SRU Sachverständigenrat für Umweltfragen

NITROGEN:
Strategies for resolving an urgent environmental problem

Summary
January 2015






INTRODUCTION

The excessive release of nitrogen compounds into the environment is one of the biggest problems of our time. Nitrogen compounds, such as nitrogen oxides and ammonia, pollute the environment and endanger human health in numerous and complex ways:

- Nitrogen-induced eutrophication and acidification contribute to biodiversity loss.
- Nitrogen oxides in ambient air have a direct detrimental impact on human health, and together with ammonia form hazardous particulate matter and contribute to ground level ozone.
- Nitrate in drinking water and food endangers human health; nitrosamines are suspected to be carcinogenic.
- Nitrous oxides damage the ozone layer and contribute to climate change.

Nitrogen cycles through the soil, air and water and is key to the existence of all living things. Virtually all nitrogen (99 per cent) occurs as relatively inert atmospheric nitrogen, which, partly through natural processes, can be converted into chemical and biologically active (i.e. reactive) nitrogen compounds. The main reactive nitrogen compounds are ammonia (NH_3), ammonium (NH_4^+), nitrogen oxides (NO and NO_2), nitrate (NO_3^-), nitrite (NO_2^-), nitrous oxide (N_2O) and organic compounds.

Human activity is seriously impacting the natural nitrogen cycle, particularly owing to the development of industrial fertilizer production about a century ago, in which non-reactive atmospheric nitrogen is converted into reactive nitrogen compounds. Reactive nitrogen-compound emissions, mainly linked to fertilizer use, livestock farming, and combustion processes, have increased almost ten-fold since the dawn of the industrial revolution. Through the concentration of agricultural activities, such as livestock farming, in specific areas, some localities have become heavily polluted.

Reactive nitrogen compounds impact the environment at various spatial levels with partially interactive effects. Pollution of surface water and groundwater is primarily a local phenomenon, whereas ocean eutrophication primarily results from more remote sources of pollution, particularly inputs

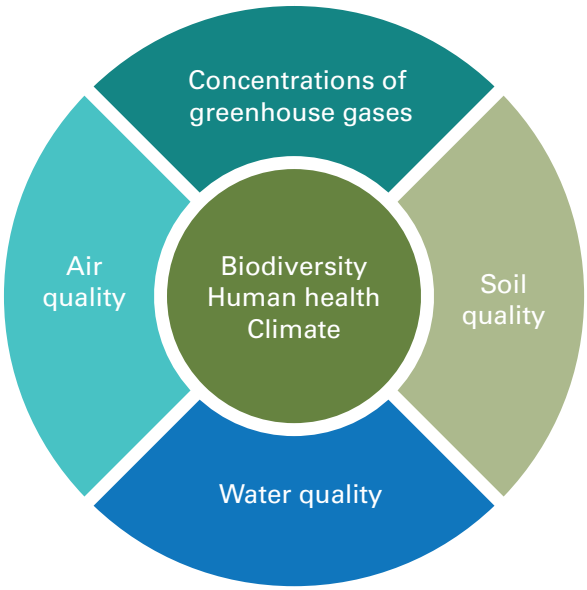

Figure 1: Nitrogen compounds have numerous deleterious effects (Source: SRU/SG 20105/Figure 1)

from rivers. On the other hand, climate change and damage to the ozone layer are global phenomena. Hence, political action is needed at all political levels.

While certain types of nitrogen emissions have been successfully rolled back, they remain unacceptably high as a whole. In Germany, the release of reactive nitrogen emissions into water, soil and air has led to severe pollution in some areas. As of 2009, 48 per cent of Germany's natural and semi-natural terrestrial ecosystems were exceeding eutrophication limits (see Fig. 3), 8 per cent were affected by acidification. The North and Baltic Seas are adversely affected by eutrophication. Around 27 per cent of all groundwater bodies exhibit a poor chemical status owing to elevated nitrogen concentrations, which also impact drinking water. In some regions, the limit value for nitrate in drinking water can only be adhered to through extensive interventions. Public health in densely populated regions is threatened by nitrogen oxide emissions and nitrogen-containing particulate matter.

Existing and partly legally binding clean air, water protection and nature conservation targets are clearly being missed. Germany has failed to adequately implement and enforce key environmental standards, leading the European Commission to introduce an infringement procedure against Germany for its failure to take actions against nitrate pollution in water.

From a global standpoint, it is a major cause for concern that ecological limits for nitrogen have already been exceeded. Long-term stability of ecosystems is threatened. According to some scientific experts, the global level of atmospheric nitrogen conversion attributable to fertilizer use needs to be reduced from its current level of 120 million tons per year to around 60 million tons per year, in order to keep nitrogen pollution below critical pollution thresholds.

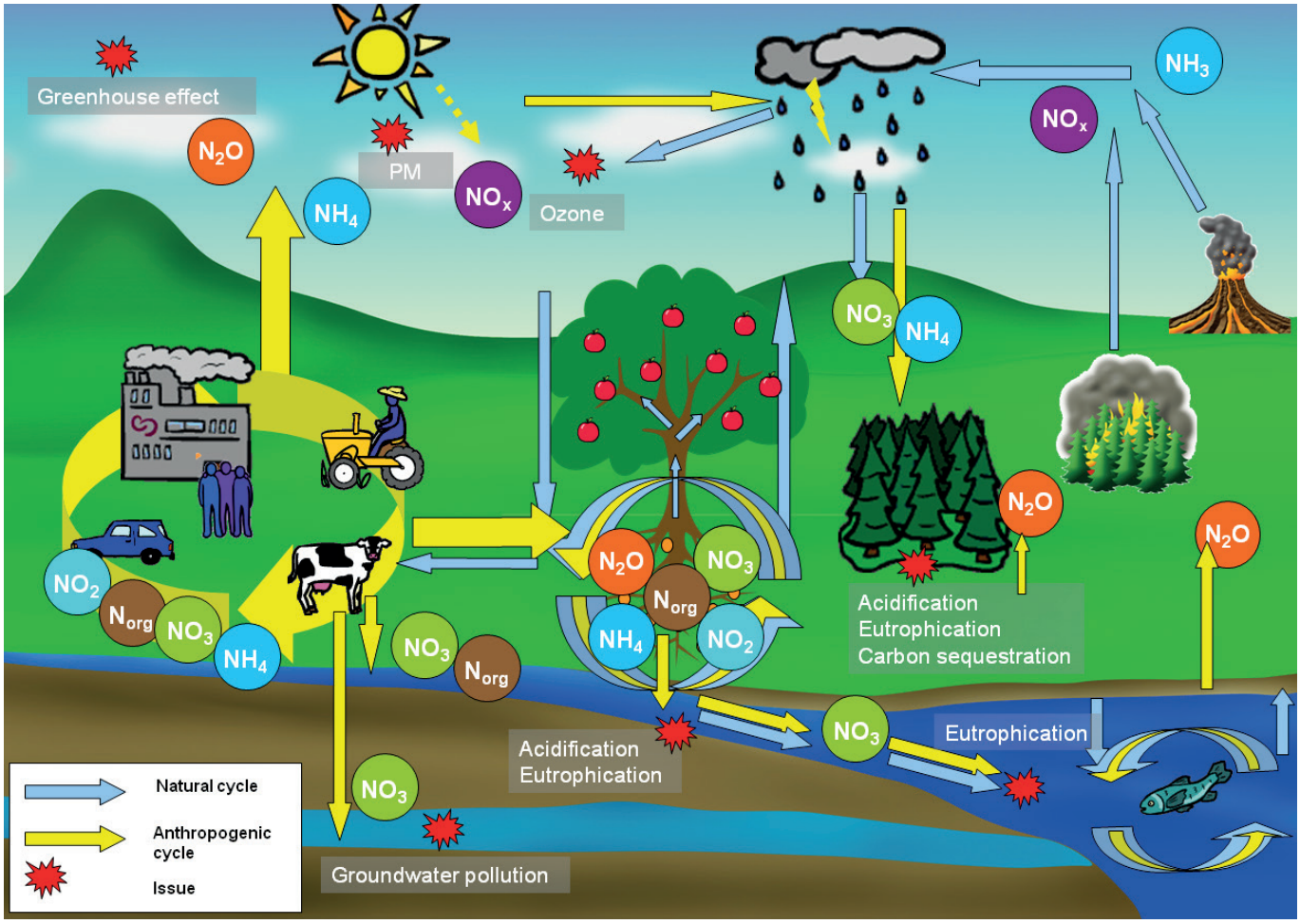

Figure 2: The nitrogen cycle (Source: Anne Christine Le Gall, INERIS (Copyright))

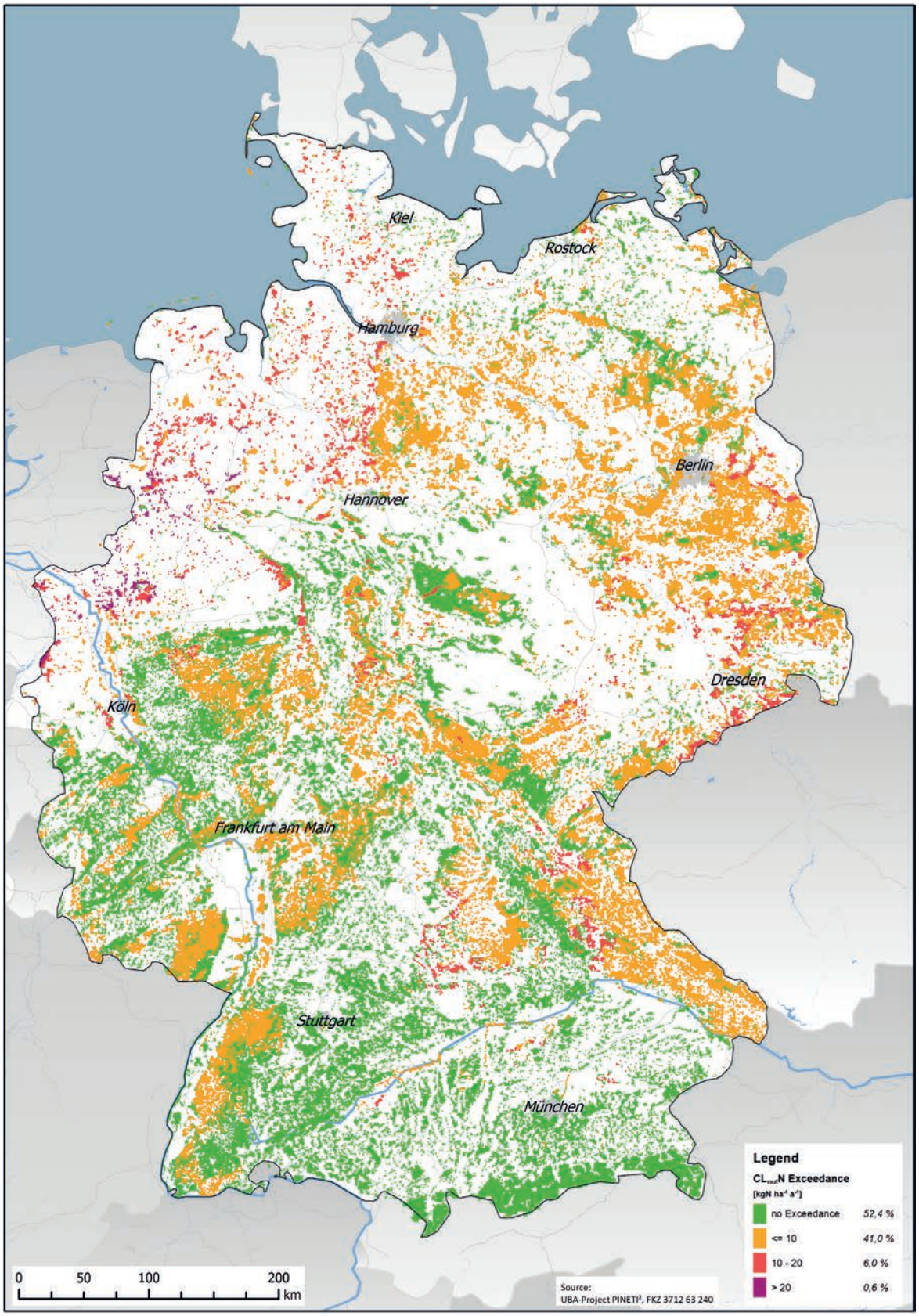

Figure 3: Exceedance of critical loads for eutrophication (Source: Schaap et al. (2014): Ermittlung und Bewertung der Einträge von versauernden und eutrophierenden Luftschadstoffen in terrestrische Ökosysteme. Interim report of the R&D project no. FKZ 3712 63 240 1, Dessau-Rosslau: Federal Environment Agency. In press.)

Biodiversity and nitrogen: a major cause for concern

Excessive emissions of reactive nitrogen are one of the main causes of biodiversity loss. Even very low input levels can have a deleterious effect on certain species and ecosystems. Without an effective strategy to reduce emissions of reactive nitrogen compounds, it will be next to impossible to achieve nature conservation targets and comply with conservation regulations, for example with the protection of species and the restoration of habitats to a "favourable conservation status" or the prevention of the "deterioration of natural habitats." Processes, such as acidification, nitrogen loading and species loss are irreversible or only reversible over long periods of time. The limit values that have been set for the protection of human health are woefully inadequate for protecting more sensitive species and ecosystems.

The key mechanisms that come into play here – eutrophication (nutrient enrichment) and acidification (reduced pH values resulting from base leaching) – alter species composition, reduce species numbers, and weaken resilience against shocks, such as the stress caused by drought and frost. The visible effects of these mechanisms include: the loss of species-rich meadows and field margins rich in wild herbs; the formation of excessive sea foam induced by algae blooms; and the substantially greater abundance of plants such as blackberries and nettle that thrive on nitrogen-rich forest soil.

The impact of these phenomena on biodiversity is in turn detrimental to ecosystem services, including the recreational value of landscapes. Also ecosystem services for agriculture are affected; when elevated nitrogen inputs result in the loss of flowering plants, then the food sources for insects are lost, and the insects are no longer available for either pollination or as food for birds.

The policy problem: inattention, fragmented responsibilities, lack of integration

For decades, environmental policy has concerned itself with regulating specific nitrogen compounds in certain environmental media. The environmental problems attributable to nitrogen are addressed by numerous policy instruments. Nonetheless, the full scope of the nitrogen pollution problem has yet to be understood or addressed. The main reason for this is that nitrogen compound emissions are inextricably connected to the basic production fundaments of the economy, particularly in the energy and agricultural sectors. In addition, there are policy and institutional restrictions:

- **Regulatory frameworks and responsibility in the environmental sector are fragmented.** The synergies between health and biodiversity protection and between water, soil, climate protection and clean air have not been given sufficient attention. Conflicts, for example between bioenergy policy and nitrogen pollution, have not been taken into account at an early stage. There is not sufficient coordination of the interconnected tasks of the various ministerial departments.
- **Environmental aspects are not sufficiently prioritized by the different ministries with their respective sectoral foci.** The ministries in charge of agriculture, transportation and energy are required to improve the nitrogen pollution problem. Certain environmental targets can only be achieved with regulations addressing these specific sectors. These ministries are sometimes directly responsible for implementing key environmental policy instruments (e.g. the Federal Ministry of Food and Agriculture is in charge of implementing the Fertilizer Regulation (Düngeverordnung, DüV) – the regulation, which governs fertilizer use). As the SRU sees it, despite the progress that has been made, administrative bodies often give too much weight to the economic interests of polluters and not enough to environmental protection and nature conservation.

RECOMMENDATIONS

1. Developing a national nitrogen strategy

The SRU recommends that the federal government and the German Länder jointly elaborate a national nitrogen strategy. Such a strategy would offer important starting points to solve the above mentioned political and institutional problems, including setting a policy agenda, creating a platform for social and political debates, providing an overarching framework for political action programmes; and formulating widely supported policy goals. A national strategy of this nature would serve as a basis for cooperation between various governmental and non-governmental actors. Such a strategy should also forge close links with the national sustainable development strategy and the National Strategy on Biodiversity. It could also promote implementation of the objectives of the EU's Seventh Environmental Action Programme, and provide a new impetus, over the long term, for European environmental policy.

The national nitrogen strategy should contain the following elements:

- Nitrogen related objectives should be bundled, and the target system further developed. As an orientation, an overarching target for the total acceptable level of reactive nitrogen input into the environment in Germany should be defined. This overarching target should be based on ecosystem resilience and should be established via an interactive process involving the scientific community and the relevant sectors of society. This process should be based on cross-media modelling of inputs and the environmental impact of reactive nitrogen compounds. The overarching target should be supported by targets for nitrogen inputs in the agricultural, as well as for nitrogen emissions in the transport and energy sectors.

- The nitrogen strategy should combine existing nitrogen reduction measures and regulations, and should identify medium- and long-term areas for action.

- The strategy should be underpinned by an ambitious action programme, and should be evaluated with regularized monitoring.

- The national nitrogen strategy should be mainstreamed. Its implementation should be promoted by adequate levels of human and financial resources, and by close cooperation with the German Länder and the relevant stakeholders.

- The first step toward roll-out of an integrated nitrogen strategy should be making nitrogen pollution a core element of the national environmental programme for 2030.

2. Improving the framework of targets on multiple levels

An ambitious strategy for the reduction of nitrogen pollution will require a target system that reflects the structure of the problem. Nitrogen pollution is characterized by its effects, nitrogen species conversion and cross-media substance flows at the local, regional and global levels. Although there are numerous quality objectives already on the books in German and EU environmental law, they are not being sufficiently implemented and lack an overarching treatment target:

- **Overarching reduction targets:** To give a directional orientation for action and to more effectively communicate this to the general public, reduction targets for the aggregate emissions of reactive nitrogen compounds should be set at the national, European and global levels. In Germany, this will presumably require that current nitrogen emission levels be at least halved, in order to meet existing national and European quality objectives. Even greater reductions will be necessary in highly polluted or sensitive areas.

- **Air emissions:** The maximum allowable national emission ceilings for nitrogen oxide and ammonia urgently need to be reduced. The reduction objectives for 2030 recommended by the European Commission in connection with the revised NEC Directive (39 and 69 per cent reduction for ammonia and nitrogen oxide, respectively) are a step in the right direction, but are insufficient in terms of environmental impact. If the European Commission's reduction objectives were met, around 40 per cent of Germany's natural and semi-natural terrestrial ecosystems would still exceed eutrophication limits in 2030, while in that same year the health hazards entailed by particulate matter and ground-level ozone would only have been reduced by 49 and 33 per cent, respectively. That said, the Federal Government should support the European Commission's recommendations nevertheless, and should make sure that these reduction objectives are under no circumstances weakened in the likely to be tough upcoming negotiations. The government should also proactively support additional legally binding interim standards for 2025, so as to ensure that the EU member states begin taking action now.

- **Air quality:** Although air-quality standards aimed at avoiding health hazards (particularly for busy roads) are still being exceeded regularly, these standards need to be strengthened. The SRU recommends that the annual mean limit value for nitrogen dioxide in the Air Quality Directive be reduced to 20 µg/m³ and that the air-quality standards for particulate matter and ozone in the directive be harmonized with the stricter standards of the World Health Organization (ozone 100 µg/m³ as an eight hour mean target value; PM_{10} 20 µg/m³ as an annual mean limit value; $PM_{2.5}$ 25 µg/m³ as a short term limit value and 10 µg/m³ as an annual mean limit value).

- **Water protection:** The existing environmental quality objectives for water protection are ambitious, but they are being egregiously undercut. The envisaged measures and management plans for implementation of the Water Framework Directive are not sufficient to reach these objectives. In terms of marine protection, the SRU recommends that regionally harmonized nitrogen reduction targets be defined for the North Sea, along the lines of the reduction targets for the Baltic Sea.

- **Biodiversity protection:** In the EU, the critical loads and critical levels for ecosystems should not be exceeded over the long term (EU's Seventh Environmental Action Programme). The government's national biodiversity strategy sets forth an ambitious target, to the effect that by 2020 even sensitive ecosystems should be protected against eutrophication. There is a good chance that it will prove impossible to meet these objectives without a rapid, long-term change in policy. The SRU furthermore recommends that, in the interest of protecting terrestrial ecosystems, limit values for ammonia be incorporated into the Air Quality Directive as well, and that compliance with these values be promoted by regional clean-air plans.

3. Pursue interrelated approaches

Because the local and regional environmental impact of reactive nitrogen compounds varies greatly, a cross-media nitrogen strategy should be based on a set of interrelated approaches:

- **Reduction of background pollution:** Reactive nitrogen emissions should be greatly reduced across the board, so as to protect sensitive terrestrial ecosystems, the oceans, and human health.

- **Reduce inputs in hotspots and sensitive areas:** Certain regions of Germany exhibit exceedingly high nitrogen surpluses from farming activities. The air in congested agglomerations exhibits very high levels of nitrogen dioxide in some cases, while other areas such as raised bogs are particularly vulnerable to nitrogen inputs. Loads in hotspot regions and sensitive areas should be reduced through efficient local and regional measures. These could, for example, take the form of air pollution control plans and implementation of the Water Framework Directive.

- **Strengthen ecosystem protection through nature conservation measures:** Where these measures do not adequately protect sensitive areas, additional nature conservation management measures should be taken. For example, existing legal instruments for local protected-area management could also be used to reduce agricultural fertilizer use. Buffer zones could be established around nature conservation areas; the land in these zones could be used for agricultural purposes, but only with certain restrictions. Moreover, contractual nature conservation and agri-environmental measures could reduce nitrogen inputs and mitigate the impact of unavoidable nitrogen inputs.

- **Protect relatively unpolluted areas:** In these areas, species and ecosystems have survived that would be under threat were nitrogen pollution to increase. Hence it is crucial that nitrogen inputs not be permitted to rise any further.

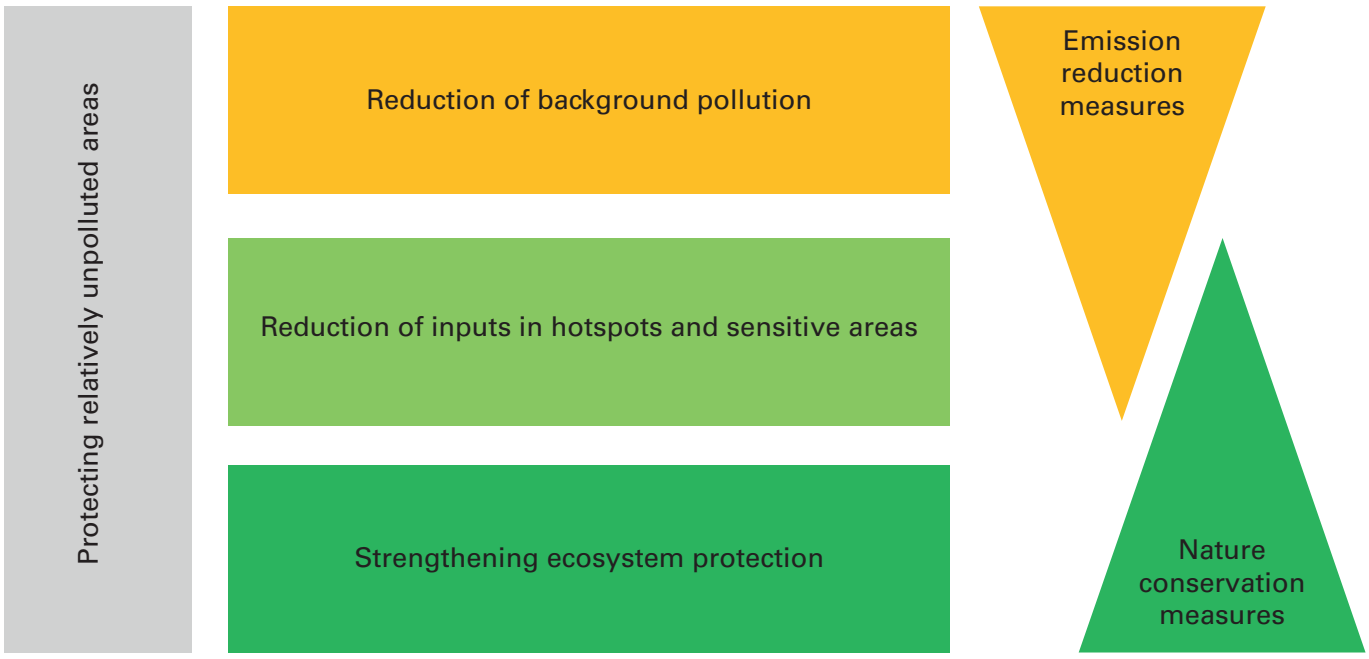

Figure 4: Four interrelated approaches to reducing reactive nitrogen pollution (Source: SRU/SG 2015/ Figure 4)

4. Reducing nitrogen emissions from agriculture

The agricultural sector is the largest single source of nitrogen emissions and should play a pivotal role in reducing such emissions. The potential for reduction in this sector is still tremendous. The existing legal frameworks need to be considerably strengthened and implementation needs to be improved.

- **Reform Common Agricultural Policy still further and implement it more ambitiously:** When it comes to environmental protection and nature conservation, the results of the Common Agricultural Policy reform are sobering. The ecological requirements for agricultural subsidies were watered down during the negotiations, an action that was also supported by the German government. The available leeway for ecologically advantageous implementation in Germany was not exploited. It is urgent that improvements be made during the 2017 mid-term review. The SRU urges that public funds be expended solely on public goods, and that agri-environmental payments be substantially increased. At the same time, the environmental requirements for agricultural subsidies should be toughened, particularly in terms of maintaining permanent grassland, setting far-reaching requirements for ecological focus areas, and crop diversification.

- **Reform and strictly enforce the Fertilizer Regulation (Düngeverordnung):** The Fertilizer Regulation is a pivotal instrument for reducing nitrogen emissions. Only if this regulation is extensively overhauled can it contribute to achieving environmental-quality objectives for surface waters, groundwater, air quality and biodiversity. With regard to the current reform of the Fertilizer Regulation, the following changes are particularly important: demanding a fertilizer plan from farmers; applying the upper limit of manure application to all types of organic fertilizer, and all biogas plant digestates, in particular; enacting more stringent requirements for manure application methods; requiring a "farm gate balancing" (Hoftorbilanz [the nutrient balance going through the farm gate]) to calculate the nutrient surplus; and, improving the enforcement of the Fertilizer Regulation. A regulatory framework should be established that allows the available data from farming operations to be centrally gathered and used for purposes of regulatory implementation. This would make it far easier for the competent authorities to oversee and monitor compliance.

- **Enact regulatory measures in the German Länder:** Apart from reforming the Fertilizer Regulation, greater efforts are needed to achieve the objectives of the Water Framework Directive. The current voluntary measures – agri-environmental measures and advisory services – are not sufficient. Hence, the German Länder should take more compulsory measures such as the designation of water protection areas, in order to better apply the polluter-pays principle.

- **Raise a tax on nitrogen surplus:** The need to reduce nitrogen pollution is so great that, apart from the aforementioned toughening of existing regulations, a tax should be imposed on the nitrogen surplus of individual farms.
  Such a tax would serve as an incentive to reduce overall nitrogen emissions in a cost efficient manner, beyond the levels required by other regulations. After administrative costs are covered, the revenue from this tax should be re-invested in the agricultural sector (e.g. for farm advisory services, promoting technical measures aimed at reducing emissions, and management measures in sensitive natural areas).

- **Differentiate requirements geographically:** Stricter overall requirements will increase the export of manure from regions with high stocking densities. This will be a step in the right direction, provided that manure replaces mineral fertilizers. However, such transport will presumably also result in a rise in nitrogen surpluses in the receiving regions, since manure is less efficient than its mineral counterpart. In regions characterized by unfavourable local conditions and proximity to sensitive ecosystems, higher nitrogen surpluses result in greater environmental damage than in the region of origin. This

will need to be countered by enacting tougher regulations in the receiving regions.

– **Make good practice really mean something:** Good practice refers to achieving required standards in farming operations without recourse to compensation. The SRU recommends that the legal requirements related to good agricultural practice be specified, that enforcement mechanisms for the administrative sphere be enacted, and that the relevant standards be toughened (e.g. by requiring that liquid manure be spread in a manner that minimizes loss).

– **Strengthen requirements for livestock facilities:** Livestock facilities are particularly relevant when it comes to ammonia loads in ecosystems. In amending the TA Luft (air pollution control regulation), clear and exacting requirements should be laid down for livestock facilities. Moreover, air-cleaning systems should be required by law for all pig fattening facilities for which ventilation is required by law, along with transition periods and, where necessary, case by case testing for existing facilities. For poultry farms, the state of the art for air-cleaning systems installations needs to be further developed. For smaller installations not governed by the TA Luft, requirements should be laid down for construction, characteristics and operation.

5. Make biogas production environmentally sustainable

Biogas production is exacerbating the nitrogen pollution problem in the agricultural sector. Hence, the SRU welcomes the fact that the amendments to the German Renewable Energy Act (EEG) of both 2012 and 2014 put a brake on the expansion of biogas production. In the view of the SRU, new biogas facilities should henceforth generate biogas mainly by using agricultural residues and waste.

However, the biggest challenge lies in reducing the negative impact of existing biogas plants. Therefore, the next time the German Renewable Energy Act (EEG) is amended, stronger incentives should be instituted to make energy production from biogas more flexible along with reduced electricity output and thus reduced substrate use. This would in turn reduce nitrogen pollution attributable to energy crop cultivation, while more flexible generation would promote the transition to a renewable energy system. Digestates used in agriculture should be fully incorporated into the fertilizer regulation, so as to reduce nitrogen emissions.

6. Gradually change food consumption patterns

Nitrogen surpluses can only be sufficiently reduced if more stringent environmental requirements for Germany's agricultural sector go hand in hand with changes in Germans' food consumption patterns. This particularly applies from a global standpoint, since shifting problems elsewhere through food imports should be avoided. The currently high level of consumption of animal products such as meat, eggs and milk needs to be reduced, along with food waste. Vegetable growing also can result in considerable environmental nitrogen inputs when vegetables are grown to look visually appealing. Consumer information in this sphere needs to be improved.

Consumption patterns are difficult to change. In the interest of gradually changing these patterns, the SRU recommends that a combination of target group-specific information and monetary instruments be instituted that ensure that environmental costs are reflected more strongly in the prices of animal products. For example, the lower value add-

ed tax for meat, eggs and dairy products should be abolished, and ways to maximize the impact of other non-monetary instruments should be considered. For example, the government could be a more effective role model in its capacity as the operator of many canteens, which could offer an appealing selection of vegetarian dishes and "half" meat portions.

7. Reshape the transportation sector by technical and structural measures

Effectively reducing transportation related nitrogen emissions requires both technical and structural measures. The SRU's main recommendations in this regard are as follows:

- **Optimization of emission standards:** The EU emission standards for cars, trucks and mobile machines need to be further developed. Particularly critical in this regard, in the SRU's view, is that the emission limits for diesel cars are in some cases greatly exceeded, because standard test-emissions are not in line with emissions during real-world driving. Action is urgently needed in this domain.

- **Improving environmental zones:** Environmental zones are currently used primarily to reduce particulate matter. This already leads to synergy effects related to nitrogen oxide emissions. These positive nitrogen oxide reducing effects could be strengthened by banning motor vehicles that do not adhere to stringent limit values. The SRU recommends that mobile machines such as construction machinery be included as well.

- **Put diesel cars on an equal footing with petrol-powered cars:** Diesel fuel enjoys tax advantages that are not granted for petrol. This is the main reason for the marked increase in the number of diesel passenger cars, whose nitrogen oxide emissions are currently higher than those of passenger cars with petrol engines. This tax advantage is not justified from an environmental standpoint.

- **Reduce truck emissions:** Expanding the scope of truck tolls to include all utility vehicles above 3.5 tons and all federal highways would provide an additional impetus to reduce nitrogen oxide emissions from trucks. In the SRU's view, it is also necessary to lay the groundwork in the EU for truck tolls to reflect the costs resulting from air pollution.

- **Reduce maritime shipping emissions:** Maritime shipping emissions are governed by international regulations. The SRU supports the efforts of the Federal Government to have the International Maritime Organization (IMO) classify the North and Baltic Seas as nitrogen emission control areas, so as to pave the way for the enactment of tougher emission standards in these areas.

However, over the long run this measure will not be sufficient to provide adequate human health and environmental protection. Also needed are farther-reaching changes in our transportation system, through measures such as: the development of integrated, eco-friendly mobility solutions in urban agglomerations; expanded electrification of road transport based on renewables; and, the development of more eco-friendly ship engines.

8. Reduce power plant emissions still further

Power plants are one of the main sources of nitrogen oxide emissions. The envisaged energy system transition (Energiewende) with its gradual reduction of fossil fuel based power generation

will reduce nitrogen oxide emissions in the long term. However, the operation of existing coal fired power plants with high nitrogen oxide emissions will remain economically feasible for many years to come, owing to their low operating costs. Power generation using biomass also results in substantial nitrogen oxide emissions. To address this situation, the SRU recommends the following:

– **Elaboration of a coal phaseout strategy:** The future development of Germany's fossil fuel power plant fleet should not be left to market forces alone. The government should advocate a negotiated coalphaseout strategy that will result in particularly inefficient coal fired power plants being retired first. This measure would be a plus for climate protection, and would promote the structural change in Germany's power plant fleet that is necessary for the energy transition.

– **Enact stricter limit values for power plants using fossil fuel and biomass:** The current limit values for nitrogen oxides are no longer state of the art and need to be strengthened. These stricter limit values should apply not only to the few new power plants that are in the planning (phase) today, but also to existing power plants as well, in view of the tremendous potential for reduction involved

The way forward

Emissions of reactive nitrogen compounds have risen to such a high level that planetary boundaries have been exceeded. The need for a substantial reduction in nitrogen emissions is evident at all levels of political action, from local to global environmental policies. In order for emission reduction policies to work, they need to include not only efficiency optimization measures, but also changes in lifestyle, eating habits being just one example. The policies need to be inherently transformational, in order to achieve – as the EU's Seventh Environmental Action Programme puts it – "Living well within the limits of our planet." Germany is certainly not in the vanguard when it comes to reducing nitrogen emissions. This situation needs to be fundamentally changed. This special report "Nitrogen: Strategies for resolving an urgent environmental problem" makes recommendations and proposes ideas as to how this can be accomplished.

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Secretariat:
Luisenstraße 46
10117 Berlin

Phone: (0 30) 26 36 96 -104
Fax: (0 30) 26 36 96 -109
E-Mail: info@umweltrat.de
Internet: www.umweltrat.de

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