (averaged over 1 yr): 40 µg m^{-3} • Limit values for NO_x for human health (averaged over 1 hr): 200 µg m^{-3} • Alert thresholds for NO_x for human health (averaged over 3 hr): 400 µg m^{-3} • Target and limit values for $PM_{2.5}$ in urban areas (average over 3 yr): 20–25 µg m^{-3}.
2008/1/EC	**Integrated Pollution, Prevention and Control (IPPC):** to prevent and control emissions from industrial activities into air, water or soil, in relation to polluting substances, including nitrogen	• Installations need a permit • Installations need to comply with environmental quality standards described in other Directives • Installations need to apply best available techniques (BATs)
2001/81/EC	**National Emission Ceilings (NEC):** to limit emissions to protect the environment and human health against risks of adverse effects from acidification, eutrophication and ground-level ozone, by establishing national emission ceilings, taking the years 2010 (and 2020) as benchmarks	• National emission ceilings for SO_2, NO_x, VOC and NH_3, for each country to be attained by 2010, expressed in kilotonnes (Gg) • In regard of the long term objectives 'not exceeding critical levels and loads and of effective protection of all people against recognized health risks from air pollution' no ceilings have been yet set for 2020 though the Directive envisages ongoing review

which contribute to eutrophication (in particular, nitrates and phosphates). The WFD allows Member States the flexibility to define specific ambitions, targets and time frames, albeit under the constraints of proper underpinning and justifications. The most important linked Directives of the WFD as regards N_r emissions to groundwater and surface waters are the 1991 Urban Waste Water Directive and the 1991 Nitrates Directive.

The 1991 Urban Waste Water Directive (UWWD; EC, 2010j) concerning urban waste water treatment was adopted in 1991 to protect the water environment from the adverse effects of discharges of urban waste water and from certain industrial discharges. The UWWD has requirements for sewerage (or collection systems) to be established and sets standards for sewage treatment. The general principle of the Directive is to provide treatment of sewage from the largest discharges first, and to protect sensitive waters. It sets secondary treatment as the normal standard, but requires tertiary treatment where discharges affect sensitive areas identified under the Directive. It also requires that discharges from urban waste water treatment plants to sensitive areas do not contain more than 10–15 mg N per litre, depending on the size of the communities, and that the waste water treatment system removes 70%–80% of the initial amount of N_r in the sewage.

The main objective of the 1991 Nitrates Directive is 'to reduce water pollution caused or induced by nitrates from agricultural sources and prevent further such pollution' (EC, 2010l). This Directive requires Member States to take the following steps: (i) water monitoring (with regard to nitrate concentration and trophic status); (ii) identification of waters that are polluted or at risk of pollution; (iii) designation of vulnerable zones (areas that drain into identified waters); (iv) the establishment of codes of good agricultural practices and action programmes (a set of measures to prevent and reduce nitrate pollution); and (v) the review at least every four years of the designation of vulnerable zones and action programmes. Waters must be identified as polluted or at risk of pollution if nitrate concentrations in groundwater and surface waters contain or could contain more than 50 mg/l per litre if no action is taken, or if surface waters, including freshwater bodies, estuaries, coastal and marine waters are found to be eutrophic or in the near future may become eutrophic if no action is taken. The action programmes must contain mandatory measures relating to: (i) periods when application of animal manure and fertilizers to land is prohibited; (ii) capacity of and facilities for storage of animal manure; and (iii) limits to the amounts of animal manure (170 kg/ha/yr) and fertilizers applied to land, which should ensure a balanced fertilization.

The 2008 Marine Strategy Directive (EC, 2010p) aims to achieve good environmental status of the EU's marine waters by 2020 and to protect the resource base upon which marine-related economic and social activities depend. It covers the following marine regions: (a) the Baltic Sea; (b) the North-East Atlantic Ocean; (c) the Mediterranean Sea; and (d) the Black Sea. It contains an indicative list of characteristics, pressures and impacts which have to be monitored and assessed regularly, and for which environmental targets have to be set. The list of pressures and impacts includes inputs of fertilizers and other nitrogen- and phosphorus-rich substances (from point and diffuse sources, including agriculture, aquaculture and atmospheric deposition). Each Member State has to draw up a programme of cost-effective measures to address adverse characteristics, pressures and impacts. Impact assessments, including detailed cost–benefit analysis of the measures proposed, are required prior to the introduction of new measures.

Table 4.5 Overview of main EU Directives related to N emissions and concentrations in water bodies (see also EC, 2010o)

Directive	Description / objectives	Requirements/Limit values
2000/60/EC	**Water Framework Directive (WFD):** to establish a framework for the protection of inland surface waters, transitional waters, coastal waters and groundwater from pollution and depletion	• Maintaining/establishing good ecological status in surface water bodies and good chemical and quantitative status in groundwater bodies • Establishment of river basement management plans • Designation of 'protected areas' • For 'limit values' and 'measures required' reference is made to other Directives
91/271/EEC	**Urban Waste Water Treatment Directive (UWWD):** to protect the environment from the adverse effects of waste water discharges from urban areas and certain industrial sectors	• All agglomerations must be provided with collecting systems for urban waste water • Identification of sensitive areas • Requirements for discharges from urban waste water treatment plants to sensitive areas: (i) a reduction of total N_r of 70%–80% of the influent; and (ii) maximum annual mean total N concentrations of 1.5–10 mg/l, depending on size of the urban area
91/676/EEC	**Nitrates Directive (ND):** concerning the protection of waters against pollution caused by nitrates from agricultural sources	• Establishment of a code of good agricultural practice, including balanced N fertilization, to be implemented by farmers on a voluntary basis • Designation of Nitrate Vulnerable Zones • Establishment of action programmes with mandatory measures in vulnerable zones, including N application limits • Water quality trigger criteria: (i) 50 mg nitrate per litre in groundwater and surface waters, and (ii) eutrophic status of surface waters • Application limit for nitrogen from animal manure: 170 kg/ha/yr
2008/56/EC	**Marine Strategy Framework Directive:** establishes a framework to take the necessary measures to achieve or maintain good environmental status in the marine environment by the year 2020 at the latest	• Determination of a set of characteristics for good environmental status • Establishment of a comprehensive set of environmental targets for marine waters to guide progress towards achieving good environmental status • Identification and implementation of measures needed to achieve or maintain good environmental status • There are no prescribed limit values
2006/118/EC	**Groundwater Directive:** establishes a regime which sets underground water quality standards and introduces measures to prevent or limit inputs of pollutants into groundwater	• Groundwater quality standards for nitrate and active substances in pesticides, including their relevant metabolites, degradation and reaction products • Threshold values for all pollutants and indicators of pollution which characterize groundwater as being at risk of failing to achieve good groundwater chemical status • Establishes the 50 mg/l for nitrate as a binding maximum quality threshold

The 2006 Groundwater Directive (EC, 2010n) complements the Water Framework Directive and requires Member States to: (i) establish groundwater quality standards by the end of 2008; (ii) carry out pollution trend studies; (iii) reverse pollution trends so that environmental objectives are achieved by 2015; (iv) operate measures to prevent or limit inputs of pollutants into groundwater; (v) make reviews of technical provisions of the Directive in 2013 and every six years thereafter; (vi) comply with good chemical status criteria (based on EU standards of nitrates and pesticides and on threshold values established by Member States).

4.4.3 EU Common Agricultural Policy and its reforms.

The Common Agricultural Policy (CAP) of the EU was established in 1958 by the EEC. The CAP has contributed greatly to the modernization and productivity of agriculture and to food security in the EU (Ritson and Harvey, 1997). Indirectly, it has also contributed to increased inputs of N in agriculture via N fertilizers and to the import of animal feed from outside the EU, as well as to increased N losses from agriculture to the environment (Romstad *et al.*, 1997).

Following the recognition and increased awareness of the effects of surpluses of agricultural products and environmental burden associated with the intensification of agricultural production, the CAP went through a series of reforms, notably in 1984 (implementation of milk quota), 1992 (set-aside regulations), 1997 (agenda 2000) and 2003 (fundamental change in the EU support to agriculture: EC, 2010q; EC, 2010t; Meester *et al*., 2005; Blandford and Hill, 2006). In 2003, it was agreed that the CAP has two pillars: (i) market policies and (ii) rural development policies. In 2008, agreement was reached to further modernize, simplify and streamline the CAP and remove restrictions on farming (the so-called 'Health Check'). This agreement includes the phasing-out of the milk quota system, the abolition of set-aside regulations and a further shift from direct aid for production support to the Rural Development Programme (EC, 2010q; EC, 2010s.). The reforms of the CAP continue to have a significant influence on N use and its loss to the environment.

'Cross-compliance' is a main policy vehicle to implement the CAP reform. In this context, cross-compliance is the requirement that farmers in receipt of payments under the CAP are also shown to be meeting other relevant European Community legislation. In June 2003, cross-compliance became an obligatory element of the first pillar of CAP, thereby coupling existing environmental policies and other policies to agricultural income support, as implemented in the so-called 'Single Farm Payments' to farmers. There are two major aspects of cross-compliance in the Single Farm Payment (EC, 2010q): (i) Compliance with 19 Statutory Management Requirements (SMRs) covering the environment, food safety, animal and plant health and animal welfare, including the provisions of the relevant directives; and (ii) Compliance with a requirement to maintain land in Good Agricultural and Environmental Condition (GAEC). Definitions of GAEC are specified at the national or regional level and address soil organic matter, soil erosion, maintenance of the land(scape) and avoidance of the deterioration of natural habitats.

A few of the SMRs directly or indirectly address N inputs and N emissions in agriculture. These include, for example, the 1991 Nitrates Directive, the 1986 Sewage Sludge Directive, the 1992 Directive on the conservation of natural habitats and of wild flora and fauna (Habitats Directive), and the 1979 Directive on the conservation of wild birds (Birds Directive).

Such cross-compliance with other environmental regulations has the potential to encourage the reduction of N_r losses from agriculture. However, this is not always the case. For example, emerging requirements for animal housing to meet new animal welfare standards (EC, 2010r) will in many cases contribute to increased emissions of NH_3 and N_2O. This interaction highlights the need to consider environmental regulation in the context of other societal pressures.

The second pillar of the CAP is the Rural Development Policy, which for the period 2007 to 2013 is set out in Council Regulation No. 1698/2005 (EC, 2010t). Under this regulation, rural development policy is focused on three themes (known as 'thematic axes') plus the LEADER approach: (i) improving the competitiveness of the agricultural and forestry sector; (ii) improving the environment and the countryside; (iii) improving the quality of life in rural areas and encouraging diversification of the rural economy; and (iv) mainstreaming the LEADER approach 'Links between Activities Developing the Rural Economy' (LEADER, 'Liaison Entre Actions de Développement de l'Economie Rurale'). To help ensure a balanced approach to the rural development policy, Member States and regions are obliged to spread their rural development funding between all these thematic axes. Within each of the first three axes, various support mechanisms have been described in articles 20 to 35 for Axis 1, in articles 36 to 51 for axis 2 and in articles 52 to 59 for axis 3, which help with improving the agronomic and environmental performances of agricultural activities in the rural areas. These measures may include the setting up of advisory services, supporting modernization of agricultural holdings, supporting operations related to access to farm and forest land, land consolidation and improvement, energy supply and water management, and agri-environmental payments. Clearly, the Rural Development Policy can contribute to measures that decrease N_r losses from agriculture to the environment.

4.4.4 EU nature conservation policies

The policy framework for preventing biodiversity loss in the EU is provided by the Birds and Habitats Directives, which are being implemented through Natura 2000, an EU-wide network of protected areas, which now covers some 18% of the territory of the EU. The 1979 Birds Directive (EC, 2010v) requires Member States to designate Special Protection Areas (SPAs) for endangered bird species. Currently, over 4000 SPAs have been designated, covering 8% of EU territory. The 1992 Habitats Directive (EC, 2010w) aims to protect other wildlife species and habitats. Each Member State is required to identify Special Areas of Conservation (SACs) and to put in place a special management plan to protect them. The SPAs and SACs together make up the Natura 2000 network.

Member States are required to improve the ecological coherence of Natura 2000 by maintaining, and where appropriate developing, features of the landscape which are of major importance for wild fauna and flora. The Birds and Habitats Directives imply restrictions on human activities within and around the Natura 2000 areas. Widely established restrictions include infrastructural, industrial and agricultural activities in and near to Natura 2000 sites. The Directives also have implications for activities taking place that are not on the site itself. In addition, the Birds and Habitats Directives establish lists of designated species and habitats, with a commitment to monitoring the performance of these across the whole of the EU. This represents an important part of the overall objective of these Directives, though it should be noted that there is a lack of measures to protect such habitats and species outside of the Natura 2000 network.

In principle, the Birds and Habitats Directives are drivers to safeguard biodiversity and to lower NH_3 and NO_x emissions, by virtue of the precautionary approach. However, this is still an area of ongoing development in learning to implement the

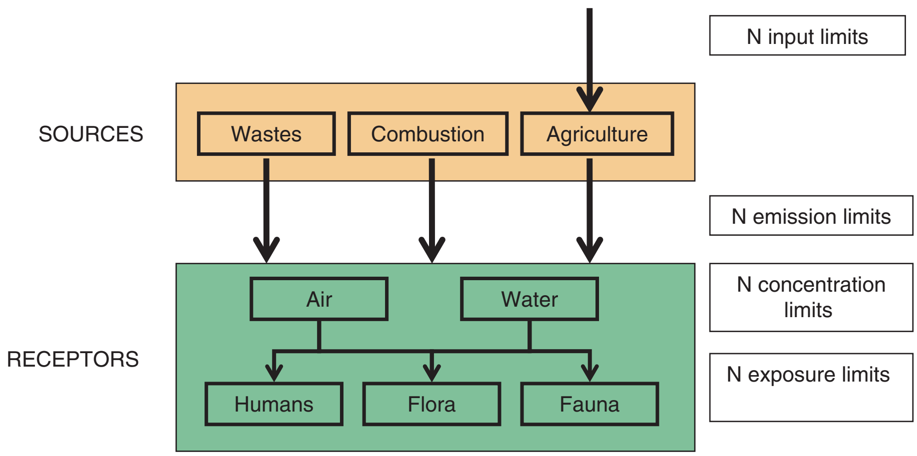

Figure 4.3 Schematic overview of the N control mechanisms of European policy measures. For the N emission sources, there are N input limits and N compounds emission limits, for the N receptors, there are N compounds concentrations limits and N compounds exposure limits, including critical loads.

existing legislation, and in evaluating its limitations (COST 729, 2009).

4.4.5 EU bio-energy policy

Current EU energy policy focuses on increasing the security of energy supply and reducing greenhouse gas (GHG) emissions, as set out in 2007 in 'The Renewable Energy Road Map' (COM(2006)848; EC, 2010u). In the Road Map, a mandatory target was set for achieving a 20% share of renewables in energy consumption in the EU by 2020 and a mandatory minimum target of 10% of all energy in transport from biofuels. The recent Directive on the promotion of the use of energy from renewable sources (2009/28/EC; EC, 2010y) amended the 2003 Biofuel Directive (2003/30/EC). Though 'nitrogen' is not mentioned explicitly in any of the energy policy documents (except for N_2O as a greenhouse gas), the EU policy on bioenergy will have influence on N use in agriculture, as bio-energy crops require N_r for their growth and release various N compounds to the broader environment during and following their growth and utilization. The EU policy on bioenergy will also have influence on the total agricultural area used for the production of food, feed and fibres.

4.4.6 Summary of nitrogen control by European policies

In summary, N flows and emissions in Europe are regulated by a broad variety of policy measures. These policy measures regulate N flows and emissions via (i) input control (e.g. N application limits in agriculture), (ii) emission control (e.g. N_r emission limits, discharge limits), (iii) concentration limits for N_r in air and water bodies, and (iv) N_r exposure limits and critical N loads (Figure 4.3).

Input controls exist only for agriculture, via application limits for N_r from animal manure and fertilizers to agricultural land, and via provisions for the protein content of animal feed. Such limits do not apply for combustion and wastes.

Emission controls exist for all major N compounds, for example via the national emission ceilings for NO_x and NH_3, NO_x emission limits for stationary and mobile combustion sources, discharge limits for industry and sewage treatment plants. Further, NH_3 emissions abatement measures exists for animal housing, manure storages and manure application, and N fertilizer application to land.

Table 4.6 provides a summary of quantitative EU limit values for various N compounds in air and water. In air, there are limit values for NO_x (NO and NO_2) and for substances that are formed in part through the presence of NO_x in air, viz., ozone (O_3) and fine particles ($PM_{2.5}$ and PM_{10}). Currently, there are no limit values for NH_3 concentrations in air. In water, there are limit values for NO_3^-, NO_2^-, NH_4^+, and N_{total}. There are no limit values for N compounds in soil.

Exposure limits for humans and N-sensitive flora and fauna are defined either via concentration limits or via input limits, such as critical loads. A critical load is defined by the CLRTAP (UNECE, 1999) and the NEC Directive (EC, 2010e) as 'a quantitative estimate of an exposure to one or more pollutants below which significant harmful effects on specified sensitive elements of the environment do not occur, according to present knowledge'. Critical N-loads for ecosystems are determined following specific methodologies and criteria for mapping critical levels/loads and geographical areas (ICP Modelling and Mapping, 2004). Critical loads form the basis for setting emission limits and ceilings (Sliggers and Kakebeeke, 2004).

4.5 Assessment of environmental policies in Europe

Assessments of environmental policy usually include analyses of its *compliance*, expressed in terms of implementation of mandatory obligations, its *effectiveness*, expressed in terms of achieving policy objectives, and its *efficiency*, expressed in terms of the economic costs of its implementation. In addition, assessments may address the possible technical, technological, socio-economic, institutional and societal changes brought about by environmental policy.

Assessment of compliance is usually the first step; it simply records whether the obligations of the policy (e.g. abatement measures, designation of specific areas, and monitoring and reporting obligations) have been satisfied. However, the effectiveness and efficiency of planned environmental policy may be

Table 4.6 Summary of limit values for N compounds concentrations in air and water as set by EU policies

Effects	Indicators	Limit values / targets	Regulatory reference
Respiratory diseases of humans	NO_x	40 µg m^{-3} (annual mean) 200 µg m^{-3} (hourly mean) 400 µg m^{-3} (threshold, 3 hrs)	Ambient Air Quality Directive (2008/50/EC)
Ibid	$PM_{2.5}$	20–25 µg m^{-3} (average of 3 yrs)	Ibid
Ibid	PM_{10}	40–50 µg m^{-3} (average of 3 yrs)	Ibid
Ibid	O_3	180–240 µg m^{-3} (hourly mean)	Ibid
Ibid	AOT40[a]	120 µg m^{-3} (hourly mean)	Ibid
Plant damage	NO_x	30 µg m^{-3} (annual mean)	Ibid
Adverse effects on humans from nitrates	NO_3^-	50 mg/l in groundwater	Drinking Water Directive (98/83/EC) Nitrates Directive (91/676/EEC) Groundwater Directive (2006/118/EC)
Adverse effects on humans by nitrites	NO_2^-	0.5 mg/l in water used for drinking water. Further, $[NO_3^-]/50 + [NO_2^-]/3 \leq 1$	Drinking Water Directive (98/83/EC)
Adverse effects on humans from ammonium	NH_4^+	Indicator value: 0.5 mg/l	Drinking Water Directive (98/83/EC)
Eutrophication of surface waters	NO_3^-	25–50 mg/l	Nitrates Directive (91/676/EEC)
Contamination of groundwater	NO_3^-	50 mg/l	Nitrates Directive (91/676/EEC) Goundwater Directive (2006/118/EC)
Eutrophication of surface waters	N_{total}	2–10 mg/l; discharge from sewage treatment plants	Urban Waste Water Directive (91/271/EEC)

[a] AOT40 stands for accumulated exposure over a threshold ozone concentration of 40 ppb.

assessed in advance (*ex-ante*) through simulation modelling and stakeholder consultation. Such ex-ante assessments provide a view of the effectiveness and efficiency of environmental policy prior to implementation (often assuming 100% compliance), and are instrumental for achieving political agreement for ratification and implementation. By contrast, retrospective (*ex-post*) assessments are usually based on analyses of data obtained through various monitoring programmes, censuses, inquiries and reviews.

Assessments of environmental policy are sometimes heavily debated and also criticized. First, there are differences of views about the appropriateness of the objectives and targets that must be achieved, e.g. emission targets, concentration targets or ecological targets. Figure 4.4 shows that there is a large 'separation' between emissions targets and the human health and ecological impacts targets, there are also many possible interactions. Second, there is debate about the accuracy of, and uncertainties in, the data and the cause–effect relationships. For example, the NO_x and NH_3 emission estimates in Europe are thought to have an uncertainty range of 30% and 50%, respectively (EEA, 2005). Third, there are often discussions about the economic cost–benefit analyses and the effects on the competitiveness of sectors.

Experiences over the past 20 years indicate that environmental policies in Europe have contributed to decreasing N_r losses to air, surface waters and groundwaters in Europe, but that critical loads are still exceeded and that the environmental and ecological status of many groundwater bodies, surface waters and natural areas are still below the set targets (Erisman *et al.*, 2011, Chapter 2 this volume). Many of these set targets reflect ecological targets and political compromises; few targets (if any) have been set at levels 'where the value of marginal damages to human health and biodiversity is (approximately) equal to the marginal cost of achieving further reductions', which would yield most societal benefit (see also Brink *et al.*, 2011, Chapter 22 this volume). By contrast, there has been a tendency to go in one of two directions: either to specify environmental targets based on their technical and political achievability or to set objectives for avoidance of adverse impacts.

Many European environmental policies are based on regulatory instruments, with frequent use of BAT requirements and emission standards, and these appear to have a relatively low economic efficiency (OECD, 2007). EU environmental Directives leave little room for the use of more flexible economic instruments (e.g. taxes or trading systems for NO_x emissions, taxes or trading systems for N-input to the agricultural sector). Economic instruments are not necessarily prohibited, but the Directives limit the flexibility these instruments could have offered (OECD, 2007).

So far, policy measures aimed at decreasing N_r species emissions have achieved larger responses from combustion sources than from urban sources or from agricultural sources especially.

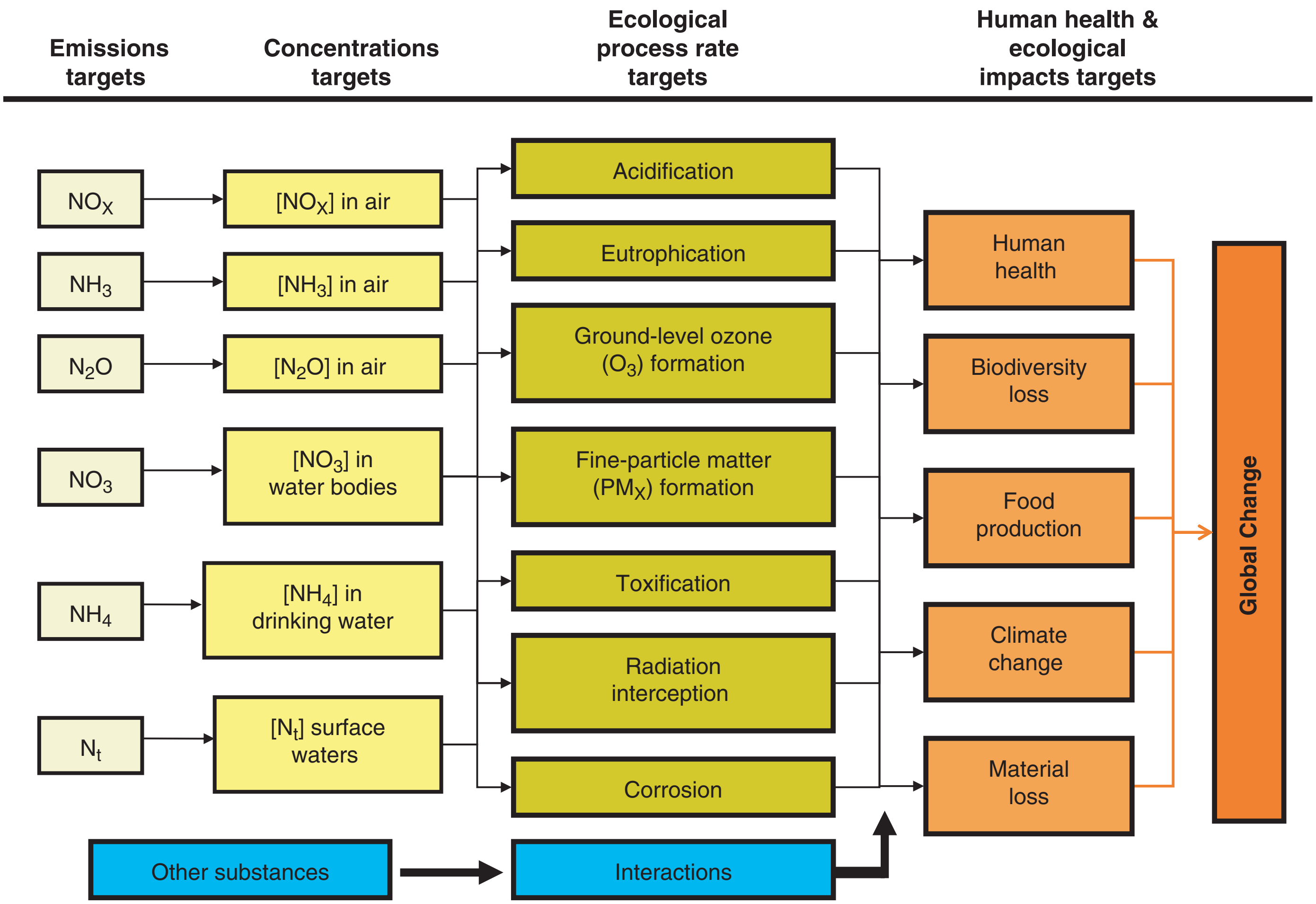

Figure 4.4 Illustration of the major links between the multiple forms of reactive nitrogen emission and the resulting impacts on different concentration, process and impact targets.

This can be shown by the fact that relative emission reductions have been achieved in the following order: NO_x emissions > N_{total} emissions from urban areas > NO_3^- leaching from agriculture > NH_3 emissions from agriculture (see Erisman *et al.*, 2011, Chapter 2, Figure 2.5).

Emission reductions may also follow from changes in economic activities. For example, significant reductions in total NO_x emissions to air in the EU-15 between 1990 and 2006 may be considered, to a large extent, influenced by environmental policies. By contrast, the decreases in total NO_x emissions to air in the 12 new Member States of the EU (EU-12) between 1990 and 2006 mainly follow from the changes in the political and economic systems after 1989 (EEA, 2005; 2008), rather than the implementation of specific environmental policies. It can be seen from Figure 4.5 that the reductions in NO_x emissions have been less successful than SO_2 emission reductions, which is largely due to increased vehicle mileage offsetting the benefits of low NO_x emission technologies (NEGTAP, 2001). By comparison, there has been only a small effect of environmental policies in reducing ammonia emissions. Figure 4.5 shows that NH_3 emissions for the EU-15 only decreased by 10% between 1990 and 2006, while the larger decrease of 49% for the EU-12 was the result of the political and economic changes following 1989, rather than due to specific environmental policies in the period.

Within the EU-15, the differences in the effects of policies are also large. The extent to which, for example, the objectives of the policies to reduce ammonia emissions and nitrate leaching from agriculture have been achieved is variable across Member States (EEA, 2008). These variable results are ascribed to:

- differences between Member States in their perceptions of EU Directives;
- differences in economic sectors and systems and environmental conditions;
- legislative delays and implementation delays;
- economic costs of the measures and lack of enforcement;
- continued economic growth, which has 'neutralized' some of the improvements in 'eco-efficiency' at the system level (e.g. increased car fleets offsetting projected NO_x reductions from low emission vehicle technology);
- ineffectiveness of some measures;
- antagonisms between some of the measures; and
- hysteresis effects, due to buffering reactions within the systems.

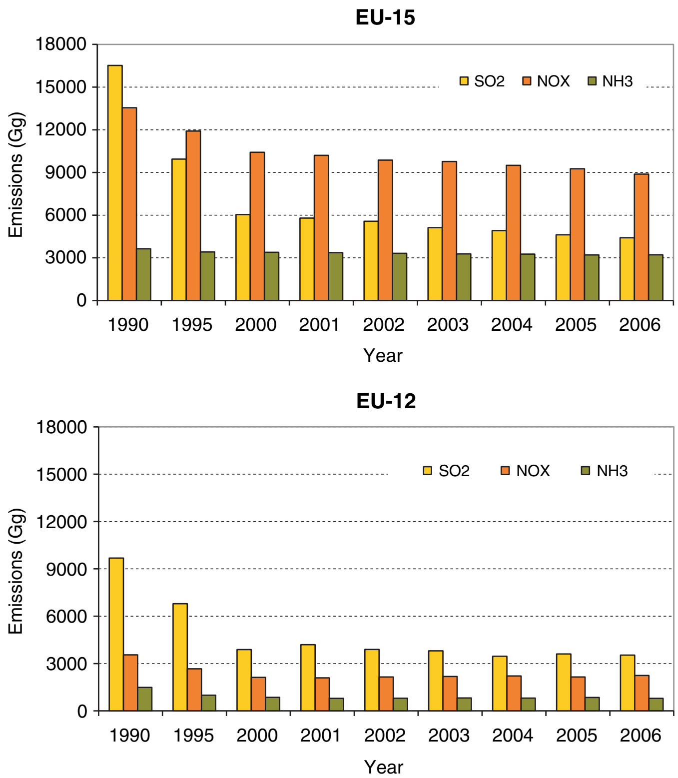

Figure 4.5. Changes in total NO_x and NH_3 emissions to air in EU-15 (top) and EU-12 (bottom) between 1990 and 2006. Emissions of SO_2 to air are shown for comparison (source: EEA, 2008).

4.5.1 Changes in NO_x emissions from combustion

Combustion is a major source of NO_x emissions and the basis for emissions abatement policy in Europe have been the 1988 Sofia Protocol on NO_x emissions (Table 4.2) and the related EU Directives (Table 4.2). The transport and energy sectors are the main sources (Erisman *et al.*, 2011, Chapter 2 this volume; EEA, 2008) and emissions of NO_x in the EU-27 have decreased on average by about 31% between 1990 and 2005. Basically, reductions have occurred in all economic sectors and most countries have reported lower emissions of NO_x in 2005 compared to 1990. The exceptions to this are Austria (7% increase), Cyprus (19%), Greece (6%), Portugal (13%) and Spain (26%). The three sectors 'responsible' for the vast majority of the decreased NO_x emissions are road transport (contributing 53% of the total reduction in NO_x emissions), energy industry (contributing 29%) and industry (energy) (contributing 15%).

The significant reduction in NO_x emissions from road transport (38% between 1990 and 2005) has been achieved despite the general increase in activity within this sector (EEA, 2008). Emissions of NO_x have also declined in the energy industry (38% between 1990 and 2005), despite again an increase in activity (EEA, 2008). The decoupling of NO_x emissions, transport and electricity and heat production has been due to (EEA, 2007; EMEP, 2007):

- the introduction of catalytic converters in car engines;
- the introduction of low-NO_x combustion technology and flue gas treatment, which led to a 49% reduction;

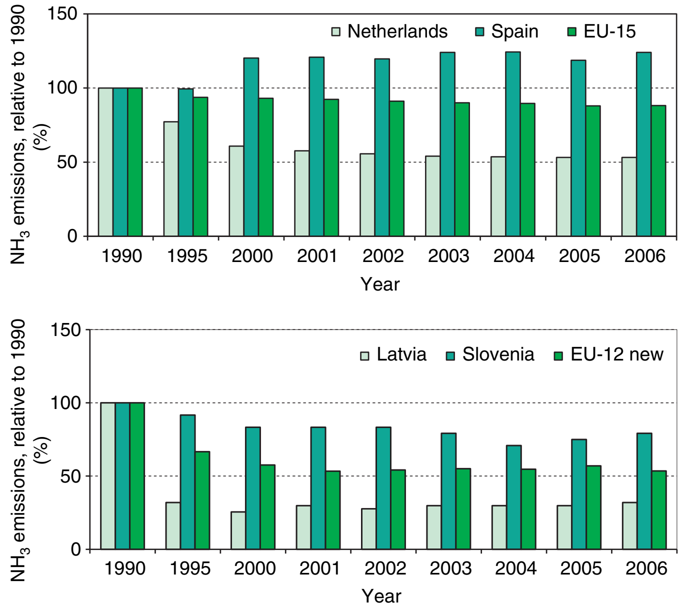

Figure 4.6 Relative changes in total NH_3 emissions to air in the EU-15, The Netherlands and Spain (top) and in the EU-12 (new), Latvia and Slovenia (bottom) between 1990 and 2006 (source: EEA, 2008).

- efficiency improvements, which resulted in a 14% reduction;
- the switch in the fuel mix, away from coal and fuel oil towards natural gas, which led to an 8% reduction;
- the lower share of nuclear and non-thermal renewable energy (i.e. excluding biomass) in 2004 compared to 1990, which actually increased emissions by 3%.

4.5.2 Changes in N losses from agriculture

Agriculture in Europe contributes, on average, to about 80%–90% of the total emissions of NH_3 into the atmosphere, to roughly 40%–60% of the N_r to surface waters, and to about 50%–70% of the emissions of N_2O to the atmosphere (EEA, 2005; Oenema *et al.*, 2007, 2009). Most of the NH_3 originates from animal manure in stables, from manure storage systems and from the application of animal manure to agricultural land.

Between 1990 and 2006, emissions of NH_3 decreased by 12% in the EU-15 and by 47% in the EU-12 (Figure 4.5). In the EU-15, abatement policy and decreases in NH_3 emissions were the greatest in the Netherlands and the least in Spain (Figure 4.6). While the Netherlands is estimated to have had a 50% reduction in NH_3 emissions between 1990 and 2006, NH_3 emissions in Spain increased by 25% due to an expansion of the animal livestock sector. For the new Member States (EU-12), the contraction of the livestock herd and the decreased use of mineral fertilizer after 1989 resulting in decreases in NH_3 emissions were greatest in Latvia (~70%) and least in Slovenia (~20%). Decreases in NH_3 emissions in Hungary following the political and economic changes have been described by Horvath and Sutton (1998).

There are a number of countries that report a decreasing trend of mean NO_3^- concentrations in shallow groundwaters following the implementation of the EU Nitrates Directive.

However, the decreases are modest and a significant number of monitoring stations show increasing NO_3^- concentrations (EC, 2007, 2010). Similarly, while 55% of the monitoring stations in surface waters in rural areas of the EU-15 had a decreasing trend in NO_3^- concentrations during the period 1996–2003, 31% of monitoring stations had stable NO_3^- concentrations and 14% of the stations showed increasing NO_3^- concentrations (EC, 2007, 2010x).

Changes in NO_3^- concentrations have been related to changes in N_r surpluses. Surpluses of N of the soil surface balance in EU countries have on average decreased since 1990, in part in response to structural changes in agriculture following changes in the common agricultural policy, in part also in response to environmental policies, such as the Nitrates Directive. In the EU-15, mean N_r surplus decreased from 65 kg per ha in 1990 to 50 kg per ha in 2000 (EEA, 2005a). Surpluses (range 150–250kg per ha) and decreases in surpluses (range 30–50 kg per ha) were largest for the Netherlands, Belgium and Germany.

The variable and slow responses of Member States to environmental policies in agriculture have been ascribed to (Romstad *et al*., 1997; Smith *et al*., 2007; MNP, 2007; Oenema *et al*., 2009; Mikkelsen *et al*., 2010):

(i) the large differences in farming systems and environmental conditions in the EU-27 combined with the complexity of the N cycle;
(ii) a variable interpretation by Member States of the targets and measures in environmental directives and regulations;
(iii) hesitation in implementing measures, due to the perceived high costs to farmers and perceived low effectiveness;
(iv) hesitation in introducing mechanisms to monitor compliance by farmers, due to the perceived high costs;
(v) legislative delays;
(vi) failure by farmers to implement measures, due to within-system constraints, perceived and actual costs, and the time needed for learning; and
(vii) potential antagonisms between measures aimed at decreasing NH_3 emissions and those aimed at decreasing NO_3 leaching.

Moreover, the recovery of the environmental and ecological status of lakes, rivers and streams often takes more time than expected from the measures implemented and associated decrease of emissions. The same point has been made for atmospheric N_r compounds, including the question of why atmospheric ammonia levels did not decrease as fast as expected following implementation of emission reduction policies in Western Europe (Bleeker *et al*., 2009). Both of these findings point to the complexity of the systems and our limited understanding of the biogeochemical connectivity of systems and controls. There are 'hysteresis' effects and feedback mechanisms that are often overlooked and that lead to slow responses. This seems also to be the case for the new Member States in central Europe where fertilizer N inputs and livestock numbers decreased drastically following the political changes in the early 1990s, while the atmospheric ammonia concentrations (Bleeker *et al*., 2009) and the environmental and ecological status of lakes, rivers and streams in rural areas have improved little yet (Stälnacke *et al*., 2004; Mourad *et al*., 2006).

4.5.3 Changes in N losses from urban waste waters

The Urban Waste Water Treatment Directive (91/271/EEC; EC, 2010j) regulates discharges of municipal waste water from towns and larger villages and specifies which kind of treatment must be installed. The Directive requires that all European agglomerations (settlements) with a size of more than 2000 population equivalents (p.e.) are equipped with collecting and treatment systems for their waste waters. The basic level of treatment is so-called secondary treatment (i.e. removal of organic pollution). In sensitive areas (68% of the EU-27 territory), a more stringent treatment is required, for example, removal of a minimum of 75% of the N and P loads. Most EU Member States have designated their whole territory as a sensitive area, but some (e.g. United Kingdom, Spain, Hungary) have designated only a small area as sensitive (EC, 2009b).

By the end of 2005, waste water collecting systems were in place for 93% of the total polluting load (in 83% of the agglomerations) (EEA, 2005b). Secondary treatment was in place for 87% of the load and was reported to work adequately for 78% of it. More stringent treatment was in place for 72% of the load and was reported to work adequately for 65% of it. The European Commission has concluded that considerable progress has been achieved in implementing the Directive, but that key challenges remain to align waste water treatment over the entire EU with the provisions of the Directive and the 'good status' environmental objective under the Water Framework Directive (EC, 2009). In particular, the secondary treatment and the more stringent treatment need to be improved, especially in the new Member States (EC, 2009b).

4.5.4 Changes in N pollution of marine waters by 50%

The treatment of urban waste water has also contributed to significant decreases in the N_r load to coastal waters and to the improvement of surface water quality in Europe in general. However, there are large spatial and temporal variations, and some contribution may have come from lower emissions from agriculture due to the implementation of the Nitrates Directive (EEA, 2005b). The 2005 OSPAR Assessment of Riverine Inputs (all sources) and Direct Discharges (urban waste water) for the period 1990–2002 noted significant decreases in total inputs of both N (up 32%) and P (up 135%) to the Arctic Waters and a significant reduction in total inputs of N (down 12%) in the Greater North Sea (OSPAR, 2005). Similarly, a downward trend in total riverine and direct point-source inputs of N and P has been observed for the Baltic Sea during the period 1994–2006, but again with large spatial and temporal variations (HELCOM, 2009). However, the overall policy target of a 50% reduction in

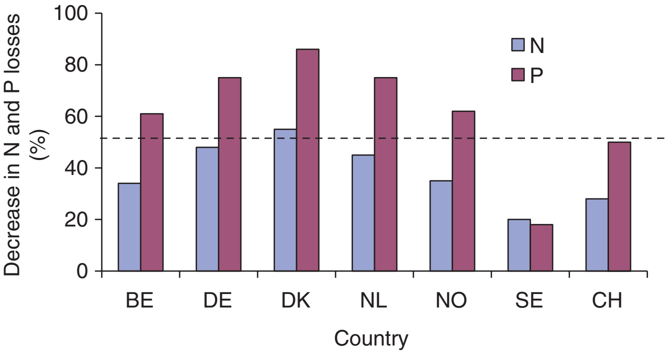

Figure 4.7 Percentage reductions in anthropogenic discharges/losses of nitrogen and phosphorous to 'eutrophication problem areas' around the Eastern North Atlantic (source of data: OSPAR, 2008b).

N and P input into marine surface waters (see Section 4.4.2) has not yet been achieved.

The 2008 OSPAR Eutrophication Assessment (OSPAR, 2008a) shows that eutrophication is still a problem in many coastal areas of the Greater North Sea. The 2008 Report on the Implementation of PARCOM Recommendations 88/2 and 89/4 (OSPAR, 2008b) concludes that Contracting Parties contributing to N and P inputs to eutrophication problem areas have mostly achieved the 50% reduction target for discharges and losses of phosphorus (P), but not for N (see Figure 4.7). Modelling studies suggest that nutrient input reductions beyond the 50% target will be needed in some areas to eliminate all eutrophication problems (OSPAR, 2008a). Agriculture is the biggest contributor to discharges and losses of N to eutrophication problem areas (OSPAR, 2008b). Combustion in power plants and traffic (including road traffic and increasing emissions from maritime shipping in the North Sea and the Atlantic) are the main contributors to airborne NO_x inputs to the OSPAR maritime area (OSPAR, 2005), while agriculture is the main contributor to atmospheric deposition of reduced nitrogen (mainly NH_3).

Eutrophication by N and P is also a major problem in the Baltic Sea (HELCOM, 2005, 2009). Total loads entering the Baltic Sea (as riverine and direct point-source discharges) amounted to 891 Gg N and 51 Gg P in 1990, and it was agreed to decrease these inputs by 50% by 1995 (HELCOM, 2010). In the Baltic Sea Action Plan, the maximum allowable nutrient input targets were set at 41% of the 1990 load of P and approximately 68% of that of N. Both targets have not yet been achieved; by 2006 the reduction for P was 45% and for N only 30%.

Eutrophication by N and P inputs is less of a problem in the Mediterranean than in the North Sea and the Baltic Sea. In fact, the Mediterranean is one of the most oligotrophic regional seas in the world (Karydis and Chatzichristofas, 2003). Eutrophication is limited to coastal zones, especially in the western and northern half of the Mediterranean. However, N and P inputs to the Mediterranean marine environment have increased steadily over the past 20 years (UNEP, 2009).

Summarizing, EU policy to treat municipal and industrial waste waters have been effective in decreasing N (and especially P) loadings to surface waters, though further improvements are needed (EC, 2009b). Diffuse N and P losses from agriculture have not decreased to the same extent. As a result, agriculture increasingly becomes a relatively large contributor to the loading of surface waters with N and P (EEA, 2005b).

4.6 Assessment of factors crucial for effective nitrogen emission abatement

4.6.1 Differences between sectors

So far, the most successful N_r emissions abatement policies have been on (see Section 4.5 and Erisman *et al*. 2011, Chapter 2 this volume): (i) reducing NO_x emissions to air from power plants and stationary combustion sources through catalytic converters, (ii) reducing emissions of NO_x from mobile combustion sources to air (catalytic converters for gasoline cars, combustion optimization and NO_x destruction by Selective Catalytic Reduction (SCR) with urea for diesel cars), and (iii) reducing N (and especially P) discharges to surface waters from industrial sources and households through sewage treatment plants. Though less spectacular than the decreases in SO_2 emissions to air (see Figure 4.5), emission reductions for NO_x to air and for N_r from human sewage to surface waters are larger than the emission reductions achieved for NH_3 and NO_3^- from agriculture. The question is therefore: 'why are certain policies more effective than others?'.

So far, there has been little cross-sector comparison on the effectiveness and efficiency of policy measures aimed at decreasing N_r emissions. The success of the emissions abatement policies for NO_x from combustion and N_r from human sewage may be ascribed to one or a combination of the following factors:

(i) use of economic instruments (subsidies and taxes) to facilitate the implementation of the policy, which results in a high degree of compliance;
(ii) availability of relatively straightforward and effective technologies to reduce the emissions effectively with few major side-effects;
(iii) the limited number of addressees who must take action to implement the measures;
(iv) the scale of investments required and the degree to which these are shared;
(v) the cost of the compliance measures are relatively small and/or can be transferred to others; and
(vi) enforcement and control, leading to a high degree of compliance with the policy measures.

Theory and practice suggest that economic instruments or a mix of economic and regulatory and persuasive instruments tend to be more effective for the implementation of policy than a single regulatory or persuasive instrument (Gunningham and Grabosky, 1998; OECD, 2007). Subsidies, premiums and taxes often provide a strong incentive to adopt the provisions. Compliance with the obligations of a policy requires that all relevant stakeholders are informed and have the necessary knowledge, tools and will to implement the provisions. Subsidies on cars with catalytic converters to decrease NO_x emissions, and

EU financial support for building sewage treatment plants, are indeed effective instruments for implementation of these emissions abatement technologies (OECD, 2007).

The larger the number of addressees (stakeholders) of the policy, the larger the transaction costs of the policy and the less resource the government can allocate to supporting individual addressees. While cars with catalytic converters are driven by numerous drivers, few of these drivers know about the details of converter operation, as these are implemented by the car industry, which encompasses only few stakeholders. Similarly, while all humans in Europe produce N_r-containing wastes, few of them are involved in sewage collection and treatment. By contrast, all individual farmers in the EU (the percentage of farmers to the total work force ranges from 2% to 25% between the Member States) have to comply with the measures of the Nitrates Directive (especially those in Nitrate Vulnerable Zones) and other EU directives relevant to agriculture (see Section 4.4).

The scale of investments in hardware and software needed to comply with policy obligations may differ greatly. Collection and treatment of urban sewage waters requires huge investments, but is done for a multitude of arguments, of which N_r emission abatement is only one, and the costs of the investments are transferred to and shared by numerous tax payers. Catalytic converters do not require much investment by the car industry (relative to other investments), although research costs may be significant. By contrast, building low-NH_3-emission housing systems, manure storage systems and manure application techniques can require relatively large investments by individual farmers, though the Rural Development Programme may provide funds for subsidizing infrastructural modernizations (see Section 4.4.3). In the case of high-investment activities, such as new animal housing systems, much of the cost may be associated with other requirements, such as new animal welfare standards. For other techniques, such as low emission manure application, additional costs may be largely offset by saving more nitrogen in the system, thereby reducing fertilizer requirements (Webb *et al.*, 2010). Compliance with the Nitrates Directive requires in principle relatively little investment, apart from the obligation of sufficient manure storage. However, the application limit of 170 kg N per ha per year can be a serious constraint to intensive livestock farms; they may have to export animal manure elsewhere (with or without prior processing) or will have to decrease livestock density.

The costs of the catalytic converters or sewage treatment plants are all transferred to consumers (or tax payers), and therefore can be implemented easily by the car industry and communities, respectively. By contrast, farmers represent in many cases small businesses which have themselves to bear the cost of the measures for abating NH_3 emissions and N leaching; they can less easily pass on costs to those further down the food production chain. For example, in a globalizing market for agricultural products, farmers in the EU may lose competitive power relative to farmers with less stringent environmental policies, unless other safeguards are put in place (such as the Rural Development Programme). There are nevertheless precedents for requiring investment in agriculture to meet policy requirements, such as animal welfare legislation. Such environmental and welfare requirements come with associated costs which must, in the end, be born by governments and/or consumers, or will have to be covered by increased income through up-scaling (larger farms).

Summarizing, the relatively variable and slow implementation of environmental EU policy and measures in agriculture to decrease N_r emissions may be ascribed to:

(1) ongoing incentives to maintain agricultural production levels and the limited ability of farmers to transfer the costs of environmental protection to consumers;
(2) huge differences in farming systems and environmental conditions in the EU-27 and the complexities that arise when making the requirements of existing EU Directives farm-specific;
(3) delays by Member States to implement measures in agriculture, fuelled by strong farm lobby groups, due to the perceived costs to farmers and the perceived low effectiveness;
(4) delays by Member States to introduce effective control mechanisms to monitor compliance by all farmers, due to the difficulties in setting up such control systems as well as the perceived cost to a Member State;
(5) failure by farmers to implement measures, due to within system constraints, perceived costs and the time needed for learning; and
(6) the possibility for, and fear of, antagonisms between measures, due to lack of integration of measures aimed at abating NO_3 leaching and measures aimed at abating NH_3 and N_2O emissions.

Table 4.7 summarizes the results of a qualitative assessment of factors influencing the abatement of N_r emissions from different sectors. Various factors are different for agriculture compared to combustion and urban wastes, although it is unclear how much each of these contributes to differences in implementation of, and compliance with, the policies. Evidently, further studies are needed.

4.6.2 Differences between regions and EU Member States

There are differences in the ways EU Member States and their regional governments implement environmental policies. These may relate to differences in the political need and political will, but also to differences in culture, environmental conditions, economic developments, institutional organization and in the availability of competent policy officers at regional and local levels. Such differences may change over time, for example, as a result of elections and changes in the political orientation of governments. Developments of civic society and pressure groups may also exert influence on the compliance to environmental policy (see Section 4.2). For example, farmers' lobby groups were strong in delaying the implementation of the Nitrates Directive in the Netherlands during the 1990s, while green lobby groups greatly contributed to increasing the political pressure by the European

Table 4.7 Qualitative assessment of factors that affect the implementation of EU policies to decrease N_r emissions: NO_x emissions from combustion, NH_3 emissions and NO_3 leaching from agriculture, and N_{tot} discharges from urban wastes

	Combustion	Agriculture		Urban wastes
Factors	**NO_x to air**	**NH_3 to air**	**NO_3 to waters**	**N_{tot} to waters**
Policy instruments	Mixed	Regulation	Regulation	Mixed
Number of stakeholders	Few	Many	Many	Few
Technology level	Advanced	Modest	Modest	High
Level of standardization in production	High	Low	Low	High
Number of techniques involved	Few	Many	Many	Few
Development costs	High	High	High	High
Implementation costs	Modest	Modest for animal feeding and manure application; high for animal housings and manure storages	Low for optimizing fertilizer applications; high for adjusting farming systems	High
Who bears costs?	Manufacturers, but transferred effectively to consumers	Farmer	Farmer + public sector (RDP)	Water companies, but effectively transferred to consumers
Management activities & knowledge involved	Essentially no activities required by car drivers	Many activities, requires both proper techniques and information and knowledge	Many activities, requires information and knowledge	Many activities, requires both proper techniques and information and knowledge
Influence of climate & soil conditions	Absent	Large	Large	Negligible
Potential side-effects (apart from costs)	Increased N_2O and NH_3 emissions	Increased N_2O emissions and energy use; fertilizer savings	Yield loss; fertilizer saving; increased / decreased NH_3 emissions	Increased N_2O emissions and energy use

Commission on the Netherland's government to fully implement the Nitrates Directive (Bavel *et al.*, 2004). Within the context of the Nitrates Directive, changes in legislation are often under pressure of infringement procedures launched by the European Commission, indicating that enforcement of legislation is a key point.

Scandinavian countries seem to have made most effort to comply with environmental policy. The effects of air pollution were already felt in the Scandinavian lakes and forests in the 1960s and 1970s, because these were highly sensitive to acidification and eutrophication. Though the origin of the air pollution largely came from outside Scandinavia, societal awareness of the effects led to the organization of the 1972 United Nations Stockholm Conference and to the foundation of CLRTAP (as discussed in Sections 4.1 and 4.3). These impacts also contributed to political will in Scandinavia to protect the environment from their own pollution sources.

Western Europe has a high density of industrial and agricultural activities, with high emission densities. It has stakes in both continuation of economic activities and protection of the environment, and hence in the need to decrease the emission densities of economic activities. Southern Europe, in many locations, has a lower emission density than Western Europe and an environment less sensitive to acidification than Scandinavia. Also, economic development and water harvesting are a societal priority in southern Europe. Finally, the 12 new Member States in central Europe had centralized political and economic systems until the early 1990s, with relatively low political priority for protecting the environment. These countries are now catching up following their accession to the EU in 2004 or 2007.

4.7 Conclusions

- Environmental policy is a relatively new subject that emerged in the 1970s and 1980s. International agreements have given a strong impetus to the establishment of policy measures related to N_r emissions. The theoretical and empirical bases of policy measures related to N_r emissions are still small.
- The toolbox for environmental policy instruments comprises regulatory instruments, economic instruments and communicative/voluntary instruments. Initially, there was a strong focus and emphasis on regulatory instruments; now there is increasing evidence that each environmental policy must have a specific mix of instruments, depending

on the capability, ability and willingness of the addressee to implement the environmental policy effectively and efficiently.

- Policy measures aimed at decreasing N_r emissions in the EU are effects-based or target-based, i.e. the policy measures aim to prevent well-defined human health effects or ecological effects or aim to meet specific threshold/target/limit values.
- The policy measures aimed at decreasing N_r emissions in the EU have been implemented through Directives, which have to be addressed by all Member States through national legislation, and to a lesser extent Regulations, which have to implemented directly by all Member States. There is a large number of Directives, many of which have been revised following review and evaluation. There is also an increasing trend towards clustering specific Directives within Framework Directives.
- The Common Agricultural Policy (CAP) of the EU has a large influence on EU agriculture and indirectly also on N_r use and N_r emissions. Through a series of reforms of the CAP, there is increasing integration of agricultural, environmental and rural development objectives in agriculture, but the number of Directives and Regulations remains large.
- The EU Directives aimed at decreasing N_r emissions from the various sources have been developed and implemented while our understanding of the functioning of N in the biosphere, atmosphere and hydrosphere are still limited and evolving. Policies have been developed initially for single N_r compounds (NO_3^-, NH_3, N_2O and NO_x), for single sectors (households, industries, traffic, crop production, animal production), for single environmental compartments (air, water, nature, humans), and for various specific impacts (e.g. human health, food security, climate change, eutrophication, acidification, biodiversity loss); this is partly because of our limited understanding of the complex N cycle, and partly because of the departmentalization of governments, These multi-compound, multi-sector, multi-receptor, multi-impact approaches have contributed to a 'wealth' of policies, with some having interactive effects (both synergistic and antagonistic). As a result, there is an increasing quest for integrating environmental policy measures.
- Most successful N_r emission abatement policy measures, in terms of abatement of N_r emissions, have been on (i) reducing NO_x emissions to air from power plants, stationary combustion sources and transport through catalytic converters, and (ii) reducing N (and especially P) to surface waters from industrial sources and households through sewage treatment plants. The success of these emission abatement policy measures has been ascribed to the availability of relatively straightforward technologies to reduce emissions, the limited number of addressees, the use of mixes of instruments and the level of governmental enforcement and control. However, there is not much literature on the comparison between Directives or between sectors of the effectiveness and efficiencies of the various Directives related to N_r emissions abatement.
- Less successful, so far, have been policies on reducing N_r emissions from agriculture. In principle, the technologies and measures to reduce these emissions are available, but there are various reasons to explain why these have not been adopted and/or have not been effective. One of these reasons is the diversity and complexity of the farming systems involved and the complex, diffuse N_r pathways, which have resulted in many different regulatory obligations, but which are not equally effective for all farms. Further studies are needed to find out the optimal mix of packages of measures and incentives to decrease the diffuse N_r losses to air, soil and water.
- Based in part on the successful reduction of SO_2 and NO_x emissions from the energy, industry and transport sectors through technological measures, there is some belief that technology will reduce all unwanted emissions from all sectors. However, management and (changes in) economic activities may be equally important factors.
- So far, Scandinavian countries have done most on the implementation of environmental measures for nitrogen, perhaps because they felt the effects of air pollution on surface waters and forests most intensively.
- Current EU Directives on agriculture consider the threats from NO_3 leaching, NH_3 emissions (and N_2O emissions) separately. However, when not combined with an integrated approach to N management, the policy measures may have the risk of antagonistic effects.

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Supplementary materials

Supplementary materials (as referenced in the chapter) are available online through both Cambridge University Press: www.cambridge.org/ena and the Nitrogen in Europe website: www.nine-esf.org/ena.

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