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ENVIRONMENT DIRECTORATE
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Working Party on Biodiversity, Water and Ecosystems

Human Impacts on the Nitrogen Cycle: Scoping Paper

7-8 November 2013, OECD Headquarters, Paris

This is a scoping paper for the new project on the human impacts on the nitrogen cycle.

2013-14 PWB item: 2.3.2.3.3. Human Impacts on the Nitrogen Cycle

Action required:
-Delegates are requested to provide feedback on this scoping note, particularly with respect to the proposed methodology and outputs scheduled for 2014 and plans for 2015-16.
-Delegates are invited to indicate their willingness to take part in the Nitrogen Expert Group (NEG)
-Delegates are invited to designate a National Focal Point (NFP) to whom the questionnaire on the inventory of country policies should be directed.

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ANALYSING AND MANAGING THE HUMAN IMPACTS ON THE NITROGEN CYCLE: SCOPING PAPER

1. Introduction

1. The purpose of this note is to provide the Working Party on Biodiversity, Water and Ecosystems (WPBWE) with an overview of the key environmental, economic and health issues surrounding nitrogen and to scope out the planned project on the issue. The note is intended to provide WPBWE Delegates with an overview of the planned project in order to obtain their feedback on the scope, methodology and outputs.

2. The project on the human impacts on the nitrogen cycle takes a holistic approach to examining the impact of nitrogen flows on the environment and economic activity and the associated policy issues. The proposed project covers nitrogen flows from agriculture, industry, transport and households and will include analysis on impacts and policy options for managing the negative externalities from nitrogen. The focus of the project will be on the impacts of nitrogen flows on air, land and water.

3. Parallel to this initiative, the Working Party on Environmental Information (WPEI) is developing economy-wide nitrogen indicators (including all sources of reactive nitrogen) as overall measures of environmental performance (linking air, land and water) [ENV/EPOC/WPEI(2012)4/REV1)].

2. Background

4. In its unreactive form (N_2) nitrogen is an abundant element, and makes up nearly 80% of the earth's atmosphere. But for plants to grow and animals to thrive, they need nitrogen in a reactive fixed form that is bonded to carbon, hydrogen, or oxygen, most often as organic nitrogen compounds (such as amino acids), ammonium (NH_4), or nitrate (NO_3). Animals get their reactive nitrogen from eating plants and other animals somewhere along the food chain. And plants get reactive nitrogen from the soil or water. Most naturally-occurring reactive nitrogen comes from nitrogen fixation by bacteria, which most often live symbiotically in leguminous plants, such as soyabeans. Thus, reactive forms of nitrogen are essential inputs to food production.

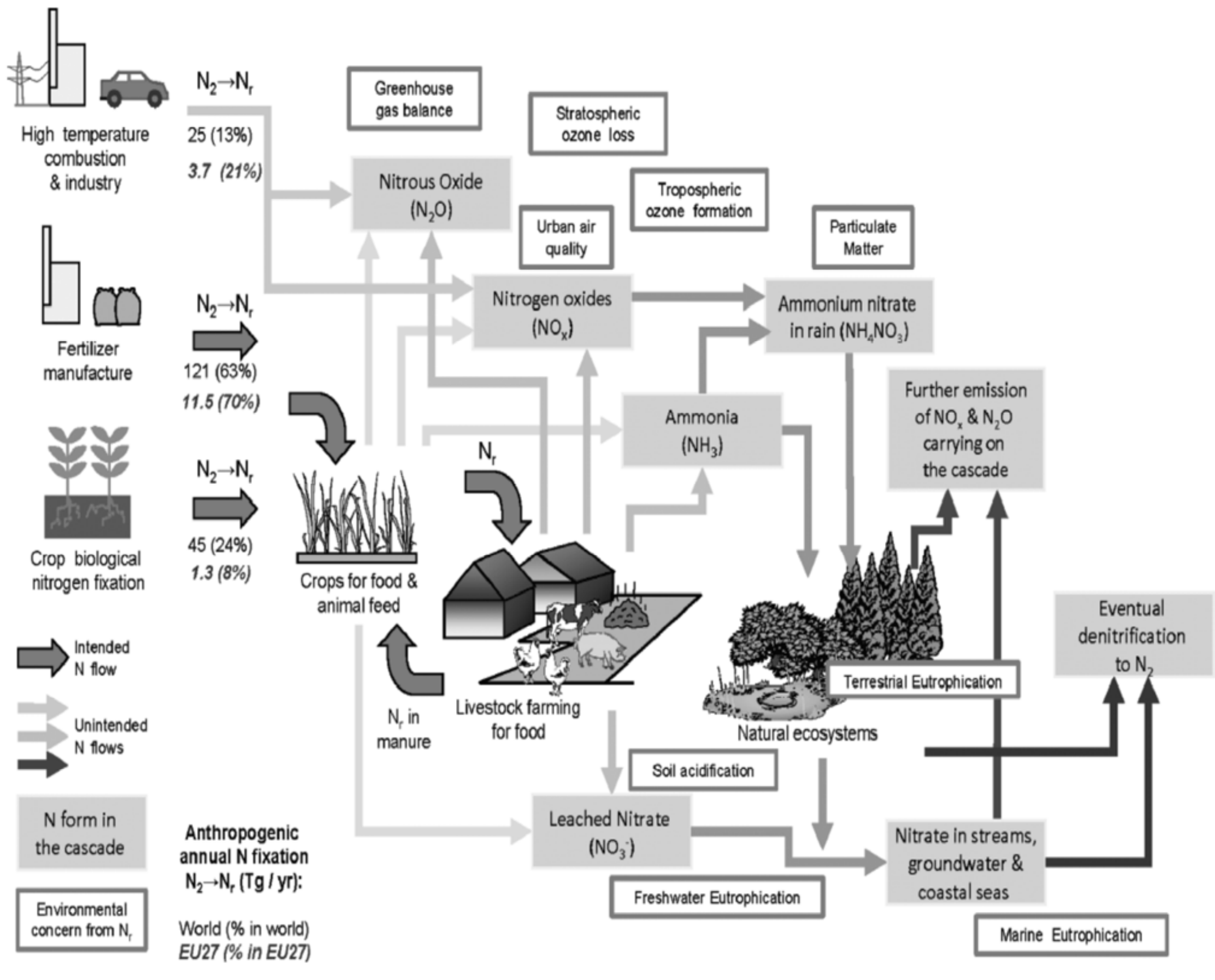
5. However, since the 1950s and as part of efforts to achieve food security, reactive nitrogen production has greatly increased, causing unprecedented changes to the global nitrogen cycle. This is largely due to the increased production of nitrogen fertiliser, by far the largest human source of reactive nitrogen. Exactly one century ago, German scientists Fritz Haber and Carl Bosch developed a way to convert unreactive atmospheric nitrogen to ammonia (the Haber-Bosch process), the reactive compound that forms the base of nitrogen fertilizer. During the twentieth century, mankind has also produced increasingly other forms of reactive nitrogen unintentionally, as a by-product of combusting fossil fuels and as a component of wastewater.

6. The global nitrogen cycle – in particular, the amount of N_2 removed from the atmosphere -- has been identified by Rockström et al (2009) as among the nine potential boundaries of the earth's ecosystem. The other boundaries are atmospheric carbon dioxide concentration, the rate of biodiversity loss, the concentration of stratospheric ozone, ocean acidification, global freshwater use, the percentage of global land cover converted to cropland, overall particulate concentration in the atmosphere, the amount of phosphorus flowing into the oceans, and chemical pollution. According to Rockström et al (2009), out of

the nine such 'planetary boundaries', three of them have already been crossed and this includes the global nitrogen cycle (the others are carbon dioxide concentration and biodiversity loss).

7. Like the earth's water, nitrogen compounds cycle through the air, aquatic systems, and soil. But unlike water, these compounds are being injected into the environment in ever-increasing quantities. There is a "cascade effect" meaning that the environmental impacts of reactive nitrogen eventually become independent of the sources (Figure 1).

Figure 1. The Nitrogen Cascade



Note. Simplified view highlighting the major anthropogenic sources of reactive nitrogen (N_r) from atmospheric nitrogen (N_2), the main pollutant forms of reactive nitrogen (shaded boxes) and nine main environmental concerns (bold-bordered boxes).
Source: Sutton et al. (2011).

8. Alteration of the global nitrogen cycle may cause possible grave environmental impacts. This includes impacts on terrestrial and aquatic ecosystems and biodiversity (eutrophying deposition of nitrogen oxides NOx and ammonia NH_3), global warming (greenhouse gas emissions of nitrous oxide N_2O), water quality (eutrophying discharge of nitrates NO_3), soil quality (acidification by nitrous acid HNO_2 and nitric acid HNO_3), air quality (NO_x emissions as a precursor of ground-level ozone) (Table 1).

Table 1. Environmental and health impacts of reactive forms of nitrogen

Water quality	eutrophication of fresh and coastal waters	• aquatic biodiversity loss (dead zones) • toxic algal blooms
	nitrate in drinking water	• colon cancer • blood oxygen deprivation (infant) • beneficial to cardio-vascular health +
	nitrate in groundwater	• aquifer contamination due to long residence time
Air quality	formation of secondary particulate matter	• respiratory problems and cancers
	formation of tropospheric (ground-level) ozone	• respiratory problems and cancers • damage to vegetation (including crops)
Climate change	nitrous oxide and tropospheric ozone	• greenhouse gases
	increases biomass growth (including forests)	• carbon sequestration +
Biodiversity	eutrophication of aquatic and terrestrial ecosystems	• species favouring high nitrogen supply out-compete other species
	acidification of terrestrial ecosystems	• direct foliar damage
Soil quality	soil acidification	• changes in soil organic matter content • loss of soil biodiversity (including some N-fixing bacteria)
	nitrogen deposition	• enhances soil fertility +

Source: Sutton et al. (2011).

9. The impacts of nitrogen on water quality are particularly evident through its contribution to the eutrophication of lakes, coastal waters and sea waters. “Dead zones”—areas of seafloor with too little oxygen for most aquatic life— are now a key stressor of water ecosystems and rank with over-fishing, habitat loss, and harmful algal blooms as global environmental problems. Diaz and Rosenberg (2008) record 405 dead zones in coastal waters worldwide, affecting an area of about the size of New Zealand. And the eutrophication risk is projected to significantly increase by 2050, as shown by the Indicator of Coastal Eutrophication Potential (ICEP)[1], putting a major threat on continued economic, social and environmental development in coastal areas.

10. Excess nitrogen is not without consequences on human health. Nitrogen is the main constituent of the air we breathe. But increased nitrogen concentrations in air may cause asphyxiation, mainly because it results in a lower oxygen concentration. Nitrogen oxides in air can cause breathing disorders. Nitrogen hydrogen acid fumes may cause irritations and heart problems.

11. We mainly absorb nitrogen as proteins.[2] These cannot be stored and are therefore directly converted to energy when not required. Nitrogen is excreted through the kidneys as urea. We also release nitrogen through the skin and the intestinal tract. When kidney failure occurs, one is incriminated with

1 Developed as part of the OECD Environmental Outlook to 2050.
2 Nitrogen is a dietary requirement, as it is a constituent of most proteins and nucleic acids.

protein decomposition products. Nitrites and amines from protein-rich food form so-called nitrosamines, which are carcinogenic substances.[3]

12. Nitrates are not generally considered toxic, but at high concentrations the body may convert nitrate to nitrite. Nitrites are toxic salts that disrupt blood oxygen transport by disrupting haemoglobin to methemoglobin conversion. This causes nausea and stomach aches for adults. For young infants it may be extremely risky, because it rapidly causes blood oxygen deprivation (blue baby syndrome). On the other hand, there is emerging evidence that the increased incidence of colon cancer in Europe is partly due to excess nitrate in drinking water.

3. The cost of inaction

13. The European Nitrogen Assessment (see section 4) has estimated the social costs of the adverse impacts of N_r in the European environment. The highest unit values (EUR/kg of N_r emission) are associated with air pollution (health effects of NO_x), water pollution (effects on aquatic ecosystems) and ammonia (health effects via particulate matter).[4] The smallest unit values are associated with nitrates (health effects of drinking water) and nitrous oxide (health effects of depleting stratospheric ozone).

14. Combining these unit costs with the total amount of N_r emissions, the European Nitrogen Assessment estimates the Nr -related damage cost in EU-27 at EUR 70–320 billion per year, of which 75% is related to air pollution (Table 2). This represents a total damage cost of EUR 150–750 per person, or 1–4% of the average European income.

Table 2. Damage costs of nitrogen pollution (EUR billion/year at 2000)

	Nitrogen oxides NO_x	Ammonia NH_3	N_r loss to water	Nitrous oxides N_2O	Total
Human health	35-100	5-70	0-20	< 5	40-190
Ecosystems	5-35	5-35	15-50	-	25-115
Climate	-	-	-	5-10	5-10
Total	40-135	10-105	15-70	5-15	70-320

Source: Sutton et al. (2011).

4. International initiatives on nitrogen

15. Other stakeholders are also working on different aspects of the nitrogen challenge. These include the International Nitrogen Initiative (INI), formed by scientists in 2003 to help minimise the adverse environmental and human health impacts of nitrogen while optimising its role in sustaining food production and energy use. A major contribution to the work of INI is the European Nitrogen Assessment, which was launched in 2011 under the auspices of the UNECE's Convention on Long Range Transboundary Air Pollution (LRTAP). Presenting the first continental-scale assessment of reactive nitrogen in the environment, the *Assessment* stresses the need for a more holistic research and management strategy in relation to nitrogen given the complex web of nitrogen-related issues and the range of instruments and bodies they involve.

3 This reaction may be prevented by the reducing and anti-oxidant properties of vitamin C.
4 There is uncertainty as to the share of Nr in the formation of secondary particulate matter and in freshwater eutrophication.

16. The European Nitrogen Assessment (ENA) has identified several policy priorities to address the global nitrogen challenge. These include measures in the agricultural sector (e.g. more efficient nitrogen use in crop and animal production through improving farm nitrogen balance and the nitrogen content in feed and manure), the energy and transport sectors (e.g. more energy efficient cars and power plants, promoting alternative energy sources), the wastewater sector (e.g. reuse instead of treat nutrients), as well as dealing with consumption patterns (e.g. reduce transport distances, promote purchase of energy-saving houses, lower the fraction of animal products in diet).

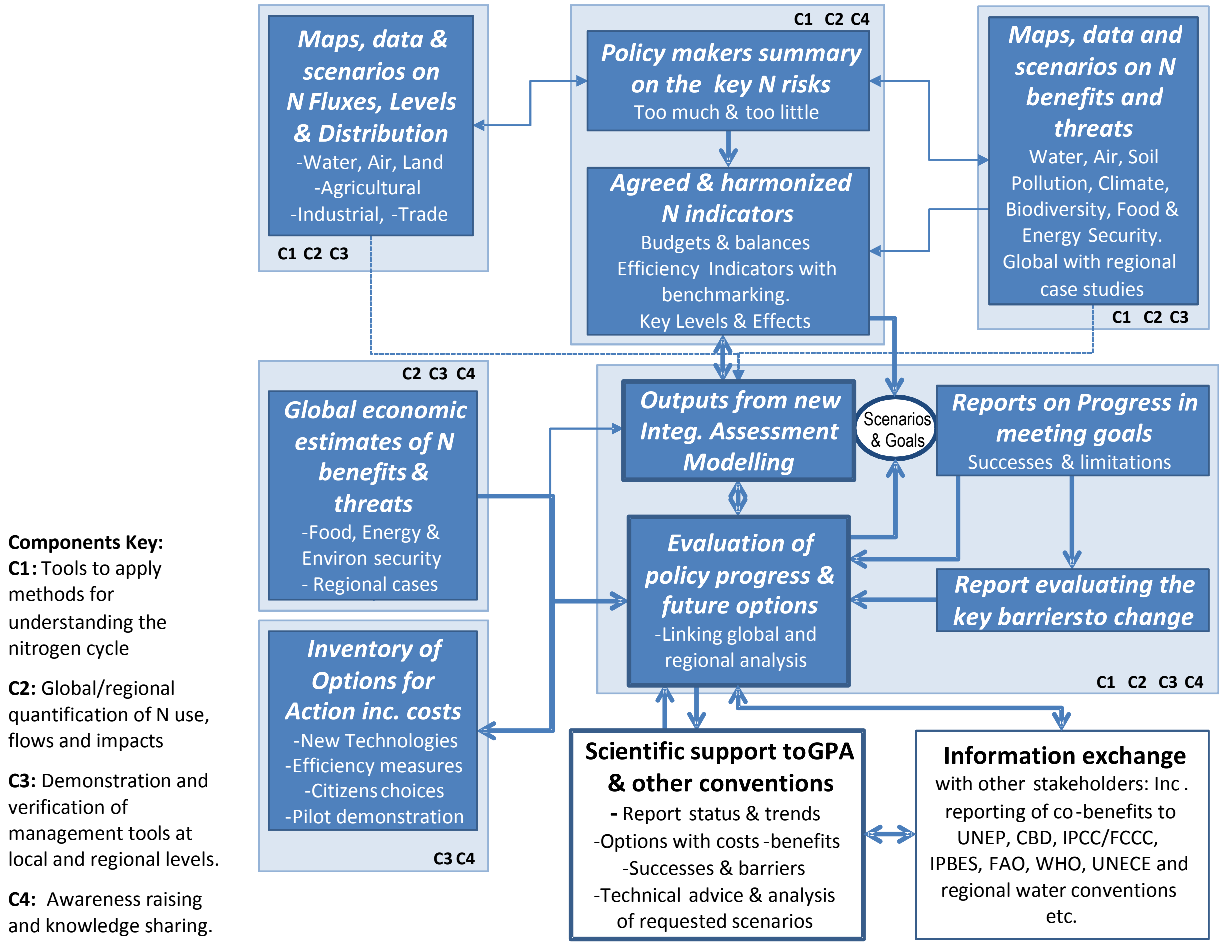
17. Adopted in 1995 and coordinated by UNEP, the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities (GPA) is the only global initiative directly addressing the connectivity between terrestrial, freshwater, coastal and marine ecosystems. The GPA is an intergovernmental body that helps governments develop and implement national programmes of action to prevent the degradation of the marine environment from land-based activities. To date 77 countries have developed national programmes of actions and are in various stages of their implementation. The 3rd Intergovernmental Review Meeting on the Implementation of the GPA (IGR-3), held in Manila in 2012, identified nutrient management (including nitrogen) as one of the core priorities for the GPA, as endorsed by the Manila Declaration.

18. Through the coordination of the GPA, UNEP provides the Secretariat of the Global Partnership on Nutrient Management (GPNM). The GPNM was established in 2007 to steer dialogue and actions to promote effective nutrient management. A key outcome from the GPNM is *Our Nutrient World*, a global overview on nutrient management that was released in 2013. The message of this overview is that everyone stands to benefit from nutrients and that everyone can make a contribution to promote sustainable production and use of nutrients.

19. But the resources available to the GPA are currently limited, while the role of the INI and GPNM are primarily partnerships/NGOs, drawing on diverse and often unconnected resources. With a view to undertake a global nitrogen assessment, on the model of the European one, scientists are proposing to develop a more structured International Nitrogen Management System (INMS), which would pull together the substantial diverse efforts to deliver the necessary coordinated global scientific input, which is currently missing from GPA, and provide input to other international policy frameworks (Figure 2). Creation of the INMS is conditional upon funding by the Global Environment Facility (GEF).

20. Launched at Rio+20, the Global Partnership for Oceans (GPO) assembles a coalition of over 140 governments, international organizations, civil society groups, and private sector interests committed to ocean health. The Partnership mobilizes finance and knowledge to tackle documented problems of overfishing, coastal and ocean habitat loss and pollution. This includes supporting implementation of the GPA to reduce pollution, particularly from marine litter, wastewater and excess nutrients, and further develop consensus for achievable goals to reduce these pollutants. The Partnership will work toward meeting the above objectives by 2022.

Figure 2. The proposed International Nitrogen Management System



Note. Key INMS deliverables as part of the scientific support process (shaded boxes) and as input to international policy processes (white boxes). The relationship of each of the work areas of INMS to the four main project components (C1, C2, C3, C4) is shown.
Source: Sutton (pers. comm.).

21. The European Nitrogen Assessment (ENA) is a major breakthrough in understanding how nitrogen management success depends on addressing all the nitrogen sources concomitantly. Indeed, an important consequence of the nitrogen cascade is that the environmental impacts of reactive forms of nitrogen (Nr) eventually become independent of the sources, so that nitrogen management requires a holistic approach. But so far, most policy measures aimed at decreasing unwanted Nr emissions from combustion, agriculture and urban wastewater have adopted an 'effects-based approach' and have focused on single Nr compounds, single sectors and either air or water. Given the range of adverse environmental effects in the Nr cascade, the most attractive mitigation options are those that offer simultaneous reductions of all Nr pollutants from all emitting sectors and in all environmental compartments.

5. Proposed scope and objective of the project

22. The EPOC project is proposed to examine:

- for each sector (combustion, agriculture and urban wastewater), the factors and policies that contribute to the effectiveness and efficiency of N_r management
- the effectiveness and efficiency of more integrated N_r management and policies

23. The project could start with a comprehensive review of policies to address N_r for all media (air, land and water) and from all sources -- including fossil fuel combustion (industry, energy production and transport), agriculture, and urban wastewater. This would include the full range of policy instruments (direct regulatory instruments, market-based instruments, public financial support). Specific attention would be paid to markets for ecosystem services as a way to meet N_r objectives by purchasing reductions, or offsets, from lower cost sources of N_r. NO_x and water quality trading are examples of such markets. The project would look at barriers to policy implementation (e.g. design issues and high transaction costs have so far limited the success of water quality trading).

24. The project would examine ongoing integrated Nr management policies. For instance, Germany's integrated Nr strategy outlines that most of the potential for reduction of Nr is in the agriculture sector (UBA 2009).

25. The project would assess risk-risk trade-offs.[5] Indeed an important consideration in any policy aimed at reducing N_r impacts on the environment is the ability of nitrogen to change chemical form and circulate throughout the environment. Focusing on a single environmental problem can exacerbate another. For example, switching from surface application of manure on farmland to incorporation/injection to reduce ammonia emissions can increase nitrate leaching and the threat to groundwater; similarly, switching from fall to spring application to reduce the threat of leaching can increase the emissions of nitrous oxide, a powerful greenhouse gas (Ribaudo, 2011).

26. Finally, the project would address policy coherence. Clearly, the effective management of the nitrogen cycle is an extremely challenging and complex task, involving many different processes, and sources from many different economic sectors. Developing integrated holistic policies to manage N_r will demand that these policies be coherent with other policies (e.g. N_r increase in agriculture is partly linked to increased biofuel production to meet climate objectives). The ultimate goal is to promote effective N_r management (i.e. reducing N_r at least cost to the economy).

27. The overall outcome of the project is to advise governments on the economic policy issues in managing economic, environmental and health risks from N_r. The project will assist countries in reform efforts through providing practical guidance on the design and use of policy instruments and identify best practices.. In particular, the project aims to:

- make the economic case for improved nitrogen management in a holistic manner through looking at the nitrogen cycle
- propose coherent and holistic approaches to manage nitrogen in air, land and water
- identify the main areas of reform as well as the analysis/tools that can support such reforms
- help a core group of governments who face severe nitrogen challenges to develop and implement policy reform.

6. Proposed methodology

28. It is proposed that the work take place over the next three years, from 2014 to 2016. The initial phase of the project would focus on information gathering and a literature review and would be undertaken in 2014. The second phase of the project could be undertaken in 2015-16 but would be subject to approval from EPOC as part of the PWB discussions for 2015-16. This second phase could address country case studies and an agenda for policy action. The following pages describe each of these phases in more detail.

[5] A risk-risk trade-off occurs when interventions to reduce one Nr risk can increase other Nr risks.

Proposed work for 2014

29. It is proposed to initiate the work in 2014 with:

- a review of the literature on the economics of nitrogen and the impacts on the economic and environmental outcomes
- an inventory of OECD and key partner countries' policies in relation to nitrogen, based on a questionnaire, with focus on the agriculture, air quality and wastewater sectors

30. These activities would parallel the indicator and modelling work carried out in the context of the global nitrogen assessment, as part of the proposed International Nitrogen Management System (INMS) initiative, and to which the Working Party on Environmental Information (WPEI) will contribute.

31. It is also proposed to include a module on phosphorus, which excess or shortage strongly influences the Nr impacts on water ecosystems.

32. The outputs in 2014 from this phase of the work would be:

- a report on the policy challenges and the current policy landscape in OECD and key partner countries
- a website with the country inventory information
- analysis of the phosphorus market and what that means for the use, disposal and recycling of phosphorus.

Proposed work for 2015-16

33. Following on the work initiated in 2014, the next phase of the project outcome could consist of two discrete, but inter-related components: a series of country case studies to review policies in place and identify best practices; a report on policies to address integrated nitrogen management.

Output 1: Country case studies

34. The project is planned to look at how countries are managing N_r in selected areas at risk with the aim to understand obstacles to reform and develop best policy practices.

35. Focus would be on policy instruments (direct regulatory instruments, market-based instruments, public financial support) for the three sectors most responsible for N_r releases: wastewater, agriculture and air quality. Building on previous OECD work in these areas, the project would review implementation of policy instruments in selected countries/areas. The aim is to develop a set of case studies in order to identify good practices in the design and implementation of policy instruments for the three sectors.

36. Country case studies would aim to build consensus on different economic and financial aspects of the policy reform agenda in the three sectors and could be supported by workshops, provided sufficient funding is made available.

37. Subject to discussions with the participating countries, each of the case studies could be structured into a number of analytical phases:

- **Phase 1 – Identify the risks**. Assess the N_r-related areas at risks that currently exist (weak spots), as well as their evolution over time as a consequence of economic and demographic growth and due to possible impacts of climate change. This would rely on existing data and models.

- **Phase 2 – Identify measures to address the risks**. This phase of work would focus on translating the N_r risk into a plan of measures that allows to manage the risks, estimate the costs of these measures, identify the available finance to cover those costs as well as a possible financing gap. The plan of measures could include discussions of reforms to improve coherence between sector policies.

Output 2: Report on policies for action

38. Drawing on the country case studies, the framework for action report would provide input and guide efforts to support in-country reform processes. In particular, the report would discuss the following issues:

- What are the key N_r challenges and the consequences of inaction
- What do we know about policies to address N_r (key concepts and instruments in air, land and water management)
- What are the main barriers to integrated N_r management
- Where is transformational change needed and how and can it be achieved

39. Analysis and papers on specific topics within this broad project could be developed to support the overall report. These could be done in conjunction with individual member countries, or a group of interested member countries, or with partner organisations (such as WBCSD). Specific issues to be pursued could include:

- **Value of an acceptable level of nitrogen**. This module would help identify and better value the benefits of acceptable levels of N_r in air, land and water as they accrue to different requirements such as human needs, business and the environment. The work would complement the preliminary ENA assessment of the estimated loss of welfare due to N_r emissions in Europe. A key outcome of the module would be to help highlight the benefits of managing N_r to the range of actors including governments, business, consumers, and NGOs, and to facilitate the dialogue between sectors and finance ministries.
- **Markets for ecosystem services as a way to meet N_r objectives**. This module would review the existing N_r markets in air and water and look at barriers to their development.
- **Market-based instruments for N_r management**. Building on previous OECD work in the areas of wastewater, agriculture and air quality (e.g. *Instrument Mixes for Environmental Policy*), this module would review implementation of market-based instruments in selected countries. The aim of the module would be to identify good practices in the design and implementation of market-based instruments in and across these sectors.

40. Delegates may wish to identify additional specific topics that they wish to see addressed as a supporting module in the project.

7. Possible project governance

41. At the technical level the project could be guided by a steering group – the Nitrogen Expert Group (NEG) – that would bring together policy makers. This group could meet regularly (including by teleconference) and would ensure a formalised and sustainable input from OECD policy-communities into the project.

8. Co-ordination with other Directorates, Committees and Working Parties

42. Co-operation with other relevant Committees and Working Parties will be sought in reviewing and commenting on intermediate and final outputs from the project. Key bodies in this regard are the Working Party on Environmental Information, the Joint Working Party on Agriculture and the Environment, and the International Transport Forum.

9. Co-operation with other organisations

43. The OECD Secretariat will liaise and coordinate with key IGOs that are engaged in nitrogen policy work. In particular, these include:

- UNEP, who hosts the Secretariat of the Global Partnership on Nutrient Management (GPNM) -- a platform for governments, UN agencies, scientists and the private sector to forge a common agenda, mainstreaming best practices and integrated assessments

- the World Bank, who hosts the Secretariat of the Global Partnership for Oceans (GPO), a growing alliance of governments, international organizations, civil society groups, and private sector interests committed to addressing the threats to the health, productivity and resilience of the ocean

- the Secretariat of the Convention of the Biological Diversity (CBD), who supports the goals of the Convention, in particular the 2020 target to bring pollution, including from excess nutrients, to levels that are not detrimental to ecosystem function and biodiversity (Aichi target 8)

44. In addition, the input of BIAC and the World Business Council on Sustainable Development (WBCSD) will be crucial in ensuring a solid engagement with the business sector in the analysis and findings of the project.

10. Action required

- Delegates are requested to provide feedback on this scoping note, particularly with respect to the proposed methodology and outputs scheduled for 2014 and plans for 2015-16.
- Delegates are invited to indicate their willingness to take part in the Nitrogen Expert Group (NEG).
- Delegates are invited to designate a National Focal Point (NFP) to whom the questionnaire on the inventory of country policies should be directed.

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