Working Group on Strategies and Review, 52nd Session
Informal document
ENA Special Report on Nitrogen and Food: Overview

During the reporting period, TFRN launched the Executive Summary of an ENA Special Report on Nitrogen and Food - *Nitrogen on the Table: The influence of food choices on nitrogen emissions and the European environment.* This informal document contains the Foreword and the Executive Summary from that report which was undertaken by the Expert Panel on Nitrogen and Food of TFRN.

Attached separately is the Westhoek et al. 2014 paper, 'Food choices, health and environment: Effects of cutting Europe's meat and dairy intake', which is an accompanying peer reviewed publication on the work of the report.

Nitrogen on the Table

Foreword

This report has its origins in the very first meeting of the Task Force on Reactive Nitrogen (TFRN-1), which took place in Wageningen, The Netherlands, May 2008. The Task Force had recently been established by the Executive Body of the UNECE Convention on Long-range Transboundary Air Pollution (LRTAP), reflecting an emerging recognition of the importance of nitrogen in the environment.

The TFRN has the "*long-term goal of developing technical and scientific information, and options which can be used for strategy development across the UNECE to encourage coordination of air pollution policies on nitrogen in the context of the nitrogen cycle and which may be used by other bodies outside the Convention in consideration of other control measures*" (UNECE, 2007). Hence, the Task Force should develop a broad view, placing nitrogen air pollution in the context of wider challenges.

Traditionally, the work of the Convention had focused primarily on technical measures as a means to achieve national reductions in air pollution emissions. But, as the discussions of TFRN-1 developed, it became clear that total reactive nitrogen (N_r) emissions are also very sensitive to society's food choices. For some in the Convention this initially seemed an uncomfortable topic for discussion. The focus of such an inter-governmental framework was seen as being on the technical options to be implemented by source sectors, such as electricity generation, transport and agriculture. Was not dietary choice outside the remit of the Convention and too sensitive a matter to discuss?

Those initial discussions at TFRN-1 made it clear that dietary choice had to be part of the wider analysis with which the group was tasked. The parallel was quickly made with emissions of nitrogen oxides (NO_x) from transport: technical measures – in the form of three-way catalysts and engine improvements– had greatly reduced emissions per vehicle mile, but these gains had been significantly offset by a substantial increase in vehicle miles driven. The discussion about nitrogen and food was, in principle, no different (Sutton, 2008). The potential gains made by future adoption of low nitrogen emission practices in farming could easily be lost by an increase in consumption of high-nitrogen foods, which in practice meant livestock products (Steinfeld et al., 2006).

This thinking led to the development of new global scenarios (up to 2100) of reduced meat and dairy consumption in the developed world, as compared with a consideration of "food equity", where rates of dietary intake would increase among the world's poorest (Erisman et al., 2008)[1]. It also fed into the development of the European Nitrogen Assessment (ENA, 2011). The same week of TFRN-1 in Wageningen saw the first workshop of the ENA process, allowing its outcomes to be reported immediately to the Task Force. It became clear that the eventual ENA product would need chapters that considered future dietary aspirations, including consideration of reduced meat consumption (e.g. 'healthy diet' scenario, Winiwarter et al., 2011) and the challenge to communicate nitrogen to society (Reay et al., 2011).

The experience of launching the ENA has shown that there is huge merit in coupling discussions about agricultural technical measures with society's food choice aspirations. Few members of the

[1] An update of the Erisman et al. (2008) scenarios, which were based on the SRES approach (Special Report on Emissions Scenarios), has recently been published by Winwarter et al. (2013) using the RCP approach (Representative Concentration Pathways).

public get excited to talk about improved manure management options. But everyone is interested in food. By discussing both together, there is the opportunity to engage the public in why they need to know about the nitrogen cycle. In this way, the scientific community can highlight the many benefits and threats of reactive nitrogen across the planet, ranging from food and energy security to threats to water, air and soil quality, climate and biodiversity. It also illustrates how a joined-up approach to managing the nitrogen cycle would lead to multiple benefits for society (Sutton et al., 2011).

While publication of the ENA represented a key advance in raising the profile of these issues, it was not possible to bring all the threads to completion by that time. The TFRN-1 meeting of 2008 had highlighted that the Task Force needed to pay increased attention to the importance of food choice. However, there were urgent matters in hand, especially in synthesizing the technical options for ammonia mitigation to support revision of the Gothenburg Protocol. These included progressing options for revision of the Protocol's Annex IX (on mandatory measures for ammonia, UNECE, 2011), updating the estimated costs of ammonia abatement (UNECE, 2011), revising the supporting Ammonia Guidance Document (UNECE, 2014; Bittman et al., 2014) and developing a new guidance document on national nitrogen budgets (UNECE, 2013). Effective progress in these actions was achieved by the Task Force working through its Expert Panel on Mitigation of Agricultural Nitrogen (EPMAN) and its Expert Panel on Nitrogen Budgets (EPNB).

In order to bring forward the scientific analysis on food choice relationships, the Task Force therefore agreed in 2009 to establish a new Expert Panel on Nitrogen and Food (EPNF) (UNECE, 2009, paragraphs 25-26). The Panel was subsequently launched in 2010 under the co-chairmanship of Mr Henk Westhoek (PBL, The Netherlands) and Mr Christian Palliere (Fertilizer Europe, Belgium).

The initial emerging messages from the work of the Expert Panel have already been reported to the LRTAP Convention's 'Working Group on Strategies and Review' (UNECE, 2012, paragraphs 19-20). Since then, the work has continued, allowing completion of the present full report, accompanied by two peer review papers (Westhoek et al., 2014; Leip et al., 2013). As a logical continuation of the European Nitrogen Assessment, we here publish the findings in the form of an 'ENA Special Report'.

Based on these outcomes, the Executive Summary of the present report was presented to the press in April 2014, supported with the further details given by Westhoek et al. (2014). The strong press interest and public feedback has clearly illustrated the power of the food choice debate in highlighting the role of nitrogen in the environment.[2]

Consistent with the mandate of the Expert Panel, the present report does not focus on how to achieve such changes in diets across European society. It is sufficient for the moment to demonstrate the close relationship between our food choices, environmental pollution and human health indicators. The next step is to develop the discussion with the public, politicians, international treaties and across academia.

In this way, the LRTAP Convention's work on nitrogen provides a starting point for governments and society to discuss what is the right balance of effort: between implementing new technical measures in agriculture and fostering change in dietary choices. Whatever the outcome of that debate, it is clear from the present report that reducing European consumption of meat and dairy products would make a significant contribution to reducing nitrogen air and water pollution and greenhouse gas emissions. At

[2] See for example, Agriculture and Rural Convention (2014), Beament (2014), Chertsey (2014), www.dNmark.org, Jones (2014), Kirby (2014), Midgely (2014), Vaugham (2014) and Webster (2014) and associated public discussion.

the same time there would be significant benefits for human health, while freeing up substantial areas agricultural land to help meet global food security and energy security goals.

Mark A. Sutton, Oene Oenema[a], Tommy Dalgaard[b]

Co-chairs of the UNECE Task Force on Reactive Nitrogen.

a, Co-chair until 2013; b, Co-chair from 2014.

Clare M. Howard

Task Force Co-ordinator, TFRN.

Edinburgh, Wageningen and Aarhus, May 2014

References

Agriculture and Rural Convention (2014) Part 1: how to cut EU agri-food Greenhouse Gas Emissions by 40%. 5 May 2014. http://www.arc2020.eu/front/2014/05/heres-how-to-cut-the-eus-agri-food-greenhouse-gas-emissions-by-40/

Beament E. (2014) Halve meat consumption to 'slash nitrogen pollution' *Press Association.* 25 April 2014. e.g. http://www.irishexaminer.com/archives/2014/0425/world/halve-meat-consumption-to-aposslash-nitrogen-pollutionapos-266476.html

Bittman, S., Dedina, M., Howard C.M., Oenema, O. and Sutton, M.A. (2014) (eds.) *Options for ammonia mitigation: Guidance from the UNECE Task Force on Reactive Nitrogen.* TFRN-CLRTAP, Centre for Ecology and Hydrology, UK. [ISBN: 978-1-906698-46-1]

Chertsey N. (2014) EU should halve meat, dairy consumption to cut nitrogen - report. *Reuters*, 25 April 2014. http://www.reuters.com/article/2014/04/25/food-environment-idUSL6N0NH1X120140425

ENA (2011) *The European Nitrogen Assessment. Sources, Effects and Policy Perpectives.* Eds. Sutton M.A., Howard C.M., Erisman, J.W., Billen, G., Bleeker, A.,Grennfelt, P.,van Grinsven, H., and Grizetti, B. Cambridge University Press.

Erisman J.W., Sutton M.A., Galloway J.N., Klimont Z. and Winiwarter W. (2008) How a century of ammonia synthesis changed the world. *Nature Geoscience* **1**, 636-639, DOI: 10.1038/ngeo325

Jones J. (2014) Halving your meat intake would be good for the environment. *Planet Earth Online*, 25 April 2014. http://planetearth.nerc.ac.uk/news/story.aspx?id=1661

Kirby A. (2014) Be a demitarian and cool the climate. *Climate News Network*, 27 April 2014. http://www.climatenewsnetwork.net/2014/04/be-a-demitarian-and-cool-the-climate/

Leip A., Weiss F., Lesschen J.P. and Westhoek, H. (2013) The nitrogen footprint of food products in the European Union. *Journal of Agricultural Science*. doi:10.1017/S0021859613000786.

Midgley O. (2014) Eating less meat will slash nitrogen pollution, scientists claim. *Farmers Guardian*, 25 April 2014 http://www.farmersguardian.com/home/livestock/eating-less-meat-will-slash-nitrogen-pollution-scientists-claim/63943.article

Reay D.S., Howard C.M., Bleeker A., Higgins P., Smith K., Westhoek H., Rood T., Theobald M.R., Sanz Cobeña A., Rees R.M., Moran D. & Reis S. (2011) Societal choice and communicating the European nitrogen challenge, Chapter 26 in: (Eds. Sutton M.A., Howard C.M., Erisman J.W., Billen G., Bleeker A., Grennfelt P., van Grinsven H. and Grizzetti B.) pp 585-601, *The European Nitrogen Assessment*, Cambridge University Press, Cambridge.

Steinfeld H., Gerber P., Wassenaar T., Castel V., Rosales M. and de Haan C. (2006) *Livestock's Long Shadow. Environmental Issues and Options.* UN Food and Agriculture Organization, Rome.

Sutton M. (2008) Snared in a homemade 'NitroNet'. *The Green Room, BBC News*, 8 July 2008. http://news.bbc.co.uk/1/hi/sci/tech/7496036.stm

Sutton M.A., Oenema O., Erisman J.W., Leip A., van Grinsven H. and Winiwarter W. (2011) Too much of a good thing. *Nature* **472**, 159-161.

TFRN (2010) Proposed aims, structure and limitation of work of the TFRN Expert Panel on Nitrogen and Food (EPNF). UNECE Convention on Long-range Transboundary Air Pollution, Working Group on Strategies and Review, 47th session. Informal document No. 18: Submitted by the Co-chairs of the Task Force on Reactive Nitrogen. http://www.unece.org/env/lrtap/WorkingGroups/wgs/docs47th%20session.htm

UNECE (2007) Establishment of a Task Force on Reactive Nitrogen Decision 2007/1. Executive Body of the Convention on Long-range Transboundary Air Pollution. United Nations Economic Commission for Europe. http://www.unece.org/env/documents/2007/eb/EB/EB%20Decisions/Decision%202007.1

UNECE (2009) Options for revising the Gothenburg Protocol. Reactive Nitrogen. Report by the co-chairs of the Task Force on Reactive Nitrogen. (Working Group on Strategies and Review 45th session). Including an Annex: Report on work in progress on annex IX of the Gothenburg Protocol ECE/EB.AIR/WG.5/2009/12 (in English, French, Russian) http://www.unece.org/env/lrtap/WorkingGroups/wgs/docs45th%20session.htm

UNECE (2011a) Options for revising annex IX of the Gothenburg Protocol. Reactive Nitrogen. Report by the co-chairs of the Task Force on Reactive Nitrogen. (Working Group on Strategies and Review 48th session). ECE/EB.AIR/WG.5/2011/6 (in English, French, Russian) (see also ECE/EB.AIR/WG.5/2010/13 and ECE/EB.AIR/WG.5/2011/16) http://www.unece.org/env/lrtap/workinggroups/wgs/docs48thsession.html

UNECE (2012) Executive Body for the Convention on Long-Range Transboundary Air Pollution. (Working Group on Strategies and Review 50th Session, Geneva 10-14 September 2012). Reactive Nitrogen. Report by the Co-Chairs of the Task Force on Reactive Nitrogen. ECE/EB.AIR/WG.5/2012/3.

UNECE (2013) Guidance document on national nitrogen budgets. UNECE Convention on Long-range Transboundary Air Pollution, ECE/EB.AIR/119

UNECE (2014) Guidance document on preventing and abating ammonia emissions from agricultural sources. UNECE Convention on Long-range Transboundary Air Pollution, ECE/EB.AIR/120

Vaugham A. (2014) Halving meat and dairy consumption could slash farming emissions. Adopting a 'demitarian' diet would lead to a 25-40% reduction in nitrogen emissions from agriculture in Europe, report shows. *The Guardian*, 25 April 2014. http://www.theguardian.com/environment/2014/apr/25/halve-meat-dairy-consumption-slash-emissions-farming

Webster B. (2014) Raise taxes on meat to turn us into demitarians, says UN. *The Times*, 25 April 2014, p 17. (Web edition: Put tax on meat to cut pollution and improve diet, says UN report: http://www.thetimes.co.uk/tto/environment/article4072005.ece

Westhoek H., Lesschen J.P., Rood T., Wagner S., De Marco A., Murphy-Bockern D., Leip A., van Grinsven H., Sutton M.A. and Oenema O. (2014) Food choices, health and environment: Effects of cutting Europe's meat and dairy intake. *Global Environmental Change* (in press) http://dx.doi.org/10.1016/j.gloenvcha.2014.02.004

Winiwarter W., Erisman J.W., Galloway J.N., Klimont Z. and Sutton M.A. (2013) Estimating environmentally relevant fixed nitrogen demand in the 21st century. *Climatic Change* **120**, 889–90. http://dx.doi.org/10.1007/s10584-013-0834-0

Winiwarter W., Hettelingh J.P., Bouwman L., de Vries W., Erisman J.-W., Galloway J., Svirijeva-Hopkins A., Klimont Z., Leach A., Leip A., Palliere C., Schneider U., Spranger T., Sutton M.A., van der Hoek K. and Witzke P. (2011) Future scenarios of nitrogen in Europe. Chapter 24 in: *The European Nitrogen Assessment* (Eds. Sutton M.A., Howard C.M., Erisman J.W., Billen G., Bleeker A., Grennfelt P., van Grinsven H. and Grizzetti B.) pp 551-569. Cambridge University Press.

Nitrogen on the Table:

The influence of food choices on nitrogen emissions and the European environment

Henk Westhoek, Jan Peter Lesschen, Trudy Rood, Susanne Wagner, Adrian Leip, Alessandra De Marco and Donal Murphy-Bokern, Mark A. Sutton and Oene Oenema.

Executive summary

Key findings

1. The European Nitrogen Assessment (ENA) [1] identified agriculture as a major source of nitrogen losses. Despite the relatively high nitrogen efficiency of agriculture in the European Union, **the current total loss of reactive nitrogen from European Union (EU) agriculture amounts to an estimated 6.5 - 8 million tonnes per year, representing around 80 % of reactive nitrogen emissions from all sources to the EU environment.** These nitrogen losses mainly are in the form of ammonia to the air, of nitrate to ground and surface waters and of nitrous oxide (a powerful greenhouse gas).

2. **This report examines these losses from the EU agri-food system** further by (i) allocating nitrogen losses to food commodity groups (to determine nitrogen 'footprints') and (ii) by exploring the effect of alternative diets on nitrogen emissions, greenhouse gas emissions and land use.

3.The results show that livestock production chains have a high share in nitrogen losses. Around 79-88% of the total emissions related to EU agriculture of ammonia, nitrate and of nitrous oxide are related to livestock production. In these values for livestock production the emissions related to feed production (as cereals and fodder crops) are included.

4. There are large differences between food commodities in terms of nitrogen losses per unit of protein produced. Plant-based foods, such as cereals, have relatively low losses while livestock products have much higher losses. Nitrogen losses per unit of food protein from beef are more than 25 times those from cereals. For pig and poultry meat, eggs and dairy, the losses are 3.5 to 8 times those from cereals. Corresponding values for nitrogen use efficiency (NUE)[2] are low for meat and dairy products (5-30%) as compared with plant-based commodities (45-75%).

5. The current average nitrogen 'footprint'[3] per person differs by a factor 2-4 between European countries, mainly as a result of differences in average food consumption patterns. Countries with high intake of animal products (such as Denmark) have considerably larger nitrogen footprints than countries with a low intake of animal products (such as Bulgaria and Slovakia).

[1] Sutton, M.A., Howard, C.M., Erisman, J.W., Billen, G., Bleeker, A., Grennfelt, P., van Grinsven, H., Grizzetti, B., (eds.) (2011) The European Nitrogen Assessment: Sources, Effects and Policy Perspectives. Cambridge University Press, Cambridge, p. 612.

[2] The nitrogen use efficiency is defined as the input/output ratio, all the way from the fertilizer input to nitrogen in the final product

[3] This footprint is calculated as the total nitrogen loss to the environment per unit of product

6. The current average per capita protein intake in the EU is about 70% higher than would be required according to the World Health Organization (WHO) recommendations. This provides opportunities for a shift towards European diets with lower nitrogen footprints, reducing adverse environmental impacts on water, air and soil quality, climate and biodiversity. The current intake of saturated fats is 42% higher than the recommended maximum dietary intake, leading to increased risk of cardiovascular diseases. As 80% of saturated fats originate from animal products, a reduction in animal products would be favourable to human health as well.

Scenarios and key outcomes

7. In this study the effect of a number of alternative diets were assessed considering their impact on nitrogen losses from EU agriculture, as well as on greenhouse gas emissions, land use and human health. A reduction in pig meat, poultry meat and eggs was explored in one set of alternative diets. In another, a reduction in beef and dairy was explored. The reduction in all types of livestock products was also explored, in each case considering the consequences of 25% and 50% reductions. The effects on feed requirement, crop production, land requirements and nitrogen losses were examined.

8. Reducing meat and dairy consumption frees up large areas of agricultural land in the EU providing new opportunities of how to manage this land. We considered two alternative scenarios: Greening Scenario and a High Prices Scenario. In the Greening Scenario, land no longer needed for feed production is used for the production of perennial biomass crops. Furthermore, the lower demand for grass is assumed to lead to an extensification of grassland use by lowering mineral N fertilizer input. In the High Prices Scenario, tight global commodity markets and therefore high cereal prices are assumed. Land no longer required for fodder production (including temporary grassland and a fraction of the permanent grasslands) is used for cereal production.

9. In the Greening Scenario, a 50% reduction in livestock product consumption and production would reduce current European agricultural reactive nitrogen emission by around 40% (Table 1, Figure 1). In this alternative diet, the ammonia emissions are 43% lower, nitrous oxide emissions are 30% lower and nitrate emissions are reduced by 36%. The emissions are reduced most in alternative diets involving decreased beef and dairy production. In general, ammonia emission reductions are higher than the reduction in nitrous oxide and nitrate leaching. This is because ammonia emissions are mainly from livestock production, whereas both livestock and arable field-based activities contribute large shares of the nitrous oxide and nitrate emissions. Bioenergy crops expands by 14.5 million, being equal to 40% of the projected use of bio-energy material in the EU in 2020.

10. In the High Prices Scenario, a 50% reduction in livestock product consumption and production would also reduce current European agricultural reactive nitrogen emission by around 40%. In this alternative diet, the ammonia emissions are 29% lower, nitrous oxide emissions are 24% lower and nitrate emissions are reduced by 28%. By contrast, greenhouse gas emissions from agriculture would only reduce by 25%. This is because cereal production is increased, no additional bio-energy crops are produced and grassland use is not extensified. In this scenario, cereal export would increase from the current 3 million tonnes per year to over 170 million tonnes.

11. In both scenarios, the requirement for imported soybeans, as meal currently used as animal feed, is reduced by 75%. The combination of increased export of cereals with reduced import of soy has great implications for global commodity markets, which in turn influence global land use change.

12. A shift to a more plant-based diet will lead to a large decrease in the nitrogen footprint of EU citizens. In the most radical scenario assessed (a 50% reduction in the consumption of all meat and dairy products), the nitrogen footprint of the average diet will be reduced by 40%. The current large differences in per capita nitrogen footprint between EU member states will also become smaller.

13. The reductions in reactive nitrogen emissions will have benefits not only within the EU but at continental and global scales. Both atmospheric ammonia and nitrates in water-bodies cross national frontiers, with the consequence that the dietary scenarios investigated make a significant contribution to reducing international pollution export. The reduced emissions of the greenhouse gases methane, nitrous oxide and carbon dioxide are relevant globally.

14. The scenarios lead to food consumption patterns that are better aligned with international dietary recommendations. All of the reduction scenarios lead to a reduced intake of saturated fats, the main source of which is animal products. Even though the reductions are significant, only the most radical scenario - representing a 50% reduction in all meat and dairy consumption, brings the average intake of saturated fats within a range recommended by the World Health Organization (WHO). This scenario represents a 40% reduction in the intake of fats. The same radical scenario is also the only one assessed where the average intake of red meat is reduced to being only slightly above the maximum recommended by World Cancer Research Fund (WCRF) (See Table 1). Based on the current WHO and WCRF dietary recommendations, the results are clear: the reduced intake of red meat and saturated fats in these reduction scenarios means that public health risks would be reduced.

15. The alternative diets would lead to major changes in EU agriculture, with the expectation of large socio-economic consequences. Livestock production is currently responsible for 60% of the value-added on EU farms, and this revenue would be greatly reduced under the alternative diets. By contrast, the scenario with increased cereal exports assumes a large increase in cereal production and associated revenue. The net farm-level economic effect would depend on world market conditions and especially whether the additional cereal can be sold at a price that is profitable for European farmers. In the scenario where additional cereals are exported, this might have beneficial effects on global commodity markets in terms of food security. However this also has the risk of suppressing production and thus market opportunities for local farmers in developing countries, which is avoided in the increased bioenergy scenario.

16. Considering the major benefits of reduced European meat and dairy consumption for environment, climate and human health, there is now a need to explore further the market, education, policy and other options which would enable the barriers-to-change to be addressed.

Supporting material

Westhoek, H., Lesschen, J.P., Rood, T., Wagner, S., De Marco, A., Murphy-Bokern, D., Leip, A., van Grinsven, H., Sutton, M.A., Oenema, O. (2014) Food choices, health and environment: effects of cutting Europe's meat and dairy intake. Global Environmental Change In Press

Leip, A., Weiss, F., Lesschen, J.P., Westhoek, H. (2013) The nitrogen footprint of food products in the European Union. The Journal of Agricultural Science FirstView, 1-14.

Table 1. Summary of data on average food intake in Europe and environmental indicators under current conditions (based on 2004) and under a 50% reduction in the consumption of animal products.

Aspect	Unit	Reference	-50% meat, dairy and eggs[1]
Protein			
Average daily intake	g per person per day	83	75
Proportion of animal origin[2]	%	60%	36%
Saturated fats			
Average daily intake	g per person per day	36	22
Compared with the RMDI [3]	%	142%	86%
Red meat			
Average daily intake	g per person per day	88	47
Compared with the RMDI [3]	%	207%	107%

		Reference	High prices scenario	Greening scenario
Environment				
Total losses of N_r (EU)	Million tonnes per year	6.5	4.1	3.8
Losses of NH_3 N to air		2.8	1.6	1.6
Losses of N_r to water		3.3	2.1	2.0
Losses of N_2O N to air		0.4	0.3	0.2
GHG emissions (EU)[4]	Million tonnes per year	464	347	268
NUE[5] food system (EU)	%	22	47	41
Agriculture				
Soy imports (as beans)	Million tonnes per year	34	8	8
Cereal exports	Million tonnes per year	3	174	54
Additional production of bioenergy	EJ per year	-	-	2.3

[1] sheep and goat meat are not reduced
[2] including fish and other seafood
[3] RMDI = Recommended Maximum Dietary Intake
[4] RMDI as advised by the World Cancer Research Fund (WCRF)
[4] Nitrogen use efficiency of the total food system (total output of N in the form of food crops and livestock products /total input of N into agricultural system)
[5] including direct emissions from agricultural production of N_2O, CH_4 and CO_2

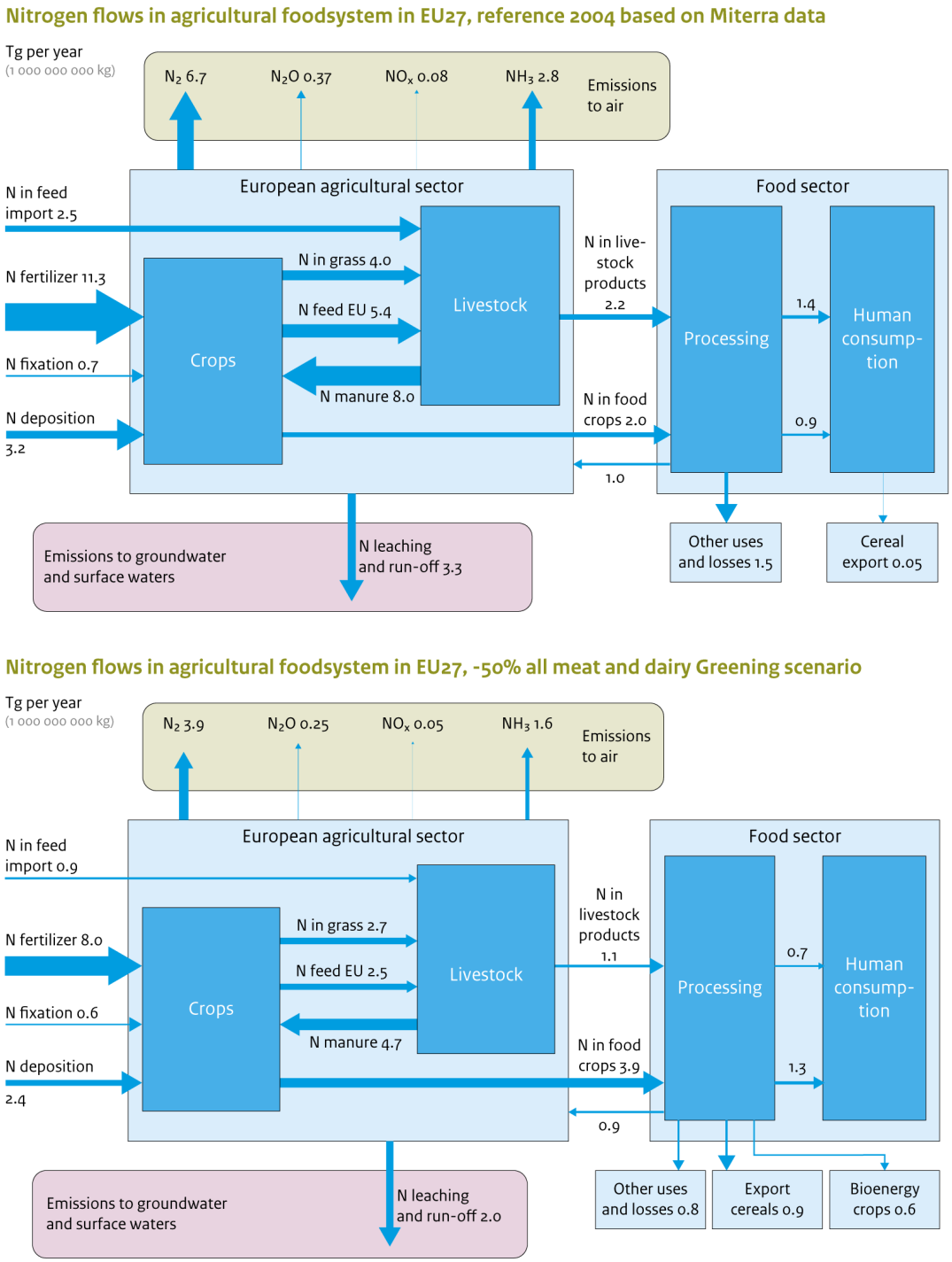

Figure 1. Nitrogen flows in the EU agricultural and food system in the reference situation for 2004 (top) and in case of the alternative diet with 50% reduction in consumption of meat, dairy and eggs in the Greening Scenario (bottom).