National Nitrogen Budgets

Summary for policy makers

Introduction

Reactive nitrogen (Nr) is a highly mobile and convertible form of an element that plays an indispensable role in nature and in many human processes. As a plant nutrient and to maintain soil fertility, nitrogen is an essential component of productive agricultural systems. At the same time, anthropogenic emissions of Nr lead to a variety of environmental problems. The release of Nr into the environment occurs in almost every area of human activity, e.g. air and water pollution through agricultural activities, transport, industry or power generation. Once set free into the earth's biogeochemical cycle, nitrogen is highly mobile and can pass through various forms and environmental media in succession and have various undesirable environmental effects (which in its sequence is called the nitrogen cascade[i]). In order to minimize the harmful effects of Nr on humans and the environment, it is of great importance for environmental policy to know as precisely as possible the quantities of reactive nitrogen that enter the environment in various forms and harm humans and the environment. It is also helpful to quantify exchange processes by which Nr is converted from one form to another or shifted from one environmental domain or sector of the economy to another.

Nitrogen budgets are a proven policy tool for quantifying the sources and fate of nitrogen.

The Convention on Long-range Transboundary Air Pollution (CLRTAP) in 2012 adopted a Guidance Document to assist in the calculation of national nitrogen budgets (NNB) (ECE/EB.AIR/119). This guidance, and its technical annexes, has been thoroughly updated for full internal consistency and usability. The revised version is ready for adoption in 2025, with the completed annexes and data templates available at https://www.clrtap-tfrn.org/epnb. NNBs are an efficient instrument for visualizing the whole N cascade of a country including losses from all sectors and their potential impact. They provide policy makers with information for identifying intervention points and developing efficient emission reduction measures, they help to monitor the impact of implemented policies and they are useful for comparisons across countries. Last but not least they can help pinpoint knowledge gaps and thus contribute to improving the scientific understanding of the nitrogen cascade. Specifically, they support the implementation of the Gothenburg Protocol of the CLRTAP (Article 7, 3. d) and of the National Emission reduction Commitments (NEC) Directive of the European Union (Annex 3, Part 2) and provide a tool for observing the attainment of nutrient reduction targets as set by the EU Farm-to-Fork-Strategy or by the Global Biodiversity Framework of the Convention on Biological Diversity (CBD).

Standardized instruments for easy application

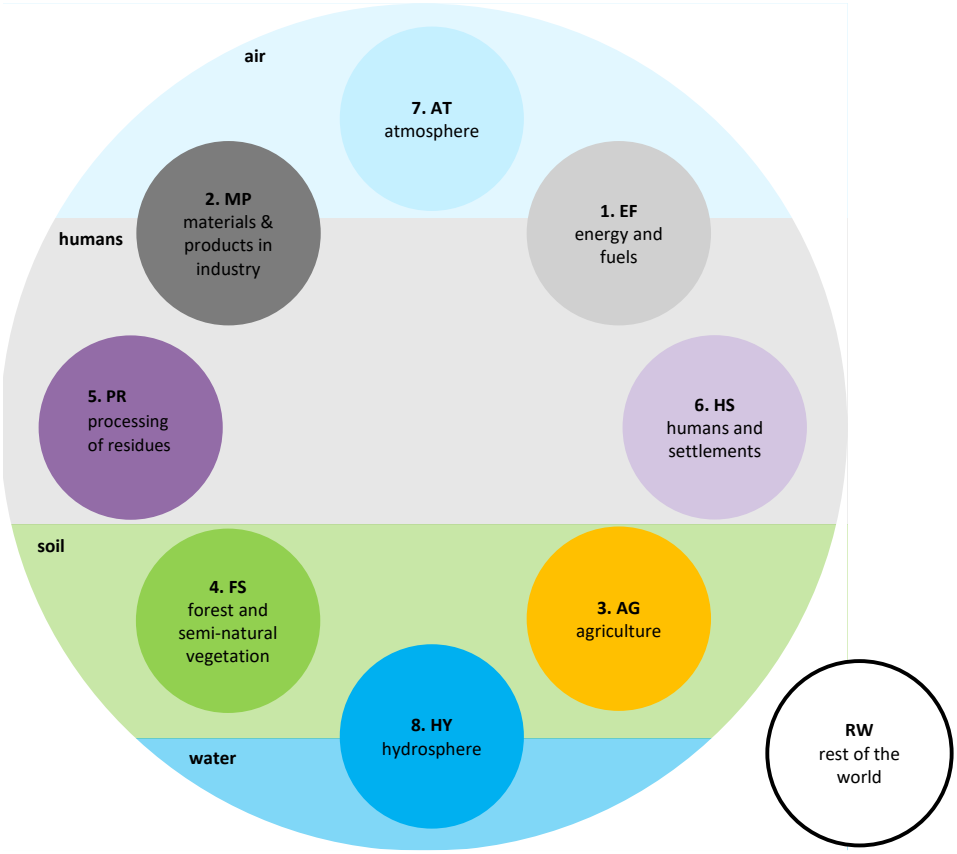
The technical annexes to the Guidance Document[ii] describe in detail the methodological approach for the development of a NNB. Nitrogen budgets explain the exchange of quantities of nitrogen between environmental compartments, the economy, and the society within the national borders. NNBs are established by describing pools, sub-pools and the flows of Nr between the pools and sub-pools. The NNB defined under the Task Force on Reactive Nitrogen includes eight pools, notably "energy and fuels (EF)", "material and products in industry (MP)", "agriculture (AG)", "forest and semi-natural vegetation (FS)", "processing of residues (PR)", "humans and settlements (HS)", "atmosphere (AT)" and "hydrosphere (HY)" (Figure 1).

Transboundary exchanges across country boundaries are considered as flows from/to the "rest of the world (RW)". For each of these pools, specific guidance is provided on how to inventory and calculate relevant Nr flows, including calculation methods and suggestions for possible data sources.

In a NNB, a mass balance can be established for each pool. For that purpose, each flow into and out of each pool is quantified, as well as the stock changes for each pool. Total N inputs then equal the sum of total N outputs plus stock changes. While the procedure requires the inclusion of all relevant flows of reactive N species (to be specified up to a country average threshold of 1 kg N per person and year), for unreactive molecular N_2, only those N flows are relevant that are connected to a transformation of N_2 to a reactive form of nitrogen or vice versa. Examples for such a transformation are the nitrogen fixation through the Haber-Bosch-Process, or the loss to the atmosphere of N in wastewater by denitrification in a treatment plant.

In addition to the Annexes, a data collection template was developed using MS Excel®, which provides a list of 192 relevant N flows. The template also allows to create figures and tables showing the results of the NNB in a harmonized way. In addition, it allows to retrieve information on the resulting nitrogen use efficiencies (NUE) and displays time series of input and output flows, as well as N waste and N losses to the environment. For visualization, the material flow modelling system STAN was set up with a "Nitrogen budget visualization tool" to directly import above-mentioned template.

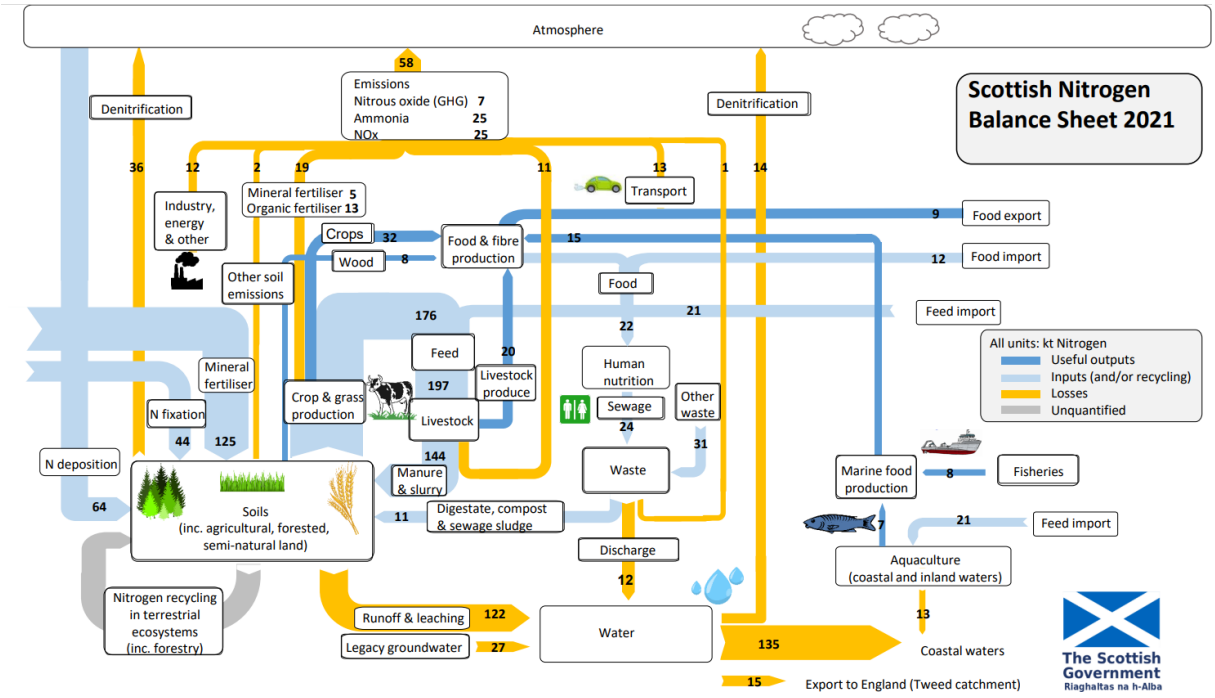
Figure 1: Overview of pools covered in National Nitrogen Budgets



Examples for successful national application

Numerous countries within and outside the UNECE have already collected experiences in setting up National Nitrogen Budgets. Examples based on UNECE Guidance Document include Germany[iii], Scotland[iv] and Austria[v]. While data for Germany are used as an indicator and scientific basis for the development of a national nitrogen strategy, in Scotland the "Climate Change (Nitrogen Balance Sheet) (Scotland) Regulations 2022" require the Scottish Ministers to establish a nitrogen balance sheet[iv], with the core purpose to record how "nitrogen use efficiency" contributes to achieving Scotland's national greenhouse gas emissions reduction targets on an annual basis.

Figure 2: Simplified Full Flow Diagram of the first Scottish Nitrogen Balance Sheet 2021[iv]



Broader international application

The concept of national nitrogen budgets has found application beyond Europe already. Based on a somewhat different and simplified approach, but enriched with a wealth of detailed data collected, nitrogen budgets have been made available for countries such as China, Australia, or Japan. For New Zealand and Canada, again with somewhat different methodology, nitrogen budgets have also been made available. Yet, for the time being, these were scientific activities, attempting to improve the robustness of nitrogen flow data for use in other modelling activities (referring to processes in the hydrosphere or atmosphere). United Nations Environment Programme (UNEP) has been instrumental in supporting the development of a framework for an International Nitrogen Management System (INMS), through the "Towards INMS" project. In the toolbox of this framework, specific account is taken of national nitrogen budgets. An INMS guidance document[vi] is due

to be released shortly, bringing together the many different attempts in quantifying the nitrogen cascade.

Main message

Nitrogen budgets as policy instruments are becoming simple and straightforward tools to validate efforts to halve nitrogen waste as proposed in the "Colombo Declaration", and to implement the UNEA resolutions on sustainable nitrogen management (UNEA 4/14 and UNEA 5/2). In this context, NNBs are able and ready to support a number of additional international agreements, such as the Gothenburg Protocol, the NEC Directive, the Montreal Protocol, the UN Framework Convention on Climate Change, the Convention on Biological Diversity, and the Global Program on Action for the protection of the marine environment from land-based activities.[vii]

References

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