Chapter 26

Societal choice and communicating the European nitrogen challenge

Lead author: **Dave S. Reay**

Contributing authors: **Clare M. Howard, Albert Bleeker, Pete Higgins, Keith Smith, Henk Westhoek, Trudy Rood, Mark R. Theobald, Alberto Sanz Cobeña, Robert M. Rees, Dominic Moran and Stefan Reis**

Executive summary

Nature of the problem (science/management/policy)

- Increased public and institutional awareness of both the benefits and threats of nitrogen has the potential to greatly increase the efficacy of nitrogen policy.
- Insufficient recognition of the financial, behavioural and cultural barriers to achieving an optimal nitrogen future risks policy antagonisms and failure.
- Here we examine some of the key societal levers for and barriers to achieving an optimal nitrogen future in Europe, drawing lessons from the more-developed societal and policy challenge of climate change mitigation.

Key findings/state of knowledge

- There is currently a very low level of public and media awareness of nitrogen impacts and policies. However, awareness is high regarding the threats and benefits of 'carbon' to society (e.g. energy use and enhanced climate change).
- Many national climate change mitigation policies now overtly recognize the importance of societal choice, and are increasingly utilizing behavioural change strategies to achieve greenhouse gas emission reduction targets.
- In achieving an optimal nitrogen future, lessons can and should be learned from existing climate change-focused communication and behavioural science (e.g. use of a 'segmented strategy' to reach disparate groups of stakeholders).
- Key sectors where societal choice has the potential to greatly influence nitrogen use efficiency include food production, consumption and waste.

Major uncertainties/challenges

- Public confusion/despair/apathy in a world of 'carbon calculators', 'doomsday environmental scenarios' and 'decision support tools' must be avoided.
- Awareness and use of proven nitrogen communication tools for policy makers, media and public should be increased.
- Succinct messages that get across the complexity of the nitrogen challenge while properly representing the balance of the pros and cons are required.

Recommendations (research/policy)

- Nitrogen policy development and implementation should more overtly include understanding of social science and societal choice.

The European Nitrogen Assessment, ed. Mark A. Sutton, Clare M. Howard, Jan Willem Erisman, Gilles Billen, Albert Bleeker, Peringe Grennfelt, Hans van Grinsven and Bruna Grizzetti. Published by Cambridge University Press.

26.1 Introduction

Whereas previous chapters of the assessment have focused on policy instruments and how these have been and could be used to address the issues posed by the 'Nitrogen Cascade' (Galloway *et al.*, 2004), we turn our attention now to societal choice and the communication of the European Nitrogen Challenge. What role could society and changing behaviour play in reducing the threat of reactive nitrogen (N_r) to our environment and how might this be better enabled? This chapter aims to address this question – the question of 'societal choice', by identifying the ways in which positive behaviour change can be engendered, and the effect alterations in societal choice could have on the nitrogen challenge. Such changes are only possible if society and the individuals, communities and stakeholder groups of which it is comprised are aware of the issues and the need to make changes – therefore this chapter also addresses the issue of 'communicating' the nitrogen problem. It examines the lessons to be learned from climate change-related communication methods, their relevance to nitrogen, and the complications faced therein. Finally, we present some tools and examples of nitrogen knowledge exchange which have been used to inform the non-specialist to date and suggest strategies for enhancing nitrogen-relevant knowledge exchange and awareness-raising in the future.

26.1.1 Human fingerprints on the global nitrogen cycle

Previous chapters have provided a wealth of information on the anthropogenic changes in reactive nitrogen fluxes and issues in Europe, but to underline just how great is the extent of human society's impact on the global nitrogen cycle it is useful to revisit the past, current and projected estimates of anthropogenic nitrogen fluxes around the world.

More reactive nitrogen is now created each year by human activities than all natural sources combined. Alongside industrialization and the associated increases in emissions of nitrogen oxides (NO_x) from fossil fuel burning, the intensification of agriculture and associated ammonia (NH_3), nitrous oxide (N_2O) and NO_x emissions has led to a three to five fold increase in reactive nitrogen emissions over the last century (Denman *et al.*, 2007). Overall global emissions of oxidized nitrogen (NO_y) and reduced nitrogen (NH_x) are mainly terrestrial in origin and in 2000 stood at 52.1 and 64.6 Tg N y^{-1}, respectively (Dentener *et al.*, 2006).

Human society and projected changes in nitrogen flux

Both NO_y and NH_x emissions are predicted to further increase in many regions during the twenty-first century (Galloway *et al.*, 2004), with population growth and dietary changes likely to be a key driver of alterations in the magnitude and geographical distribution of these emissions. Emissions of NO_y from fossil fuel combustion are intrinsically linked to societal choice, through changing demand for domestic electricity use, space heating and private transport. However, these emissions may be most influenced in coming years by top-down drivers such as the Gothenburg protocol, and by national and international efforts to reduce fossil fuel combustion as a means to cut greenhouse gas emissions (e.g. UNFCCC). Though demand-side management will be a key part of national and regional strategies to reduce these emissions, decarbonization (and simultaneous 'denitrogenization') of supply is the central plank of current policy (e.g. UK Climate Change Act 2008).

Given the large increases in population and demand for animal protein projected in some regions for 2030, it is likely that NH_x emissions will become an increasingly important source of N_r deposition globally. Indeed, a 20% decrease in NH_x deposition over Europe, but a 40–100% increase in Central and South America, Africa, and parts of Asia by 2030 is predicted (Dentener *et al.*, 2006). Looking further into the future, N_r deposition over land may increase by a factor of 2.5 by 2100 (Lamarque *et al.*, 2005), with a concurrent increase in deposition to marine systems of around 50% (Krishnamurthy *et al.*, 2007). As such, it is on agriculture and food consumption that much of this chapter focuses and, in particular, on the role that behaviour change may play in reducing nitrogen wastage – the implications of human dietary choice are considered in more detail in Section 26.3.2.

26.2 Societal choice

The concept of 'societal choice' is complex and contested, but is central to any debate on human responses to an environmental issue. Its importance, and the role that levels of awareness and education play in informing such choice, cannot be overstated when it comes to successfully implementing any policy, environmentally focused or otherwise. Blennow and Persson (2009) provide the specific example of forest owners in Sweden and their adaptive response to climate change. They show that the level of 'belief' in climate change held by the forest owners was a crucial factor in determining the adaptation choices made. Such a finding highlights the key role that engagement and awareness can play in realizing change and it is on these drivers of societal choice, in the context of the European nitrogen challenge that we concentrate.

For the practical purposes of this chapter, society is defined as the group of individuals that live within 'Europe' (exactly which definition of Europe is not important at this point, more the notion of a geographic region with broadly similar problems, behaviours and choices). Many of the examples used hereafter to support our statements are drawn from Northern and Western Europe, owing to the geographical bias of the authors' expertise and the greater preponderance of published studies for these areas than for Southern and Eastern Europe. However, we believe that the fundamental points we address in this chapter on the efficacy of communication and engagement strategies apply across the whole of Europe and, in most cases, right across the developed world.

It is important to recognize that a 'society', certainly on a national or European scale cannot be expected to 'make choices'. Whilst politicians may make choices on behalf of society, other forms of decision-making are made at the individual rather than societal level. Individuals may also choose to ally themselves with smaller groups which may, and frequently do, establish and promote differing stances on an issue. As alluded to above, such individual and collective decisions are based on a complex interplay between a wide range of factors such as knowledge and understanding, self-interest, altruism, social- or peer-pressure, etc. In the case of the environmental significance of nitrogen the lack of public awareness, certainly in comparison with CO_2, is plain from the lack of media coverage which is both a reflection of and a contributor towards poor societal understanding of the issue (see Sampei and Aoyagi-Usui, 2009).

Consequently, the portrayal of nitrogen as both an integral part of Earth systems and as an environmental issue, with its attendant benefits and more negative impacts at a local level is crucial to public understanding and societal (individual) choice (Bickerstaff and Walker, 2001). Such a portrayal must be scientifically accurate (as far as possible) but recognize that choices will be based on value judgements. Hence this chapter discusses a range of issues pertinent to nitrogen and human society, but also acknowledges that reactive nitrogen is a double-edged sword – providing great benefits to so many people but posing a great threat to others. This duality is highlighted by the existence of this publication, the recent establishment of a United Nations Economic Commission for Europe (UNECE) Task Force on Reactive Nitrogen under the Convention on Long-Range Transboundary Air Pollution (UNECE, 2010), plus a range of policies and initiatives (at various scales, from regional to European) aimed at integrated (or sectoral) mitigation and management of the 'Nitrogen Cascade'. In order to maximize the benefits of human society's interaction with the global nitrogen cycle, and minimize the penalties, governments can employ several kinds of strategies, including improved communication and education, the incentivization of good practice, and the use of legal requirements and penalties to deter bad practice. Whilst communication and education are the focus of this chapter, it should be noted that public understanding of the issue is also a valuable prerequisite for the more prescriptive approaches open to government. Indeed, it is plainly hazardous to assume that a single top-down strategy will be successful without some degree of engagement with and awareness in the stakeholder community at which the strategy is aimed.

26.2.1 Behavioural change

The cryptic, indirect and interlinked nature of many of the impacts of nitrogen on society inevitably means that both awareness of its importance and the responses to the causes can be low or non-existent. For instance, those affected by harmful algal blooms, either through lost revenue from fish-kills or even by shellfish poisoning, are unlikely to connect such impacts with inland nitrate leaching or ammonium pollution from a distant sewage processing plant. Indeed, such connections can be almost impossible to prove even where they are specifically looked for, given the complex array of determinants that can combine with enhanced nitrogen availability to induce such blooms. For stakeholders to respond in the most appropriate way requires awareness of the complexity of the nitrogen issue, the transboundary nature of most nitrogen fluxes and, most importantly, its direct relevance to them.

To date there is a dearth of research into how the nitrogen-related behaviour of human society and its myriad stakeholder groups is determined, and how such behaviour might be most effectively changed as part of addressing the overall nitrogen challenge. The inducement of pro-environmental behaviours is a fast developing area of study for behavioural scientists, but most relevant studies to date have focused on topics such as climate change adaptation or carbon management (Urwin and Jordan, 2008), rather than reactive nitrogen. While it is true that nitrogen plays an important role in global climate change, as well as in other high-profile environmental challenges – such as acidification and eutrophication – the links between societal or individual nitrogen-relevant choices and their resulting impacts remain much more opaque than those for carbon. Given the many parallels and cross-cutting themes between the two topics, it therefore makes sense to examine the current evidence and views on eliciting carbon-related behavioural change and see how these might be applied in the context of nitrogen.

26.2.2 Segmented strategy

As mentioned previously, a 'one size fits all' approach to achieving behaviour change is very likely to fail. There are myriad cultures, backgrounds, priorities and awareness levels across the range of stakeholder groups of importance to nitrogen management in Europe, and such a strategy will inevitably prove ineffective in eliciting widespread change across all of them. Instead, the concept of a segmented strategy has been developed for climate change mitigation whereby the stakeholder groups and their characteristics are defined and the methods then employed to achieve the desired change are tailored to reflect these different characteristics (DEFRA, 2008). We recommend a similar approach be applied to the European nitrogen issue, with due recognition of differing awareness levels and priorities.

Figure 26.1 shows a segmented approach to eliciting behaviour change that could be applied to the European nitrogen issue. The key tools (shown in green) for engendering change are categorized as follows.

- **Encourage**: a 'carrot and stick' approach whereby undesirable practice is discouraged by taxation, fines or negative public exposure (e.g. performance league tables) and desirable practice is encouraged through grants, reward schemes and positive public exposure.
- **Enable**: the removal of technological or policy barriers to change, the provision of alternatives, and support of the education necessary to inform the desired behaviour change.
- **Engage**: provision of forums, support networks, awareness raising (e.g. media campaigns).
- **Exemplify**: use of consistent policies and exemplars within the target group (e.g. early adopters of a nitrogen reduction strategy) who can inform and support their peers.

The seven categories of 'stakeholder' positions shown in Figure 26.1 and the associated approaches, though inevitably still broad in scope, can be usefully applied in the context of the European nitrogen issue, for example as follows:

Categories 1, 3 and 4 '*Positive Greens, Concerned Consumers, and Sideline Supporters*' are characterized by those who are

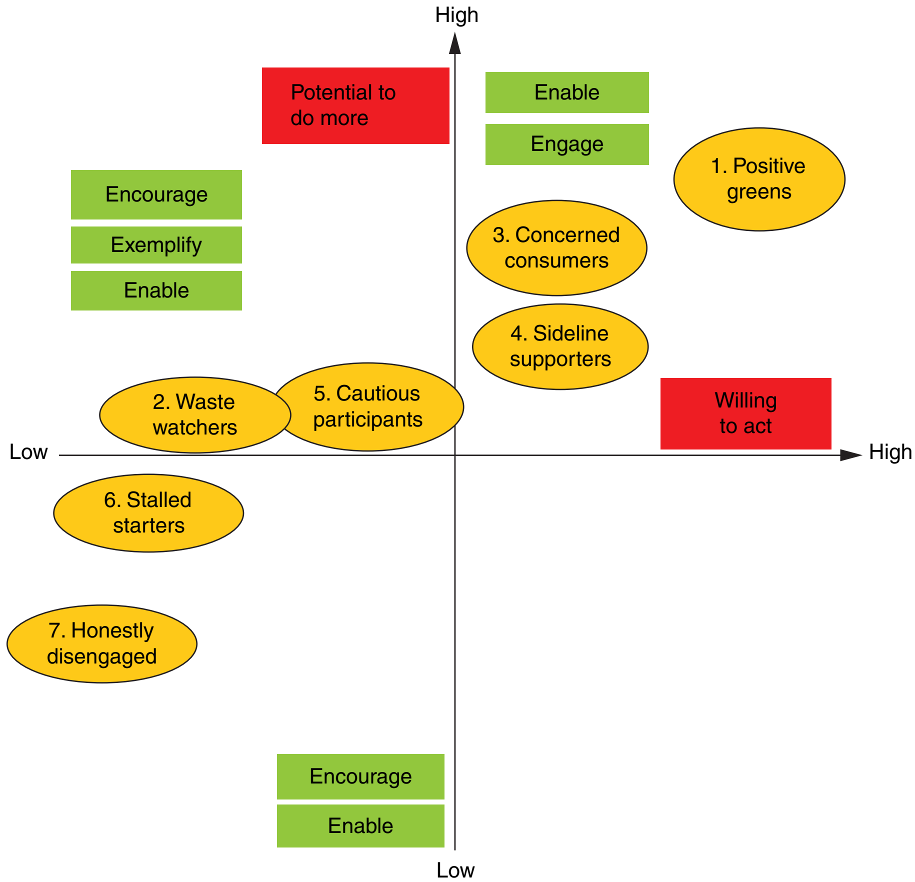

Figure 26.1 Segmented strategy for eliciting behaviour change. Red boxes denote axes, green boxes the tools for engendering change, and yellow elipses the stakeholder categories (adapted from DEFRA, 2008).

already willing to change behaviour and require enabling, for example through top-down policy, to take action. These groups have a very high capacity for change given the correct support, in particular the strategies of 'Engage' and 'Enable'. In a nitrogen context such a grouping could include consumers who, when provided with information on the nitrogen impacts of their purchases (e.g. red meat) may reduce consumption of these products for less nitrogen-intensive alternatives. Enabling such change includes the provision of alternatives and, in this example, information on recommended protein intake and diet.

Categories 2 and 5 *'Cautious Participants, Waste Watchers'* are often very substantial groupings and can be exemplified by, for instance, the many farmers in Europe who have a reasonable level of nitrogen awareness and willingness to act, but are cautious of being an early adopter of new recommendations or are jaded by tides of other pressures, advice and policies. Here, a combination of 'Encourage', 'Enable' and 'Exemplify' has the potential to achieve very extensive behaviour changes, for example as below.

- Encourage: e.g. through financial rewards for improved nitrogen management.
- Enable: e.g. provision of tailored nitrogen management advice/model outputs.
- Exemplify: e.g. providing visits or for where farmers are able to see recommended nitrogen management being successfully used.

Finally, categories 6 and 7 (*Honestly Disengaged, Stalled Starters*) represent groupings where *'Engage'* and *'Exemplify'* strategies are unlikely to yield much change. Increased awareness, by itself, is likely to have only a limited effect on behaviour for these groups, with negative impacts perceived as being spatially or temporally distant from the 'polluter' and any significant change being seen as a threat to competitiveness, profit and financial sustainability. An example of this in the context of nitrogen may be the simple linking in the media of adipic acid production (used in the production of nylon) with climate forcing by N_2O, without any attempt by government or industry bodies to support change in industry behaviour through *'Encourage'* and *'Enable'* strategies. In such cases, it is likely that directed policy that either rewards the producer for reduced N_2O losses or penalizes them for failure to act (*'Encourage'*) will have much more effect than their simply being aware of the negative consequences of emission for people thousands of miles distant or indeed generations to come. Similarly, ensuring effective technology is available for reducing N_2O emissions is vital if such 'carrot and stick' approaches are not to result in industry-wide penalties and leakage of production and emissions to non-European producers benefiting from the competitive advantage that would arise.

A segmented approach to communication and to eliciting behaviour change can be further adapted for use within many discrete groups of nitrogen stakeholders. For policy makers, such an approach could allow differentiation of those with priorities in one geographical area from another, and so potentially improve the relevance of and engagement with the information provided. At the other extreme, a segmented approach applied to European householders could identify and make use of discrete groupings based on factors such as income, culture, location and climate to inform and tailor the strategy employed.

In summary, the segmented approach to behaviour change championed for climate change mitigation would seem equally appropriate for engendering behaviour change with the aim of addressing the European nitrogen challenge. Clearly, the individuals and groups that this approach addresses may be very different in the context of nitrogen, but the core message – that a tailored approach will be more successful than a generic one – remains central to this chapter and its recommendations.

26.3 Realizing a low nitrogen economy and society

26.3.1 Marginal costs as a driver of change

Economic sustainability is a critically important driver in human decision-making and this is especially true in relation to farmers – a group of individuals that exert influence on the nitrogen cycle through their daily working practices. While farmers may show enthusiasm for environmental initiatives that contribute to a nitrogen-efficient economy, this can be constrained by their ability to pay, both financially and in terms of effort, for any required changes in farming practice. Understanding of these relative costs and benefits is therefore crucial to policymakers tasked with engendering behaviour change in the farming community and increasing nitrogen use efficiency across Europe.

To help inform policymakers on the cost and benefit implications of achieving significant levels of change, Marginal Abatement Cost Curve (MACC) analyses have been applied to many sectors (most commonly in terms of reducing greenhouse gas emissions). The MACC identifies both the amount of 'benefit' (e.g. greenhouse gas savings) and its 'cost' through the introduction of different mitigation measures. For example, Moran *et al.* (2008) ranked mitigation options in the Land Use and Land Use Change and Forestry (LULUCF) sector in the UK in terms of their cost and the amount of greenhouse gas (GHG) emission avoided (Figure 26.2). This exercise is helpful given that it can identify measures that both save money and reduce GHG emissions. As such, the MACC approach may also be applied in assessing the most cost-effective measures to enhance nitrogen use efficiency and reduce negative impacts in the European LULUCF sector and more widely. In reality though, such an approach would likely serve only as a qualitative guide to policy makers, the complexities and interactions inherent in nitrogen management making any robust assessment of opportunity and abatement costs very problematic.

One of the major difficulties in an analysis of this sort is the estimation of current fluxes (whether GHGs or nitrogen) and the further problem of anticipating how these fluxes will change through the adoption of mitigation measures. Another difficulty, as mentioned above, is linked to the problem of anticipating how mitigation measures might interact. It is likely in many circumstances, that a number of mitigation measures would be used in combination in order to achieve a certain level of emission reduction or nitrogen use efficiency. However measures that are used in combination do not necessarily lead to effects that are simply additive. In many circumstances, the adoption of the first mitigation option (e.g. reduced nitrogen fertilizer applications) may lead to a reduced potential for additional mitigation measures (e.g. use of nitrification inhibitors).

In devising such curves for GHG abatement or nitrogen management, assumptions must be made about future changes in key factors such as land use and farming practice, the wider policy and market context, and about how climate and technology may change. Such assumptions and uncertainties further limit the usefulness of these curves for decision makers, particularly when applied across national boundaries. In summary, though MACCs can provide a useful visualization of relative costs and benefits of a range of nitrogen management strategies available, decision makers will inevitably need to draw on the wider nitrogen management knowledge base to reduce the risk of unexpected and unwanted outcomes.

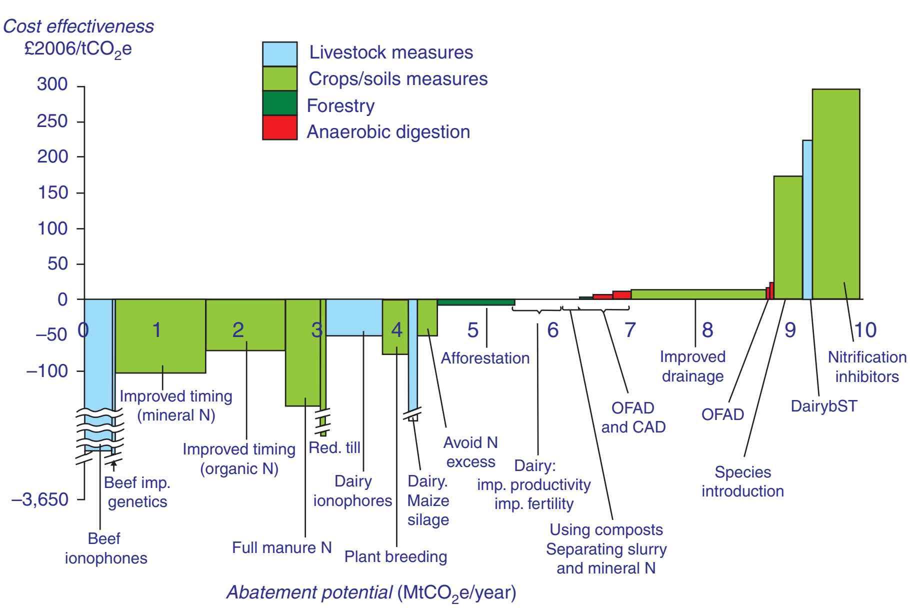

Figure 26.2 A projected mitigation abatement cost curve for UK agriculture for 2022 assuming a discount rate of 3.5% (from Moran *et al.*, 2008). Negative values represent values that save costs.

26.3.2 Behaviour and culture

Even where the MACC approach is able to identify least- or even negative-cost measures that can serve to improve nitrogen use efficiency and reduce nitrogen pollution, the simple demonstration of such abatement costs rarely, by itself, results in overtly fiscal-led behaviour change. Similar analyses for CO_2 mitigation in the built environment sector show huge financial savings for strategies such as improved insulation, yet adoption of these strategies remains patchy. Individual behaviour often appears 'irrational' with respect to what the 'market' would indicate (Oikonomou *et al*., 2009), but then the true opportunity costs of a given strategy may be poorly represented in MACC analyses; for example, the disruption caused to a householder during installation of insulation, or the time cost to a farmer of collating and analysing farm-scale nitrogen budgets. As discussed later, the social behaviour and culture that underpin the actions of humans must be acknowledged as a potential barrier to addressing nitrogen through behaviour change, even where the economics would appear to make it an entirely rational transition.

With nitrogen being so integral to so many facets of human life, its use and impacts have also become engrained in human behaviours and cultures. From the farmer who applies a few tens more kilograms of nitrogen per hectare to his fields each year 'to be on the safe side' to the desire for meat with every main meal so prevalent in the West, any balanced nitrogen policy must take some account of the social and cultural landscape in which it will operate – a segmented strategy once again. Nitrogen's role in human society is poorly understood by the public in comparison to, for instance, carbon. Indeed, there is the risk that the limited awareness that does exist is based upon a poor evidence base or a long-standing misinterpretation. Behaviours based upon poor or out of date information – for instance, the direct link drawn in the 1950s and 1960s between nitrate concentrations in drinking water and methemoglobinemia in babies (Smil, 2004) – may hinder moves to increase the effectiveness and efficiency of nitrogen use by human society.

Livestock production as a barrier to change

There are numerous examples of how behaviour and culture represent barriers to achieving a low nitrogen economy and society, and these range from contemporary society's high dependence on fossil fuel, through to the strong political elements common to many trade agreements and subsidies. As one such example of the issues associated with human behaviour and culture, this section examines some of the potential barriers to achieving a reduction in livestock production-related nitrogen emissions (or at least a reduced growth rate) through a reduction in consumption of animal products. A more in depth analysis of human dietary choice and its impact on nitrogen fluxes is also provided in Section 26.3.5.

Producers and suppliers

The livestock sector is an important economic sector in Europe. The value of livestock production of the EU-27 in 2007 was €136 billion – almost 40% of the total economic value of EU agricultural production (EC, 2008). The economic interests of many actors and stakeholders in the livestock sector may lead to resistance to nitrogen-focused change, where this is seen as potentially damaging to livelihoods. Many livestock farmers are specialists who cannot switch easily to forms of non-livestock production. Many of these farmers have also invested heavily in grazing land, animal housing, human resources, machinery and other infrastructure geared specifically to livestock or dairy production. Curtailing these activities across Europe could therefore mean a large loss of capital, turnover and jobs.

In addition, there are many additional stakeholders in the livestock and dairy production chain outside of the production units themselves (Herrero *et al*., 2009). The European feed sector, for example, has an annual turnover of €36 billion (FEFAC, 2008), while the meat and dairy processing industry, transport companies and retailers also have significant stakes in the livestock industry. Finally, the livestock sector is strongly interlinked with other sectors across Europe and globally, many by-products of the food industry being used as feed, and the livestock industry itself providing many valuable by-products, such as leather and medicines.

Consumers

There exist major barriers to the successful implementation of any strategy aimed at reducing the consumption of meat and other animal products in Europe. Meat and other animal products are a very important (for some the most important) component of meals and play an important role in dietary traditions, social interaction and social norms (Kenyon and Barker, 1998). Portion size is also a consideration, as there is not always a choice of portion size (in relation to the animal protein content) and portion sizes have increased markedly in recent decades (Nielsen and Popkin, 2003), therefore the consumer must choose between being either meat-free, or to consume a portion of meat that may well be larger than the amount needed or desired (see, e.g., NinE, 2009).

Cultural values and co-benefits

The extensive production of some livestock types (notably cattle and sheep) may lead to subjectively positive impacts on landscape aesthetics and on biodiversity (Luick, 1998). Reduced livestock demand and cessation of grazing in such areas – with the consequent changes in appearance, vegetation and biodiversity – may therefore result in a negative response and resistance from some land users. Indeed, many so-called 'High Nature Value (HNV) farmlands' are grazed pastures (Paracchini *et al*., 2008) and as such the cultural, aesthetic and conservation values placed upon many grassland areas in Europe must also be considered as a potential barrier to strategies aimed at reducing livestock consumption.

The concept of 'ecosystem services' is worth mentioning at this point, as it encompasses the cultural, aesthetic and conservation values that may be applied to different land-uses. Essentially, an economic value can be estimated for each ecosystem service (e.g. biodiversity value) with a view to market-based initiatives then providing greater protection for types and uses of land that might otherwise be at risk of change to more overtly commercial uses. Much of the impetus for this approach has come from the carbon markets and the desire to improve their coverage of forestry by acknowledging the biodiversity value of forest ecosystems, as well as that of the carbon they store. The concept of placing a value (or cost) on nitrogen that will then enable market forces to drive management improvements has recently been proposed in the context of water quality trading (Gross *et al*., 2007) and is discussed in detail by Brink *et al*. (2011, Chapter 22, this volume).

There are some important co-benefits to reduced livestock consumption in addition to reduced nitrogen losses and their impacts. These include potential human health improvements, through avoidance of excessive protein intake and reduced obesity rates (de Boer *et al*., 2006), and in particular the potential reduction of greenhouse gas (GHG) emissions and the associated anthropogenic enhancement of global climate change. For the latter, livestock production is estimated to result in some 18% of global anthropogenic GHG emissions, with approximately one third of these emissions arising as CO_2 emissions from land use change, another third from livestock-related N_2O emissions, and most of the rest from ruminant and manure-derived methane emissions (Herrero *et al*., 2009).

If significant per capita reductions in meat consumption are needed, it is unlikely that such changes could be effected through consumer choice alone. Policy makers would need to play a role, but the big questions are: what reduction is necessary or feasible, and how can this reduction be achieved? McMichael *et al*. (2007) argue that from a climate change perspective, average per capita meat consumption will have to be reduced to 90 g per day globally in order to stabilize greenhouse gas emissions from livestock production. Deckers (2010) suggests that this would be a modest reduction compared with the ambitions to reduce greenhouse gas emissions from other sectors and considers the necessity of more extreme policy options from increasing meat prices to a qualified or complete ban on the consumption of meat products. As discussed previously, national and international climate change mitigation policy may therefore play an increasingly powerful role in driving change in livestock production practice and nitrogen management in future years and decades.

26.3.3 Budgets

There are many potential strategies that may be employed in order to help realize a low nitrogen society. Here we examine the concept of 'Budgets', not with a view as to how they would bring about a low nitrogen society in themselves, but rather as to how such tools might raise awareness and inform decision makers as to how best to address the European nitrogen challenge. There are several ways to consider budgets in the context of nitrogen management, including the use of a sectoral approach, the examination of direct and indirect fluxes (e.g. end user versus supply chain), and separation into scope 1, 2 or 3 categories (see WRI/WBCSD, 2010). Here we examine budgets in the context of broad stakeholder groupings, using the three categories of 'personal/household', 'business', and 'regional' to highlight key considerations and issues.

Personal and household budgets

In principle, these types of budgets are well known and utilized – there are numerous calculators now available for calculating a personal or household carbon budget for example. These individual and household budget calculators invariably show the consequences of personal choices with respect to energy consumption (Directgov UK, 2010), with some of the more sophisticated versions including analysis of and recommendations on water use and food consumption as part of the user's so called 'ecological footprint' (EPA Victoria, 2010). These calculators and personal budgets are not directly intended for policymaking, but are focussed more on raising public awareness with a view to engendering behavioural change.

In addition to carbon footprinting, personal 'Nitrogen Footprint' calculators have also been developed (e.g. 'N-Print' model under development by the International Nitrogen Initiative and CBF, 2010). These calculators demonstrate to a consumer the potential nitrogen use, and associated losses, that would occur as a consequence of their behaviour. Like the more established ecological footprint calculators, it is primarily related to food consumption, waste and energy use. In the case of nitrogen, it is the food consumption and waste of an individual that will often have both the major impact on their overall nitrogen use and be the area of behaviour where their choices and actions can make the greatest impact.

Although personal nitrogen calculators are useful as a means of communication and awareness-raising, they do bring 'yet more calculators' into this already crowded public domain. There is a risk that uptake and resulting actions will be limited by public apathy towards nitrogen-related problems and overexposure to such footprint calculators. Therefore, for any calculator to be successful (i.e. to raise awareness of the nitrogen issue, leading to increased nitrogen use efficiency) it has to be well developed, with an interesting and clear story to communicate to the public. Consistency between different versions of a nitrogen calculator is also very important, to maintain credibility with users.

Business budgets

Although nitrogen budgets for businesses may be of broadly the same type as those described above for personal or household use, the overall aim is often rather different. In carbon budgeting for example, many businesses have looked to provide information on the carbon footprint of their operations for reasons of corporate social responsibility and at the behest of the investment community in general (e.g. The Carbon Disclosure Project, 2010). Experience from carbon budget reporting has shown that the very process of calculating a budget can yield benefits in terms of identifying efficiency savings and improving public relations. Such nitrogen budgeting for businesses remains in its infancy, but the models that exist for calculating the carbon budgets of business and their supply chains provide an excellent framework for adaptation to nitrogen budget calculation. Recent evidence from the Carbon Disclosure Project (Nigel Topping, CDP, personal communication), for example, has indicated that, as large corporations increasingly quantify their carbon budgets (i.e. scope 1 and 2 – direct and indirect emissions from energy use respectively) and those of their suppliers (i.e. scope 3 – indirect emissions not covered by scope 2), they are driving supply chain emissions cuts in addition to those under their direct control. Such 'mainstreaming' of carbon budget calculation and mitigation by the business community, if applied to nitrogen, has the potential to radically improve the awareness of and action on avoidable nitrogen losses.

National and government budgets

On a national or governmental scale, calculation of nitrogen budgets is again possible. Such budgets give a general view of the inputs, outputs, and losses of nitrogen nationally (see de Vries *et al.*, 2011, and Leip *et al.*, 2011, Chapters 15 and 16, this volume). As such, they can be used as a broad basis for policy making, allowing key areas of loss and inefficiency to be identified at the macro scale. The clear downside of such budgets is their lack of detail, with any regional or local scale anomalies likely to be missed with such an approach. Here, again, established carbon and GHG budget methods provide an example of how flux budgets at smaller scales can be nested within national budgets to allow policy makers to make better-informed decisions and avoid antagonisms and undesirable outcomes from any strategy that is developed (compare, e.g., the Paris nitrogen budget, Svirejeva-Hopkins *et al.*, 2011, Chapter 12, this volume). Finally, some governments (e.g. the Scottish Government) are now required to calculate the carbon budget and impact of their own spending decisions; this process allows them to scrutinize and compare the climate change implications of the options open to them. Yet again, a similar approach for nitrogen budgeting and auditing can be envisaged, whereby proposed investment in new transport networks or in farm subsidy provision can be assessed in terms of its impact on nitrogen fluxes and losses.

26.3.4 Choice in food production

Previous chapters of this assessment have demonstrated the many choices that society has in determining nitrogen use efficiency, equity of access, wastage and negative impacts of reactive nitrogen. Of these, food production and consumption choices represent a key area where these choices may have major implications for nitrogen fluxes. Here we assess in more depth some of these choices and the extent to which they may affect nitrogen use efficiency and fluxes.

Market choice and nitrogen imports

Despite their potential advantages in contributing to more efficient use of nitrogen in agricultural systems, legume crop and forage production has declined in the EU. Wider European (as defined by the FAO, including Ukraine, etc.) pulse crop production declined from 11.3 Mha in 1961 to about 3.4 Mha in 2005. Forage legume area also showed significant decline between 1980 and 2001 (Rochon *et al.*, 2004). The area data for peas and beans are typical of a wide range of legume crops (Figure 26.3). Grain legumes occupy less than 2% of the agricultural land in Europe compared with 8% in Australia and western Canada. Furthermore the distribution of legume crops across Europe is uneven with 86% of the EU grain legume production in 2005 occurring in only five countries – Spain, France, UK, Italy and Germany (see AEP, 2007).

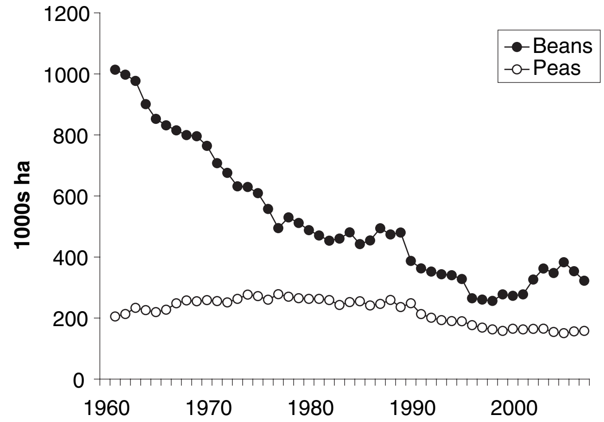

Figure 26.3 Changes in areas planted with bean and pea crops in the EU between 1961 and 2007 (FAO, 2009).

However, European agricultural systems rely heavily on legumes – particularly soybeans grown in South America. The global trade in soy equates to a movement of more than 10 million tonnes of reactive nitrogen (UNEP and WHRC, 2007). This, combined with the other plant nutrients, particularly phosphorus, represents a challenge to geochemical cycles on a global scale. The import of soybeans and soymeal into Europe increased from the equivalent of 3.4 million tonnes of soybean in 1961 to 55 million tonnes in 2006. EU consumption now accounts for about 25% of the world crop and an even larger proportion of the soybean production in Argentina and Brazil. Soy is directly or indirectly linked to deforestation, and in the Amazon in particular (Nepstad *et al.*, 2006; Simon and Garagorry, 2005). Soy imports are central to a global flow of resources from South America, supporting intensive livestock production in Europe. The resulting separation of livestock from the natural resource base that they would naturally draw on is associated with high losses from the nitrogen cycle (Galloway *et al.*, 2007). Europe's dependence on imported soy is a major economic and environmental challenge for European livestock production which will intensify (Steinfeld *et al.*, 2006) as the global demand for livestock products increases, as predicted by many sources.

Per unit of protein, meat and dairy require more land, mainly because of losses caused by transformation in the production chain. Not all nutrients used to grow crops end up in the feed, not all feed nutrients will be converted into animal tissue and not all of an animal is marketable or edible. Mother animals are also needed to maintain the herd – this requires considerable quantities of feed especially for cattle and to a lesser extent for pigs. Measured over the entire chain, in beef (steers) just 4% of the protein from animal feed is converted into protein. In pigs this conversion is 8% and in chickens 23% (Sebek and Temme, 2009). The global movement of nutrients in animal feed (Naylor *et al.*, 2005) may warrant international and global approaches (UNEP and WHRC, 2007) that actually limit the market-based choice of producers and drive a move towards reduced global exchange of nitrogen-rich products.

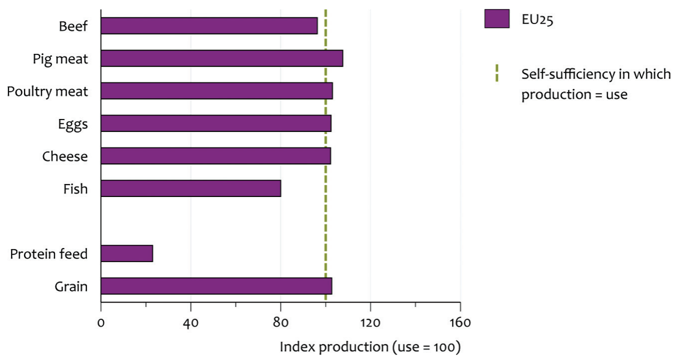

Figure 26.4 Current extent of self-sufficiency in nitrogen-rich products in the EU 25. Figure reproduced with permission of the Netherlands Environmental Assessment Agency (PBL).

Overall, European consumption of livestock feed, together with imported fish, meat and dairy products, puts pressure not only on the local environment, but also on that outside of Europe (Figure 26.4).

Cultivation choices

The use of legumes in pasture presents special challenges and opportunities. Despite the low overall response of grass-clover pasture to synthetic nitrogen application (Bax and Schils, 1993), the use of high applications of synthetic fertilizer in pastures is common and is reducing the role of clover in forage production. In addition to nitrogen fixation and drought resistance, clover and other forage legumes offer opportunities to improve forage quality and end-product quality. In summary, the choice of many arable farmers in Europe to reduce their reliance on legume production, and for livestock producers to opt for an increasing proportion of imported feed legumes (especially soybeans from South America) has resulted in substantial inefficiencies in European and global nitrogen use. An international or global approach is beginning to emerge (see Legume Futures, 2010) to address such nitrogen and land-use change 'leakage' from European agriculture and provide alternative choices for producers.

Several European studies (e.g. Flessa *et al.*, 2002; Olesen *et al.*, 2006; Petersen *et al.*, 2006) have also compared the greenhouse gas emissions from conventional farming systems (i.e. those using synthetic fertilizers and pesticides) with those from organic systems that rely on the use of animal manures, crop residues and biological nitrogen fixation as nutrient sources. The study by Flessa *et al.* (2002) of two adjacent farms in south Germany, with arable cropping and beef steer production, showed the important contribution of nitrous oxide (N_2O) emissions from soils to total greenhouse gas emissions (even though indirect sources of N_2O emission were not included). As Figure 26.5 shows, the fraction of emissions coming from N_2O was very similar in the conventional and organic farms. The conversion from conventional to organic farming resulted in reduced emissions per hectare, *but yield-related emissions were not reduced*. The authors conclude that conversion to organic farming may contribute to the reduction of greenhouse gas emissions from agriculture if policies seek to reduce the intensity of agricultural production. However, if lower intensity is compensated for by the use of larger land areas for the same production, then the reductions will be cancelled out. More generally, the contribution of meat in food production is a key factor: about 80%–95% of the nitrogen intake with feed is excreted as dung and urine, so crop production for human nutrition rather than animal is one of the most efficient measures for mitigating greenhouse gas emissions from agriculture.

26.3.5 Choice in food consumption

As discussed previously, human dietary choices are a key determinant of anthropogenic nitrogen fluxes and impacts at scales from the individual to worldwide. Since 1960, global consumption of meat, fish and dairy products has risen sharply, with both positive and negative consequences for public health. In 2005, the average global consumption was 39 kg of meat per year per person. In Europe (EU-15), protein consumption was almost three times higher than this – at 91 kg. This compares to 121 kg for North America, 54 kg in China and only 14 kg of meat per year per person in Africa (FAO, 2009). For fish, the average was 16 kg per person (included in live-weight) and for EU-27 it was 23 kg. The consumption of dairy products also varies widely, consumption rates for Europe (and North America) being 5–6 times higher than that in Asia and Africa.

Protein is an important part of the human diet and meat, fish and dairy products are important sources of it. It is interesting, therefore, to look at consumption patterns of total protein from these different sources by geographical area. Such analysis shows that total protein consumption in Europe is more than 4 times that in Africa. This, along with high levels of consumption in North America and OECD-Asia means that 10% of the world population are consuming 25% of the animal protein (Figure 26.6).

Dietary evolution and human health

Global consumption of animal proteins has more than doubled in comparison to 1970 (Figure 26.7). EU consumption of animal protein is 14 kg per person per year, which is higher than the world average of 11 kg. Globally, 15% of the animal protein originates from fish, in the EU this figure is 11%. Clearly, there are great differences in the consumption of proteins from meat, milk and fish between countries. Consumption in Europe and the United States together double the world average (FAO, 2006, 2009). It is expected that meat consumption in the most developed countries will grow by approximately 10% between 2005 and 2030. However, the biggest growth is expected in the rest of the world (Figure 26.6). Global demand for animal proteins is projected to increase some 60% (Figure 26.7), whereas in Europe the projected increase in demand is much smaller. If all countries are to obtain a diet equal in animal protein to that of the Western world then global meat production will need to triple.

In the most developed countries in the period of 1960–1990 meat, milk and fish consumption increased rapidly – in the Netherlands, the consumption of meat and fish has doubled since 1960. As on the global scale, so the consumption of animal products in Europe differs between countries. Consumption is related to both economic productivity and nation-specific social-cultural aspects (De Boer *et al.*, 2006).

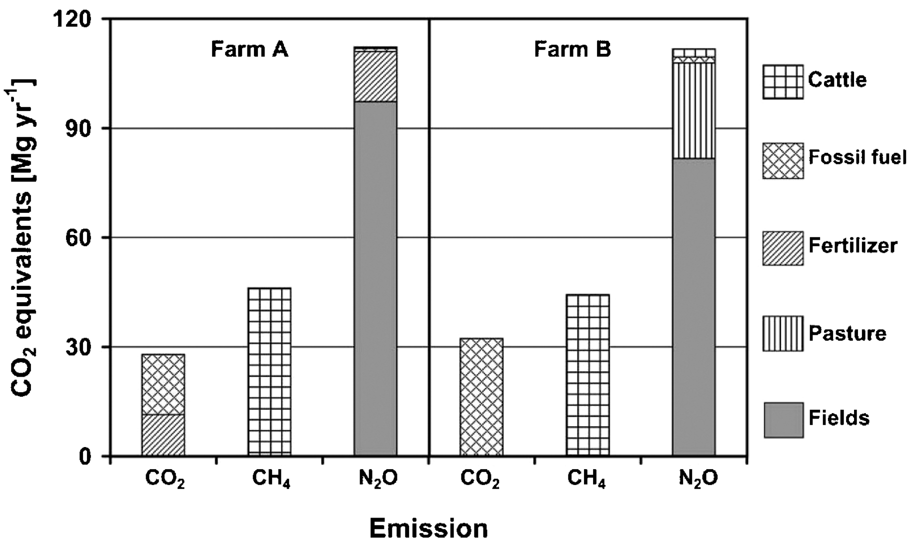

Figure 26.5 Total CO_2, CH_4 and N_2O emissions (from Flessa *et al*., 2002) from the agricultural production of two farming systems (A: conventional and B: organic) in southern Germany and the contributuion of different sources to these emissions. The farming systems are described in more detail in Table 1 of Flessa *et al*., 2002).

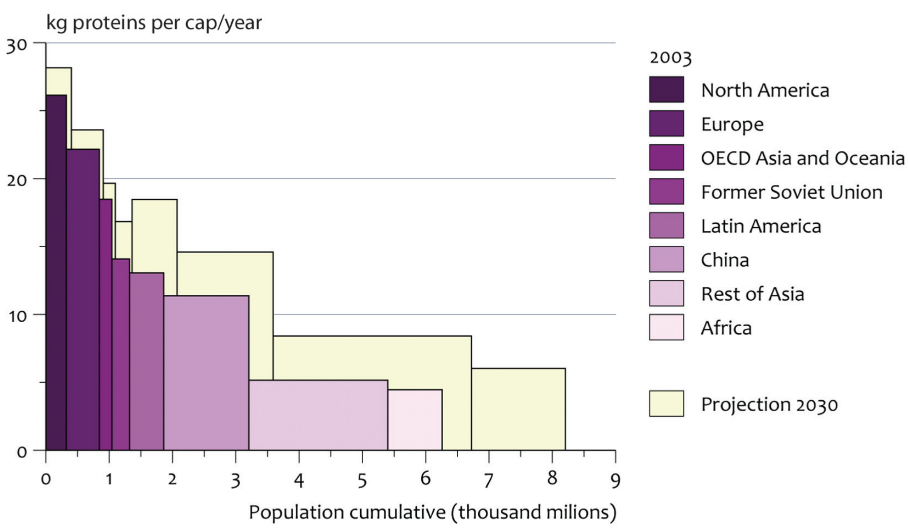

Figure 26.6 Per capita consumption of animal protein in 2003 by geographical region and projection to 2030 (FAO, 2006a; FAO, 2009a,b). Figure reproduced with permission of the Netherlands Environmental Assessment Agency (PBL).

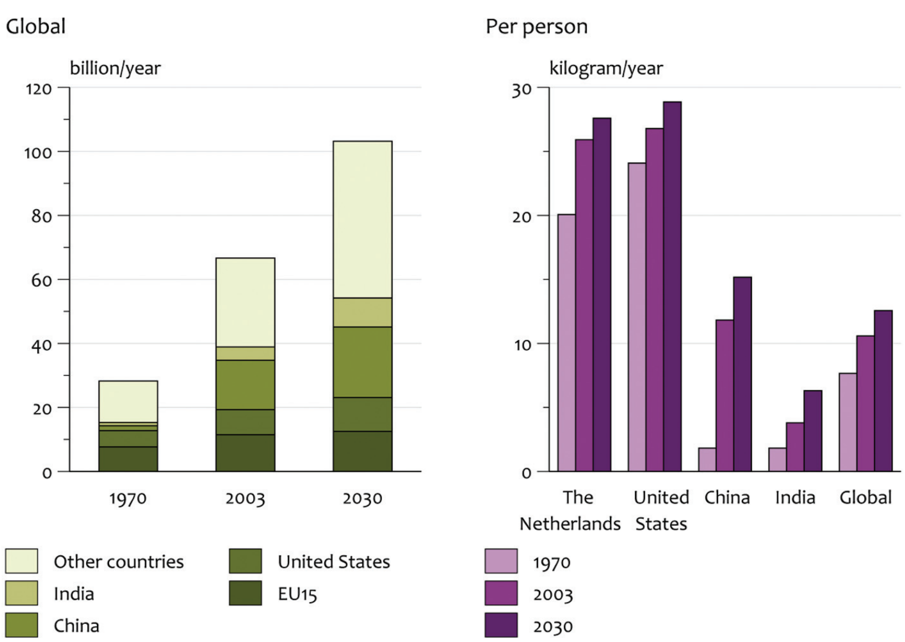

Figure 26.7 Past, recent and projected global (billion kg y^{-1}) and per capita (kg y^{-1}) consumption of animal protein by geographic region. Figure reproduced with permission of the Netherlands Environmental Assessment Agency (PBL).

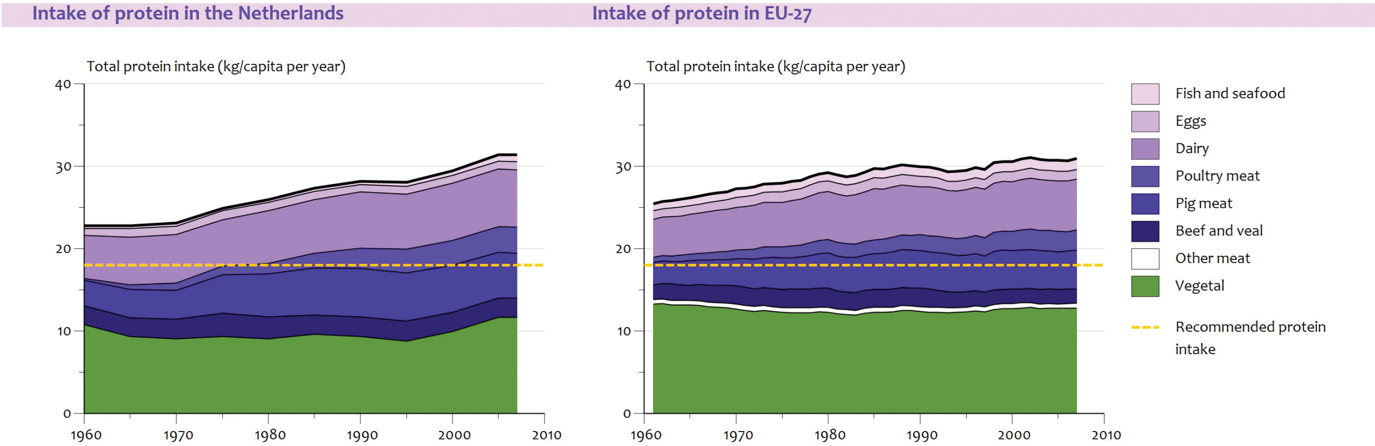

Figure 26.8 Per capita protein consumption by source in the Netherlands between 1960 and 2007 (PBL-calculations based on FAO). Figure reproduced with permission of the Netherlands Environmental Assessment Agency (PBL).

Although protein consumption is necessary for humans, in Europe (and the USA) more protein is consumed than is required in EU-27 an average of around 31 kg protein (23 kg of animal origin) was consumed per person per year in 2007. European consumption of protein is 70% higher than the minimum amount which is recommended (see Fig. 26.8) and although this is not always harmful, European consumption is also 15% higher than the upper limit set by WHO (T Rood personal communication).

Too much saturated fat – often associated with meat and dairy-rich diets – also increases the risk of cardiovascular diseases (Lloyd-Williams, *et al.*, 2008). With three thousand cases of heart disease and over 700 deaths every year in the Netherlands (from a population of 16 million) being a consequence of excessive intake of saturated fats from animal products (Büchner *et al.*, 2007). Eating too much red meat (>160 grams per day) may also increase the risk of colorectal cancer (Norat *et al.*, 2005).

The promotion of healthier diets to reduce the burden to society of non-communicable diseases therefore holds huge potential for simultaneous indirect reductions in nitrogen wastage and increased efficiency of use across Europe and globally. Indeed, initiatives aimed at engendering behaviour change away from animal product-intensive diets – by emphasizing the health benefits that may accrue to the individual consumer – may prove far more successful in addressing food-related nitrogen challenges than approaches based solely on communicating the nitrogen-related externalities of meat-rich diets to consumers.

Food wastage

In addition to what is eaten, European consumers discard some 20%–30% of purchased food, representing an important component of overall nitrogen wastage centered on consumer behaviour. In the UK alone, an estimated £10.2 billion of food is purchased, but not eaten, each year. Discarded meat and fish meals amount to approximately 161 000 tonnes of waste each year, at a total cost to UK households of £602 million (Ventour, 2008). The main reasons given by consumers for this wastage include meat and fish being out of date (35% of UK household wastage) or left over after meals (25% of UK household wastage). Efforts to reduce such high levels of consumer-based wastage have centered on highlighting the financial cost to individual households (e.g. £420 per UK household per year) and provision of consumer advice on food purchasing, storage and preparation (WRAP, 2008). As with dietary choice, addressing the negative externalities of household food wastage – such as increased nitrogen pollution and environmental degradation – may best be achieved by aligning new policy and behaviour change initiatives with the existing health and financial cost approaches.

Nitrogen and animal welfare

Animal welfare is an important issue which is addressed by policy and periodically receives media attention. It is an emotive subject which can influence consumer choices (Duffy and Fearne, 2009), depending on other issues such as cost, knowledge and understanding. However, modifying the living conditions of animals may cause changes in the 'Nitrogen Cascade' (e.g. it can be more difficult to manage manure if animals are allowed to roam outside rather than housed inside), leading to potential trade-offs, antagonisms and synergies – these need to be assessed and communicated to the industry and public, so as to move forward with animal welfare without moving backwards in farm nitrogen management. Similarly, consumer choice for organic rather than conventional food production has the potential to alter nitrogen fluxes and use efficiencies, but again with numerous trade-offs – such as changes in nitrous oxide flux, as discussed previously – being inherent in such alterations in production methods.

Reduction in the consumption of animal products, as discussed above, is the most far-reaching but potentially the most effective option. The net impact on the environment depends not only on the extent to which the consumption declines, but also on the products which are then used to replace animal protein. There are also substantial leakage risks where reductions in consumption are confined to only one region – a drop in market price potentially enhancing consumption in other areas and negating any net reduction on a global scale.

Overall, decreasing animal product consumption may create very substantial positive benefits for both human health and the environment (De Boer *et al.*, 2006), however a large scale shift in European consumption would require careful management of the industries that depend on the livestock sector and consideration of how policies and markets outside of Europe may negate some or all of the environmental benefits.

26.3.6 Prioritizing response and importance

A clear task for future nitrogen policy in the EU, and globally, is to increase the awareness of the role of nitrogen in myriad processes and impacts, and whether they have a positive or negative net outcome for society. Central to achieving such increased awareness is the use of audience-tailored messages on the role of nitrogen. These can range from user-friendly farm nitrogen management models that provide individual farmers with recommendations on how to improve nitrogen use efficiency and the resulting fiscal benefits, to online 'Nitrogen Policy Cross-referencing' databases that allow potential issues of pollution-swapping and synergies to be flagged up at an early stage of policy development or revision. Importantly, the nitrogen policy agenda should avoid 're-inventing the wheel'. Where policies already exist that address nitrogen-related issues, such as on diet, transport or energy, then these should be assessed to identify what 'win-wins' or antagonisms exist and to identify any key nitrogen-related gaps that new or revised policy could meet. With such a plethora of information and advice directed at consumers on these issues, especially on carbon emissions, it is likely that nitrogen policy directed at the key supply-side sector (i.e. primary food production) will provide the greatest net impact. On the consumer behaviour side, aligning nitrogen-related policy with that aimed at improving human dietary health would appear to hold the greatest potential for achieving significant and sustained success.

26.4 Communication

As discussed earlier in this chapter, the communication of nitrogen as an environmental issue is problematic because of its perceived complexity. In addition, its profile in formal education and the media remains very low, with current public understanding likely to be based on school curricula which have traditionally focussed on the perpetual recycling of compounds through the nitrogen cycle. This is further compounded by frequent mass-media and public misunderstanding of 'the scientific method'. The fact that scientists generally communicate their findings with caution and explicitly state their uncertainties may give their peers confidence in their work and their integrity, but this is often not seen as helpful by those looking for 'answers'. Furthermore, dealing with nitrogen as an environmental issue is likely to be costly and inconvenient and hence a message that many will be reluctant to accept – again with parallels to climate change communication.

The communication of consistent messages is important yet problematic. As curricula from school through to higher education are subject to only periodic validation procedures, they are necessarily slow to respond to changing scientific understanding, whilst media and political responses can be immediate and unpredictable for the reasons noted above. To be effective in increasing public understanding scientists will need to engage actively with educationists, journalists (in general but also specifically those working with farmers, industrialists and environmental groups) and politicians. Informal electronic communication will also have an increasing role, especially in youth culture. Whilst messages need to be consistent, they also need to be audience-specific in level and tone. Below we provide some examples of past and current nitrogen communication activities to different stakeholder groups.

26.4.1 Current examples of communication (case studies)

This section provides an opportunity to look at how the nitrogen issue has been communicated so far, where instances of its influence have reached the public domain, and how related environmental messages (especially those which have asked the public to make behavioural changes) have been successfully (or unsuccessfully) communicated. It also demonstrates the delicate interplay between the science providers (researchers), science users (policymakers) and the main communicators in this arena (the media). This provides a useful resource on which to develop our own communication resources and strategies (not 're-inventing the wheel') and to think about how best (or how not) to manage the policy, science, media interface.

Changing behaviour with farmers

As discussed earlier, an analysis of marginal Abatement Cost Curves has indicated that there are many actions that could be taken by farmers that would achieve GHG reductions at negative costs (in other words save money) (Moran *et al.*, 2008), and it is therefore surprising to some that these opportunities have not been realized. The reasons for this may be complex, but it is likely that profit maximizing is not the only driver determining farmer behaviour, and that a range of other factors in addition to market conditions (i.e. input and output prices) are likely to be important (cf. Oenema *et al.*, 2011, Chapter 4, this volume). Market conditions can be considered as a part of a wider set of considerations that influence farm decision making, which includes: internal factors (e.g. cognition, habit and attitude); social factors (e.g. norms and roles); the policy environment; and other farm business constraints (Pike, 2008). It is also possible that farmers lack sufficient information to make rational decisions in the face of complex and multifaceted farm management decisions. A study carried out on a group of Danish livestock farms has shown that indicators of nutrient balance (for nitrogen and phosphorous) can prove to be useful tools for farmers on which to base management decisions in order to improve nutrient use efficiency (Halberg, 1999). A combination of modelling and measurement that has been introduced in the UK to improve fertilizer nitrogen efficiency also aims to provide farmers with a greater degree of understanding in order to help develop more efficient use of nutrient resources (Nicholson *et al.*, 2000). It has been argued that we need to develop better feedback loops between practice and theory in order to share knowledge and develop policy (Deugd *et al.*, 1998). This essentially involves a three-way dialogue between farmers or practitioners, researchers and policy makers.

Biofuels and nitrous oxide

Biofuels are fuels from plant derivatives that gain their carbon from the atmosphere as CO_2, and when they are burnt no new CO_2 is released, so they are said to be 'carbon-neutral'. In Europe, concern about global warming has been the driving force behind efforts to partly replace fossil fuel with biofuels, whereas in the USA the main stimulus for biofuel production came originally from the Bush Administration's desire to reduce dependence on imported oil. Both factors have led to rapid expansion of the biofuels industry, but the idea that this trend is environmentally desirable has been increasingly challenged, and social impacts such as threats to food supplies have also been highlighted. These offsets are encompassed in Life Cycle Analysis (LCA) models, which also include an allowance for the N_2O emission associated with fertiliser use in the production of the biofuel crop.

There is a strong case for reconsidering these N_2O emissions, and their impacts on the LCA of biofuels. Crutzen *et al.* (2008) have estimated that, globally, 3%–5% of all new reactive nitrogen input into terrestrial systems is converted to N_2O. They estimated that the consequent extra N_2O emission from the production of ethanol from maize or wheat, and from the production of biodiesel from rapeseed, calculated in 'CO_2-equivalent' terms, can contribute as much or more to global warming than the quasi-cooling effect it achieves by 'saving' emissions of fossil-fuel-derived CO_2.

Thus, the way the benefits and problems associated with biofuel production (especially the nitrogen relevant elements) have been communicated to policy makers and the public have provided a prime example of the need for such communication and awareness to follow robust, peer-reviewed research, rather than to precede it. The challenge for research is to provide this communication before important policy decisions are made.

e-Nitrogen

Recent years have seen an increase in the availability of nitrogen-relevant information and advice to the public via websites and downloadable resources. As with climate change science and mitigation, the easy availability of such resources worldwide can increase awareness, debate and knowledge exchange on a scale that would have been impossible 20 years ago. The International Nitrogen Initiative (INI, 2010) is an example of an organization that has made increasing use of the internet for communication – it aims to increase awareness of the nitrogen challenge and to enhance the integration of stakeholder expertise and activity. As well as organizing regular workshops for stakeholders from around the world to exchange views and knowledge, it has been active in developing nitrogen communication tools and resources, including its 'Nitrogen Visualization Tool' (see Figure 26.9). Such stakeholder-focussed resources are now complemented by websites such as Nitrogen News (www.nitrogennews.org) that provide online news and opinion articles, accessible background documents, and the chance for the public to interact with experts working on various aspects of nitrogen. In coming years, more e-resources focussed on the nitrogen challenge will be required, making use of emerging technologies and delivery platforms (e.g. iPad applications, virtual world environments).

The N-visualization tool is not a 'policy-making' instrument in itself, but rather it shows the complexities policy makers have to face, and that there are different ways to approach solving the nitrogen problem.

26.4.3 Useful messages and tools

To effectively communicate the European nitrogen issue requires the targeted approach discussed throughout this chapter. This includes recognition of the issues that are most important to the target audience, their level of awareness, and the ultimate outcome that is desired as a result of the communication. For climate change, O'Neill and Hulme (2009) have suggested the use of an 'iconic' approach, whereby an iconic species, landscape or activity affected by climate change is employed to engage and inform a given community more successfully. In the case of reactive nitrogen, a similar approach could also prove successful where such local or regional 'icons' and their interaction with nitrogen can be identified. For example, the destruction of an iconic building due to nitric acid erosion, or the loss of keystone ombrotrophic wetland plant species due to reactive nitrogen deposition. Which icon is used will depend on its importance to the target community and how robustly the link between nitrogen and the highlighted consequences can be made.

The nitrogen 'issue' as we have seen frequently in the preceding chapters is a complex one. Like climate change, such complexity necessitates well thought-through messages and tools to make the information accessible to a wide range of audiences. There is a requirement for useful analogies and metaphors to be developed that will better help communicators get their message across. Similarly, the further development of tools, such as N-cockpit, can help communicators and educators reach stakeholder groups (e.g. children) who would find the existing nitrogen-relevant knowledge exchange resources uninteresting and/or inaccessible (see Figure 26.10).

Below we provide an example of this segmented communication approach in the context of raising nitrogen awareness in Europe.

Nitrogen Young Scientists

In 2008 a Workshop was organized jointly by the ESF *Nitrogen in Europe* programme and the NitroEurope Integrated Project to encourage enthusiastic young scientists to develop novel ideas for engaging the public with research into nitrogen and its effects on the environment. One stage of this process was to produce a list of messages that could be discussed with different target audiences (Figure 26.11). In order to be focused, the group concentrated on three target audiences: interested adults; schools and policy makers/NGOs.

During the course of the workshop, the young scientists worked in groups to develop prototype communication tools aimed at one or more of these target audiences. Examples included: illustrated stories and role-plays introducing the different forms of nitrogen, their associated environmental impacts and possible solutions; suggested lesson plans for schoolchildren;

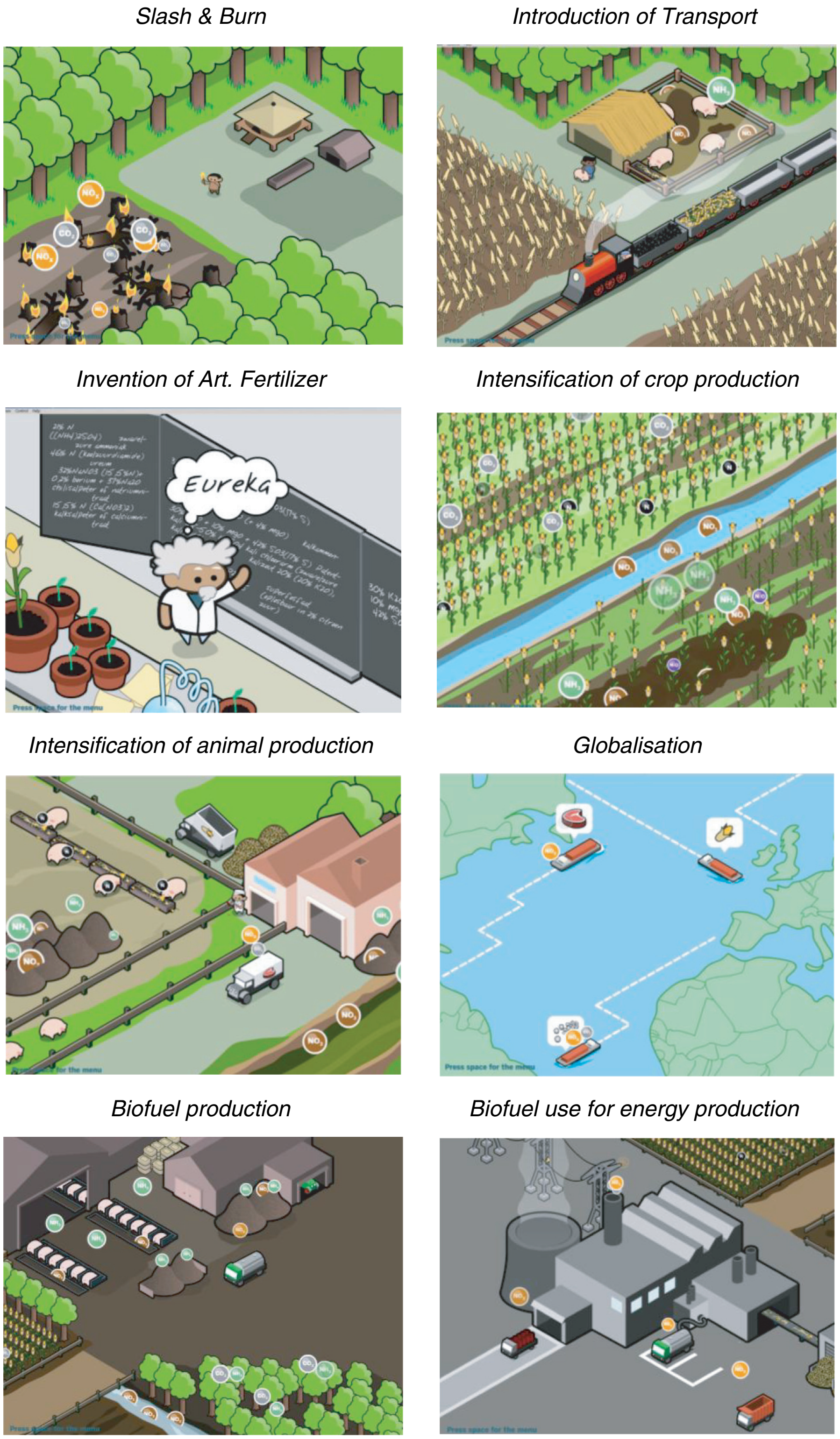

Figure 26.9 Graphics from N-Vis tool, showing steps where nitrogen plays a role, and with increasing nitrogen production/consumption.

leaflets; short films; games and a website design. With additional development, these ideas will provide a resource for laboratory open-days, science fairs and scientist-teacher partnerships as well as an online source of information for the general public (for more information, see NitroEurope, 2010).

26.5 Summary

To summarize this chapter, we pose two key questions focused on the need for understanding of societal choice and communication in the context of the European nitrogen challenge.

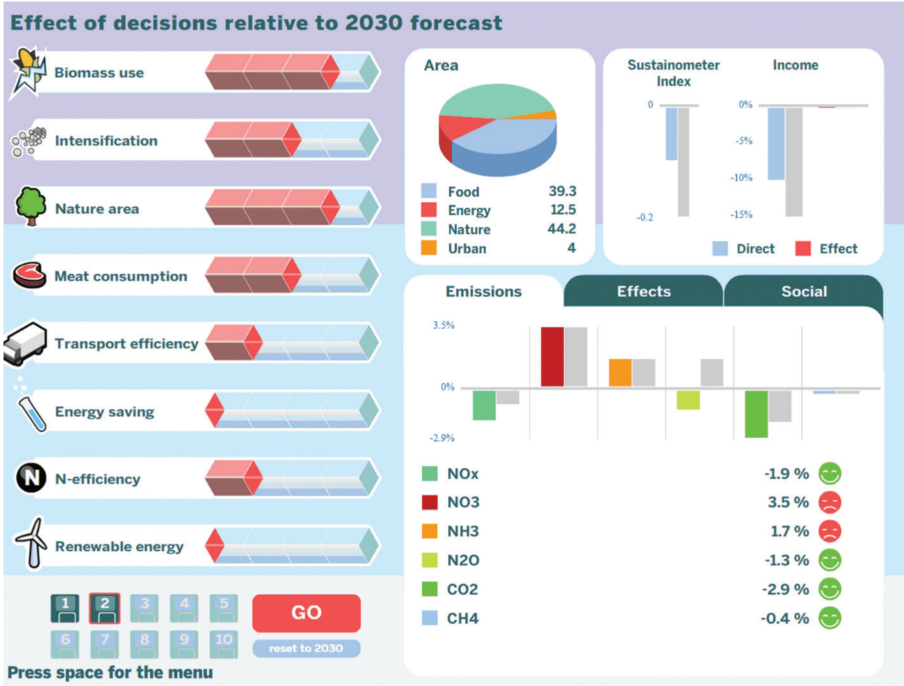

Figure 26.10 Graphics from the N-cockpit vizualization and decision support tool.

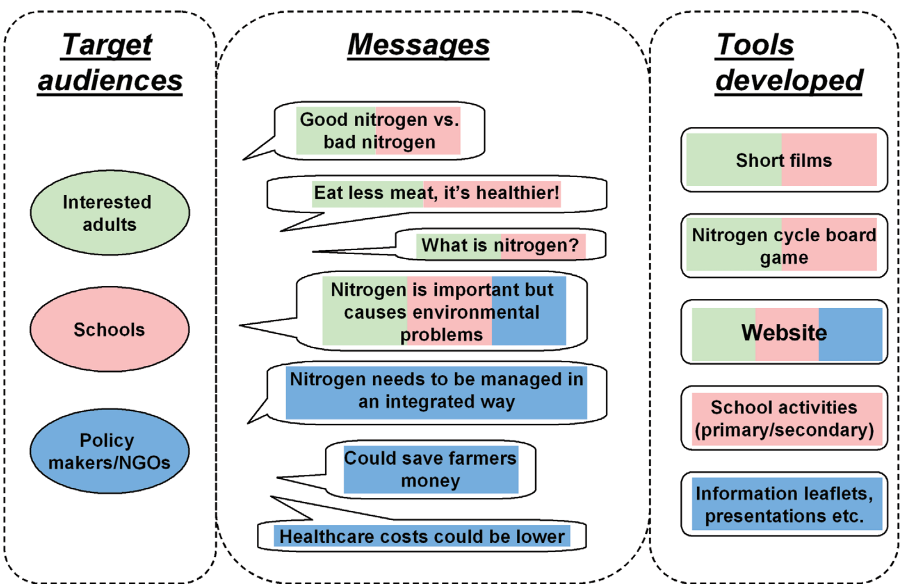

Figure 26.11 The three selected target audiences, the key messages that could be used when engaging with these audiences, and the tools developed during the 'Nitrogen Young Scientists' Workshop' to aid this communication. The colours indicate the different target audiences.

Do we need public awareness of nitrogen?

Though public awareness of nitrogen remains very low across Europe and globally, this offers the chance for very significant improvements in nitrogen-related communication and knowledge exchange with the public. As we have discussed, increased awareness of the nitrogen issue may be able to change behaviour in certain groups of individuals (e.g. the 'Positive Greens'), but such direct impacts of enhanced awareness are likely to be limited. More important are the wider indirect impacts that can be engendered and the way this can affect public acceptability of policy change. Climate change and carbon communication again serves as an exemplar of this, with the public acceptability of 'carbon' policies likely to be greater where levels of understanding of the topic and the need for policy action are also high. The answer must therefore be that public awareness of nitrogen is needed, providing an essential foundation to develop solid actions.

Do we need more 'policy' awareness of nitrogen?

Again the answer must be: yes. However, with the myriad messages, competing priorities and mission briefs of policy making institutions in Europe, the application of an additional set of nitrogen assessment criteria to every decision may prove a challenge to be adopted by policy-makers. However, a very significant step change would be for the nitrogen-awareness level of policy-makers to at least reach a level where the basic nitrogen implications of the policy are assessed. For some policy decisions nitrogen will have little real import and further consideration will be unnecessary. However, on many issues, such a 'scope 1' examination of nitrogen implications could serve to highlight potentially very important antagonisms, and indeed significant synergies that reinforce the putative policy's aims. In the longer term a 'mainstreaming' of nitrogen issues in European policy making – as already exists in many sectors for carbon – could provide a strategy by which many of the key policy gaps, overlaps and antagonisms highlighted in earlier chapters could be effectively addressed.

Finally, it is important to reiterate the central conclusion and recommendation of this chapter: that a 'segmented' approach to engendering choice, behavioural change and communication is required. This approach is one that will need to evolve as attitudes, awareness and policy aims change over time. It has a well-established basis in the context of climate change mitigation and we believe that its adoption to address the European nitrogen challenge is one that can deliver far-reaching and lasting benefits for Europe and the world.

Acknowledgements

The authors are grateful for financial support from the European Science Foundation programme Nitrogen in Europe (NinE), the COST Action 729, the UK Department for Environment, Food and Rural Affairs, and the European Commission Integrated Project NitroEurope.

References

AEP (2007). European Association for Grain Legume Research. www.grainlegumes.com/aep/production/growing_gl_in_europe/grain_legumes_crops_adapted_to_all_european_regions (Site accessed 1 August 2010).

Bax, J. A. and Schils, R. L. M. (1993). Animal responses to white clover. In: *White Clover in Europe: State of the Art*, pp. 7–16. FAO, Rome.

Bickerstaff, K. and Walker G. (2001). Public understandings of air pollution: the 'localisation' of environmental risk. *Global Environmental Change*, **11**, 133–145.

Blennow, K. and Persson, P. (2009). Climate change: motivation for taking measure to adapt. *Global Environmental Change*, **19**, 100–104.

Brink, C., van Grinsven, H., Jacobsen, B. H. *et al*. (2011). Costs and benefits of nitrogen in the environment. In: *The European Nitrogen Assessment,* ed. M. A. Sutton, C. M. Howard, J. W. Erisman *et al.* Cambridge University Press.

Büchner, F. L., Hoekstra, J., van den Berg, S. W., Wieleman, F. and van Rossum, C. T. M. (2007) *Quantifying Health Effects of Nutrition*, RIVM Report 350080001/2007.

Carbon Disclosure Project (2010). www.cdproject.net (Site accessed 1 August 2010).

CBF (2010). Chesapeake Bay Foundation. Your Bay Footprint. http://www.cbf.org/yourbayfootprint/ (Site accessed 1 August 2010).

Crutzen, P. J., Mosier, A. R., Smith, K. A. and Winiwarter, W. (2008). N_2O release from agro-biofuel production negates global warming reduction by replacing fossil fuels, *Atmospheric Chemistry Physics*, **8**, 389–395.

De Boer, J., Helms, M. and Aiking, H. (2006). Protein consumption and sustainability: diet diversity in EU-15. *Ecological Economics*, **59**, 267–274.

Deckers, J. (2010) What policy should be adopted to curtail the negative global health impacts associated with the consumption of farmed animal products? *Res Publica*, **16**, 57–72.

DEFRA (2008). A Framework for Pro-Environmental Behaviours. www.defra.gov.uk/evidence/social/behaviour/documents/behaviours-jan08-report.pdf

Denman, K. L. *et al*. (2007) In: *Climate Change 2007: The Physical Science Basis*, ed. S. Solomon, *et al*., pp. 499–587. Cambridge University Press.

Dentener, F. *et al*. (2006). Nitrogen and sulfur deposition on regional and global scales: a multimodel evaluation. *Global Biogeochemical Cycles*, **20**, GB4003.

Deugd, M., Roling, N. and Smaling, E. M. A. (1998). A new praxeology for integrated nutrient management, facilitating innovation with and by farmers. *Agriculture, Ecosystems and Environment*, **71**, 269–283.

EPA Victoria (2010). www.epa.vic.gov.au/ecologicalfootprint/calculators/personal/results.asp (Site accessed 1 August 2010).

de Vries, W., Leip, A., Reinds, G. J. *et al.* (2011). Geographic variation in terrestrial nitrogen budgets across Europe. In: *The European Nitrogen Assessment,* eds. M. A. Sutton, C. M. Howard, J. W. Erisman *et al.* Cambridge University Press.

Directgov UK (2010). *UK Government Digital Service: Carbon Calculator*. http://carboncalculator.direct.gov.uk/index.html (Site accessed 1 August 2010).

Duffy, R. and Fearne, A. (2009). Value perceptions of farm assurance in the red meat supply chain. *British Food Journal*, **111**, 669–685.

EC (2008). *Agriculture in the European Union*: *Statistical and Economic Information 2007*. European Commission, Brussels.

FAO (2006). *Livestock Report 2006*. Food and Agriculture Organization of the United Nations, Rome.

FAO (2009). *FAOSTAT Statistical Database*. Food and Agriculture Organization of the United Nations, Rome. http://faostat.fao.org/

FEFAC (2008). *Feed and Food Statistical Yearbook 2007*. FEFAC-European Feed Manufacturers Federation, Brussels.

Flessa, H., Ruser, R., Dörsch, P. *et al*. (2002). Integrated evaluation of greenhouse gas emissions (CO_2, CH_4, N_2O) from two farming systems in southern Germany. *Agriculture, Ecosystems and Environment*, **91**, 175–189.

Galloway, J. N., *et al*. (2004). Nitrogen cycles: past, present, and future. *Biogeochemistry*, **70**, 153–226.

Galloway, J. N., Burke, M., Bradford, G. E. *et al*. (2007). International trade in meat: the tip of the pork chop. *Ambio*, **36**, 622–629.

Gross, C., McKinney, S. and Harbans, L. (2007). Nitrogen credit trading tool to facilitate market based water quality trading. *Proceedings of the Soil and Water Conservation Society*, Florida, USA, July 2007.

Halberg, N. (1999). Indicators of resource use and environmental impact for use in a decision aid for Danish livestock farmers. *Agriculture, Ecosystems and Environment*, **76**, 17–30.

Herrero, M., Thornton, P. K., Gerber, P. and Reid, R. S. (2009). Livestock, livelihoods and the environment: understanding the trade-offs. *Current Opinion in Environmental Sustainability*, **1**, 111–120.

INI (2010). International Nitrogen Initiative. www.initrogen.org (Site accessed 1 August 2010).

Kenyon, P. M. and Barker, M. E. (1998). Attitudes towards meat-eating in vegetarian and non-vegetarian teenage girls in England: an ethnographic approach. *Appetite*, **30**, 185–198.

Krishnamurthy, A., Moore, J. K., Zender, C. S. and Luo, C. (2007). Effects of atmospheric inorganic nitrogen deposition on ocean biogeochemistry. *Journal of Geophysical Research,* **112**, G02019.

Lamarque, J.-F. *et al.* (2005). Assessing future nitrogen deposition and carbon cycle feedback using a multimodel approach: analysis of nitrogen deposition. *Journal of Geophysical Research,* D19303.

Legume Futures (2010). www.legumefutures.eu (Site accessed 1 August 2010).

Leip, A., Achermann, B., Billen, G. *et al.* (2011). Integrating nitrogen fluxes at the European scale. In: *The European Nitrogen Assessment,* ed. M. A. Sutton, C. M. Howard, J. W. Erisman *et al.* Cambridge University Press.

Lloyd-Williams, F., Mwatsama, M., Birt, C. *et al.* (2008). Estimating the cardiovascular mortality burden attributable to the Common Agricultural Policy on dietary saturated fats. *Bulletin of the World Health Organization,* **86**, 535–545.

Luick, R. (1998). Ecological and socio-economic implications of livestock-keeping systems on extensive systems in south-western Germany. *Journal of Applied Ecology*, **35**, 979–982.

McMichael, A. J., Powles, J. W., Butler, C. D. and Uauy, R. (2007). Food, livestock production, energy, climate change, and health. *The Lancet*, **370**, 1253–1263.

Moran, D., MacLeod, M., Wall, E. *et al.* (2008). UK marginal abatement cost curves for the agriculture and land use, land-use change and forestry sectors out to 2022, with qualitative analysis of options to 2050. In: 83rd Annual Conference, Agricultural Economics Society, March 30-April 1, 2009, Dublin, Ireland.

Naylor, R., Steinfeid, H., Falcon, W. *et al.* (2005). Losing the links between livestock and land. *Science*, **310**, 1621–1622.

Nepstad, D. C., Stickler, C. M. and Almeida, O. T. (2006). Globalization of the Amazon soy and beef industries: opportunities for conservation. *Conservation Biology*, **20**, 1595–1603.

Nicholson, F. A., Smith, K. A., Chambers, B. J. and Lord, E. I. (2000). Prediction of farm manure nitrogen availability and losses following land application (manner). *Animal, Agricultural and Food Processing Wastes*, 441–448.

Nielsen, S. J. and Popkin, B. M. (2003). Patterns and trends in food portion sizes, 1977–1998. *Journal of the American Medical Association*, **289**, 450–453.

NinE (2009). *The Barsac Declaration: Environmental Sustainability and the Demitarian Diet*, prepared under the lead of the Nitrogen in Europe (NinE) programme of the European Science Foundation. www.nine-esf.org/sites/nine-esf.org/files/Barsac%20 Declaration%20V3.pdf.

NitroEurope IP (2010). NitroEurope Young Scientists' Forum. www.nitroeurope.eu/ysf (Site accessed 1 August 2010).

Norat, T., Bingham, S., Ferrari, P. *et al.* (2005). Meat, fish and colorectal cancer risk: The European Prospective Investigation into Cancer and Nutrition. *Journal of the National Cancer Institute,* **97**, 906–916.

Oenema, O., Bleeker, A., Braathen, N. A. *et al.* (2011). Nitrogen in current European policies. In: *The European Nitrogen Assessment,* ed. M. A. Sutton, C. M. Howard, J. W. Erisman *et al.* Cambridge University Press.

Oikonomou, V., Becchis, F., Steg, L. and Russolillo, D. (2009). Energy saving and energy efficiency concepts for policy making. *Energy Policy*, **37**, 4787–4796.

Olesen, J. E., Schelde, K., Weiske, A. *et al.* (2006). Modelling greenhouse gas emissions from European conventional and organic dairy farms. *Agriculture, Ecosystems and Environment*, **112**, 207–220.

O'Neill, S. J. and Hulme, M. (2009). An iconic approach for representing climate change. *Global Environmental Change*, **19**, 402–410.

Paracchini, M. L., Petersen, J.-E., Hoogeveen, Y. *et al.* (2008). *High Nature Value Farmland in Europe: An Estimate of the Distribution Patterns on the Basis of Land Cover and Biodiversity Data*. Joint Research Centre, Institute for Environment and Sustainability, Ispra, Italy.

Petersen, S. O., Regina, K., Pöllinger, A. *et al.* (2006). Nitrous oxide emissions from organic and conventional crop rotations in five European countries. *Agriculture, Ecosystems and Environment*, **112**, 200–206.

Pike, T. (2008). *Understanding Behaviours in a Farming Context: Bringing Theoretical and Applied Evidence Together from across DEFRA and Highlighting Policy Relevance and Implications for Future Research*. DEFRA, London.

Rochon, J. J., Doyle, C. J., Greef, J. M. *et al.* (2004). Grazing legumes in Europe: a review of their status, management, benefits, research needs and future prospects. *Grass and Forage Science*, **59**, 197–214.

Sampei, Y. and Aoyagi-Usui, M. (2009). Mass-media coverage, its influence on public awareness of climate-change issues, and implications for Japan's national campaign to reduce greenhouse gas emissions. *Global Environmental Change: Human Policy Dimensions*, **19**, 203–212.

Sebek, L. B. J. and Temme, E. H. M. (2009). *Human Protein Requirements and Protein Intake and the Conversion of Vegetable Protein into Animal Protein*, External Report. Animal Sciences Group, Wageningen UR, Wageningen, The Netherlands.

Simon, M. F. and Garagorry, F. L. (2005) The expansion of agriculture in the Brazilian Amazon. *Environmental Conservation*, **32**, 203–212.

Smil, V. (2004) *Enriching the Earth*. MIT Press, Cambridge, MA.

Steinfeld, H., Gerber, P., Wassenaar, T. *et al.* (2006). *Livestock's Long Shadow: Environmental Issues and Options*. FAO, Rome.

Svirejeva-Hopkins, A., Reis, S., Magid, J. *et al.* (2011). Nitrogen flows and fate in urban landscapes. In: *The European Nitrogen Assessment,* ed. M. A. Sutton, C. M. Howard, J. W. Erisman *et al.* Cambridge University Press.

UNECE (2010). *Options for Revising the 1999 Gothenburg Protocol to Abate Acidification, Eutrophication and Ground-Level Ozone: Reactive Nitrogen*, Report by the co-chairs of the Task Force on Reactive Nitrogen, Presented to the Working Group on Strategies and Review 47th session. ECE/EB.AIR/WG.5/2010/13. www.unece.org/env/lrtap/WorkingGroups/wgs/docs47th%20session.htm

UNEP and WHRC (2007). *Reactive Nitrogen in the Environment: Too Much or Too Little of a Good Thing*. United Nations Environment Programme, Paris.

Urwin, K. and Jordan, A. (2008). Does public policy support or undermine climate change adaptation? Exploring policy interplay across different scales of governance. *Global Environmental Change*, **18**, 180–191.

Ventour, L. (2008). *The Food We Waste*, Food Waste Report version 2, RBC405–0010. Waste and Resources Action Plan.

WRAP (Waste and Resource Action Plan) (2008). The food we waste. http://www.wrap.org.uk.

WRI/WBCSD (2010). *The Greenhouse Gas Protocol Initiative*. World Resources Institute and the World Business Council for Sustainable Development. www.ghgprotocol.org (Site accessed 1 August 2010).