Detailed Annexes to ECE/EB.AIR/119 – "Guidance document on national nitrogen budgets"

(https://www.unece.org/fileadmin/DAM/env/documents/2013/air/eb/ECE_EB.AIR_119_ENG.pdf)

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Content

Annex 0 – Definitions and Principles

1 Introduction

The annexes to the Guidance Document on National Nitrogen Budgets provide detailed description, for each individual pool covered, how to develop such budgets. Items common to all pools are dealt with in this "Annex 0". Thus it describes the system boundaries, principles and definitions to be generally used in establishing nitrogen budgets.

National Nitrogen budgets (NNB's) are to be established by describing environmental pools and the flows between the pools. The respective pools are covered in the individual annexes. These topics applicable to all pools need to be determined in advance:

- Entities and detail levels to be assessed and reported
- Systematic nomenclature of pools and sub-pools including unique identifiers
- Unambiguous identification of N flows
- Compounds and materials containing nitrogen ('matrix' for N flows)
- Concept of uncertainty treatment

As national budgets, they conform to a territorial principle. This means they cover all N flows occurring within the territory of a country, irrespective of e.g. the citizenship of the person responsible for it.

2 Level of detail

Nitrogen budgets describe the exchange of quantities of reactive nitrogen between components of the environment, here termed pools. Reactive nitrogen is understood as all chemical forms of the element nitrogen that can be readily assimilated by biosubstrates, mostly all compounds other than the elemental gaseous form (N_2). It is contained in chemical compounds and in materials (the 'matrix'). Flows of reactive nitrogen thus depend on the quantity of matrix material to be exchanged, and on the nitrogen content within the material.

In a nitrogen budget, not all flows will be covered in detail. Some will be dealt with as agglomerates, and others may even be neglected. This is part of the individual pool descriptions, guided by the following principles:

- *Tier level*: Depending on the ambition level of national nitrogen budget, a simple or a more comprehensive approach may be selected. Each individual annex provides guidance to create a simple "Tier 1" (basically using international sources) or a more detailed "Tier 2" budget that is able to reflect national circumstances.
- *Flow thresholds*: Following the principle of efficient resources use in developing nitrogen budgets, no efforts should be spent on nitrogen flows that are considered negligible. Instead, aggregated flows should be assessed and reported. Based on experience obtained for Switzerland (Heldstab et al., 2005) and for Germany (Umweltbundesamt, 2009), a minimum detail level is here set at 100 g N per person and year (equivalent to 100 t per million inhabitants and year). Flows identified in the respective annexes may be combined if smaller than this threshold, or even omitted.
- *Flows between pools:* While some flows will occur within individual pools (between sub-pools) and thus will be covered in the description of the very pool, many of the flows will occur between pools, but still are described in only one of the annexes. Within this set of annexes,

it is agreed that flows are described in the pool for which more information is available. Implicitly this means that many of the flows will be described in the pool they originate, as the flows are often consequences of processes in these pools and thus linked to information stored together with the outflows.

While the individual annexes have been established to accommodate for the requirements as outlined above, there may be specific country cases where a more stringent coverage is advisable. Compilers of NNB's should consider to *split* flows that exceed the minimum detail level by a factor of 10, i.e. 1 kg N per person and year. In splitting, care should be taken that more different elements are separated into different sections of the split flow (e.g., those partial flows that are available from separate statistics, or that can be distinguished by very different N contents etc.). Moreover, compilers may *add* flows if flows into and out of a pool (or sub-pool) differ by more than 10%. In both cases, consistent nomenclature should be chosen, and recommendations for improving the NNB guidance annexes put forward. However, as outlined in the respective annexes, specific conditions of the respective pools may render it impossible to provide that kind of information, so no general level of standard can be set.

3 Nomenclature of pools

For the purpose of numerical handling a unique (alphanumeric) ID must be given to each (sub)pool and flow.

For the purpose of readability a unique (textual) code can be given to each (sub)pool and flow

3.1 Pools

All pools have a two-letter code and a unique pool-ID, which conceptually follows the UNFCCC and NFR reporting of greenhouse gases and air pollutants (see IPCC, 2006, and EEA, 2013) for pools 1 - 5. Following the recent changes in these reportings of gaseous emissions, a slight inconsistency of the numbering with respect to the Guidance Document is inevitable. Moreover, a pool 'Rest of the World' for the quantification of flows that enter or exit the national boundaries has been added, for which no specific description in form of an Annex will be made available.

Tab. 1: List of pools contained in NNB's

1	EF	Energy and Fuels
2	MP	Materials and Products
3	AG	Agriculture
4	FS	Forest and Semi-natural Vegetation
5	WS	Waste
6	HS	Humans and Settlements
7	AT	Atmosphere
8	HY	Hydrosphere
*	RW	"Rest of the World", trans-boundary nitrogen flows

*) purely representing imports/exports, no specific annex has been provided

3.2 Sub-pools

All sub-pools have a two-letter code to be combined with the two-letter code of their parent pool as well as a one-letter code which is combined with the pool-ID and following conceptually the UNFCCC and NFR reporting systems. Also here CRF coding (the "common reporting format" for reporting to UNFCCC) is maintained whenever possible, and asterisks denote a deviation from that principle. For example, the agriculture pool has three sub-pools: animal husbandry (AH or 3A), manure storage and management (MM or 3B) and soil management (SM or 3D). Note that, for the sake of simplicity, sub-pools can be referred to also as 'pools', as long as they are clearly defined.

Tab. 2: List of all sub-pools defined

ID		
2A	MP.FP	Industrial processes - Food processing
2B	MP.NC	Industrial processes - Nitrogen chemistry
2C	MP.OP	Industrial processes - Other producing industry
3A	AG.AH	Agriculture - Animal husbandry
3B	AG.MM	Agriculture - Manure management and manure storage
3C	AG.SM	Agriculture - Soil management
4A	FS.FO	Forests and semi-natural area - Forest
4B	FS.OL	Forests and semi-natural area - Other Land
4C	FS.WL	Forests and semi-natural area - Wetland
5A	WS.SW	Waste - Solid waste
5B	WS.WW	Waste – Wastewater
6A	HS.OW	Humans and settlements - Organic world
6B	HS.HB	Humans and settlements - Human Body
6C	HS.MW	Humans and settlements - Material World
6D	HS.PE	Humans and settlements - Non-agricultural animals (pets)
7	AT	Atmosphere (no sub-pool)
8A	HY.GW	Hydrosphere – Groundwater
8B	HY.SW	Hydrosphere - Surface water
8C	HY.CW	Hydrosphere - Coastal water

3.3 Sub-sub-pools

Many sub-pools need to be further sub-divided for the purpose of the construction of an NNB. For example, data collection and calculation for the AG.AH pool needs to be done at the level of animal types. The decision on the number of sub-sub-pools and the level of detail depends on the national circumstances. If applicable, the annexes will contain some guidance to facilitate the choices to be made.

The identification of sub-sub pools shall be done by a systematic approach:

(1) Each sub-sub-pool **must** be identified by a number, which is added to the ID code of the sub-pool. For example, dairy and non-dairy cattle could have the IDs 3A1 and 3A2. Again, the coding follows guidance as in CRF, as long as this is possible.
(2) Further subdivision should be avoided – if absolutely needed, it should use lower case letters, e.g. 1A2f – again, following CRF when available, which will hardly be the case.

Each sub-sub pool **can** be identified by a four letter 'code' that can be freely chosen by national NNB experts. Harmonisation between countries is nevertheless favorable, thus the annexes will contain some guidance, if applicable. For example, dairy and non-dairy cattle could be identified by the acronyms DAIR and NDAI, respectively. A complete description would then also include the pool and sub-pool information such as AG.AH.DAIR, i.e. linking the respective acronyms with dots (".").

4 Flows

All flows will be given in tons N per year. A nitrogen budget covers reactive nitrogen compounds only. Flows of molecular nitrogen (N_2) and other fully unreactive forms (e.g., N in mineral oil, or in polymer fibers) need not to be considered or should be reported separately – see details in the respective pool descriptions. “Activiation” of fully unreactive nitrogen thus needs to be seen as a source of Nr, in a similar way as fixation of molecular nitrogen.

A nitrogen budget thus is determined by its flows. The country total as well as each individual pool or sub-pool must comply with the equation:

$$\sum N_{inflow} + \sum N_{source} = \sum N_{outflow} + \sum N_{sink} + \sum N_{stockchange} \quad (1)$$

In the interaction between pools, it is the flows (inflows and outflows) which need to be addressed.

For a unique identification of a flow the following information should be given:

(1) The pool the flow starts / is flowing out of ($pool_{ex}$)
(2) The pool the flow ends / is flowing into ($pool_{in}$)
(3) The matrix in which the nitrogen is transported between $pool_{ex}$ and the $pool_{in}$
(4) The nitrogen form or any other information considered relevant to distinguish, e.g. (i) the compound (chemical species) that flows between the ex-pool and the in-pool (if no information is given it is by default total N), (ii) additions like max (maximum) or min (minimum) etc.

The first three topics are always required. The fourth information is required in case the first three are not uniquely identifying a flow, or if the NNB expert wishes to provide some additional information. Start and end pools should be indicated at the highest level of detail the flow has been quantified. For example, the start pool of manure excretion from fattening pigs would be AG.AH.PIGF.

In the case of environmental emission flows, where a nitrogen form is transported in a medium, the matrix is considered to be the nitrogen form itself. Thus, information about $pool_{ex}$, $pool_{in}$ and the matrix is required (see examples in Tab. 3).

In some cases, flows between the same pools and in the same matrix might use different pathways or different media, such as for example N emissions to the hydrosphere could use surface water or groundwater. If such distinctions are captured in a NNB, the fourth type of information is required.

In analogy to the pool description, we employ the pool system with codes to mark starting and endpoint, as well as the code of the matrix. The codes of the four types of information are separated by dashes. This total code is very useful for definition, but difficult to read. Adding a verbal explanation to flows thus is recommended (as suggested in the respective pool-specific annexes).

Tab. 3: Examples of flows in NNB's

$Pool_{ex}$	$Pool_{in}$	Matrix*	Other info	Total code	Annex where guidance is given	Description
MP	AG.AH.NDAI	SOYC	-	MP-AG.AH.NDAI-SOYC	3	Soya cake in compound feed fed to non-dairy cattle from industrial processing
AG.SM	AT	NH3		AG.SM-AT-NH3	3	Ammonia emission to the atmosphere from agricultural soil management
AG.SM	HY	NO3	Runoff in surfaces waters	AG.SM-HY-NO3-SURFW	3	surface water runoff NO_3-N losses to the hydrosphere from agricultural soil management

*) Substance in which N is embedded

5 Nitrogen content

For the identification of 'what' is flowing the following definitions are made:

- *Nitrogen forms* (see also Guidance Document): There are thousands of individual chemical compounds containing nitrogen that are listed by Chemical Abstract Services (CAS). Nitrogen contents can be assessed from the chemical formulae by stoichiometry using the respective atomic and molecular weights (see e.g. Supplementary Information to Pelletier & Leip, 2014). Examples for important nitrogen forms are ammonia (NH_3), nitrous oxide (N_2O) or also total nitrogen (Ntot).
- *Matrices*: total nitrogen flows embedded in a matrix with a fixed N content. Examples for important matrices are food products (soft wheat, eggs, wood, explosives, ..). Methods are available to assess the respective nitrogen contents, which in practice will cover a range. In case the table lists N content estimates from different sources with 'conflicting' values, the expert shall identify those values that are most suitable for the national conditions.
- *Media:* Environmental nitrogen emissions often occur in a medium such as 'exhaust fume' or 'surface water' where the N content is variable and dynamic.

Each nitrogen form or matrix is identified by a 'code'. Table 4 gives the code for the listed nitrogen forms and matrices. Moreover, the nitrogen contents calculated for relevant compounds, or typical measured or estimated nitrogen contents of important matrices are presented. These default values shall be used unless proven evidence of different national factors can be provided. NNB experts may wish to include other matrices, in which case harmonization between countries should be strived for.

Tab. 4: N-contents of specific compounds or generalized matrices in NNB's

a) ***Nitrogen compounds***	Acronym	N content [%]	Data source	Chemical formula / description
Molecular nitrogen	N2	100	stoichiometry	N_2
Ammonia	NH3	82.35	stoichiometry	NH_3
Nitrogen oxides (expressed as mass of NO_2 by definition)	NOx	30.43	stoichiometry	NO_x
Nitrous oxide	N2O	63.64	stoichiometry	N_2O
Urea	UREA	46.67	stoichiometry	$(NH_2)_2CO$
Ammonium nitrate	AMMN	35.00	stoichiometry	NH_4NO_3
Ammonium sulfate	AMMS	21.21	stoichiometry	$(NH_4)_2SO_4$
20/20/20 fertilizer		20	definition	Fertilizer defined by nutrient contents

b) Matrix*	Acronym	N content [%]	Data source	description
Protein	PROT	16		Polymer of different amino acids
Egg	EGGS	2.02		N mainly in egg protein
Meat	MEAT	3.5-5.3		N mainly in meat protein
Manure	MANU	1-3		Urea or uric acid (for chicken manure) are important components
Milk	MILK	0.5		N mainly in milk protein
Wood	WOOD	0.05		Forest products
Food	FOOD	See Table 12 in annex 6 (HS)	Heldstab et al. 2010, Souci et al. 2008	Broad range of food products
Food waste	FOWS	See Table 12 in annex 6 (HS)	Heldstab et al. 2010, Souci et al. 2008	Equal to average N content of food products
Synthethic Polymers	POLY	10 - 47	See Table 13 and Table 16 in annex 6 (HS)	Mixture of PU (Polyurethanes), PA (Polyamides), and MF/MUF/UF (Melamine/Urea Formaldehyde Resins)
PU		12		
PA		10		
MF		47		
UF		28		
Textiles	TEXT	0.2-15	See Table 14 and Table 16 in annex 6 (HS)	Crop fibres: cotton, cellulose, flax etc. Animal hair / animal fibres: wool, leather, fur, silk, etc.
Made of crop fibres		0.2		

b) Matrix*	Acronym	N content [%]	Data source	description
Made of animal hair / animal fibres		15		
Detergents & Surfactants	DETG	2.1	calculated	Cationic surfactants, mass weight representative calculated basing on an esterquat (quaternary ammonium cations with a relative molecular weight of 648 g/mol
Solid material waste	SOWS		Obernosterer & Reiner 2003	Mixture of different waste fractions
Residual waste / mixed municipal waste		0.4		
bulky waste, textiles, electronic scrap		0.4		
Paper & wood waste		0.1		
Plastics (if no information on composition)		0.4		
Fertilizer	FERT	-		N fertilizer is usually reported as Ntot.
Compost	COMP	0.6 – 2.3	BMLFUW 2010	Dry matter compost
Green waste & garden waste	GRWS	0.8	Vaughan et al. 2011, Kumar et al. 2010	Fresh green waste and garden waste
Pet food	PFOD	-		Broad range of products, reported as protein requirements

*) Substance in which N is embedded

6 Treatment of uncertainty

This section specifies a general approach to assess uncertainties in the utilized data sets. In general, NNB's use many data that lack of established and reliable data sources. Many flows have to be determined as residuals from other flows within the pool, and quantifications are frequently based on assumptions. This is why it is of particular importance to indicate a range of uncertainty for all flows.

Analogous to Hedbrant and Sörme (2001), it is suggested to assign the data to a set of uncertainty levels and the respective uncertainty factors (UF, see Table 5). These are compatible with the ratings and typical error ranges from the EMEP/EEA air pollutant emission inventory guidebook 2013 (EEA 2013). Based on the likely value for a flow, the uncertainty interval can be derived by both multiplying and dividing by the respective uncertainty factor[1]. Uncertainty levels can be assigned to both N contents and mass flows of products. If two uncertain numbers with different uncertainty factors are

[1] e.g., for a likely value of 2530 t N/year with an UF of 1.33 the uncertainty interval would range from 1902 t N/year (=2530/1.33) to 3365 t N/year(=2530*1.33)

combined,[2] the higher UF should be used for the result. In those (rare) cases, when uncertainty margins are presented in the original literature (e.g. emissions from human body – data used by Sutton et al. (2000) have a low estimate, high estimate, and best estimate), the UF that fits best to the given uncertainty interval should be chosen.

Table 5: Levels of uncertainty (based on Hedbrant and Sörme 2001, Egle et al. 2014, Thaler et al. 2011)

Level	Uncertainty Factor (UF)	Application
1	1.1	current official statistics, measurement data, data from appropriate literature
2	1.33	expert estimates, outdated official statistics, unofficial statistics, presentations, industry reports
3	2.0	assumptions for which neither official statistics nor expert estimates were available often based on on-line data sources or publications without accurate literature reference
4	4.0	an estimate based on a calculation derived from assumptions only

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[2] Typically, this is for instance a multiplication such as: mass flow * N content = N flow

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9 Glossary

CLRTAP	Convention on Long Range Transboundary Air Pollution (Geneva convention)
CRF	Common Reporting Format
EPNB	Expert Panel on Nitrogen Budgets
IPCC	Intergovernmental Panel on Climate Change
NNB	National Nitrogen budget
Nr	reactive Nitrogen
Ntot	total Nitrogen
TFRN	Task Force on Reactive Nitrogen
UN-ECE	United Nations Economic Commission for Europe
UNFCCC	United Nations Framework Convention on Climate Change

Annex 1 – Energy and Fuels

1 Introduction

This annex describes the pool "Energy and fuels" and provides methodologies for the computation of the major nitrogen flows to the other pools of the NNB. It comprises methodologies for both a simplified approach in case of limited data availability based on default values (Tier 1) and a more detailed approach (Tier 2) that requires additional data and allows accounting for different types of combustion technologies and abatement techniques. In addition, the inherent uncertainties related to each of these approaches and data sources and limitations in the estimation of nitrogen flows and stock changes in the pool are documented.

2 Definition

2.1 Activities and flows encompassed by the pool

The pool "Energy and fuels" comprises all fuel combustion and energy conversion activities.

- Energy conversion processes include heat and electricity production as well as refineries and other fuel production processes apart from biogas production from agricultural waste, which is accounted for in the pool Waste.
- Fuel combustion includes the transport sector, fuel combustion in industrial processes, in the commercial/institutional and in the residential sector.

The most important flows of reactive nitrogen originate from fuel combustion activities. During combustion processes, atmospheric nitrogen N_2 is transformed into reactive nitrogen species, such as NO_x, NH_3 and N_2O. Emissions of nitrogen oxides formed by thermal fixation of atmospheric nitrogen are also referred to as "thermal NO_x". Besides fixation of atmospheric nitrogen, various types of fuels (e.g. coal) contain chemically bound nitrogen that is also emitted as NO_x during the combustion process. The weight fraction of chemically bound nitrogen varies depending on the fuel type. During combustion processes, chemically bound nitrogen is also converted to NO_x. These NO_x emissions are referred to as "fuel NO_x" (Note that thermal NO_x typically dominates the total NO_x emissions). Therefore, each nitrogen pool that provides a source of fuels is linked to the pool "Energy and fuels" by a flow of nitrogen. This includes agricultural fuels, wood fuel, fossil fuels and waste fuels. All the flows entering the pool "Energy and fuels" consist of non-reactive nitrogen. In addition, there are flows of non-reactive nitrogen from the pool "Energy and fuels" to the pools Agriculture and Waste, since production of certain biofuels (e.g. bioethanol, biodiesel) results in nitrogen containing residues (Yuan et al. 2015). These residues are transferred to the pool Waste (e.g. waste incineration plants, composting sites, landfills) and to the pool Agriculture (e.g. fertilizers or animal feed) (FAO 2012).

The nitrogen contained in fuels is released only in the combustion process and therefore reactive nitrogen compounds are exchanged only between the pool "Energy and fuels" and the pool Atmosphere. All the other exchanges consist of inactive forms of nitrogen. Their quantification is not required (see ECE/EB.AIR/119, chp. V.A., "Energy and fuels"), but it is recommended to include these flows of nitrogen in order to achieve a more complete nitrogen balance. Therefore, the present guidance document also provides a method for assessing emission of inactive forms of nitrogen.

The nitrogen flows between the pool “Energy and fuels” and the other pools of the NNB and the pool “Rest of the world” are represented in Figure 1. The methodology for estimating N flows is described in detail in section 4 of this Annex.

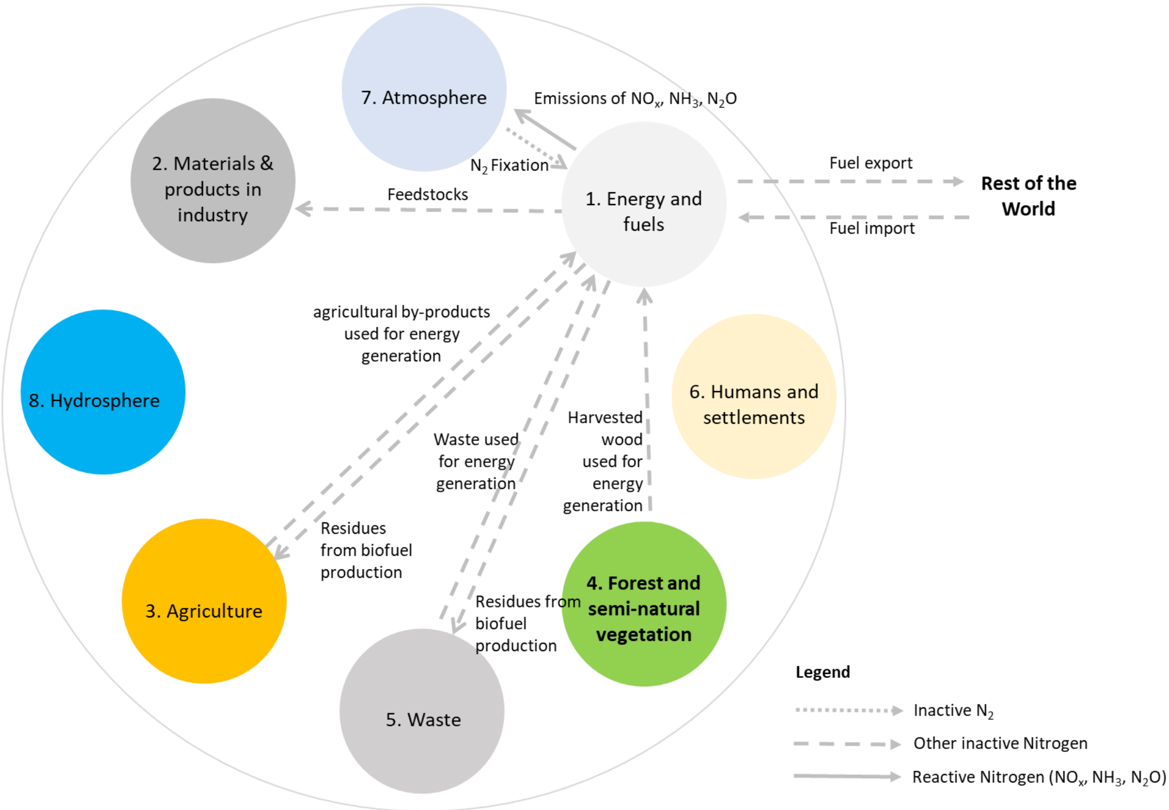

Figure 1: Nitrogen flows between the pool „Energy and fuels“ and the other pools of the NNB (including the pool “Rest of the world”). Solid arrows indicate flows of reactive nitrogen compounds (NO_x, NH_3, N_2O); dotted arrows represent flows of N_2, and dashed arrows indicate flows of other forms of inactive nitrogen (e.g. chemically bound nitrogen in fuels).

2.2 Nitrogen species involved

Table 1 summarizes the different nitrogen compounds that need to be accounted for in the exchanges with the pool "Energy and fuels". The exchange with the pool Atmosphere includes emissions of gaseous forms of nitrogen, such as nitrous oxide (N_2O), ammonia (NH_3) and nitrogen oxides (NO_x) as well as fixation of N_2 during fuel combustion. Exchanges with other pools and within the pool "Energy and fuels" occur in the form of chemically bound nitrogen contained in certain types fuels (e.g. coal, biofuels). The share of nitrogen contained in fuels varies depending on the fuel type and it can also vary within a given fuel type (see Table 2).

Table 1: Forms of nitrogen present in the pool "Energy and fuels"

Nitrogen forms	Acronym	Chemical formula	N content [%]	State	Description
Nitrogen	N_2	N_2	100.00	Gas	Atmospheric nitrogen
Nitrogen oxides (expressed as mass of NO_2 by definition; see Annex 0, Tab. 4)	NO_x	NO_x	30.43	Gas	Emission of NO_x is generally in the form of nitric oxide (NO) with a small proportion present as nitrogen dioxide (NO_2). Emissions of NO_x are comparatively low in residential furnaces compared to larger furnaces, partly due to lower furnace temperatures in residential furnaces. The term NO_X, by convention, refers to the sum of NO (nitrogen monoxide) and NO_2 (nitrogen dioxide). In most combustion processes NO contributes to over 90 % of the total NO_X emissions. However, as it is rapidly oxidised to NO_2 in the atmosphere, emissions of NO are expressed as NO_2 (BAT, 2015).
Ammonia	NH_3	NH_3	82.35	Gas	Small amounts of ammonia may be emitted as a result of incomplete combustion process of all solid fuels containing nitrogen. This occurs in cases where the combustion temperatures are very low (fireplaces, stoves, old design boilers). NH_3 emissions can generally be reduced by primary measures aiming to reduce products of incomplete combustion and increase combustion efficiency. Emissions of NH_3 can be the result of an incomplete reaction of NH_3 additive in NO_x abatement systems - selective catalytic and non-catalytic reduction (SCR and SNCR) (BAT, 2015).
Nitrous oxide	N_2O	N_2O	63.64	Gas	Nitrous oxide emissions from the energy sector are formed during fuel combustion.
Nitrogen in fuels	fuel-N	fuel specific	fuel specific (see Table 2:)	Solid/ Liquid	Nitrogen is chemically bound in solid and liquid fuels. Even though the nitrogen content of crude oil is low, it contains a number of nitrogen-organic compounds: pyridine, quinolone, azapyrine, pyrrole, indole, carbazole, tetrapyrrole macrocycle (porphyrin core), isobutyramide, hydroxyquinolone, pyrrolecarboxylic acid, imidazole, etc. (Prado, 2017).

2.3 Definition of boundaries

2.3.1 System boundaries of the pool „Energy and fuels"

NNBs are determined at the national level following the territorial principle (see Annex 0, chp. 1). Basis for the quantification of nitrogen flows is therefore the amount of fuel used within the territory rather than the amount of fuel sold. This implies that the amount of fuel sold needs to be corrected for all fuel exports and imports. Besides exports and imports provided by the customs statistics this includes also fuel tourism due to fuel price differences between countries, which is mostly relevant in the transport sector.

Data sources used for quantification of the NNB therefore need to be provided for the same system boundaries. National inventories on emissions of air pollutants and greenhouse gases differ in terms of their system boundaries. Under the United Nations Framework Convention on Climate Change (UNFCCC), the national total for assessing compliance is based on fuel sold within the national territory. Under the Convention on Long-range Transboundary Air Pollution (CLRTAP), two types of reporting occur based on fuel sold as under the UNFCCC and based on fuel used within the territory. Thus, transport fuel sold in a country but consumed abroad ("fuel tourism") is accounted for in greenhouse gas inventories, but not in every country reporting under the CLRTAP[3]. The system boundary for countries reporting under the CLRTAP based on fuel used is therefore consistent with the present guidance documents. For other countries, the national air pollutant and greenhouse gas inventories differ in terms of the amount of fuel consumed abroad and therefore the reported emissions of NO_x, NH_3 and N_2O need to be corrected for net import and export of fuels due to "fuel tourism".

2.3.2 Fuels covered in the pool „Energy and fuels"

The pool „Energy and fuels" covers emissions of nitrogen containing compounds (NO_x, NH_3 and N_2O) from fuel combustion processes. During the fuel combustion process, nitrogen fixation from the atmosphere as well as chemical transformation of nitrogen contained in the fuels result in emissions of reactive nitrogen to the atmosphere. Calculation of these emissions relies on fuel- and process-specific emission factors. A list of potentially relevant fuels is provided in Table 2.

Since most fuels contain chemically bound nitrogen, the flow of these fuels across the different pools and within the „Energy and fuels" pool should be accounted for as N flows as well (see Figure 1). For the most important fuel types, Table 2 provides ranges of typical nitrogen contents. If no country-specific information is available on the nitrogen contents, it is recommended to apply average nitrogen contents provided in Table 2 as default values. This corresponds to the Tier 1 approach for calculating the N exchanges with the pool „Energy and fuels".

[3] „For Parties for which emission ceilings are derived from national energy projections based on the amount of fuels sold, compliance checking will be based on fuels sold in the geographic area of the Party. Other Parties within the EMEP region (i.e., Austria, Belgium, Ireland, Lithuania, Luxembourg, the Netherlands, Switzerland and the United Kingdom of Great Britain and Northern Ireland) may choose to use the national emission total calculated on the basis of fuels used in the geographic area of the Party as a basis for compliance with their respective emission ceilings." (cit. from §23 of ECE/EB.AIR/125, 14.03.2014, UN ECE 2014)

Table 2: List of fuels according to IPCC 2006 Guidelines (IPCC 2006) and typical nitrogen contents. Where available, data on nitrogen contents [weight %] are taken from the Guidebook EEA 2013/2016, Vol. 1A1 Energy industries, appendix B.

Fuel class		Fuel type	min [wt%]	max [wt%]	avg. [wt%]	Reference
Liquid fossil	Primary fuels	Crude oil	0.1	2	1.05	Chempedia 2017
		Orimulsion	-	-	4.0	HUT 2017
		Natural gas liquids	-	-	*	-
	Secondary fuels	Gasoline	-	-	0	Wielgosiński, G. (2012) (petrol)
		Jet kerosene	-	-	0.1	Flagan et al 1988
		Other kerosene				
		Shale oil	-	-	*	-
		Gas/diesel oil	-	-	0.0133	EV 2005
		Residual fuel oil	0.1	0.8	0.45	EEA 2013/2016 (heavy fuel oil)
		Liquefied petroleum gases (LPG)	-	-	*	-
		Ethane	0	0	0	-
		Naphtha	-	-	*	-
		Bitumen	0.2	1.2	0.70	AI (2015)
		Lubricants	-	-	*	-
		Petroleum coke	0.6	1.55	1.075	EEA 2013/2016
		Refinery feedstocks	-	-	*	-
		Other oil	0.005	0.07	0.0375	EEA 2013/2016 (fuel oil)
Other liquid fossil			-	-	*	-
Solid fossil	Primary fuels	Anthracite	0.2	3.5	1.85	EEA 2013/2016 (hard coal)
		Coking coal	0.57	1.68	1.04	Daishe et al. 2011
		Other bituminous coal	0.5	2.0	1.25	USE 2017a
		Sub-bituminous coal	0.5	2.0	1.25	USE 2017b
		Lignite	0.4	2.5	1.45	EEA 2013/2016
		Oil shale and tar sand	-	-	*	-
	Secondary fuels	BKB[4] and patent fuel	-	-	*	-
		Coke oven/gas coke	-	-	12	Wielgosiński, G. (2012)
		Coal tar	-	-	1.51	Kershaw et al. (1993)
Other solid fossil			-	-	*	-
Gaseous fossil		Natural gas (dry)	0	0	0	EEA 2013/2016
Other gaseous fossil			-	-	*	-
Waste (non-biomass fraction)			0.3	1.4	0.85	EEA 2013/2016 (waste)
Other fossil fuels			-	-	*	-
Peat			0.7	3.4	2.05	EEA 2013/2016
Biomass		Solid biomass	0.1	0.3	0.2	EEA 2013/2016 (wood)
		Liquid biomass	-	-	1	HUT 2017 (sewage sludge)
		Refined biogas	0	0	0	EEA 2013/2016 (natural gas)
		Other non-fossil fuels (biogenic waste)	-	-	*	-

* no default value available

[4] Brown Coal Briquettes

3 Internal structure

The pool „Energy and fuels“ consists of four sub-pools (Figure 2) as described in Annex 0, Tab. 2. The sub-pool „Energy conversion“ (EC) comprises all fuel conversion activities, such as refining processes, manufacturing of solid fuels and heat and electricity production. It includes also production of biofuels other than biogas (e.g. biodiesel, bioethanol). The sub-pool „Manufacturing industries and construction“ (IC) includes all fuel combustion processes in the industrial sector and in construction. The sub-pool Transport (TR) comprises all fuel combustion in transport activities (land, water, air) and the sub-pool „Other energy and fuels“ (OE) accounts for all remaining fuel combustion processes out of which residential heating is one of the most important sources.

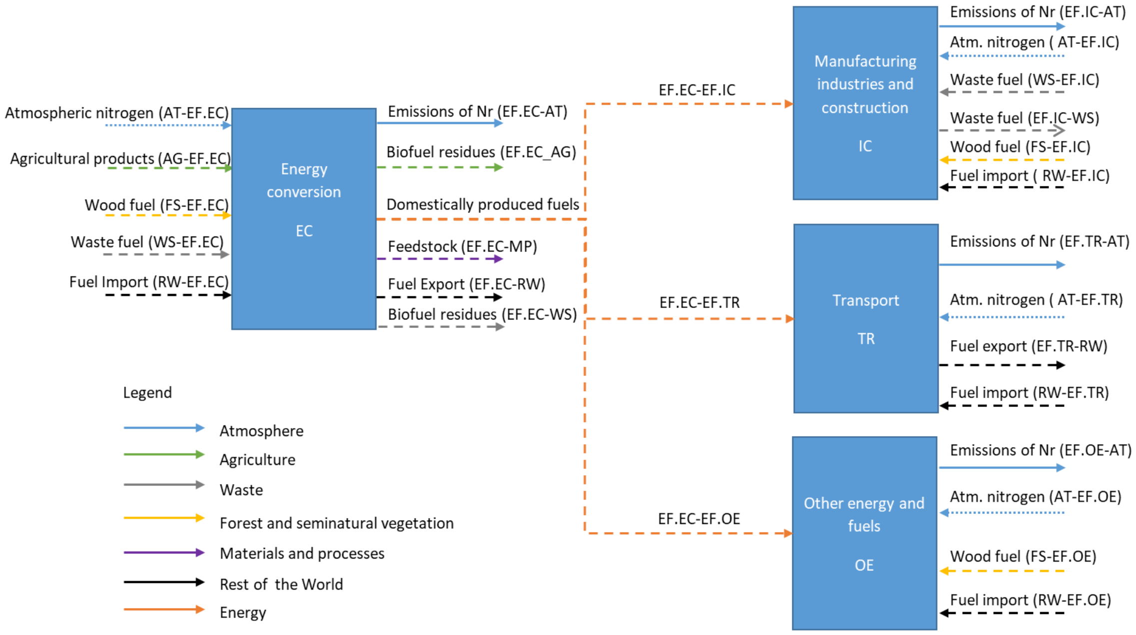

Figure 2: Schematic representation of the sub-pools within the pool „Energy and fuels“. Solid arrows indicate flows of reactive nitrogen compounds (NO_x, NH_3, N_2O); dotted arrows represent flows of N_2, and dashed arrows indicate flows of other forms of inactive nitrogen.

In some countries, the information necessary to differentiate between consumption of fuels that were imported and consumption of fuels that were produced within the country might not be readily available. Therefore, a simplified approach as shown in Figure 3 is recommended in cases where this information is missing. It covers the same sub-pools and exchanges with the other pools of the NNB, but it neglects exchanges within the pool „Energy and fuels“, i.e. the exchange between the sub-pool „Energy conversion“ and the other sub-pools within the pool „Energy and fuels“ (Manufacturing industry and construction, Transport, Other energy and fuels). This simplification does not affect the resulting N flow to the atmosphere, since the emission factors of fuel combustion processes provided in IPCC 2006 and EEA 2013/2016 account for total emissions of each nitrogen containing compound (NO_x, N_2O, NH_3). They do not distinguish between nitrogen originating from the atmosphere (N_2 fixation, thermal NO_x) and nitrogen contained in the fuel (fuel NO_x).

The nitrogen balance can be simplified even further. In the most basic approach, all N flows exclusively consisting of inactive forms of nitrogen (e.g. nitrogen contained in fuels) can be neglected. In this case, the only remaining N flows are the emissions of NO_x, NH_3 and N_2O to the atmosphere. In countries that dispose of national inventories of air pollutants and greenhouse gases the N flow to the atmosphere can directly be derived from these inventories. Calculation of the N flows does in this case not require any additional data collection.

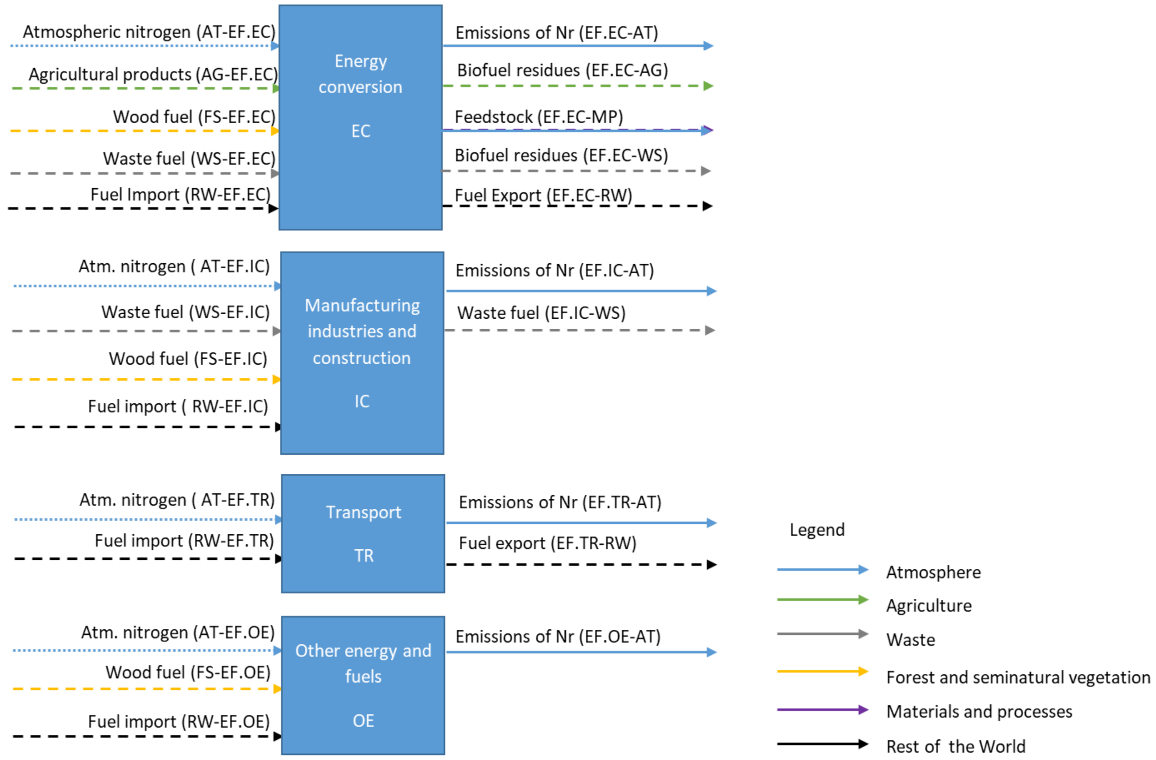

Figure 3: Simplified schematic representation of the sub-pools within the pool „Energy and fuels“. Solid arrows indicate flows of reactive nitrogen compounds (NO_x, NH_3, N_2O); dotted arrows represent flows of N_2, and dashed arrows indicate flows of other forms of inactive nitrogen.

The relevant fuel combustion processes and related emission factors of air pollutants and greenhouse gases are documented in the EMEP/EEA Guidebook (EEA 2013) and in the IPCC 2006 Guidelines (IPCC 2006) respectively. Both guidance documents provide a nomenclature for reporting (NFR), which assigns each process to a source category. They also provide a methodology for estimating related emissions.

Potentially relevant sources of nitrogen flows to the atmosphere can be identified from existing inventories of greenhouse gas and air pollutant emissions. Since the submissions of the European Union cover a wide range of different types of processes, potentially relevant sources of nitrogen emissions were identified based on the inventories of the EU[5] for the year 2016. The following section provides an overview of the relevant source categories.

3.1 Sub-pool “Energy conversion” (EC)

This sub-pool comprises all domestic heat and electricity production, except waste incineration plants, which are included in the pool Waste (Annex 5). Fuel production processes (e.g. refining of petroleum, biofuel production, manufacturing of solid fuels) is also accounted for in this sub-pool. Biogas

[5] UNFCCC Submission 2016 European union:
http://unfccc.int/files/national_reports/annex_i_ghg_inventories/national_inventories_submissions/application/zip/eua-2016-crf-9sep16.zip
UNECE Submission 2016 European union:
http://webdab1.umweltbundesamt.at/download/submissions2016/EU_NFR2016.zip?cgiproxy_skip=1

production forms an exception since it is accounted for in the pool Waste. Furthermore, emissions from flaring processes and fugitive emissions from fuels are also covered in the pool “Energy and fuels”.

Oil refining: Oil represents the most important source of energy in Europe. About 94 % of the fuels required for transport originated from oil products. In 2012, there were 655 refineries worldwide, with a total capacity of around 4,400 million t / yr (BAT, 2015). The oil industry uses a wide range of processes. Petroleum refining processes require a large amount of thermal energy, which is obtained by burning different fuels. As part of the technological processes at the refinery, there are three main categories that are relevant for the pool “Energy and fuels”:

(1) Separation processes of crude oil into boiling fractions. The main amount of reactive nitrogen is released when fuel is burned. A small amount of reactive nitrogen can also be formed when the crude oil and its fractions are heated;
(2) Oil processing processes stabilize and improve petroleum products. Undesirable elements, such as nitrogen, are removed from the intermediates. In the industry, the hydrotreating method is mainly used. At the hydrotreatment stage, nitrogen is released from the oil fractions in the reactive form (ammonia). The obtained purified products are sent to other pools (sub-pools) for use or to the next stage of processing;
(3) Deasphalting is used to separate asphalt from other products. The basic source of bitumen or asphalt is the residue remaining after vacuum distillation of crude. Asphalt is sent to the “Material and products in industry” (MP) pool, where it is used to create pavements. Asphalt contains the residues quantity of nitrogen, which can form reactive nitrogen when heated. The flow of nitrogen contained in the asphalt is described in the Annex “Energy and fuels”.

When constructing the nitrogen budget of the pool “Energy and fuels”, it is necessary to consider reactive nitrogen released during fuel combustion processes (N_2O, NO_x) as described in the IPCC Guidelines for National Greenhouse Gas Inventories and the EMEP EEA Guidebook 2013/2016 for air pollutants.

In addition, emissions of ammonia (NH_3) result from an incomplete reaction of NH_3 additive in NO_x abatement systems, i.e. selective catalytic and non-catalytic reduction (SCR and SNCR). These emissions also need to be accounted for in the NNB (BAT, 2015). The Tier 2 methodologies described in the EMEP EEA Guidebook 2013/2016 account also for emissions from application of abatement technologies, such as SCR and SNCR. In addition, reactive nitrogen is formed in the purification of certain fuels in the so called hydrotreating process (BAT, 2015). Examples of air emissions generated by hydrotreatment units are provided in BAT 2015, Table 3.65 chp. 3, p.228.

Table 3 – Assignment of NFR sectors to the sub-pool "Energy conversion" (EC). Potentially relevant emission sources, according to greenhouse gas (GHG) and air pollutant inventories of the EU in 2016, are indicated with "x". NE indicates that the emissions are "not estimated" within the existing inventories.

NFR sectors to be reported		Compound		
		N_2O	**NO_x**	**NH_3**
NFR Code	**Description**			
1A1a	Public electricity and heat production	x	x	x
1A1b	Petroleum refining	x	x	x
1A1c	Manufacture of solid fuels and other energy industries	x	x	x
1B1a	Fugitive emission from solid fuels: Coal mining and handling		x	x
1B1b	Fugitive emission from solid fuels: Solid fuel transformation	x	x	x
1B1c	Other fugitive emissions from solid fuels	x	x	NE
1B2ai	Fugitive emissions oil: Exploration, production, transport	x	x	x
1B2aiv	Fugitive emissions oil: Refining / storage	x	x	x
1B2av	Distribution of oil products	x	x	NE
1B2b	Fugitive emissions from natural gas (exploration, production, processing, transmission, storage, distribution and other)		x	NE
1B2	Venting and flaring (oil, gas, combined oil and gas)		x	x
1B2d	Other fugitive emissions from energy production		NE	NE

3.2 Sub-pool "Manufacturing industries and construction" (IC)

This sub-pool accounts for all fuel combustion processes in the manufacturing industry and construction sector, such as iron and steel production, non-ferrous metal industry, chemical industry, pulp and paper production, food processing and production of non-metallic minerals. Besides stationary combustion, mobile combustion from machinery and vehicles operating on construction sites as well as industrial vehicles are included in this sub-pool.

Note that potential N flows from the manufacturing industry that do NOT originate from fuel combustion activities, are reported in the pool 2 Materials and products in industry.

Table 4 – Assignment of NFR sectors to the sub-pool "Manufacturing industry and construction" (IC). Potentially relevant emission sources, according to GHG and air pollutant inventories of the EU in 2016, are indicated with "x".

	NFR sectors to be reported	Compound		
		N_2O	**NO_x**	**NH_3**
NFR Code	**Description**			
1A2a	Stationary combustion in manufacturing industries and construction: Iron and steel	x	x	x
1A2b	Stationary combustion in manufacturing industries and construction: Non-ferrous metals	x	x	x
1A2c	Stationary combustion in manufacturing industries and construction: Chemicals	x	x	x
1A2d	Stationary combustion in manufacturing industries and construction: Pulp, Paper and Print	x	x	x
1A2e	Stationary combustion in manufacturing industries and construction: Food processing, beverages and tobacco	x	x	x
1A2f	Stationary combustion in manufacturing industries and construction: Non-metallic minerals	x	x	x
1A2gvii	Mobile Combustion in manufacturing industries and construction: (please specify in the IIR)	x	x	x
1A2gviii	Stationary combustion in manufacturing industries and construction: Other (please specify in the IIR)	x	x	x

3.3 Sub-pool Transport (TR)

This sub-pool covers all fuel combustion activities within the transport sector. This includes road and rail transport as well as shipping and aviation. Pipeline transport is also included in this sub-pool.

Table 5 – Assignment of NFR sectors to the sub-pool Transport (TR). Potentially relevant emission sources, according to GHG and air pollutant inventories of the EU in 2016, are indicated with "x". NE indicates that the emissions are "not estimated".

	NFR sectors to be reported	Compound		
		N_2O	**NO_x**	**NH_3**
NFR Code	**Description**			
1A3ai(i)	International aviation LTO (civil)	x	x	x
1A3aii(i)	Domestic aviation LTO (civil)	x	x	x
1A3bi	Road transport: Passenger cars	x	x	x
1A3bii	Road transport: Light duty vehicles	x	x	x
1A3biii	Road transport: Heavy duty vehicles and buses	x	x	x
1A3biv	Road transport: Mopeds & motorcycles	x	x	x
1A3bv	Road transport: Gasoline evaporation		NE	NE
1A3bvi	Road transport: Automobile tyre and brake wear		NE	NE
1A3bvii	Road transport: Automobile road abrasion		NE	NE
1A3c	Railways	x	x	x
1A3di(ii)	International inland waterways	x	x	x
1A3dii	National navigation (shipping)	x	x	x
1A3ei	Pipeline transport	x	x	x
1A3eii	Other (please specify in the IIR)	NE	x	x

3.4 Sub-pool "Other energy and fuels" (OE)

This sub-pool accounts for all energy combustion activities that are not already covered in one of the other sub-pools. The most important activity is stationary fuel combustion in the residential and commercial sector. Furthermore, this sub-pool includes emissions from mobile sources, such as off-road vehicles and other machinery used in the commercial and residential sector (i.e. household devices and gardening equipment) as well as in the agriculture, forestry and fishing sector.

Table 6 – Assignment of NFR sectors to the sub-pool "Other energy and fuels" (OE). Potentially relevant emission sources, according to GHG and air pollutant inventories of the EU in 2016, are indicated with "x".

NFR sectors to be reported		Compound		
		N_2O	NO_x	NH_3
NFR Code	**Description**			
1A4ai	Commercial/institutional: Stationary	x	x	x
1A4aii	Commercial/institutional: Mobile	x	x	x
1A4bi	Residential: Stationary	x	x	x
1A4bii	Residential: Household and gardening (mobile)	x	x	x
1A4ci	Agriculture/Forestry/Fishing: Stationary	x	x	x
1A4cii	Agriculture/Forestry/Fishing: Off-road vehicles and other machinery	x	x	x
1A4ciii	Agriculture/Forestry/Fishing: National fishing	x	x	x
1A5a	Other stationary (including military)	x	x	x
1A5b	Other, Mobile (including military, land based and recreational boats)	x	x	x

4 Description of flows

4.1 Overview of the nitrogen flows

This section describes the major flows of nitrogen between the pool „Energy and fuels" and the other pools[6] of the NNB, specifying when possible the flows per sub-pool. It also provides information on possible approaches and data sources for quantifying these flows. An overview of the nitrogen flows between the pool „Energy and fuels" and the other pools of the NNB is presented in Table 7.

Besides exchanges with other pools, there are also N flows within the pool "Energy and fuels" to be accounted for, notably the exchange between the sub-pool "Energy conversion" (EC) and the sub-pools "Manufacturing industry and construction" (IC), Transport (TR) and "Other energy and fuels" (OE).

[6] Acronyms of the different pools used in the National Nitrogen Budget (NNB) are documented in Annex 0, Tab. 1

Table 7 - Nitrogen flows between the pool „Energy and fuels" and the other pools and sub-pools of the NNB

Flow name	Pool Out	Pool In	Pro-cess	Major N forms	Sub-pools involved	Flow Codes	Description	Annex describing the method
		Materials & Products						
EF_MP	EF	MP	Feed stock	N feedstock	EC	EF.EC_MP.OP	Fuels used as feedstock in industrial processes	Annex EF
		Agriculture						
AG_EF	AG	EF	Agricultural fuels	N fuel	EC	AG_EF.EC	Agricultural products used for energy generation and fuel production	Annex AG
EF_AG	EF	AG	Digestate	N_{org}	EC	EF.EC_AG	Residues from biofuel production that are used as animal feed	Annex EF
		Forest and semi-natural vegetation						
FS_EF	FS	EF	Wood fuel	N fuel	EC, IC, OE	FS.FO_EF.EC FS.FO_EF.IC FS.FO_EF.OE	Direct use of wood fuel and use of wood fuel in energy conversion processes	Annex FS
		Waste						
WS_EF	WS	EF	Waste fuel	N fuel	IC	WS_EF.IC	Direct use of waste fuel in industrial processes	Annex WS
EF_WS	EF	AG	Digestate	N_{org}	EC	EF.EC_WS	Residues from biofuel production that are incinerated in waste incineration plants or transferred to landfills or composting sites	Annex EF
		Atmosphere						
EF_AT	EF	AT	Emissions	NH_3, NO_x, N_2O	EC, IC, TR, OE	EF.EC_AT EF.IC_AT EF.TR_AT EF.OE_AT	Release of reactive nitrogen species during fuel com-bustion processes	Annex EF
AT_EF	AT	EF	N fixation	N_2	EC, IC, TR, OE	AT_EF.EC AT_EF.IC AT_EF.TR AT_EF.OE	Technical Fixation of nitrogen during fuel combustion processes	Annex EF
		Rest of World						
RW_EF	RW	EF	fuel import	N fuel	EC, IC, TR, OE	RW_EF.EC RW_EF.IC RW_EF.TR RW_EF.OE	Import of fuels	Annex EF
EF_RW	EF	RW	fuel export	N fuel	EC, IC, TR, OE	EF.EC_RW EF.IC_RW EF.TR_RW EF.OE_RW	Export of fuels	Annex EF

As described in Annex 0, the Annex "Energy and fuels" only provides a methodology for quantifying N flows, which originate from the pool „Energy and fuels" except for the fixation of atmospheric nitrogen, which is also described in the Annex „Energy and fuels". The methods for quantifying N flows entering the pool "Energy and fuels" are described in the Annexes of the pools from which these N flows originate.

Theoretically, the nitrogen budget of the pool „Energy and fuels" should be closed. According to the balance equation, the sum of the net nitrogen flows between the pool „Energy and fuels" and the other pools (EF_{net}, kgN/yr) and the change in stocks (ΔStock, kgN/yr) should equal zero:

$$EF_{net} + \Delta Stock = 0 \qquad \text{(Eq1)}$$

EF_{net} is defined as the sum of the net nitrogen flow between the pool „Energy and fuels" and each of the other pools:

$$EF_{net} = EF\_AT_{net} + EF\_MP_{net} + EF\_AG_{net} + EF\_FS_{net} + EF\_WS_{net} + EF\_RW_{net} \quad \text{(Eq2)}$$

However, a lack of information, inconsistent data, unaccounted flows and errors can affect the NNB and contribute to its uncertainty (UN ECE 2013, ECE/EBAIR/119).

4.2 Exchanges with the pool Atmosphere (EF_AT)

The net N flow between the pool „Energy and fuels" and the pool Atmosphere (EF_AT_{net}) is defined as:

$$EF\_AT_{net} = AT\_EF - EF\_AT \qquad \text{(Eq3)}$$

AT_EF indicates N flows related to the processes of fixation of atmospheric nitrogen and EF_AT comprises the emissions from fuel combustion. These emissions cover on one hand gaseous nitrogen compounds originating from nitrogen that is chemically bound in the fuels ("fuel NO_x") and on the other hand emissions that result from fixation of N_2 during the combustion process ("thermal NO_x"). The emission factors provided in the Guidebook (EEA 2013) and Guidelines (IPCC 2006) provide only information on the total NO_x emissions. They do not distinguish between NO_x originating from nitrogen that is chemically bound in the fuel and from fixation of N_2 from the atmosphere.

The flow from the atmosphere to the pool „Energy and fuels" consists of inactive nitrogen (N_2). It can be quantified based on a mass balance. The total emissions of nitrogen from fuel combustion processes (EF_AT) must be equal to the sum of nitrogen contained in the fuel (N_{fuel} = Activity data x nitrogen content, f_N) and the fixation of atmospheric nitrogen. Since the nitrogen content of different fuel types is known (see Table 2 for default values), the amount nitrogen from the atmosphere can be estimated by computing the total emissions of nitrogen from fuel combustion (EF_AT) and subtracting the nitrogen that originated from the fuel (N_{fuel}).

Table 8 – Overview of N exchanges with the pool Atmosphere

Flow name	Description	Method of computation	Suggested data sources
AT_EF	Fixation of N_2	$EF\_AT - N_{fuel}$	This flow consists of fixation of unreactive nitrogen (N_2) during fuel combustion. This flow can be computed from a mass balance: Total emissions of nitrogen from fuel combustion (EF_AT) minus nitrogen contained in the fuels ($N_{fuel} = AD \times f_N$) equal fixation of atmospheric nitrogen. • AD (Activity data): National statistics • f_N (N content): EEA 2013 1A1 Energy industries, appendix B, scientific literature, measurements of fuel composition (see Table 2 for default values)
EF_AT	Emissions of NO_x, NH_3 and N_2O from fuel combustion.	AD (activity data) x EF	1) If national inventories are available: • NH_3, NO_x: CLRTAP Inventory Submissions[7] • N_2O: UNFCCC National Inventory Submissions[8] 2) If no national inventories are available: • AD (activity data): National statistics on fuel consumption • EF (emission factor): ○ NH_3, NO_x: EMEP/EEA Guidebook 2013/2016 ○ N_2O: IPCC Guidelines 2006

Methodology

The N flows from the pool „Energy and fuels" to the atmosphere can be quantified based on the amount of fuel consumed (activity data, AD) and the emission factors (EF) of all nitrogen containing compounds formed in the combustion process.

$$EF\_AT = AD \cdot EF \quad \text{(Eq4)}$$

The emission factors of gaseous nitrogen compounds formed in combustion processes differ depending on the fuel type and depending on the combustion process and technology applied. Therefore, the corresponding N flows need to be determined for each type of combustion process separately accounting for country-specific circumstances in terms of combustion technologies that are applied.

The N flow from each sub-pool to the atmosphere (EF_AT) consists of the sum of N flows from each combustion process (j) covered by the sub-pool, fuel (i) and pollutant/GHG (k). Activity data need to be disaggregated according to combustion process (j) and fuel type (i) and corresponding emission factors depend on the combustion process (j), the fuel type (i) and the pollutant/GHG (k).

$$EF\_AT = \sum_i \sum_j \sum_k EF_{i,j,k} \cdot AD_{i,j} \quad \text{(Eq5)}$$

[7] http://www.ceip.at/status_reporting/
[8] http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/9492.php

Emissions of NO_x, NH_3, N_2O occur in each of the four sub-pools of the pool „Energy and fuels“ (“Energy conversion” EC, “Manufacturing industries and construction” IC, Transport TR and “Other energy” OE). Table 3 - Table 6 summarize, which source categories are covered in each sub-pool and which nitrogen containing compounds need to be accounted for in each source category (i.e. NO_x, NH_3, N_2O).

The methodology for estimating the N flow from the pool „Energy and fuels“ to the pool Atmosphere is based on the EMEP/EEA Guidebook (EEA 2013/2016) for NO_x and NH_3 and on the IPCC 2006 Guidelines 2016 (IPCC 2006) for N_2O. These documents provide default emission factors for all relevant chemical compounds (NO_x, NH_3, N_2O) for commonly applied combustion process and technologies. To derive the flow of nitrogen, the emissions of each nitrogen containing compound need to be converted into the respective amount of nitrogen based on the stoichiometric conversion factors as shown in Table 1.

For each source category, both a simplified method based on default values (Tier 1) and a more elaborate method based on technology- or country-specific emission factors (Tier 2 or Tier 3) is provided in the guidance documents. For estimating nitrogen flows at a Tier 1 level it is recommended to apply a Tier 1 method as described in the EMEP EEA Guidebook (EEA 2013/2016) and IPCC 2006 Guidelines (IPCC 2006) respectively. For estimating nitrogen flows at a Tier 2 level, it is recommended to estimate emissions at a Tier 2 or 3 level according to the Guidebook/Guidelines.

The methodology for estimating the N flow from the pool Atmosphere to the pool „Energy and fuels“ is based on a mass balance. Total emissions of nitrogen from fuel combustion processes (EF_AT) must be equal to the sum of nitrogen contained in the fuel (N_{fuel} = AD x f_N) and the fixation of atmospheric nitrogen.

Based on the nitrogen content of different fuel types (see Table 2), the amount nitrogen from the atmosphere can be estimated as follows. The amount of atmospheric fixation of nitrogen corresponds to the difference between total emissions of nitrogen from fuel combustion (EF_AT, see Eq5) and the amount of nitrogen originating from the fuel (N_{fuel}) itself. The latter is estimated based on the amount of fuel used (AD) and its nitrogen content (f_N).

AT_EF = EF_AT – N_{fuel}

AT_EF = $\sum_i \sum_j \sum_k EF_{i,j,k} \cdot AD_{i,j} - \sum_i \sum_j f_i \cdot AD_i$ (Eq6)

Data sources

For countries that submit national greenhouse gas inventories and air pollutant inventories, emission data are readily available from the UNFCCC and EEA websites respectively:

- Data on NOx and NH3 emissions can be downloaded from emission database of EMEP (Co-operative programme for monitoring and evaluation of long range transmission of air pollutants in Europe) link: http://www.ceip.at/status_reporting/
- The N2O emissions can be quantified by following the IPCC guidelines for National Greenhouse Gas Inventories (IPCC, 2006). Related emission data can be downloaded from the UNFCCC website. link:

http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/10116.php

If a country does not submit an air pollutant or a greenhouse gas inventory, the corresponding emissions need to be calculated according to the Tier methods described in the EMEP EEA Guidebook (EEA2013/2016) and IPCC 2006 Guidelines (IPCC 2006). For a Tier 1 approach based on default emission factors, the only data requirement are fuel quantities consumed in each process. For higher Tier methods, additional information on combustion technologies used and application of abatement technologies is required. In addition, higher Tier methods may require country-specific emission factors.

The flow AT_EF can be quantified based on activity data for the fuel consumption from industry statistics. The nitrogen content of the fuels can be determined either by scientific literature (Tier 1) or by measurements (Tier 2).

Uncertainties

Table 5 in Annex 0 provides guidance on how to assess uncertainties.

- If emissions of gaseous nitrogen compounds are estimated primarily based on a Tier 1 method, an uncertainty level of 3 or 4 is recommended, since the method relies on default emission factors, which might not be representative of the national situation. An uncertainty level of 3 is recommended, if mostly official, up to date statistics or measurements are used to determine activity data. Otherwise, the recommended uncertainty level is 4.
- If primarily a Tier 2 method (i.e. Tier 2 or Tier 3 according to the EMEP EEA Guidebook 2013/2016 or IPCC 2006 Guidelines) is applied, the uncertainty level is likely to be 1 or 2. An uncertainty level of 1 is recommended, if mostly official, up to date statistics or measurements are applied. Otherwise, the recommended uncertainty level is 2.

4.3 Exchanges with the pool Agriculture (EF_AG)

Exchanges with the pool Agriculture comprise the use of agricultural products for energy generation. The net nitrogen flow between the pool „Energy and fuels“ and the pool Agriculture (EF_AG_{net}) is defined as:

$$EF\_AG_{net} = AG\_EF - EF\_AG \quad \text{(Eq7)}$$

The N flow AG_EF comprises the flow of nitrogen contained in agricultural by-products that are used for energy generation. This excludes production of biogas, which is accounted for in the Annex WS.

Residues from the anaerobic digestion process in biofuel production (digestate) are used as animal feed in the agricultural sector. The N flow EF_AG accounts for nitrogen contained in these residues from biofuel production other than biogas production. Energy combustion in the agricultural sector itself is covered in the sub-pool EF.OE.

Table 9 – Overview of N exchanges with the pool Agriculture

Flow name	Description	Method of computation	Suggested data sources
AG_EF	Biomass fuels from the pool Agriculture	Annex AG	see Annex AG
EF_AG	Digestate/Residues from biofuel production that are used as animal feed in the pool Agriculture	AD x f_N	AD (Activity data): industry statistics f_N (N content): scientific literature, measurements

Methodology

It is assumed that agricultural fuels are used solely in the sub-pool "Energy conversion". Therefore, only the flow AG_EF.EC needs to be accounted for.

AG_EF = AG_EF.EC (Eq8)

As this flow originates from the pool agriculture, the method of computation can be found in the corresponding Annex AG.

The flow EF_AG consists of residues from biofuel production that are used as animal feed in the pool Agriculture. This nitrogen flow can be quantified based on the amount of digestate produced in the sub-pool "Energy Conversion" (activity data, AD) and the respective nitrogen content (f_N) of the digestate. The nitrogen content needs to be determined based on scientific literature or country-specific measurements.

EF_AG = EF.EC_AG = AD x f_N (Eq9)

Data sources

For quantification of the flow AG_EF, see Annex AG.

The flow EF_AG can be quantified based on activity data for the biofuel residues from industry statistics. The nitrogen content of the residues can be determined either by scientific literature (Tier 1) or by measurements (Tier 2).

Uncertainties

For quantification of uncertainties in the flow AG_EF, see Annex AG.

Table 5 in Annex 0 provides guidance on how to assess uncertainties.

- If emissions are estimated based on a Tier 1 method, an uncertainty level of 3 or 4 is recommended, since the method is based on default nitrogen content of biofuel residues, which might not be representative of the national circumstances. An uncertainty level of 3 is recommended, if official, up to date statistics or measurements are used to determine activity data. Otherwise, the recommended uncertainty level is 4.

- If a Tier 2 method is applied, the uncertainty is likely to be 1 or 2. An uncertainty level of 1 is recommended, if official, up to date statistics or measurements are applied. Otherwise, the recommended uncertainty level is 2.

4.4 Exchanges with the pool "Forest and semi-natural vegetation" (EF_FS)

The net nitrogen flow between the pool „Energy and fuels" and the pool "Forest and semi-natural vegetation" (EF_FS_{net}) is defined as:

EF_FS_{net} = FS_EF (Eq10)

The N flow FS_EF comprises the flow of nitrogen contained in biomass from the pool "Forest and semi-natural vegetation" that is used as fuel to the pool „Energy and fuels". No flow exists from the pool „Energy and fuels" to the pool "Forest and semi-natural vegetation".

Table 10 – Overview of N exchanges with the pool Forest and semi-natural vegetation

Flow name	Description	Method of computation	Suggested data sources
FS_EF	Biomass fuels from the Forest and semi-natural vegetation pool	Annex FS	Annex FS

Methodology

As the flow FS_EF originates from the pool "Forest and semi-natural vegetation", the method of computation can be found in the corresponding Annex FS.

The partitioning of this flow into the different sub-pools of the „Energy and fuels" pool corresponds to the shares of biomass that is consumed in the different sub-pools. Biomass from the pool "Forest and semi-natural vegetation" is used mainly in the sub-pools "Energy conversion" (EC), "Manufacturing industries and construction" (IC) and "Other energy and fuels" (OE). The total N flow can therefore be partitioned as follows:

FS_EF = FS_EF.EC + FS_EF.IC + FS_EF.OE (Eq11)

By defining for each fuel i used in sub-pool j a corresponding share $C_{i,j}$, the total N flow can be calculated by the following equation:

FS_EF = $\sum_i \sum_j C_{i,j} \cdot \mathrm{FS\_EF}$ (Eq12)

Thus for each sub-pool, the corresponding N flow can be computed as follows:

FS_EF.EC = $\sum_i C_{i,EC} \cdot \mathrm{FS\_EF}$ (Eq13)

FS_EF.OE = $\sum_i C_{i,OE} \cdot \mathrm{FS\_EF}$ (Eq14)

FS_EF.IC = $\sum_i C_{i,IC} \cdot \mathrm{FS\_EF}$ (Eq15)

Data sources

see Annex FS

Uncertainties

see Annex FS

4.5 Exchanges with the pool "Materials and products" (EF_MP)

The net nitrogen flow between the pool „Energy and fuels" and the pool "Material and Products" (EF_MP_{net}) is defined as:

EF_MP_{net} = EF_MP (Eq16)

EF_MP_{net} equals the N flow from the pool „Energy and fuels" to the pool "Materials and processes" (EF_MP). This flow comprises the non-energy use of fuels, which includes for example the use of bitumen and asphalt for road paving and roof covering or the use as lubricating oil in engines as well as other uses of oils and greases for industrial purposes (e.g. heat transfer, cutting oil). Production of these fuels is covered in the sub-pool "Energy conversion" and the use of these fuels is accounted for in the pool "Materials and processes". The nitrogen compounds contained in these fuels is considered inactive. To improve completeness of the NNB, it is recommended to include these nitrogen flows as well. There are no flows from the pool Materials and processes and the pool „Energy and fuels".

Table 11 – Overview of N exchanges with the pool Materials and products

Flow name	Description	Method of computation	Suggested data sources
EF_MP	Non-energy use of fuels in industrial processes (lubricants, bitumen)	AD x f_N	AD (Activity data): National energy balances, industry statistics, UNFCCC National Inventory Submissions f_N (N content) EEA 2013, 1A1 Energy industries, appendix B, scientific literature, measurements (see Table 2: for default values)

Methodology

Fuels used in industrial processes originate only from the sub-pool "Energy conversion". Therefore, only the flow from this sub-pool (EF.EC_MP) needs to be accounted for.

EF_MP_{net} = EF.EC_MP (Eq17)

The exchange of nitrogen with the pool "Materials and processes" is computed by multiplying for each type of fuel, i, the amount of fuel (AD) with the respective N content (f_N). The total flow corresponds to the sum over all fuel types.

$EF.EC\_MP = \sum_i AD_i \cdot f_{N,i}$ (Eq18)

Data sources

Tier 1:

- Nitrogen content (fN): For a Tier 1 approach the nitrogen content can be estimated using default values for the N content provided in Table 2.
- Activity data (AD): The quantities of fuel used in non-energy uses can be taken from UNFCCC national inventory submissions, national energy balances or industry statistics.

Tier 2:

- Nitrogen content (fN): In a Tier 2 approach, the nitrogen content is determined based on country-specific data for each type of fuel.
- Activity data (AD): see Tier 1.

Uncertainties

Table 5 in Annex 0 provides guidance on how to assess uncertainties.

- If emissions are estimated based on a Tier 1 method, an uncertainty level of 3 or 4 is recommended, since the method is based on default nitrogen content of fuels, which might not be representative of the national circumstances. An uncertainty level of 3 is recommended, if official, up to date statistics or measurements are used to determine activity data. Otherwise, the recommended uncertainty level is 4.
- If a Tier 2 method is applied, the uncertainty is likely to be 1 or 2. An uncertainty level of 1 is recommended, if official, up to date statistics or measurements are applied. Otherwise, the recommended uncertainty level is 2.

4.6 Exchanges with the pool Waste (EF_WS)

The net nitrogen flow between the pool "Energy and fuels" and the Waste pool (EF_WS_{net}) is defined as:

$$EF\_WS_{net} = WS\_EF - EF\_WS \qquad \text{(Eq19)}$$

WS_EF is the flow of nitrogen contained in waste fuels used as fuel in industrial combustion processes (e.g. cement production). The flow EF_WS accounts for nitrogen contained in the digestate and residues of biofuel production that is generated as a by-product in the sub-pool „Energy conversion" and transferred to the pool Waste, e.g. to waste incineration plants, landfills or composting sites.

Waste incineration plants are not included in the pool „Energy and fuels", independent of whether the energy produced in the waste incineration process is recovered or not. All waste incineration plants are accounted for in the pool Waste.

Table 12 – Overview of N exchanges with the pool Waste

Flow name	Description	Method of computation	Suggested data sources
WS_EF	Combustion of waste fuels excluding waste incineration plants	Annex WS	Annex WS
EF_WS	Digestate/Residues as by-products from biofuel production that are transferred to waste incineration plants, landfills or composting sites.	Activity data (AD) x Nitrogen content (f_N) AD x f_N	AD (Activity data): industry statistics f_N (N content): scientific literature, measurements

Methodology

Waste fuels are primarily used in the sub-pool “Manufacturing industry and construction” (EF.IC). Therefore, only the flow WS_EF.IC needs to be accounted for.

WS_EF = WS_EF.IC (Eq20)

The nitrogen flow from the pool waste to the pool „Energy and fuels” (WS_EF.IC) is quantified in the Annex WS.

The flow from the pool „Energy and fuels” to the pool waste (EF.EC_WS) consists of digestate that is incinerated in waste incineration plants or digestate that is composted. These flows are computed by multiplying the activity data (amount of digestate incinerated in waste incineration plants or amount of composted digestate) and the corresponding nitrogen content of the digestate (f_N).

EF_WS = EF.EC_WS = AD x f_N (Eq21)

Data sources

For quantification of the flow WS_EF, see Annex WS.

The flow EF_WS can be quantified based on activity data for the biofuel residues from industry statistics. The nitrogen content of the residues can be determined either by scientific literature (Tier 1) or by measurements (Tier 2).

Uncertainties

For quantification of uncertainties in the flow WS_EF, see Annex WS.

Table 5 in Annex 0 provides guidance on how to assess uncertainties.

- If emissions are estimated based on a Tier 1 method, an uncertainty level of 3 or 4 is recommended, since the method is based on default nitrogen content of biofuel residues, which might not be representative of the national circumstances. An uncertainty level of 3 is recommended, if official, up to date statistics or measurements are used to determine activity data. Otherwise, the recommended uncertainty level is 4.

- If a Tier 2 method is applied, the uncertainty is likely to be 1 or 2. An uncertainty level of 1 is recommended, if official, up to date statistics or measurements are applied. Otherwise, the recommended uncertainty level is 2.

4.7 Exchanges with the pool "Rest of the world" (EF_RW)

Fuel imports can occur all sub-pools. Fuel exports are primarily relevant for the sub-pools "Energy conversion" and Transport (i.e. "fuel tourism").

The net nitrogen flow between the pool „Energy and fuels" and the Rest of the world pool (EF_RW_{net}) is defined as:

EF_RW_{net} = RW_EF - EF_RW (Eq22)

RW_EF and EF_RW are the N flows associated with the import and export across the national borders respectively.

Table 13 – Overview of N exchanges with the pool Rest of the world

Flow name	Description	Method of computation	Suggested data sources
RW_EF	Fuel import	Activity data (AD) x Nitrogen content (f_N) AD x f_N	AD (Activity data): Customs statistics f_N (N content): EEA 2013 1A1 Energy industries, appendix B, scientific literature, measurements of fuel composition (see Table 2: for default values)
EF_RW	Fuel export	Activity data (AD) x Nitrogen content (f_N) AD x f_N	AD (Activity data): Customs statistics, National energy balances, Sectoral energy statistics of transport sector f_N (N content): EEA 2013 1A1 Energy industries, appendix B, scientific literature, measurements of fuel composition (see Table 2: for default values)

Methodology

The exchange of nitrogen with the pool "Rest of the world" is computed by multiplying for each fuel, i, the amount of imported and exported fuel (AD) with the respective N content (f_N).

RW_EF = $\sum_i AD_i \cdot f_{N,i}$ (Eq23)

EF_RW = $\sum_i AD_i \cdot f_{N,i}$ (Eq24)

As these flows comprise only inactive nitrogen compounds, they do not need to be quantified (see ECE/EB.AIR/119, chp. V.A., „Energy and fuels"). However, it is recommended to include these N flows in the NNB to achieve a more complete balance.

The Tier 1 and Tier 2 approaches are both based on the same methodology. They differ only in terms of the data sources used for estimating the fraction of nitrogen.

Data sources

Tier 1:

- Nitrogen content (fN): For a Tier 1 approach the nitrogen content can be estimated using default values for the N content provided in Table 2.
- Activity data (AD): The quantities of imported and exported fuel are provided in national customs statistics. Activity data in the sub-pool Transport consist of an estimate of the net amount of fuel imported or exported due to “fuel tourism”. Corresponding data might be available in national energy balances or in sectoral energy statistics of the transport sector.

Tier 2:

- Nitrogen content (fN): In a Tier 2 approach, the nitrogen content is determined based on country-specific data for each type of fuel.
- Activity data (AD): see Tier 1.

Uncertainties

Table 5 in Annex 0 provides guidance on how to assess uncertainties.

- If emissions are estimated based on a Tier 1 method, an uncertainty level of 3 or 4 is recommended, since the method is based on default nitrogen content of fuels, which might not be representative of the national circumstances. An uncertainty level of 3 is recommended, if official, up to date statistics or measurements are used to determine activity data. Otherwise, the recommended uncertainty level is 4.
- If a Tier 2 method is applied, the uncertainty is likely to be 1 or 2. An uncertainty level of 1 is recommended, if official, up to date statistics or measurements are applied. Otherwise, the recommended uncertainty level is 2.

4.8 Exchanges within the pool „Energy and fuels“ (EF_EF)

The net nitrogen flow within the pool „Energy and fuels“ consists of three flows from the sub-pool “Energy conversion” to the sub-pools “Manufacturing industry and construction”, “Transport” and “Other energy and fuels”:

$$EF\_EF_{net} = EF.EC\_EF.IC + EF.EC\_EF.TR + EF.EC\_EF.OE \qquad \text{(Eq25)}$$

These N flows account for the flow of nitrogen in fuels that are produced and consumed within the country.

Table 14 – Overview of N exchanges within the pool „Energy and fuels“

Flow name	Description	Method of computation	Suggested data sources
EF.EC_EF.IC	N flow from fuels produced within the country to the sub-pool “Manufacturing industry and combustion”	Activity data (AD) x Nitrogen content (f_N) AD x f_N	AD (Activity data): Sectoral energy statistics (IC) on amount of fuel produced and used in the country f_N (N content): EEA 2013/2016 1A1 Energy industries, appendix B; Measurements of fuel composition, scientific literature (see Table 2: for default values)
EF.EC_EF.TR	N flow from fuels produced within the country to the sub-pool Transport	Activity data (AD) x Nitrogen content (f_N) AD x f_N	AD (Activity data): Sectoral energy statistics (TR) on amount of fuel produced and used in the country f_N (N content): EEA 2013/2016 1A1 Energy industries, appendix B; Measurements of fuel composition, scientific literature (see Table 2: for default values)
EF.EC_EF.OE	N flow from fuels produced within the country to the sub-pool “Other energy”	Activity data (AD) x Nitrogen content (f_N) AD x f_N	AD (Activity data): Sectoral energy statistics (EO) on amount of fuel produced and used in the country f_N (N content): EEA 2013/2016 1A1 Energy industries, appendix B; Measurements of fuel composition, scientific literature (see Table 2: for default values)

Methodology

The exchange of nitrogen within the pool „Energy and fuels“ is computed by multiplying for each fuel, i, the amount of fuel (AD) consumed in each sub-pool with the respective N content (f_N). The same methodology can be applied for each nitrogen flow within the pool „Energy and fuels“ (EF.EC_EF.IC, EF.EC_EF.TR and EF.EC_EF.OE).

EF.EC_EF.IC = $\sum_i AD_i \cdot f_{N,i}$ (Eq26)

EF.EC_EF.TR = $\sum_i AD_i \cdot f_{N,i}$ (Eq27)

EF.EC_EF.OE = $\sum_i AD_i \cdot f_{N,i}$ (Eq28)

As these flows comprise only inactive nitrogen compounds, they do not need to be quantified (see ECE/EB.AIR/119, chp. V.A., „Energy and fuels“). However, it is recommended to include these N flows in the NNB to achieve a more complete nitrogen balance.

The Tier 1 and Tier 2 approaches are both based on the same methodology. They differ only in terms of the data sources used for estimating the fraction of nitrogen.

Data sources

Tier 1:

- Nitrogen content (fN): For a Tier 1 approach the nitrogen content is estimated using default values for the N content provided in Table 2.
- Activity data (AD): To quantify the nitrogen flows within the pool „Energy and fuels“ the amount of fuels produced and consumed within a country need to be determined. Furthermore, the amounts of fuels consumed need to be differentiated according to the sub-pools (Transport, Manufacturing industry and construction, Other energy). These data can be obtained from sectoral energy statistics.

Tier 2:

- Nitrogen content (fN): In a Tier 2 approach, the nitrogen content is determined based on country-specific data for each type of fuel.
- Activity data (AD): see Tier 1.

Uncertainties

Table 5 in Annex 0 provides guidance on how to assess uncertainties.

- If emissions are estimated based on a Tier 1 method, an uncertainty level of 3 or 4 is recommended, since the method is based on default nitrogen content of fuels, which might not be representative of the national circumstances. An uncertainty level of 3 is recommended, if official, up to date statistics or measurements are used. Otherwise, the recommended uncertainty level is 4.
- If a Tier 2 method is applied, the uncertainty is likely to be 1 or 2. An uncertainty level of 1 is recommended, if official, up to date statistics or measurements are applied. Otherwise, the recommended uncertainty level is 2.

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6 Document version

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Annex 2 – Material and Products in Industry (Processes)

1 Introduction

This annex defines the pool "Material and products in industry" (MP) and its interaction with other eight essential pools: 1) Energy and fuels (EF), 3) Agriculture (AG), 4) Forest and semi-natural vegetation including soils (FS), 5) Waste (WS), 6) Humans and settlements, 7) Atmosphere (AT) and 8) Hydrosphere (HY) in an NNB (external structure). The internal structure of pool MP describes it with sub-pools and relevant flows. It furthermore provides specific guidance on how to calculate relevant nitrogen flows related to the MP pool, presenting calculation methods and suggesting possible data sources. Furthermore, it points to information that needs to be provided by and coordinated with other pools. General aspects of nomenclature, definitions and compounds to be covered are being dealt with in the "General Annex" to the guidance document.

2 Definition

2.1 Activities and flows encompassed by the pool

The MP pool covers industrial processes following the concepts employed by UNFCCC and UNECE for atmospheric emissions (IPCC, 2006; EEA, 2013). Activities described are those of transformation of goods with the purpose of creating a higher-value product to be made available to general economy. Specifically excluded from this pool are energy carriers, which are being dealt with in the EF pool.

Flows of reactive nitrogen (Nr) change this pool by ways of other pools, by imports or exports, or from an Nr source within the pool. For MP, clearly the main source of nitrogen fixation is the Haber-Bosch ammonia synthesis. Industry processes also use nitrogen in agricultural products for food and feed products, and in chemical industry for fertilizers, explosives, fibers and other formable material (plastics), and dyes. During such processes, Nr contained in raw materials may become unreactive by formation of molecular nitrogen (N_2 released to the atmosphere) or otherwise by "sealing" it into a form inaccessible to further transformation, and thus also rendering it inactive for environmental purposes. While flows of all forms of nitrogen other than molecular nitrogen need to be reported, situations exist when it is useful to separate inactive nitrogen from reporting of reactive nitrogen. This is the case when a certain process is needed to make the "sealed" nitrogen bioavailable again as a new source (most typically, this would be a combustion).

The following groups of industrial processes relevant for nitrogen budgets can be distinguished:

1) Processing of biomass that contains nitrogen, for example, the food industry;

2) Producing inorganic and organic components that contain) nitrogen, such as ammonia, nitric acid, fertilizers, polymers, etc.;

3) Usage of nitrogen-containing reagents to produce compounds which themselves do not contain nitrogen, for example, synthesis of adipic acid;

Processes that use fuels, which contain nitrogen as an impurity (for example, cement or soda production, etc.), are discussed in Annex 1, Energy and Fuels.

Global supply of nitrogen for use in the economy occurs in two main ways. Firstly, it is biological nitrogen fixation by plants, and secondly, it is an industrial process for producing ammonia according to the method of Haber-Bosch process. Both processes eventually provide nitrogen for MP, the first one as imports from the AG pool, the second as source within the MP pool itself (molecular N_2 in the Haber-Bosch process is taken up from the atmosphere).

The major flows of nitrogen regard the delivery of products to the consumers. For the purpose of this report it is important to distinguish two separate streams of products. One stream of materials is meant for bioavailability (food and feed), with nitrogen contained mostly in form of protein. The other stream subsumes products that apply nitrogen components in many different ways, from fibers to moldable plastics, from dyes to explosives. Some of these products contain nitrogen in a form that will seal it from further transformation – such a sealing process will be considered as a nitrogen sink which needs to be specifically evaluated to balance out against the generally well-recorded production/fixation statistics.

In the interaction between pools, it is the flows (inflows and outflows) which need to be addressed. Figure 1 provides an overview on the most important interactions between MP and other pools. Especially for MP, imports and exports are very relevant also. An overview on the relationship between MP with respect to each of the other pools is presented in Table 1. Section 4 describes the respective relevant flows in detail, considering the overall boundary of significance of 100 g N per inhabitant (see general annex).

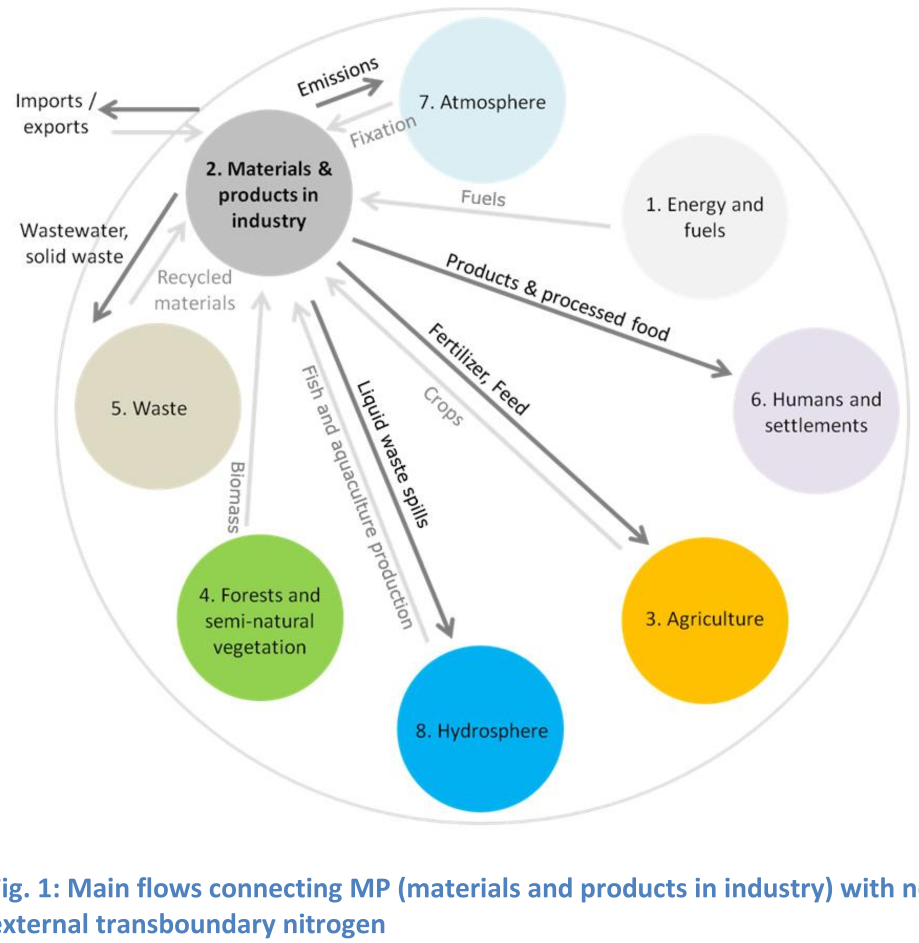

Fig. 1: Main flows connecting MP (materials and products in industry) with neighbouring pools and external transboundary nitrogen

While covering large economic entities, the MP pool does not cover the energy sector, or energy-related N flows within the entities. In agreement with UNFCCC and UNECE guidance (IPCC, 2006; EEA, 2013), such N-flows remain with the EF pool. Also, energy conversion installations (refineries, power plants) are by definition not considered part of MP.

2.2 Definition of boundaries

MP pool consists of all industrial processes that use nitrogen containing substances. The boundaries of the basin are defined by a set of industrial processes involving nitrogen-containing substances. There are the processes of obtaining targeted nitrogen-containing substances and the processes in which nitrogen-containing substances are participating as a precursor. The sources of nitrogen for the MP pool are nitrogen in atmosphere, fossil raw materials and nitrogen-containing organic products

Since the MP pool integrates a large number of chemical and biological substances and processes that take place inside the pool, a division of MP pool for several sub-pools will be beneficial to the nitrogen budget calculations (Tab. 1).

Tab. 1: Definition of the simplified conceptual compartments considered in the Material and Products in Industry (Processes)

ID	Acronym	Sub-pool	Definition (from EU legislation)
2A	MP.FP	**Industrial processes – Food and Feed processing**	According to the “Competitive position of the European food and drink industry Final report, the "food and drink industry" is defined by codes C10 and C11 within the statistical context of the NACE rev. 2 nomenclature (EA0416075ENN.pdf). Food and drink industry sector include: Meat Processing, preservation of meat and production of meat products Fish Processing and preserving of fish, crustaceans and molluscs Fruit-vegetable Processing and preserving of fruit and vegetables Dairy Manufacture of dairy products Cereals Manufacture of grain mill products, starches and starch products Bakery Manufacture of bakery and farinaceous products Other food Manufacture of other food products According to the REGULATION (EC) No 178/2002, Article 2, ‘feed’ (or ‘feedingstuff’) means any substance or product, including additives, whether processed, partially processed or unprocessed, intended to be used for oral feeding to animals (EC, 2002). Protein Sources for feed (FAO, 2004) Plant Protein Sources: Soybean; Other oil meal crops; Legumes; Quality Protein Maize (QPM); cereals protein; Synthetic amino acids Food industry crop by-products: Fishmeal; Animal By-products, approved for use in the manufacture of animal feed.
2B	MP.CI	**Industrial processes - Chemical Industry**	For the purpose of sub-pool, production within the meaning of the categories of activities contained in this section means the production on an industrial scale by chemical or biological processing of substances or groups of substances listed in points 4.1 to 4.6 DIRECTIVE 2010/75/EU, Annex I (EC, 2010). 4.1. Production of organic chemicals, such as: (d) nitrogenous hydrocarbons such as amines, amides, nitrous compounds, nitro compounds or nitrate compounds, nitriles, cyanates, isocyanates; (h) plastic materials (polymers, synthetic fibres and cellulose-based fibres); (i) synthetic rubbers;

ID	Acronym	Sub-pool	Definition (from EU legislation)
			(j) dyes and pigments; (k) Surface-active agents and surfactants. 4.2. Production of inorganic chemicals, such as: Gases, such as ammonia, nitrogen oxide, (b) acids, such as nitric acid, nitrosylsulfuric acid; (c) bases, ammonium hydroxide, (d) salts, such as ammonium chloride, 4.3. Production of nitrogen- based fertilisers (simple or compound fertilisers) 4.4. Production of nitrogen- based plant protection products or of biocides 4.5. Production of nitrogen- based pharmaceutical products including intermediates 4.6. Production of explosives
2C	**MP.OP**	**Industrial processes - Other producing industry**	Sub-pool includes industrial processes which utilize feedstocks and/or products containing nitrogen in various forms.

*) Nr is created in the MP pool, the process thus is considered an Nr source

3 Internal Structure and Description of Sub-Pools

In order to adequately reflect the fate of Nr in processing industry, we specify subsections of different product treatment (see Figure 2). These subsections refer to communality of treatment and of statistical attribution. They do not follow the categories of IPCC (2006), as these categories extend much beyond the topic of nitrogen while not adequate to include important natural or synthetic products containing nitrogen. Instead, we distinguish food and feed related industry, focussing on biomaterials that need to be processed at a quality level that allows human ingestion, nitrogen-related chemical industry that fixes nitrogen from the atmosphere and uses it in several kinds of bulk processes, and other industry that mainly functions as recipient of N-containing products, often connected with a sink function (destruction of Nr) (Tab.1).

As mentioned before, fuel related emissions are considered N flows from the EF pool and thus are not covered here.

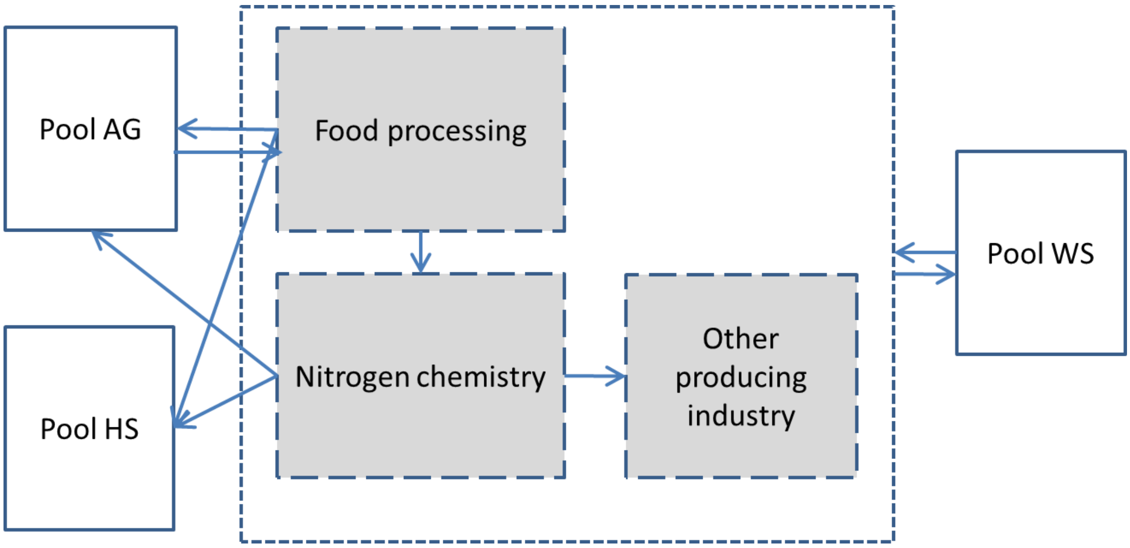

Fig. 2: Internal structure of the MP pool

3.1 Sub-pool 2A Food and Feed processing (FP)

Food processing converts agricultural produce (staple crops, vegetables, animal carcasses) into products ready for consumption (meat products, processed food). The chemical form of nitrogen will remain unaltered, as protein. Still the nitrogen contents will differ between raw material and final products, e.g. due to changes in the protein structures and loss of water after heat treatment etc. These changes need to be considered, together with the amounts of input and product, respectively. Some losses to waste need to be accounted for; also, imports/exports play a major role.

3.2 Sub-pool 2B Chemical Industry (CI)

Chemical industry encompasses the production of seven key nitrogen products: ammonia, urea, nitric acid, ammonium nitrate, nitrogen solutions, ammonium sulfate and ammonium phosphates. Such nitrogen products had a total worldwide annual commercial value of about $US 50 billion in 1996. The cornerstone of this industry is ammonia (Maxwell, 2004).

Traditionally, conversion of nitrogen compounds has been a key element of chemical industry. Production of ammonia (Haber-Bosch synthesis from the elements) provides the basis e.g. for urea fertilizer or the production of nitric acid (for fertilizer production, for explosives, or other chemical industry) at a subsequent stage. Ammonia and / or nitrates are compounds to produce organic compounds with use as fibers (polyamids, e.g., Nylon, Perlon) or as dyes. Moldable plastics (e.g. melamine), foams (e.g. polyurethane) or similar polymers often contain nitrogen compounds. In these forms, nitrogen typically is locked and does not affect the environment. These compounds thus are not considered reactive nitrogen; nevertheless the flow of inactive nitrogen is also traced according to this document. Due to the size of production, a few of the processes are considered of specific importance.

3.2.1 Ammonia production (source category 2.B.1)

The process of ammonia production is based on the ammonia synthesis reaction (also referred to as the Haber-Bosch process) of nitrogen (derived from process air) with hydrogen to form anhydrous liquid ammonia. (European Commission, 2007; Smil, 2001; Haber, 1920)

$$N_2 + 3H_2 = 2NH_3$$

The process takes place under high pressure in a closed system and in the the presence of catalyst. The amount of inflowing nitrogen from atmosphere ($\Sigma N_{Atmosphere}$) is equal to the sum of the nitrogen in the synthesized ammonia ($\Sigma N_{Ammonia}$) and emission ($\Sigma N_{Emission}$). $\Sigma N_{Emission} \geq 0$.

$$\sum N_{Atmosphere} = \sum N_{Ammonia} + \sum N_{Emission}$$

3.2.2 Nitric acid production (source category 2.B.2)

Nitric acid production is a large scale process in the chemical industry. The major part, about 80%, of the nitric acid produced globally is used by the fertilizer industry. Other important consumers of nitric acid are producers of industrial grade ammonium nitrate, which is used for explosives (Uhde, 2004; Smil, 2001). Nitric acid production typically goes along with nitrogen oxide (NOx) emissions.

The process involves the catalytic oxidation of ammonia by air (oxygen) yielding nitrogen oxide. Then it is oxidized into nitrogen dioxide (NO_2) which is absorbed in water. The reaction of NO_2 with water and oxygen forms nitric acid (HNO_3) with a concentration of generally 50–75 wt.% ('weak acid'). For the production of highly concentrated nitric acid (98 wt.%), firstly nitrogen dioxide is produced as described above. Then it is absorbed in highly concentrated acid, distilled, condensed and finally converted into highly concentrated nitric acid at high pressure by adding a mixture of water and pure oxygen (http://eippcb.jrc.ec.europa.eu/reference/BREF/lvic_aaf.pdf)

$$NH_3 + 2O_2 = HNO_3 + H_2O$$

For nitrogen oxide (NOx) emissions, the relevant process units are absorption tower and tail gas cleaning units, e.g. selective catalytic or non-catalytic reduction (SCR, SNCR). Small amounts of NOx are also lost in acid concentrating plants. The NO_x emissions ('nitrous gases') contain a mixture of nitric oxide (NO) and nitrogen dioxide (NO_2), dinitric oxide (N_2O_3) and dinitric tetroxide (N_2O_4). Emissions of N_2O have to be reported separately.

$$\sum N_{Ammonia} = \sum N_{NHO_3} + \sum N_{NitrogenOxidesEmission}$$

3.2.3 Other main chemicals

Here the generic product classes "fertilizers" and "explosives" are subsumed, in order to follow up on the industrial use of nitrogen compounds. The related polymer products are dealt with under "other producing industry".

3.3 Sub-pool 2C Other producing industry (OP)

Basic chemical materials as produced in chemical industry (CI) are often used also in other industry. Nitrogen compounds here are either considered throughput (no change of nitrogen content during the use/integration of materials) or they are split or used up (e.g. by using explosives, or by applying nitric acid). Part of the nitrogen may recombine into molecular N_2, while parts may be contained in the end product or released into the environment, e.g. as wastes or atmospheric pollutants

4 Flows

4.1 General description

The main flows to be considered in this pool are listed in Tab. 2. While even product quantities are not easy to assess (confidentiality issues), estimating nitrogen contents becomes even more difficult on the product level. Production statistics exist, however, and may serve as a quantification tool together with professional organizations. As defined in Annex 0, relevant flows originating from another pool are not considered here; they are covered in that respective pool. As it may be difficult or impossible to estimate nitrogen content by product categories, it is worthwhile to obtain information on the material composition of products, or quantify the production of specific materials and their elemental composition rather than that of the final products.

Table 2: Flows going out of the pool MP

$Pool_{ex}$	$Pool_{in}$	Flow	Process	MP sub-pools involved
MP	EF			
MP	AG	MPAG	Fertilizers, Feed for farm animals	MP.FP; MP.CI
MP	FS	MPFS	Fertilizers	MP.CI
MP	WS	MPWS	Waste	MP.FP; MP.CI; MP.OP
MP	HS	MPHS	Food and food products. Fodder for pets. Industrial products (plastics, fibers, ...)	MP.FP; MP.CI; MP.OP
MP	AT	MPAT	Emissions of process flue gases (process specific: mainly NH3, NOx, N_2O)	MP.CI
MP	HY	MPHY	Hydrosphere	MP.FP; MP.CI; MP.OP

Table 3: Flows entering to the pool MP

$Pool_{ex}$	$Pool_{in}$	Flow	Process	MP sub-pool involved
EF	MP	EFMP	N_2 in process feed stocks	
AG	MP	AGMP	Agricultural row materials	MP.FP; MP.OP
FS	MP	FSMP	Biomass, forest fruits and mushrooms	MP.FP; MP.CI; MP.OP
WS	MP	WS MP	Waste for recycling	MP.FP; MP.CI; MP.OP
HS	MP	HS MP	-	
AT	MP	ATMP	Atmosphere Molecular nitrogen N_2 as the source for ammonia synthesis by the Haber-Bosch method	MP.FP; MP.CI
HY	MP	HYMP	Fish, algae (water abstractions)	MP.FP; MP.CI; MP.OP

4.2 Food and feed production

Processing of agricultural goods into ingestable goods to be used by humans, by lifestock or by pets frequently is done at an industrial setting

$$F = \sum_{i=1}^{n} \boldsymbol{pFOOD_i} * \boldsymbol{cPROTEIN_i} * 0.16 \quad (4.1)$$

$$F = \sum_{i=1}^{n} \boldsymbol{pFEED_i} * \boldsymbol{cPROTEIN_i} * 0.16 \quad (4.2)$$

$$F = \sum_{i=1}^{n} \boldsymbol{pPETF_i} * \boldsymbol{cPROTEIN_i} * 0.16 \quad (4.3)$$

Where:

pFOOD, pFEED, pPETF is the production of food, feed, and pet food, respectively, by category *i* [t N/year]
cPROTEIN = content of protein in food/feed category (as share, dimensionless)
$F_{MP.FP-HS}$ = total outflow of N from food/feed production [t N/year]

4.3 Chemical Industry

National data collection is usually based on official (international) statistical nomenclatures, such as the statistical Classification of Products by Activity (CPA 2008), "PRODuction COMmunautaire" (PRODCOM), Combined Nomenclature (CN) or the Standard International Trade Classification (SITC). All classifications are linked by their structure or by conversion tables (for further information see: http://ec.europa.eu/eurostat/web/prodcom/overview).

The use of CPA classification is suggested. From the broad range of product classes, on level 1 only class "C – Manufactured Products" is relevant for the material flows considered here. Ten main types of goods containing significant levels of N were identified according to CPA 2008 classes on level 2 (see Table 3).

Table 4: European Classification of Products by Activity (CPA 2008) *

CPA Code	2008 Level	CN Chapter	Description (referring to CPA 2008)	
C	1	-	MANUFACTURED PRODUCTS	SUB-POOLS
10	2	01-23	Food products (relevant, but other estimation approach)	FP
11	2		Beverages (relevant, but other estimation approach)	CI, OP
12	2	**24**	Tobacco products	OP
13	2	**50-60**	Textiles	CI, OP
14	2	**61-63, 65**	Wearing apparel	CI, OP
15	2	**41-43, 64**	Leather and related products	OP
16	2	**44-46**	Wood, products of wood and cork, except furniture; articles of straw and plaiting materials	OP
17	2	**47-49**	Paper and paper products	OP
18	2	-	Printing and recording services (no significant N flow)	CI, OP
19	2	27	Coke and refined petroleum products (captured by the pool Fuels and Energy)	CI, OP
20	2	**28, 29, 31-38**	Chemicals and chemical products	CI,
21	2	**30**	Basic pharmaceutical products and pharmaceutical preparations	CI, OP
22	2	**39, 40**	Rubber and plastic products	CI
23	2	25-26 68-71	Non-metallic mineral products (no significant N flow)	CI, OP
24	2	72-83, 93	Basic metals (no significant N flow)	OP
25	2		Fabricated metal products, except machinery and equipment (incl. weapons and ammunition)	CI, OP
26	2	85, 90, 91	Computer, electronic and optical products[9]	CI, OP
27	2		Electrical equipment[9]	CI, OP
28	2	84	Machinery and equipment n.e.c.[9]	CI, OP
29	2	86-89	Motor vehicles, trailers and semi-trailers[9]	CI, OP
30	2		Other transport equipment[9]	CI, OP
31	2	**94**	Furniture	OP
32	2	92, 95, 96 97-99, 66, 67	Other manufactured goods[10]	CI, OP
33	2	-	Repair and installation services of machinery and equipment (no significant N flow)	CI, OP

*) Classified 2nd levels within Section C, Level 1 Manufactured Products needed for business cycle statistics and equivalent chapters of the Combined Nomenclature (CN) needed for trade statistics. Shaded rows are needed for the N flow estimation. Other rows are not considered relevant.

4.3.1 Bulk production of chemicals

Quantifying nitrogen content of large-tonnage chemical synthesis can take advantage of stoichiometric factors, while the activity data may be taken from international statistics (for Tier 1, e.g. from fertilizer manufacturing organizations). For higher Tiers, national or plant level production information is needed.

[9] Note that computers, electronics and machineries contain N, mainly in form of synthetic polymer components. Those materials are considered in Annex 6 – Humans and settlements, section - **Flow M1.**

[10] N-Polymers, e.g. for sporting goods or toys, etc. are included in synthetic polymers for material production (in Annex 6 section - **Flow M1).**

Tier 1

$$F = \sum_{i=1}^{n} prodcap\ BULK_i * caputil\ BULK_i * cN_i \qquad 4.4$$

Where:

prodcap BULK = production capacity of bulk product BULK in installation *i* [t N/year]
caputil BULK = capacity utilization in installation *i* [share, dimensionless] – default is 0.8
cN = nitrogen content of bulk product BULK in installation *i* [share, dimensionless]
$F_{MP.CI.AMMO}$ = total outflow of N from bulk chemical production [t N/year]

Tier 2

$$F_{MP.CI.AMMO} = \sum_{i=1}^{n} pBULK_i * cN_i \qquad 4.5$$

Where:

pBULK = production of product BULK in installation *i* [t N/year]
cN = nitrogen content of product BULK in installation *i* [share, dimensionless]
$F_{MP.CI.AMMO}$ = total outflow of N from bulk chemical production [t N/year]

4.3.2 Synthetic Polymers for product use

Materials of synthetic polymers are very diffusely distributed in different products and thus are hard to quantify relating to single products (see Table 13 in Annex 6 – HS – for an overview on different N-containing synthetic polymers and their application). To get an overview which product groups contain relevant amounts of N, it would be useful to categorize respective products in general sectors. However, calculating N-content factors for defined product groups is not realistic. That is the reason why a top down approach is suggested as the most feasible strategy to account for this flow in a NNB. For a practical implementation it is proposed to break down the utilization of raw material to individual nations, or in more detail to different application categories (see see Table 16 in Annex 6 – HS – or CPA classes listed in Table 3 above).

Nitrogen compounds contained in synthetic polymers will be inaccessible for biological substrates. Formation of synthetic polymers can thus be considered a sink of Nr. As nitrogen remains fixed (even if "locked"), flows still should be assessed in order to be able to maintain an understanding of the further fate of the material.

Definitions

- ***Polyurethanes (PU):*** Polyurethanes are a polymer group synthesized of diisocyanates (containing N) and polyoles. These polymers are characterized by high versatile properties depending on their molecular composition. This leads to a broad field of application possibilities, ranging from insulating foams, foams for furniture to corrosion and weather resistant coatings.
- ***Polyamides (PA):*** Polyamide is a group of polymer basically synthesized of aliphatic diamines and dicarboxylic acids or by polymerization of ε-caprolactam. Common PAs are Nylon (PA66) and Perlon (PA6). Together they account for about 95 % of PA overall production, which is why other kinds of PAs can be neglected. These polymers are mainly used as synthetic textile fibers for clothes, carpets and yarns.
- ***Melamine/Urea Formaldehyde Resins (MF, MUF, UF):*** Melamine and urea resins are thermosetting polymers and are very heat resistant, durable and hard, but cannot be recycled.

These resins are basically synthesized of melamine and formaldehyde (which leads to the commercial abbreviation MF) or urea and formaldehyde (UF) and are used for formed parts in the electronic industry (e.g. socket outlets), as break-proof material for dishes, as adhesives or binder agents in wood-based panels or as coatings and flame retardants.

- ***Others:*** Other synthetic polymers that contain reactive N, but are of minor relevance include polyacrylonitrile (PAN), acrylonitrile butadiene styrene (ABS), nitrile butadiene rubber (NBR), Polyimide, or Chitosan (see see Table 13 in Annex 6 – HS).

Tier 1

This approach is based on the total European polymer consumption, to be broken down to the national population. It is recommended to do this estimation at least for the three polymer groups: polyurethanes (PU), polyamides (PA), and melamine. Table 5 gives an overview on the estimated consumption of these polymers in Europe.

$$cPOLYMER_iN_{nat} = cPOLYMER_iN_{EUcapita} * P_{nat} \qquad 4.6$$

$$F_{MP.CI.MP.OP} = \sum_{i=1}^{n} cPOLYMER_iN_{nat} \qquad 4.7$$

Where:

$cPOLYMER_i\text{-}N_{nat}$ = total national annual consumption of N by polymer group [t N/year]

$cPOLYMER_i\text{-}N_{EUcapita}$ = average annual consumption of N by polymer group per million inhabitants for all of Europe (see European population as listed in Table 5) [t/(million capita*year)]

P_{nat} = national population [million capita]

$F_{MP.CI.MP.OP}$ = total outflow of N from synthetic polymers for product use [t N/year]

Table 5: Estimated consumption of Polyurethanes (PU), Polyamides (PA), and Melamine in 2010 (PU and Melamine) or 2007 (PA), respectively.

	Polyurethanes (PU)	Polyamides (PA)	Melamine/Urea Formaldehyde Resins (MF, MUF, UF)
Demand worldwide **[million t]**	14	7	0.676
Demand Europe **[million t]**	5	3.08	0.384
N Consumption Europe [t N/million inhabitants]	676	499	244
Sources	BASF 2012	Plastemart 2007a, b	OCI Nitrogen 2011, IHS chemical sales 2010

European and worldwide demand based on own calculations; assumed number of European inhabitants: 740 million; N content factors as given in Annex 6 (HS), Table 14.

Tier 2

This approach is based on the total national polymer production, if adequate data is available. It is recommended to do this estimation for all three polymer groups listed above.

$$pPOLYMER_iN_{nat} = POLYMER_{i\_nat} * N_{POLYMER_{i\_coeff}} \qquad 4.8$$

$$F_{MP.CI.MP.OP} = \sum_{i=1}^{n} cPOLYMER_iN_{nat} \qquad 4.9$$

Where:

$pPOLYMER_i\text{-}N_{nat}$ = national annual production of N by polymer group i [t N/yr]
$Polymer_{i\_nat}$ = annual national production of polymer group i [t/yr]
$N_{POLYMER\_i\ coeff}$ = average content of N in polymer group (see Table 14) [m%]
$F_{MP.CI.MP.OP}$ = total outflow of N from synthetic polymers production [t N/year]

Ideally, polymer production is estimated in a way to be reconciled with consumption and trade statistics, i.e. it will be broken down to different areas of utilization, if adequate data is available (e.g. according to CPA or CN classes, or higher aggregated sectors, as for example listed in Table 17 in Annex 6 – HS). It is recommended to conduct this estimation for all three polymer groups. The detailed method must be developed depending on the available data sources.

4.3.3 Release of nitrogen compounds from bulk industry to the atmosphere and to wastewater

Emissions from large industry to the atmosphere is well covered and described in much detail due to reporting requirements to the UNFCCC and to the UNECE. Detailed instructions are available (IPCC, 2006; EEA, 2013).

Release of nitrogen compounds to water bodies (via wastewater treatment) is well covered in the waste sector, where statistical information is available.

4.4 Other Producing Industry

This sector comprises, specifically, the following sectors, for which flows should provided: "Detergents and Washing preparations"; "Textiles, Wearing apparel and Leather products", and "Wood & Paper and Products thereof".

For all of these flows, the calculation is based on the national product production – consumption (relevant for the HS pool) then is assessed as the "apparent consumption", i.e. imports minus exports plus sold domestic production. M2 in particular might not be above the boundary of significance and could be aggregated.

$$F_1 = p(cS) * N_{coeff} \qquad 0.10$$

$$F_2 = c(T\&W)_{crop} * N_{coeff} + (p(T\&W)_{animal} + p(LP)) * N_{coeff} \qquad 0.11$$

$$F_3 = p(W\&P) * N_{coeff} \qquad 0.12$$

Where:

p(cS) = national annual production of cationic surfactants, [t/yr]
$p(T\&W)_{crop}$ = total national annual production of Textiles and Wearing apparel made of crop fibres [t/yr]
$p(T\&W)_{animal}$ = total national annual production of Textiles and Wearing apparel made of animal hair/fibres [t/yr]
p(LP) = total national annual production of Leather products [t/yr]
p(W&P) = total national annual production of wood & paper and products thereof
N_{coeff} = N content factors referred to in chapter 5 (given in Table 13, 14 and 16 in Annex 6 - HS).
$F_{1\ MP.OP.HS.MW}$ = total production of N in detergents and washing preparations [t N/year]
$F_{2\ MP.OP.HS.MW}$ = total production of N in textiles, wearing apparel and leather products [t N/year]
$F_{3\ MP.OP.HS.MW}$ = total production of N in wood & paper and products thereof [t N/year]

5 Suggested data sources

5.1 N contents

N content factors are given in Table 13, 14 and 16 in Annex 6 (HS). Estimated factors are based on calculations of the molecular (monomeric) formula of the respective component. Note that synthetic polymers have high variation in their molecular structure and composition. This applies in particular to polyurethanes (PU), polyimides, and nitrile butadiene rubbers (NBR). But also natural products like clothes vary widely in their N contents, especially between animal fibers that consist of high-N protein and plant fibers from cellulosic material, which contain Nr only in traces. The latter thus is also the case for wood or paper.

5.2 Production data – food and feed

Tier 1 may take advantage of interantional statistics like FAOStat data (e.g. http://faostat3.fao.org/browse/FB/CC/E).

For Tier 2, national Agriculture and Nutritional Statistics are needed.

5.3 Production data - chemicals and polymers

Frequently, detailed data about polymer and ammonia production is kept in confidence. But there are a number of alliances and industry associations that provide some information. The estimations provided in Table 5 have been derived from these sources. It is recommended to check these data sources for more recent and accurate data.

- Plastics Europe (European trade association): Annual reports, such as "Plastics – the Facts 2012. An analysis of European plastics production, demand and waste data for 2011." www.plasticseurope.org
- The European Chemical Industry Council www.cefic.org
- ISOPA (European trade association for producers of diisocyanates and polyols), specialized on PUs. www.isopa.org
- PCI Nylon (market research consultancy focused on the global nylon and polyamide industry) www.pcinylon.com
- www.plastemart.com
- National chemical alliances (e.g. Association of the Austrian Chemical Industry: www.fcio.at, German chemical industry association VCI: www.vci.de)

5.4 Production data - detergents, textiles, wood products

The national consumption can be calculated via the "apparent consumption", based on official statistics (import – export + sold domestic production). If possible, consumption data can also be gathered from published data e.g. of industry associations.

- The following data sources for domestic production amounts can be used:
    - domestic production of resources for Textiles, Wearing apparel and Leather products: FAO-Stat Production/Crops (http://faostat3.fao.org/faostat-gateway/go/to/download/Q/QC/E)
      query: "Production Quantity" for "Fibre Crops Primary + (Total)" and "Jute & Jute-like Fibres + (Total)"
      FAO-Stat Production/Livestock Primary
      query: "Production Quantity" for "Hair, horse" and " Hides, buffalo, fresh" and "Hides, cattle, fresh" and "Silk-worm cocoons, reelable" and "Skins, furs" and "Skins, goat, fresh" and "Skins, sheep, fresh" and "Skins, sheep, with wool" and "Wool, greasy".

- domestic production of resources for Wood & Paper and Products thereof: FAO-Stat_Forestry (http://faostat.fao.org/site/630/default.aspx). *query: "Production Quantity" for "Industrial Roundwood + (Total)" and "Chips and Particles"* [11]
- domestic production of detergents: National business cycle statistics. Use the domestic sold production volume of cationic surfactants as a representative flow.
- Industry reports published by national industry associations (e.g. paper and pulp industry, wood and wood manufacturing industry, chemical industry) often contain mass flow analyses or information about production amounts, kind of products, waste generation and more.

6 Uncertainties

Data quality and quantity available in the sector "industry" represents a state that can be covered using semiquantitative uncertainty assessments as outlined in the general annex. Thus it is recommended to use this method.

In case country experts consider their respective data sources to be of high quality, these experts may extend to develop a more refined methodology to quantitatively process uncertainties, following error propagation schemes and stochastic approaches (Monte-Carlo simulation) according to IPCC (2006).

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[11] Values of the FAO-Stat_Forestry are given in m^3. Following conversion-factors can be used: Density of industrial roundwood ~0.65 kg/m^3 (mean value of 48 wood species with a moisture of 13 m%). Density of chips and particles ~0.20 kg/m^3 (0.33 m^3 roundwood gives 1 m^3 wood chips G30 or fine saw-dust on average (Francescato et al. 2008)).

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8 Document version

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Annex 3 – Agriculture

1 Introduction

1.1 Purpose of this document

The Agriculture (AG) pool is highly relevant for the NNBs since the biggest N flows of N within the whole NNBs are nearly always triggered by agriculture, including very big N flows between the AG subpools of the pools and between the AG pool and the(atmosphere (AS pool and hydrosphere (HY pool).This annex defines the pool "Agriculture" (AG) and its interaction with other pools in a National Nitrogen Budgets (NNB) (external structure) and describes its sub-pools and relevant flows (internal structure). It furthermore provides specific guidance on how to calculate relevant nitrogen flows related to the AG pool, presenting calculation methods and suggesting possible data sources. This annex also refers to other comittees concerned with reporting N forms like NH_3, NO_x and N_2O to promote integration of methods. Furthermore, it points to information that needs to be provided by and coordinated with other pools.

2 Overview of the agriculture pool

2.1 Links between agriculture and other pools

Figure 1 shows how the pool "Agriculture" (pool 3, AG) interacts with other pools in a National Nitrogen Budget (NNB).

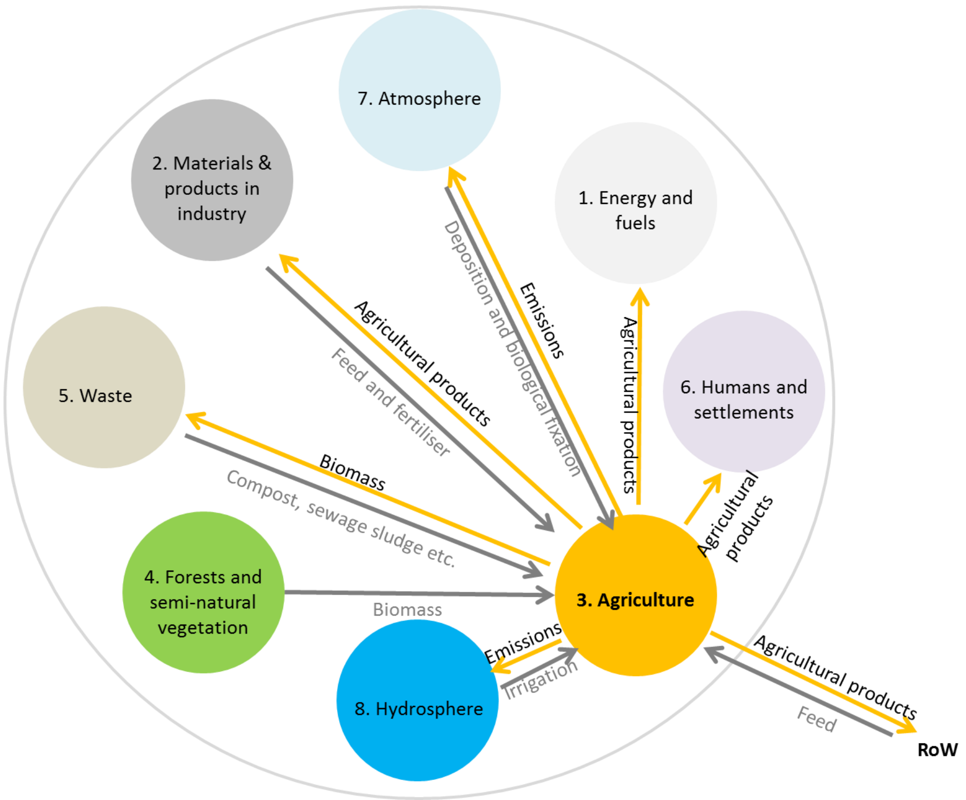

Figure 1: Agriculture pool and links to other pools considered in a National integrated Nitrogen Budget

Agriculture delivers agricultural products for direct consumption by consumers (pool 6, Human and Settlements, HS) and for export to the Rest of the World (pool RoW). Furthermore it delivers agricultural products for processing in industry (pool 2, Material and products in industry, MP), to be used for secondary food products, feed processing, and as biofuels or non-food products (pool 1, Energy and Fuels, EF).

Biomass is given to biomass handling systems (as part of pool 5 Waste, WS) and fertilizer is returned to agriculture in form of compost, sewage sludge, biogas digester etc. Manure management and manure storage (MM) are considered as a sub-pool of AG (Figure 2) and not included in the biomass handling systems of the WS pool. Biogas installations are part of the WS pool (biomass management systems) thus even if they are operated exclusively from agricultural products (manure, maize, etc.) the flow of the biomass to the digesters and the final products are represented as an exchange between the AG and the WS pools. Biomass can also come from natural areas (pool 4, Forest and Semi-natural Vegetation, FS), with the major aim to increase the soil C content, but this includes also nutrients coming from pool 4 to the agricultural pool.

N losses to the atmosphere (pool 7, AS) and hydrosphere (pool 8, HS) are all flows that disperse to the environment before the products are sold at the farm. Return from the environmental compartments is by atmospheric deposition and with irrigation water (hydrosphere). Biological N fixation delivers new reactive N to the NNB.

Feed and fertilizer come from the industry (pool 2, MP) as compound feed and mineral fertilizer. For fertilizer and compound feed from imported sources no differentiation is made whether processing occurs within the (national) boundaries or not. Consequently, imported fertilizer passes conceptually always through the pool MP. Feed is also imported from the RoW if it is not compound feed. Energy use in agriculture is significant, but as NNBs follow a territorial-sectoral approach all energy consumption and fuel use is lumped to the EF pool. One exception is the use of biofuels or manure as fuel, which might occur under some national circumstances.

2.1.1 Food production in households

No flows from the HS pool to the AG pool exist. Household compost etc. is transferred to the AG pool via the biomass management systems. A complexity might be household gardens producing fruits and vegetables for own consumption, or grasslands used as golf courses or for other sports (private gardens and public green spaces in the HS pool). In some data sets relevant for the AG pool household gardens and golf courses are not included. On the other hand, food consumption surveys do not distinguish between commercially and privately produced food and account also for products from household gardens. The NNB constructors are responsible to use the best available statistical data and to be aware of potential implications.

2.1.2 Agricultural products for direct consumption or processing in industry

All **food products** that can be sold directly from farmers to the consumers are flowing directly from AG to the HS pool: fruits and vegetables including tuber and root vegetables, leguminous, oils, sugar, milk and dairy products including yoghurt, fresh cheese and cheese, and processed cereals (bread, pasta, etc.).

Also ingredients of **convenience food** are assumed to flow directly from the AG to the HS pool as long as they are not significantly altered. Milk and fruits in yogurt fall under this category, while food colorants, thickening agent etc. are coming from the industry. The reason for this differentiation is mainly of pragmatic nature, as possible data sources include national agricultural market balances, food balance sheets or food consumption surveys. In all cases, no information is readily available on processing steps, thus as a rule of thumb all identifiable food ingredients which can be linked to primary agricultural products are represented in an NNB as a direct flow from AG to HS. This avoids extensive data requirements and increases transparency in the NNBs, as long as the assumption is justified that the processing steps do not significantly modify the N content of the products. Releases of reactive nitrogen flows from fuels consumed in the processing step are estimated in the EF pool.

Non-food agricultural products that flow directly from the AG to the HS pool include: flowers, Christmas trees, wool, cotton and other fibers, tobacco.

Not considered as flows from the AG to the HS pool are **products used in industry** such as biofuels, bio-plastics or other industrial products on a (non woody) biomass basis. Exceptions are secondary products used as animal feed. Thus, while soy oil flows from AG to HS, soy cakes used as feed (likely in compound feeds) are passed through the MP pool (from AG or RoW). A further exception is the material of slaughtered animals which is not included in the carcass: hide, offal, bones, blood, which are further processed in industry and are thus currently accounted for as 'industrial waste WS' in many NNBs.

2.2 Boundaries of the agriculture pool

For the purpose of describing all flows within the agriculture pool and between the agriculture pool and other pools of a country, the agricultural system of the country is regarded as one 'farm' that is representative for all farm activities and associated nitrogen flows. The boundary of the agriculture pool is therefore understood as an 'extended farm gate' including housing systems, manure storage systems, dairies, slaughter houses, bakeries, wineries and breweries etc.

Accordingly, the best description of the required flows is given applying the 'farm budget approach' (Oenema et al., 2003; Leip et al., 2011a). Internal structure of the agriculture pool

Figure 2 shows the three first-level sub-pools of the AG pool, the animal husbandry (pool 3A, AG.AH), manure management and manure storage, (pool 3B, AG.MM), and soil management (pool 3C, AG.SM).

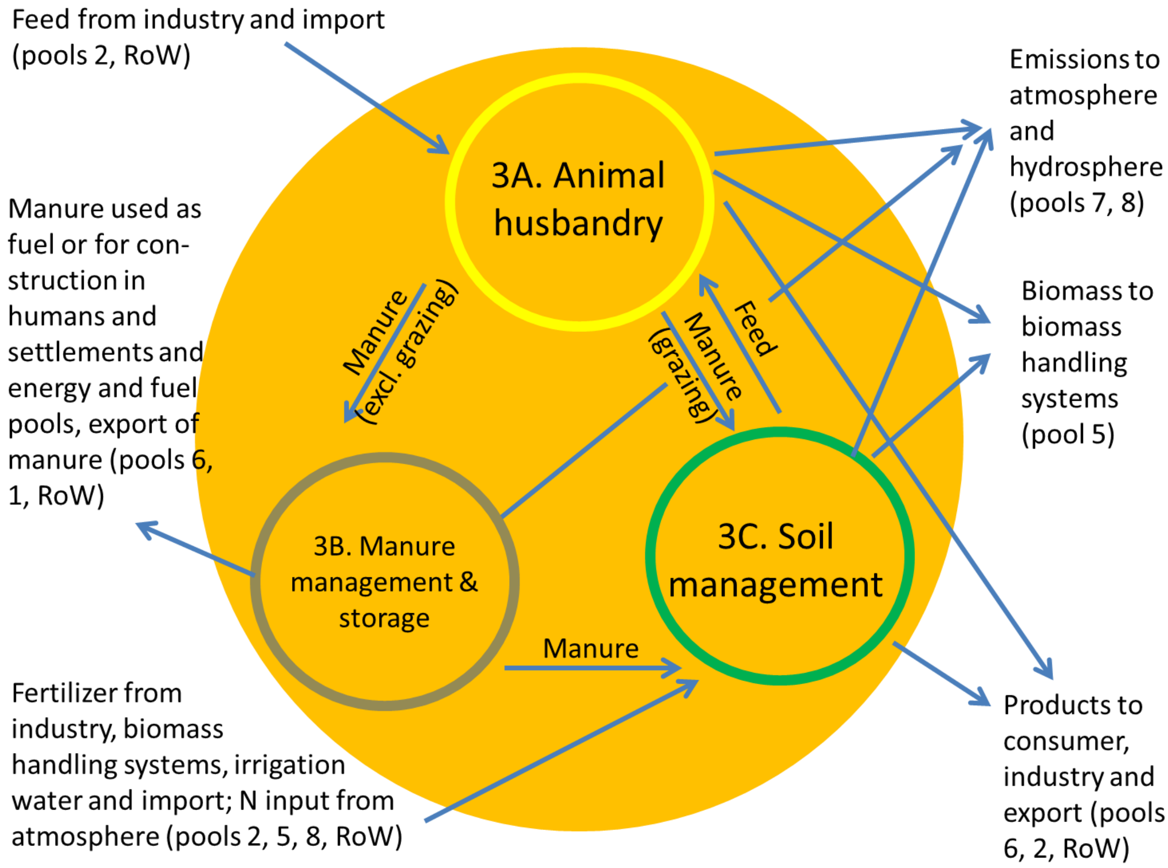

Figure 2: Internal structure of the AG pool

All three sub-pools 3A, 3B and 3C release reactive nitrogen (Nr) to the atmosphere and hydrosphere. Futher important N flows in or out of the sub-pools include:

(i) **Sub-pool "Animal husbandry (AH)"**: N Feed intake by animals, N retention in animals, and N manure excretion in the AH system;
(ii) **Sub-pool "Manure management and manure storage system (MM)"**: emissions, including flows between MM on one side and AH and SM systems on the other side, and possible other use of manure;
(iii) **Sub-pool "Soil management system (SM)"**: soil inputs by mineral fertilisers, organic fertilizer, organic wastes, irrigation, seed and plant inputs, biological N fixation and atmospheric deposition and soil outputs by N uptake by fodder and crop production, N soil emissions (NH_3 and other N compunds) and N leaching/runoff, and the difference between them being soil nitrogen stock changes.

Livestock receives N in feed from industry and the RoW and deliver livestock products for consumption, processing (including non-consumed parts, see above) and export. Manure flows are split and enter (i) the AG.SM pool if livestock is depositing manure directly (on pasture, range and paddock) during grazing; (ii) the waste biomass management systems (WS.BM **to be cross-checked with annex WS**) if it is used for energy generation, for example in biogas plants; all other manure passes the AG.MM sub-pool for manure management and storage until application on agricultural land (to the AG.SM pool), unless it is exported to another country (RoW). Agricultural soil management receives mineral fertilizer from the industry and organic fertilizers from biomass handling systems and manure management and storage, as well as with biomass from forests. Reactive N is further supplied in irrigation water and from wet and dry deposition, as well as through biological N fixation.

3 Methodologies to quantify N flows for agricultural sub-pools

In this section we present for each of the three subpools, i.e. animal husbandry (AH), manure management (MM) and soil management (SM) (sections 4.2 through 4.4):

(i) The overall methodology and existing guidelines
(ii) Suggested disaggregation of the sub-pools,
(iii) Characterization of the sub-pool in terms of parameters that determine N flows in the sub-pool and
(iv) Calculation of implied unit flows in cases that a flow at the suggested disaggregation level can be further broken down

Before going into the details of the three sub-pools though, two important issues are addressed in secion 4.1:

(a) Description of the concept of the **basic methodology** for constructing an agricultural national nitrogen budget, making use of already available data. A significant number of flows are already quantified because of reporting obligations for climate and air pollution conventions, and the quantification of agri-environmental data by international organizations (UNFCCC, CLRTAP).
(b) A recipe for finding the **proper level of disaggregation** for the calculation of flows in order to maximize accuracy of the budget while minimizing efforts.

3.1 Introduction

3.1.1 Existing guidelines and definition of 'basic' methodology

Agricltural data are collected by national agencies in response to legislation serving global or regional environmental agreements:

- So-called Annex I-countries need to put in place **annual GHG inventories** that are submitted to the UNFCCC and its Kyoto Protocol to reduce national anthropogenic GHG emissions. National GHG emission inventories are publicly available at the UNFCCC website[12] for Annex I countries and contain both quantitative data ("CRF tables") and a detailed description of the methodology ("National Inventory Reports", NIRs). The emission estimates need to be quantified in compliance with the IPCC (2006) guidelines which prescribes country-specific or Tier 2 methodologies for so-called 'key source categories'. For most countries, activities such as 'dairy cattles' and 'mineral fertilizer application to soils' are key source categories and therefore data of high relevance for NNBs in pool AG should be available at high quality. Furthermore, this data and reports go through a very strict review process done by sectoral

[12] https://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/8812.php

experts appointed from the UNFCCC secretariat; for countries of the European Union, another in-depth review is carried out in the frame of the 'EU Effort Sharing Decision'[13].

- Countries being parties to the UN-ECE Convention on Long-Range Boundary Air Pollution (CLRTAP) are required to provide annual (gridded) **emission inventories for air pollutans**, for which NH3 and NOx are of direct relevance for NNB in pool AG. Emission inventories need to be prepared based on the EMEP/EEA air pollutant emission inventory guidebook 2013 (EEA, 2013). The methodologies provided in EEA (2013) are partly more detailed than the IPCC (2006) guidelines and estimate emissions of NH3 and NO and N2O if relevant for the estimation of NH3 and NO and consider also losses of N2. They thus might be preferred over the information contained in the GHG emission inventories. However, CRLTAP emission inventories do not go through a review process and information available does often not include details on activity data and factors used. Furthermore, agricultural emissions of NH3 and NOX are important precursors for indirect N2O emissions and need to be reported to UNFCCC as well. Consistency beteen data reported to UNFCCC and UN-ECE CLRTAP is desirable, but not obligatory.
- Estimates of the **Gross Nitrogen Budget** (GNB) are seen as key agri-environmental indicators (AEI) and are included in the lists of AEIs regularly reported by OECD[14] and Eurostat[15]. Eurostat/OECD published a Methodology and Handbook, Nutrient Budgets for EU27, NO, and CH (Eurostat, 2013). These guidelines give detailed recommendations on the estimation of all flows relevant for the quantification of the gross N budget (GNB, also called land N budget). In particular, N flows with a strong link to statistical data sources are discussed in great detail, while for N emissions reference is made to other guidelines (IPCC, 2006; EEA, 2013).
- The N**ex-Guidelines** for a common methodology for the quantification of Nitrogen excretion factors for reporting of Agri-Environmental Indicators (Nex-guidelines, Oenema et al., 2014) can be regarded as supplementary material to the Eurostat (2013) GNB and gives more specific guidelines on the quantification of country-specific nitrogen excretion factors. These guidelines are targeted for countries that are member of the Eurostat Committee of Agricultural Statistics and its Working Group on Agri-environmental Indicators (AEI). Much emphasis is put on the harmonization of the approach across different reporting obligations (such as GHG to the UNFCCC and the EC; GNB to OECD and Eurostat, NH_3 and NO_x to the UNECE and the EC; but also NNB to the UNECE) and to make best use of the data available at Eurostat. The Nex-guidelines are strictly compliant with the IPCC (2006) guidelines, but also give methodological recommendations to ensure the accurate, complete, and transparent estimation of nitrogen excretion coefficients of livestock categories to calculate nitrogen excretion at national scale.

We define the specific situation that most of the relevant flows required have already been estimated and are used for official purposes as the **basic approach** to construct agricultural NNBs as defined in Box 1. According to this basic approach, available data shall be used and improved in cooperation with the relevant groups if necessary. Depending on the significance of the flows, they will be estimated using a Tier 1, Tier 2, or even Tier 3 approach.

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[13] DECISION No 406/2009/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 23 April 2009 on the effort of Member States to reduce their greenhouse gas emissions to meet the Community's greenhouse gas emission reduction commitments up to 2020

[14] Data are published at http://stats.oecd.org//Index.aspx?QueryId=48675

[15] See http://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:Gross_nitrogen_balance

Box 1. Definition of the 'Basis approach' that needs to be applied to construct an AG-NNB

The **basic approach** for constructing an Agriculture Pool (AG) a National Nitrogen Budget requires to using data already available by national agencies in the frame of reporting to UNFCCC, UN-ECE CLRTAP, and OECD/Eurostat GNB.

It is the responsibility of the agency performing NNB estimations to obtain the relevant data and background data. In case of inadequate quality and/or missing data the methodology/data should be improved in cooperation with the relevant expert groups.

Only for a few remaining flows own estimates need to be calculated using the approaches (Tier 1 or higher) described in this document (Tier 1 or higher).

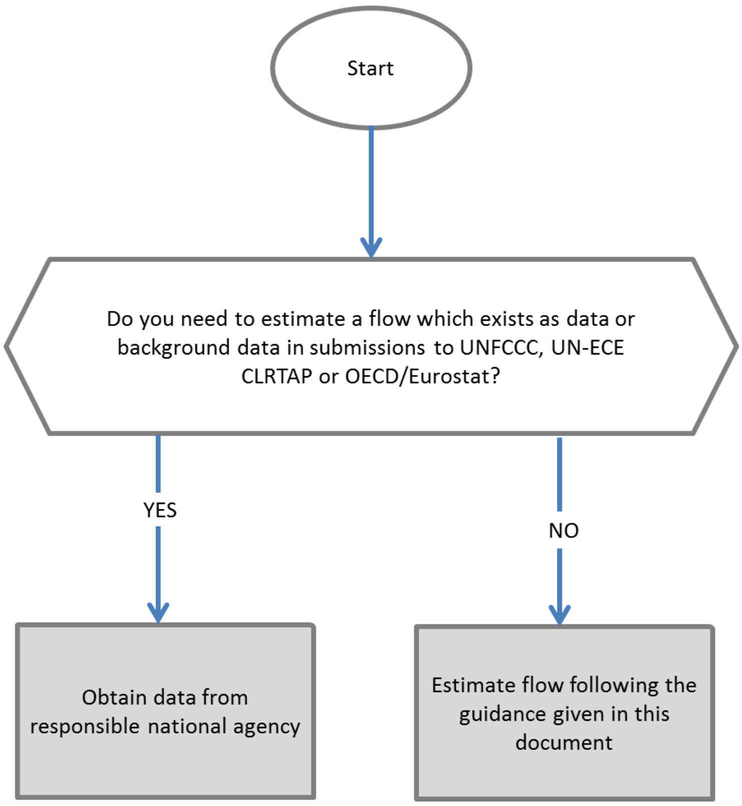

Figure 3. Decision tree to define the 'basic approach' that needs to be applied to construct an AG-NNB

3.1.2 Determining the correct level of disaggregation

A nitrogen budget should be as comprehensive as possible and capture all nitrogen flows. However, it will often not be possible to quantify all minor flows separately. On the contrary, very large flows often aggregate over a number of different sub-flows and should be dis-aggregated in order to increase accuracy of the quantification. The decision which flows to disaggregate and which could be neglected is an essential part of the NNB planning phase and should be carried out carefully. Often, Tier 1 default data and some basic information on the expected gain or loss in accuracy and comprehensiveness is required.

Generally, the following criteria need to be considered:

1. What is the absolute magnitude of the flow? It is suggested to use thresholds based on the population size of the country considered (see also general annex)
2. What is the share of the flow on the total in- or outflows of the two connected pools?
3. What is the expected gain/loss in accuracy/completeness?

According to the general annex, the following thresholds F_{min}, F_{min}, δ_σ are defined:

$$F_{min} = 100 \text{ t N } (10^6 \text{ capita})^{-1} = 0.1 \text{ kg N capita}^{-1} \quad (1)$$

$$F_{max} = 1000 \text{ t N } (10^6 \text{ capita})^{-1} = 1.0 \text{ kg N capita}^{-1} \quad (2)$$

$$\delta_\sigma = 10\% \quad (3)$$

N flows contributing more than F_{min} should be accounted for in every case using default values or to approximate the flows by using suitable factors of 'similar' flows. If flows are below this threshold, they may be neglected, but it is nevertheless recommended to provide approximation. If more than one flow connecting two pools are below the threshold, criterion #1 has to be evaluated on the basis of the sum of all flows rather than on the individual flows.

Large flows should be considered to be split if they are above F_{max}. It is good practice to look for sub-groups which maximize the difference in the unit flow *f* [kg N (unit)$^{-1}$] while minimizing the difference in the absolute flows. In case the difference of the unit flows of the two sub-groups is larger than δ_σ it is recommended to split the flow. In case a flow is split, it is possible to define corresponding sub-pools, or the resulting groups could be used to quantify the flow *F* [kg N yr^{-1}] on the basis of a representative unit flow *iuf* [kg N unit^{-1} yr^{-1}] using the unit flows *f* of the groups. Sub-pool Animal husbandry (AG.AH)

3.1.3 Overall methodology and existing guidelines

The animal husbandry (AG.AH) pool is structured by animal type. A good characterization of animal husbandry is at the core of the construction of an AG N budget, as it co-determines largely the flows in and through the AG.MM pool and the AG.SM pool.

With regard to the AG.AH pool, this document builds entirely on existing guidelines relevant for N flows in the animal husbandry sector:

- **IPCC2006 guidelines** (IPCC, 2006), Volume 4 (Agriculture, Forestry and Other Land Uses, AFOLU) – Chapter 10 (Emissions from livestock and manure management) – Section 10.2 (Livestock population and Feed Characterization, pages 8-23). This section of the IPCC (2006) guidelines explains the methodology for selecting the appropriate level of detail with regard to animal types to be included and estimated separately, on the estimation of the annual average populations (AAP, average number of animals present during a year, corrected for the time between production cycles when the animal house is empty) and other data required for a Tier 2 livestock characterization (e.g. feed intake, feed composition and digestibility, and feeding situation; live weight and average weight gain; percent of females giving birth in a year and number of offsprings; production of milk, eggs, wool etc. Section 10.5.2 (Choice of emission factors, Annual average nitrogen excretion rates, Nex(T), pages 57-61) gives additional guidance on the estimation of N excretion rates.

- The N**ex-Guidelines** for a common methodology for the quantification of Nitrogen excretion factors for reporting of Agri-Environmental Indicators (Nex-guidelines, Oenema et al., 2014).

Before constructing the nitrogen budget of the AG.AH pool, decisions according to Figure 4 have to be made. In many cases, a suitable quantification of N flows in the AG.AH pool exists for the quantification of the national GNB. In such cases, the NNB practitioner just needs to check on compliance with the two guidelines mentioned above; in case the data are ok, they can be directly used, otherwise they need to be improved *in cooperation* with the GNB expert, taking into consideration the points outlined below. It is expected, that consistency between GNB and GHG reporting to UNFCCC is already established. If GNB data do not exist the NNB practitioner needs to go directly to the national experts for agriculture reporting to UNFCCC and use or improve the data in cooperation with the UNFCCC expert.

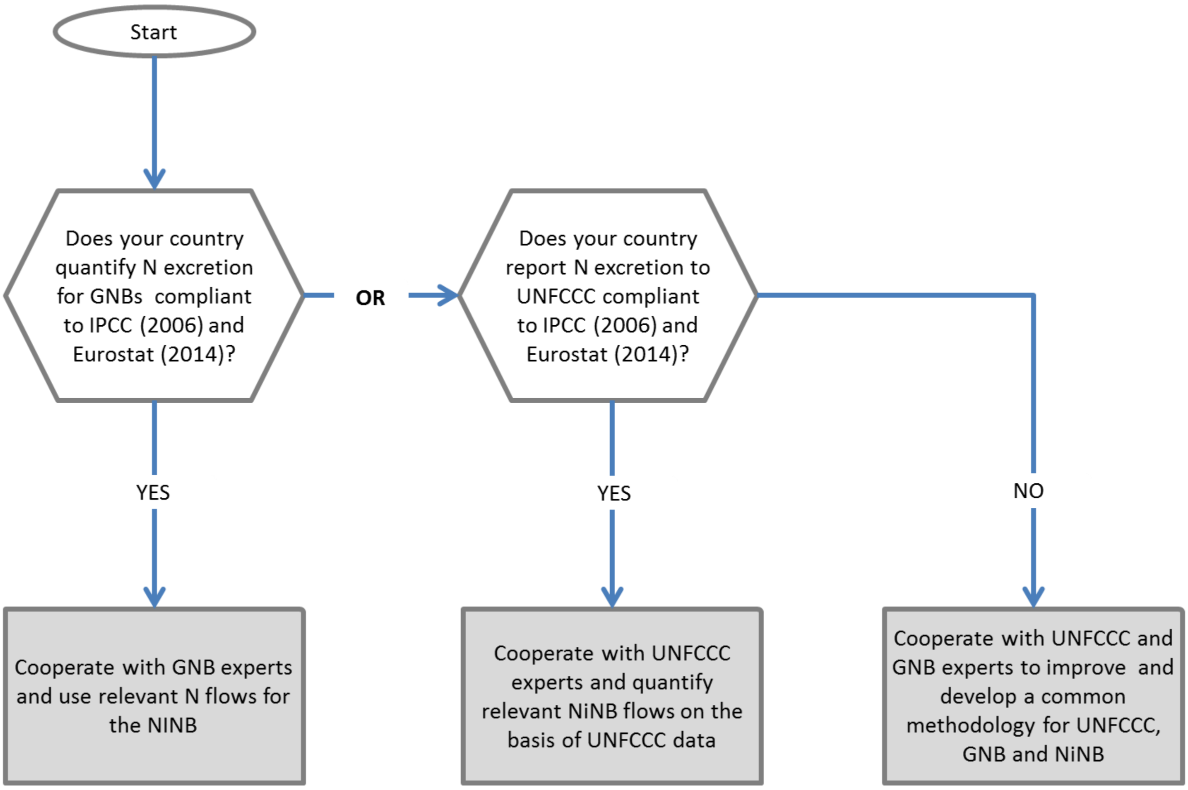

Figure 4: Decision tree to define the methodology for quantifying relevant N flows for the AG.AH pool. Details on the individual flows see below.

3.1.4 Suggested AG.AH disaggregation

In the animal husbandry pool, flows need to estimated at the level of animal types. The reason is both to increase accuracy and because statistical information are available per animal types.

A list of animal types as used in the UNFCCC reporting format (CRF, Common Reporting Format) is given in Table 1.

For countries where aquaculture plays a significant role, fish cultivated in aquaculture must be included as separate animal type in the AG.AH pool. As a methodology for aquaculture is not given in either of the above guidelines, additional data sources and statistics have to be consulted.

In a NNB, wild catch is considered as flowing from RoW to HS, game is considered as flowing from the FS pool to HS.

For the purpose of NNBs, in most countries the following categories are most important: dairy and non-dairy cattle, swine and poultry. Sheep and goats are important in some countries. Table 2 lists the animal types required for IPCC reporting together with the recommended acronym to be used for NNB reporting. The hierarchical level of the animal type is indicated together with the Tier level.

Tier 1 links mainly with the data that can be obtained from the national GHG inventories. Tier 2 requests some additional disaggregation, in particular of swine and poultry. Further disaggregation is possible for other animal types (equidae, other poultries, fur bearing animals) following the tresholds in the frame on page 10: Eq. 1-3. However, it might be more meaningful to further break-down of the cattle or pigs populations. For countries covered by the EU Farm Structure Survey (FSS), Oenema et al. (2014) recommend an animal categorization starting from the FSS classification which includes detailed classes for bovine animals, swine, sheep and goats.

Note however that the Tier levels becomes only relevant in case no data from UNFCCC reporting (basic approach) exist or if this data needs to be improved! In case suitable data are available from GHG emissions inventories and/or GNB estimates, the only additional flows to quantify are those for aquaculture AG.AH.FISH.

Table 1. List of animal types considered in the CRF (Table 3A) for reporting of GHG emissions from animal husbandry according to the IPCC (2006) guidelines. Explanations referring to CH_4 emissions are not relevant for NNBs

1. Cattle
Option A:
Dairy cattle[3]
Non-dairy cattle
Option B:
Mature dairy cattle
Other mature cattle
Growing cattle
Option C (country-specific): [4]
Drop-down list
Other *(please specify)*
2. Sheep
Other *(please specify)*
3. Swine
Other *(please specify)*
4. Other livestock[5]
Drop down list
Buffalo
Camels
Deer
Goats
Horses
Mules and asses
Poultry
Other *(please specify)*
Rabbit
Reindeer
Ostrich
Fur-bearing animals[6]
Other

(1) Parties are encouraged to provide detailed livestock population data by animal type and region, if available, in the national inventory report (NIR), and provide in the documentation box below a reference to the relevant section. Parties should use the same animal population statistics to estimate methane (CH4) emissions from enteric fermentation, CH4 and nitrous oxide (N2O) from manure management, N2O direct emissions from soil and N2O emissions associated with manure production, as well as emissions from the use of manure as fuel, and sewage-related emissions reported in the waste sector.

(2) Ym refers to the fraction of gross energy in feed converted to CH4 and should be given in per cent in this table.

(3) Including data on dairy heifers, if available.

(4) Option C should be used when Parties want to report a more disaggregate livestock categorization compared with option A and option B.

(5) If data are available, Parties are encouraged to report at the disaggregated level available from the pre-defined drop-down menu. Furthermore, Parties are encouraged to the extent possible to use the pre-defined category definitions rather than to create similar categories. This ensures the highest possible degree of comparability of the reporting. If detailed data are not available, Parties should include all emissions from other livestock not included in subcategories 3.A.1-3.A.3 under other (please specify).

(6) This could include fox and raccoon and mink and polecat.

Table 2. List of animal types and their codes considered in the CRF (Table 3A) for reporting of GHG emissions as proposed to be used for the construction of NNBs. The level indicates the logical structure of the categorization. The Tier indicates the degree of detail required for simple (Tier 1) or more sophisticated (Tier 2 or 3) budgets

Animal type code	Level	Tier	Animal type description
AG.AH.BOVI	1		Bovine animals
AG.AH.CATT	2		Cattle
AG.AH.DAIR	3	**1**	Dairy cattle
AG.AH.NDAI	3	**1**	Non-dairy cattle
AG.AH.BUFF	2	**1**	Buffalo
AG.AH.SRUM	1		Small ruminants (sheep, goats, other small ruminants)
AG.AH.SHEE	2	**1**	Sheep
AG.AH.GOAT	2	**1**	Goats
AG.AH.DEER	2	**1**	Deers
AG.AH.REIND	2	**1**	Reindeers and other small ruminants not included elsewhere
AG.AH.SWIN	1	**1**	Swine
AG.AH.SOWS	2	2	Sows
AG.AH.PIGS	2	2	Fattening pigs and other pigs not included in 'sows'
AG.AH.EQUI	1	**1**	Animals of the genus equidae (horses, donkeys, mules, zebra, …)
AG.AH.HORS	2	3	Horses
AG.AH.DONK	2	3	Mules and asses incl. other animals of the genus equidae
AG.AH.POUL	1	**1**	Poultry
AG.AH.HENS	2	2	Laying hens
AG.AH.POUF	2	2	Broilers
AG.AH.OPOU	2	2	Other poultry (poultry not considered elsewhere)
AG.AH.OSTR	3	3	Ostriches
AG.AH.TURK	3	3	Turkeys
AG.AH.FISH	1	**1**	Fish
AG.AH.OANI	1	**1**	Other animals (animals not considered in any of the other reported animal types)
AG.AH.CAME	1	2	Camelidae (incl. camels, alpaca, and other animals of the camelidae family)
AG.AH.FURS	1	2	Fur-bearing animals
AG.AH.RABB	2	3	Rabbits
AG.AH.FURS	2	3	Other fur-bearing animals

3.1.5 AG.AH characterization

Parameters that characterize or determine N flows in the AG.AH pool are:

- Animal numbers per animal category [places yr^{-1}]
- Feed intake [kg dry biomass $place^{-1}$ yr^{-1}],
- N contents of feed [kg N (kg dry biomass)$^{-1}$],
- Animal production [kg product or live weight yr^{-1}]
- N contents of the animal products [kg N kg^{-1}].

For each of the animal types the Average Annual Population (AAP) needs to be determined. The **AAP** represents the average population of a livestock type present during a year, this includes fall-out (animals which die before coming to production age). Details are described in (Eurostat, 2013, section 3.6.1 page 35) and (IPCC, 2006, Volume 4, section 10.2.2, page 10.8) as follows:

- For livestock types without seasonal variations in the population and empty stable places (e.g. dairy cows) AAP can be considered equal to the population counted at any specific day.
- For livestock types with seasonal variations (e.g. sheep, goats) or occurrence of periods that the barn is empty stables the population counted on a specific day or data on animal places need to be corrected for these factors to represent AAP present in a year.
- For livestock types involving multiple production cycles within a year (e.g. broilers), AAP can be derived from the Number of Animals Produced Annually (NAPA) based on slaughter or production statistics corrected for non-sold or non-slaughtered animals (animals dying before production age has been achieved) divided by number of cycles (Eqn 4) (IPCC, 2006, Volume 4, Chapter 10, Equation 10.1). AAP of livestock types involving multiple production cycles can also be derived from number of animal places corrected for average amount of days the animal house is empty during a year.

$$\boldsymbol{AAP = \frac{d_{alive}}{365} \cdot NAPA} \qquad 4$$

where

AAP: Average Annual Population (or herd-size) [places yr^{-1}]

d_{alive}: Average days an animal is alive [days $head^{-1}$]

365: Number of days per year [days yr^{-1}]

NAPA: Number of Animals Produced per year [heads $place^{-1}$]

Flows to be estimated for each animal type consist of N in feed intake for major feedstuff categories, N retention in living animals and in animal products (meat, milk, eggs, wool, etc.), and manure excretion. Consistency between these flows must be ensured on the basis of an animal N budget approach (Oenema et al., 2014) thus following the Tier 2 approach of the IPCC 2006 guidelines. Generally, no flows occur between animal types, with the exception of fed milk (dairy cows → calves sub-pools).

Each of the animal types for which an animal budget is quantified is in the following referred to as AG.AH.ANIM. All relevant flows *F* [kg N yr^{-1}] of the AG.AH pool must be quantified as unit flows *f* [kg N $place^{-1}$ yr^{-1}] for each ANIM category considered. Further guidance on data collection strategy is given in (Oenema et al., 2014, section 2.3 and 2.4, page 30ff)

For the construction of NNBs we recommend to first collect data at detail level 1 (see Table 1), and select those animal categories for which a higher level of detail is recommended for data collection using the thresholds of 50 kg N (F_{min}) excretion ha^{-1} and 200 kg N excretion ha^{-1} (F_{max}), whereby the total N excretion is quantified in relation to the agricultural area. In case this screening suggests for a certain animal type that a higer level of detail is recommended, it is also possible to think of a disaggregation of the animal type (see section in the implied unit flow below) to reduce the burden on data collection. With this approach, investment for data collections at high level of detail can be concentrated and restricted to 'hotspots'.

Flows to be quantified for the AG.AH sub-pool are listed in Table 3.

Table 3. Flows in the Animal husbandry N-budget, indicating the Tier level. With regard to animal types (ANIM), a disaggregation of the flows according to Table 2 is recommended.

Pool ex	Pool in	Matrix	Flow code	Tier	Description/note
RW	**AG.AH.ANIM**	**FEED**	**RW-AG.AH.ANIM-FEED**	**1**	**Imported feed: Total feed imported for animal type ANIM. If details are known, the following feed groups that are potentially imported are proposed (Tier 2): FEED=FPRO+FENE+FCER+FOTH. Note that if some but not all individual feedstuffs are known, the 'other' can be grouped into FOTH.**
RW	AG.AH.ANIM	FPRO	RW-AG.AH.ANIM-FPRO	2	Imports of soy or other (oil seed) cakes or other protein-rich feedstuff
RW	AG.AH.ANIM	FENE	RW-AG.AH.ANIM-FENE	2	Imports of energy-rich feedstuff, e.g. starch etc
RW	AG.AH.ANIM	CROP	RW-AG.AH.ANIM-CROP	2	Imports of food crops (e.g. cereals) used as feed
RW	AG.AH.ANIM	FOTH	RW-AG.AH.ANIM-FOTH	2	Imports of other feeds
MP	**AG.AH.ANIM**	**FEED**	**MP-AG.AH.ANIM-FEED**	**1**	**Domestic compound feed: Total protein-rich (FPRO) and energy-rich (FENE) compound feed from domestic production; FEEDcompound = FPRO + FENE**
MP	AG.AH.ANIM	FPRO	MP-AG.AH.ANIM-FPRO	2	Soy or other (oil seed) cakes or other protein-rich feedstuff from domestic production
MP	AG.AH.ANIM	FENE	MP-AG.AH.ANIM-FENE	2	Energy-rich feedstuff, e.g. starch etc. from domestic production
AG.SM	**AG.AH.ANIM**	**FEED**	**AG.SM-AG.AH.ANIM-FEED**	**1**	**Domestic non-compound feed: Total domestic feed fed to animal type ANIM excluding protein-rich and energy-rich compound feed. If details are known, the following feed groups are proposed: FEEDdirect=CROP+FNMK+FOFA+ FGRA+FMILK+FOTH. FEED=FEEDcompound + FEEDdirect Note that if some but not all individual feedstuffs are known, the 'other' can be grouped into FOTH.**
AG.SM	AG.AH.ANIM	CROP	AG.SM-AG.AH.ANIM-CROP	2	Food crops (e.g. cereals) from domestic production used as feed
AG.SM	AG.AH.ANIM	FNMK	AG.SM-AG.AH.ANIM-FNMK	2	Non-marketable fodder used as feed. This includes straw (FSTR), fodder maize (FMAI) and fodder roots (FROO). It does not include (permanent or temporal) grass or other fodder on arable land such as legume (grasses).
AG.SM	AG.AH.ANIM	FSTR	AG.SM-AG.AH.ANIM-FSTR	3	Straw used as feed. Note that straw used as bedding material is not included here!
AG.SM	AG.AH.ANIM	FMAI	AG.SM-AG.AH.ANIM-FMAI	3	Fodder maize used as feed
AG.SM	AG.AH.ANIM	FROO	AG.SM-AG.AH.ANIM-FROO	3	Fodder beet and other fodder root crops used as feed
AG.SM	AG.AH.ANIM	FOFA	AG.SM-AG.AH.ANIM-FOFA	2	Other fodder on arable land used as feed (such as temporal grassland, legumes, …)
AG.SM	AG.AH.ANIM	FGRA	AG.SM-AG.AH.ANIM-FGRA	2	Gras intake as hay, silage or during grazing from permanent grassland
AG.SM	AG.AH.ANIM	FGRAG	AG.SM-AG.AH.ANIM-FGRAG	3	Gras intake during grazing> Note that this included grazing on both permanent and temporary grassland (FOFAG). It is important to subtract N intake through grazing from the total N intake of the respective flows of non-marketable fodder (FNMK).
AG.AH	AG.AH.ANIM	FMILK	AG.AH-AG.AH.ANIM-FMILK	2	Milk or milk products used as feed
AG.AH	AG.AH.ANIM	FCOM	AG.AH-AG.AH.ANIM-FCOM	3	Cow milk used as feed (e.g. suckler cows)
AG.AH	AG.AH.ANIM	FSGM	AG.AH-AG.AH.ANIM-FSGM	3	Sheep and Goats milk as as feed
AG.AH	AG.AH.ANIM	FMILP	AG.AH-AG.AH.ANIM-FMILP	3	Milk products used as feed
AG.SM	AG.AH.ANIM	FOTH	AG.SM-AG.AH.	2	Other feed stuff from domestic production

Pool ex	Pool in	Matrix	Flow code	Tier	Description/note
			ANIM-FOTH		
AG.AH.ANIM	**HS**	**MILK**	**AG.AH.ANIM-HS-MILK**	**1**	**Total milk production excl. milk used as feed**
AG.AH.ANIM	HS	COMI	AG.AH.ANIM-HS-COMI	2	Total cow milk production
AG.AH.ANIM	HS	SGMI	AG.AH.ANIM-HS-SGMI	2	Total sheep and goat milk production
AG.AH.ANIM	HS	MILKS	AG.AH.ANIM-HS-MILKS	2	Total secondary milk products (yoghurt, creme, cheese, …). It is important to not double count milk equivalents in fresh milk and milk products!
AG.AH.ANIM	**HS**	**MEAT**	**AG.AH.ANIM-HS-MEAT**	**1**	**Total meat production (carcass)**
AG.AH.ANIM	HS	BEEF	AG.AH.ANIM-HS-BEEF	2	Total beef production (carcass)
AG.AH.ANIM	HS	PORK	AG.AH.ANIM-HS-PORK	2	Total pork production (carcass)
AG.AH.ANIM	HS	POUM	AG.AH.ANIM-HS-POUM	2	Total poultry meat production (carcass)
AG.AH.ANIM	HS	SGMT	AG.AH.ANIM-HS-SGMT	2	Total meat production from small ruminants (carcass)
AG.AH.ANIM	HS	OMEAT	AG.AH.ANIM-HS-OMEAT	2	Total meat production not considered elsewhere (e.g. horse meat)
AG.AH.ANIM	**HS**	**WOOL**	**AG.AH.ANIM-HS-WOOL**	**1**	**Total wool production**
AG.AH.ANIM	**HS**	**EGGS**	**AG.AH.ANIM-HS-EGGS**	**1**	**Total eggs production**
AG.AH.ANIM	**WS**	**NMEAT**	**AG.AH.ANIM-WS-NMEAT**	**1**	**Total non-meat animal retention (live weight minus (carcass and wool)). Non-meat can be disaggregated by meat category (cattle: NBEEF, swine: NPORK, poultry: NPOUM, small ruminants: NSGMT).**
AG.AH.ANIM	WS	CAT3	AG.AH.ANIM-WS-CAT3	2	Category 3 animal by-products according to regulation EC(2009)1069. This includes carcass and part of slaughtered animals that are fit for human consumption but not intended for human consumption for commercial reasons and other animal parts not showing any signs of disease communicable to humans or animals used for industrial processing. This includes the use for the leather industry (skin and hide), production of pet food, or other industrial uses.
AG.AH.ANIM	HS	LEAT	AG.AH.ANIM-HS-LEAT	3	Category 3 animal by-products used in the leather industry
AG.AH.ANIM	HS	PETF	AG.AH.ANIM-HS-PETF	3	Category 3 animal by-products used as pet food
AG.AH.ANIM	WS	OCAT3	AG.AH.ANIM-WS-OCAT3	3	Other cateogory 3 animal by-products not considererd elsewhere
AG.AH.ANIM	HS	WAST	AG.AH.ANIM-HS-WAST	2	Category 1 and category 2 animal by-products according to regulation EC(2009)1069. This includes animals with signs of diseases, containing environmental contaminants, or otherwise animal by-products declared unfit for human consumption. Manure (category 2 animal by-product) is not included here. In case Category 1 & 2 animal by-products used for energy generation or as fertilizer are not quantified separately they are included here.
AG.AH.ANIM	EF	ENER	AG.AH.ANIM-EF-ENER	2	Category 1 and 2 animal by-products used for energy generation
AG.AH.ANIM	AG.SM	FERT	AG.AH.ANIM-AG.SM-FERT	2	Category 1 and 2 animal by-products used as fertilizer
AG.AH.ANIM	**RW**	**ANIM**	**AG.AH.ANIM-RW-ANIM**	**1**	**Export of live animal**
RW	**AG.AH.ANIM**	**ANIM**	**RW-AG.AH.ANIM-ANIM**	**1**	**Import of live animal**
AG.AH.ANIM	**AG.MM**	**NEXC**	**AG.AH.ANIM-AG.MM-NEXC**	**1**	**Manure excretion**

3.1.6 Quantification of flows in the AG.AH sub-pool

3.1.6.1 Animal Feed intake of nitrogen

3.1.6.1.1 Introduction

There are two approaches for estimating feed intake, i.e., (i) quantifying the intake of offered feed, and (ii) calculating the feed requirements on the basis of animal productivity and literature data. Both approaches should yield similar results and they may be used both for giving insight into the relative accuracy of the estimated feed intake (Oenema et al 2014).

For key source categories, IPCC (2006) requires an enhanced characterization of livestock sub-categories, regarding (i) definition of livestock sub-categories (see above); (ii) livestock population by sub-category; (iii) feed intake estimates for the typical animal in each sub-category. Average daily feed intake is expressed in energy consumed (MJ day^{-1} $place^{-1}$ or kg dry matter day^{-1}. Detailled guidance is given in Section 10.2.2 of IPCC (2006, Volume 4, Chapter 10, pages 10.8ff). IPCC indicates that it is good practice to collect data to describe the animal's typical diet and performance in each sub-category. Equations are presented to calculate the Net Energy Requirement, and on this basis the Gross Energy Requirement using feed characteristics to estimate average feed digestibility. Total N-intake rates can be calculated using the crude protein content of the feed (IPCC 2006, Volume 4, Chapter 10, Section 10.5.2, pages 10.57ff).

For the purpose of NNBs not only the total N intake by animal sub-category is important, but also the origin of the feed in order to quantify the connection with various other pools:

- RW-AG.AH.ANIM-FEED: import of feed from the RoW.
- MP-AG.AH.ANIM-FPRO and MP-AG.AH.ANIM-FENE: flow of N in feed from the MP pool
- AG.SM-AG.AH.ANIM-CROP and AG.SM-AG.AH.ANIM-FNMK: flow of N in feed from the AG.SM pool
- AG.AH-AG.AH.ANIM-FMILK: Milk or milk products used as feed

The distinction between protein-rich and energy-rich compound feeds is recommended because of their very different characteristics and role in animals feed rations.

The distinction between marketable (CROP) and non-marketable (FNMK) feeds is recommended because they are very different with regard to data sources and data quality.

3.1.6.1.2 Approaches

<u>Stock Taking</u>:

- Check with national experts responsible for agricultural GHG inventories and the GNB on the availability for national reports on the availability of Tier 2 characterizations of animal sub-categories including the quantification of feed intake by feed category
- If not yet available convert feed intake into a N flow using N content data, such as available at Feedipedia http://www.feedipedia.org/ or from literature (e.g., Lassaletta et al., 2014)
- If not yet available, estimate the share of the feed intake from domestic production and import from the RoW, for example using the FAO food sheet balance data (see http://www.fao.org/docrep/003/x9892e/x9892e02.htm for background and http://faostat3.fao.org/download/FB/FBS/E for data)

The main challenge is the split between domestic production and imports of feed. For some feed products information might be available (such as for compound feed from the feed industry) and some other feed products are not traded (non-marketable feed) and are to 100% from domestic productions. For all other feed products, it is recommended to use trade balances (such as the FAO Food Balance Sheets):

$$F_{RW-ANIM-FEED} = \frac{F_{FEED,import}}{F_{FEED,production} + F_{FEED,import}} \cdot (F_{RW-ANIM-FEED} + F_{AG.SM-ANIM-FEED}) \quad 5$$

where:

ANIM:	Animal category for which the flow is calculated. Here for AG.AH.ANIM
FEED:	Feed category
$F_{FEED,x}$	Flow of total product imported (x=import) or domestically produced (x=production)
$F_{y-ANIM-FEED}$	Flow of feed from imports (y=RW) or from domestic production (y=AG.SM)

Tier 1:

Tier 1 method shall be applied for those animal sub-categories (see animal categorization, Tier 1 in Table 2) where no data is available from existing reporting and total N excretion from this animal sub-category is less than 10% of total N excretion in the country's agriculture (according to Table 3.B(b) from the national GHG inventory, CRF tables on the basis of IPCC(2006)).

$$f_{FEEDT,ANIM} = f_{NEXC,ANIM} + f_{LIVEW,ANIM} + f_{PROD,ANIM} \quad 6$$

where:

ANIM:	Animal category for which the unit flow is calculated.
$f_{FEEDT,ANIM}$	Total feed intake per animal place and year
$f_{NEXC,ANIM}$	Total nitrogen excretion per animal place and year, from CRF Table 3B(b) of the national GHG inventory
$f_{LIVEW,ANIM}$	Total N retention in the animal body mass per animal place and year. Data can be obtained from slaughtering statistics or from scientific literature
$f_{PROD,ANIM}$	Total N retention in animal products produced during the animal's life time (e.g. milk, eggs, wool). Data can be obtained from agricultural production statistics

All values in kg N place^{-1} yr^{-1}

The distribution of the total animal feed intake over the different feed products shall be done in two steps: first, check available data, e.g. from the feed industry, the share of grazing for the respective animal sub-category, or information on good feeding practices; second, distribute the total available marketable and non-marketable feed (which has not yet been assigned to any animal sub-cagegory on the basis of the Stock-Taking or Tier 2 methodology) proportionally over the animal sub-categories according to the un-accounted for total feed intake (thus, the part of the total feed intake for which no independent data on specific feed consumption is available).

For each feed product, the share of domestically produced and imported feed is calculated as indicated above.

Tier 2:

If feed intake (and N excretion) amounts to more of 10% of the total AG.AH.ANIM-AG.MM-NEXC flow and no data are available from national GHG or GNB reporting, it is likely that national statistical information is insufficient to apply IPCC (2006) Tier 2 methodology. In this case it is recommended to cooperate with the GHG, NH_3 and GNB teams to collect required data and develop a common methodology to quantify the animal N-budget of the animal sub-category.

The Tier 1 method can be applied if N excretion is above the threshold until more detailed data is available, but efforts towards a Tier 2 method should be demonstrated.

3.1.6.1.3 Data sources

- FAO food balance sheets http://faostat3.fao.org/download/FB/FBS/E for data
- Feed requirement models (e.g. IPCC), based on animal performance
- Models such as CAPRI (combining FBS with feed requirement models) (Leip et al., 2011a, 2014)
- Feeding standards
- Combination of above to constrain the estimates; for major animal pools it is good practice to combine the use of ‘top-down’ (statistical) with ‘bottom-up’ (feeding standards) method to constrain the feed intake estimates
- Feed chacateristics incl. protein content, digestibility etc. is available from Feedipedia: http://www.feedipedia.org/ .
- Literature compilations on N contents (e.g., Lassaletta et al., 2014)
- Feed companies (providers of concentrated feeds) have data on compound feed use (by animal category), production, imports etc. (e.g. http://www.fefac.eu/)
- More information might be available through routine laboratory analyses for crop and feed on farmers’ request, extension services, which may implement sampling programmes, and research institutes, that execute feed trials.

3.1.6.1.4 Uncertainties

- Animal population data are usually available with high accuracy (uncertainty level 1)
- For animal sub-category with multiple cycles per year or with significant fluctuation or a high share of deaths (e.g. diseases, epidemic outbreaks, …) accuracy decreases (uncertainty level 2).
- The share of grass in the animals ration is uncertain (uncertainty level 3). The share of manure on grazing land is often based on expert data as surveys have not collected data in sufficient quality and temporal resolution. Grassland yield and N-content (share of legume grasses) is adding further to the uncertainty.
- Trade and food balance sheets are available at a good accuracy. However, the dependence of the share of imports on the use of the product is unknown (i.e. preference of imported crop for food consumption over domestic production or vice versa) and is likely to vary between countries and product (uncertainty level 2).
- Quality of feeding data varies between country, farm size, animal type etc. While in some countries feeding standards are available (e.g. Denmark), or for certain animal categories and farm sizes (large pig farms) best feeding practices are defined (see e.g. Best Available Techniques Reference Document (BREF) for Intensive Rearing of Poultry and Pigs, http://eippcb.jrc.ec.europa.eu/reference/irpp.html), for other countries or some farm types

and/or animal sub-categories data on feeding practices is scarce. Food Balance Sheets give total use of feed, but do not differentiate by animal type (they can be used to constrain total feed use in the country). Data on compound feed use should be available from the feed industry at good quality.

- Data on feed N-content and other relevant parameters is available in international data bases and are of a good quality. There might be differences between countries though and the collection of national data could increase accuracy.

3.1.6.1.5 Specific guidance for aquaculture

Specific attention needs to be given to feed intake from aquaculture as this is not included in national reporting of GHG or air pollutant inventories and also not included in the Eurostat/OECD GNB calculations.

3.1.6.2 Nitrogen retention in animals

3.1.6.2.1 Introduction

Nitrogen retention in animals comprises retention in livestock products that (a) are extracted from the system as products (milk, eggs, wool, etc.) or (b) retention in animal biomass until death by slaughtering (delivering carcass and non-carcass products) or by other causes (generally being wasted).

Special attention needs the 'production' of offspring: they can either be regarded as a 'product' from the mother-individuum but care has then to be taken to subtract the N in the 'child' biomass at the end of its life to avoid double-counting. Alternative option is to regard feed intake required for pregnancy by the 'mother' individuum.

There are two possibilities to estimate nitrogen retention:

(i) Using available statistical information, such as milk and eggs production statistics and slaughtering data. Care has to be taken to avoid any bias from animals that are not included in slaughtering statistics because of death (animals classified as category 1 and 2) or animals slaughtered on-farm or otherwise not registered in national statistics. It is therefore good practice to cross-check statistical information with production-based estimates of N retention (method ii)

(ii) Using production-based estimation methods, such as given in IPCC (2006, Volume 4, Chapter 10, Equation 10.33, page 10.60 for cattle). The production-based methodology uses milk yield, daily weight gain and net energy required for growth to estimate N retention in milk and body tissue.

3.1.6.2.2 Approaches

<u>Basic approach:</u>

Data on nitrogen retention in animals are not necessarily collected for reporting of GHGs, GNBs or NH_3 emissions. Nevertheless, information on available data might be obtained from the respective experts.

Tier 1:

Production of milk, eggs and meat are generally available from national statistical offices. Generally, also the protein content of milk is recorded. For example, Eurostat provides a data base (apro_mk_fatprot) of milk and fat content of collected cow milk by country. If possible data on wool production should be collected as well. Wool is a protein fibre and contains about 25% protein (keratin).

Where data on N retention is not available from statistical sources and no N retention data can be obtained via the "Stock Taking" methodology, IPCC default data on N retention by livestock sub-category can be used: IPCC (2006, Volume 4, Chapter 10, Table 10.20, page 10.60) lists default values for the fraction of N in feed intake of livestock that is retained by the different livestock species/categories (kg N retained animal^{-1} yr^{-1})/(kg N intake animal^{-1} yr^{-1}).

Data on N retention should be cross-checked with data on N in feed intake and N excretion, as the sum of total N retention and N excretion for each animal (sub) pool must give total N feed intake.

Tier 2:

N retention should be constrained by collecting available information on livestock production and by cross-checking the data with productivity-based estimation methods as proposed by IPCC(2006).

3.1.6.2.3 Data sources

- FAO food balance sheets for animal products
- Production statistics and protein content (e.g. Eurostat)
- Models such as CAPRI (Leip et al., 2011a, 2014)
- Livestock production associations (e.g. European Livestock and Meat Trades Union, http://www.uecbv.eu/en/index.php or the meat processing industry http://www.clitravi.eu/)
- Literature compilations on N contents (e.g., Lassaletta et al., 2014). Production data and their relation to N excretion and N retention for European conditions is provided by Oenema et al. (2014)

3.1.6.2.4 Uncertainties

- Milk and egg production data are usually available with high accuracy (uncertainty level 1).
- Data on wool production is usually less available and recourse to literature data might be required (Uncertainty level 2)
- Slaughter statistics are usually of high quality (Level 1), but for livestock sub-categories with significant fluctuation or a high share of deaths (e.g. diseases, epidemic outbreaks, …) accuracy decreases and might drop to uncertainty level 2.
- Data on livestock products N content are of good quality (uncertainty level 1) for food products (milk, meat) but attention should be taken for individual sub-flows (e.g. bones, hides, other category 3 by-products etc.).

3.1.6.3 Animal excretion of nitrogen

3.1.6.3.1 Introduction

Excretion factors of N in manure are central for many reporting obligations: N_2O emission from manure management and of N_2O emissions from agricultural soils upon application of manure or deposition by grazing animals. Manure is also the main cause of NH_3 emissions. Finally, Manure excretion of 7.8 Gg N yr^{-1} was almost at the same level as the application of mineral fertilizer at 9.7 Gg N yr^{-1} for EU28 in 2012 (EEA, 2014).

Methodologies to assess N production or excretion in manure, called guidelines on practical implementation, possible data sources and coherence with UNFCCC/UNECE guidelines are given on the pages 35-41 of the Eurostat GNB handbook (Eurostat, 2013) and the Guidelines for a common methodology to estimate nitrogen and phosphorus excretion coefficients per animal category in EU-28 (Oenema et al., 2014).

Manure excretion can be estimated with two methodologies:

(i) Based on representative measurements of manure volumes and manure N contents for representative samples of livestock sub-categories or typical N-excretion rates obtained from guidelines or literature

(ii) Based on an animal-N budget; N excretion is calculated as the difference between total N intake with feed and N retention in livestock products and in animal biomass at death.

Note that the choice of the method used for feed intake, N retention and N excretion is not independent.

3.1.6.3.2 Approaches

<u>Basic approach:</u>

Total N excretion (by manure management systems) is reported in Table 3.B(b) of the CRF for submission of national GHG inventories to the UNFCCC (see Table 4). This data should be calculated according good practice thus based on Tier 2 methodology for key source categories.

For livestock sub-categories representing at least 10% of total national N excretion the compliance with IPCC Tier 2 methodology should be checked and – if this is not the case – cooperation with relevant national experts to improve the national data availability and methodology to estimate N excretion should be initiated.

For livestock sub-categories which are regarded as significant (see Section 0) and for which no N-excretion data have been reported, Tier 1 methods should be used but the issue should be discussed also with the relevant national experts to improve other reporting obligation as well.

Table 4. Template for reporting of N_2O emissions from manure management systems (according to IPCC 2006 reporting guidelines). The table indicates the livestock categorization required (and options to select from). Obligatory information to be provided include population size, N excretion rate, typical animal mass, and N excretion pre manure management systems including pasture range and paddock. The figure cuts off data to be reporting on direct implied emissions factor for N_2O per livestock category, as well as volatilization of NH_3 and NO_x, and N lost through leaching and run-off and associated indirect emissions (factors) of N_2O.

TABLE 3.B(b) SECTORAL BACKGROUND DATA FOR AGRICULTURE
N_2O Emissions from Manure Management
(Sheet 1 of 1)

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	ACTIVITY DATA AND OTHER RELATED INFORMATION												
	Population size	Nitrogen excretion rate	Typical animal mass (average)	Nitrogen excretion per manure management system (MMS) (kg N/yr)									Tot excr
				Anaerobic lagoon	Liquid system	Daily spread	Solid storage and dry lot	Pasture range and paddock (1)	Composting	Digesters	Burned for fuel or as waste(2)	Other (3)	
	(1000s)	(kg N/ head/yr)	(kg/ animal)										(kg
1. Cattle													
Option A:													
Dairy cattle													
Non-dairy cattle													
Option B:													
Mature dairy cattle													
Other mature cattle													
Growing cattle													
Option C (country-specific): (5)													
Drop-down list													
Other *(please specify)*													
2. Sheep													
Other *(please specify)*													
3. Swine													
Other *(please specify)*													
4. Other livestock(6)													
Drop-down list													
Buffalo													
Camels													
Deer													
Goats													
Horses													
Mules and asses													
Poultry													
Other *(please specify)*													
Rabbit													
Reindeer													
Ostrich													
Fur-bearing animals(7)													
Other													
5. Indirect N_2O emissions													
Total N handled per MMS (kg N/year)													
IEF direct N_2O (kg N_2O-N/kg N handled)													
Direct N_2O emissions per MMS (Gg[kt] N_2O)													

Livestock numbers and excretion coeffients [kg head-1 yr-1] and annual excretion [t N yr-1] are also reported in Tables 2.1. – 2.3 of the GNB reporting file[16].

Tier 1:

Default N excretion values for important livestock sub-categories are given in IPCC (2006, Volume 4, Chapter 10, Table 10.19, page 10.59) in kg N (1000 kg animal mass)$^{-1}$ day^{-1}.

Oenema et al. (2014) provide N excretion data for cattle and pigs as a function of animal productivity (milk yield and/or growth rate) and feed protein content (Table 22, page 78 for dairy cattle, Table 27, page 83 for suckler cows, Tables 23-26 for other cattle, pages 81-83).

Tier 2:

If N excretion amounts to more of 10% of total N excretion in agriculture, and no data is available from national GHG or GNB reporting, it is likely that national statistical information is insufficient to

[16] Model_national_level_N_(CPSA_AE_110N)_corrected.xls from 17/05/2013

apply IPCC (2006) Tier 2 methodology. In this case it is recommended to cooperation with the GHG, NH_3 and GNB teams to collect required data and develop a common methodology to quantify the animal N-budget of the animal sub-category.

3.1.6.3.3 Data sources

- National GHG inventory reports, reports on GNB, reports on the Nitrate directive
- Scientific literature

3.1.6.3.4 Uncertainties

- Default N excretion factors are relatively uncertain. IPCC (2006, page 10.59) indicates an uncertainty of about +/-50% for the values given. N excretion determined on the basis of the animal budget depends on the uncertainty of feed intake and animal retention, but is commonly more reliable (Level 1 or Level 2)

3.1.7 AG.AH animal categorization

The animal categorization chosen are based on animal species, age (or weight) and sex, but not on the basis of the type of production system. The type of production system may have a significant effect on the relevant flows of the AG.AH pool. Therefore, a further disaggregation of the flows needs to be considered when more than one type of production systems co-exist within a region and/or country and if these different production systems differ significantly for important flows.

In such cases, representative unit flows are calculated on the basis of the further break-down of the national animal population into animal type sub-categories (ANIMs). In accordance to IPCC terminology, these are referred to as *implied unit flows (iuf)*:

$$\boldsymbol{iuf}_{ANIM} = \frac{\sum_{ANIMs}\{\boldsymbol{f}_{ANIMs} \cdot \boldsymbol{AAP}_{ANIMs}\}}{\sum_{ANIMs}\{\boldsymbol{AAP}_{ANIMs}\}} \qquad 7$$

where

ANIM:	Animal category for which the implied unit flow is calculated
ANIMs:	Sub-category of the animal category ANIM
AAP:	Average Annual Population (or herd-size) [places yr^{-1}]. The total animal places over all animal sub-categories must be representative for the whole population of the animal category: $\sum_{ANIMs}\{\boldsymbol{AAP}_{ANIMs}\} \geq \boldsymbol{0.95} \cdot AAP_{ANIM}$
iuf_{ANIM}:	Implied unit flow for animal category ANIM [kg N $place^{-1}$ yr^{-1}]
f_{ANIMs}:	Unit flow of the animal sub-category ANIMs [kg N $place^{-1}$ yr^{-1}]

Guidance on the selection of the appropriate categorization of animals is given by Oenema et al. (see Oenema et al., 2014, section 3.3, page 52):

> The type of production systems depends on many factors, including the geographical situation, climate, culture and market demands. Production systems may be defined on the basis of:
>
> - Animal breeds (small vs large breeds, low vs high productive animals),
> - Production level (e.g., milk production per cow per year, number of piglets per sow per year)
> - Marketed animal products (small vs large final weight, young vs old animals)
> - Feed rations (e.g., low vs high protein)

- Use of (veterinary) supplements in the animal feed (including antibiotics, hormones)
- Housing systems, including grazing vs restricted grazing vs zero-grazing systems

Animal productivity may also vary between regions. This holds as well for the composition of the animal feed (diets), due to differences in feed availability. These two factors may lead to significant differences in the N and P excretion coefficients between regions, and therefore justifies a secondary categorization and regional differentiation. We recommend that countries make a consideration of the various types of production systems for estimating accurate N and P excretion coefficients. These considerations relate especially to:

- Fast-growing and heavy breeds vs slow-growing breeds
- Organic production systems vs common production systems
- Housed ruminants vs grazing ruminants
- Caged poultry vs free-range poultry

The choices should be made in accordance to the general guidance on the selection of the appropriate level of disaggregation as described below.

3.2 Sub-pool Manure Management and Manure Storage (AG.MM)

3.2.1 Overall methodology and existing guidelines

The AG.MM pool is structured by animal housing and manure management and storage systems. We define the boundary between the AG.AH and the AG.MM sub-pools as the moment of manure excretion; thus, manure is immediately distributed over the different housing and manure management and storage systems. Manure excreted by grazing animals is considered as part of the AG.SM pool as it passes then directly to the land the animals are grazing on (AG.SM.LAND).

In AG.MM, emissions of ammonia (NH_3), nitrous oxide (N_2O), nitric oxide (NO) and molecular nitrogen (N2) can occur, and run-off of nitrate (NO_3). The amount of the losses depends on the type of manure management system (MMS).

Guidance for the AG.MM pool builds entirely on existing guidelines relevant for the flow in manure management and storage systems:

- IPCC2006 guidelines (IPCC, 2006), Volume 4 (Agriculture, Forestry and Other Land Uses, AFOLU) – Chapter 10 (Emissions from livestock and manure management) – Section 10.5 (N_2O emissions from manure management, pages 52-70). This section of the IPCC (2006) guidelines explains the methodology for calculating direct and indirect N_2O emissions from MM as well as the coordination with emissions from manure occurring in the AG.SM pool. The IPCC2006 guidelines give also default factors of total N losses in MM including losses of N2 (see Table 10.23, page 10.67).
- EMEP/EEA air pollutant emission inventory guidebook 2013 (EEA, 2013).

Estimates of N_2O flows should be done using the differentiation of manure systems according to the definitions given in the IPCC (2006) guidelines (see Table 10.21 on page 10.62 of IPCC, 2006). For the emissions of NH_3 and NO, the EEA2013 distinguishes MMS on the basis of solid manure or liquid slurry.

Before constructing the nitrogen budget for the AA.MM pool decisions according to Figure 5 have to be made. In many cases, a suitable quantification of N flows in the AG.MM pool exists for NH_3, NO_x and N_2 emissions from reporting to UN-ECE under the Convention on Long-Range Transboundary Pollution (CRTAP) and (direct and indirect) N_2O emissions for reporting to UNFCCC. Note that for the quantification of N flows in a NNB, the Tier 2 approach (according to EEA (2013): mass-flow approach) must be used!

Priority is therefore given to estimates of NH3 and NOx flows according to EEA (2013) as submitted to UNECE. Ideally, the same estimates are used also for reporting to UNFCCC. If this is not the case and data are reported only to either of the two conventions, the available data should be used but cooperation between the respective experts should be improved.

Generally the basic approach should be used and flows in the AG.MM sub-pool should be taken from UNECE or UNFCCC reporting, possibly checking their quality and – if necessary – improved in cooperation with the respective experts. A few flows might/will not be available and should be estimated in addition for "Tier 2 budgets": N from spilled feed in housing; N in Litter from crop (eg straw) added the manure in the housing systems; N manure imported or exported. Furthermore, a differentiation according to the implementation of mitigation measures (see section 3.1.7) improving the accuracy of Tier 2-AG.MM budgets (if they are not yet considered in the basic approach).

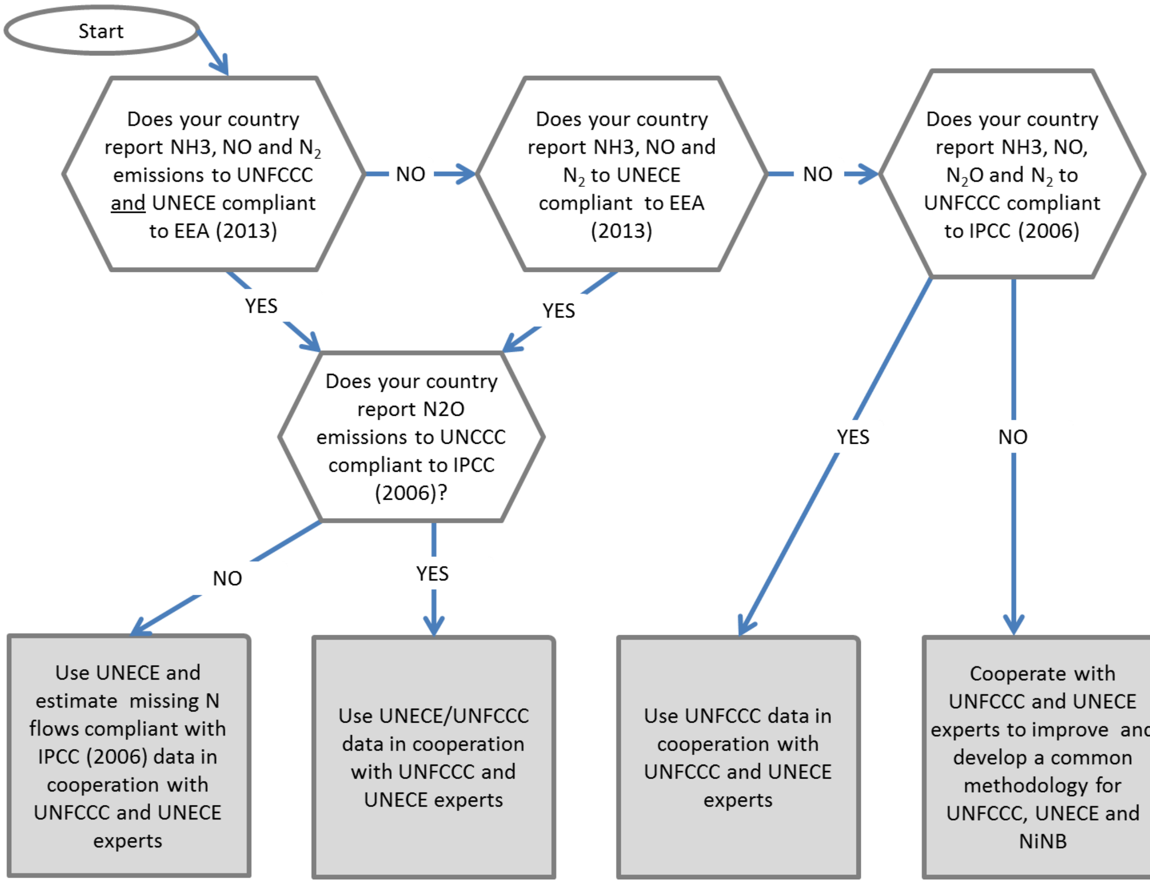

Figure 5: Decision tree to define the methodology for quantifying relevant N flows for the AG.MM pool. Details on the individual flows see below.

3.2.2 Suggested AG.MM sub-pools

In the AG.MM pool, flows need to be estimated at the level of livestock housing and manure management and storage systems. Manure is stored in livestock houses and in storages outside livestock houses, such as tanks and heaps. To quantify the manure flows over housing systems, uncovered yards, grazing systems and storages, inventories of existing systems and their implementation level should be made. Manure needs not be stored all year round. Only part of the manure ends up in storage. Storage time depends on storage capacity and manure management in the housing, as well as on regulations for manure application such as the nitrate directive. The nitrate directive prohibits the application of manure to grass and crops outside the growing season, meaning that storage of manure is inevitable. How much outside storage is needed depends on the configuration of the housing system. When the housing has a deep manure pit underneath slatted floors, hardly any outside storage might be needed. However when animals are kept on solid floors, no storage capacity in the house makes need of large outside storages.

A list of Management systems as defined in Table 10.21 of Chapter 10.5.3 of Volume 4 (AFOLU) to estimate N_2O is given below (see Table 5). Table 6 (Table A3-8 from Annex A3 in the EEA, 2013 guidebook) compares the manure storage types for consistency. It is important that consistency between EMEP/EEA and IPCC management systems and the N-flows quantified for the AG.MM pool is maintained.

Table 5. List of housing and manure management and storage systems used in the IPCC2006 (Table 10.21, page 10.62) as proposed to be used for the construction of NNBs. The level indicates the logical structure of the categorization. The Tier indicates the degree of detail required for simple (Tier 1) or more sophisticated (Tier 2 or 3) budgets. The level/Tier are coinciding for the AG.MM sub-pool.

Code	Level /Tier	Housing and manure management/ storage systems description
AG.MM.GRAZ	**1**	**Pasture/Range/Paddock: Grazing on temporary grassland, GRAT, or permanent grassland, GRAS.**
AG.MM.YARD	**1**	**Uncovered yards**
AG.MM.DSPR	**1**	**Daily spread: N in manure from animal housing systems with daily removal daily from confinery and spread on cropland or pasture**
AG.MM.SDLT	**1**	**Solid storage and dry lot**
AG.MM.SOLM	2	Solid storage: N stored on heaps as solid manure
AG.MM.SOLE	2	Effluent of solid storage: N lost as effluent from solid storage
AG.MM.DLOT	2	Dry lot: N deposited on dry lot, paved or unpaved
AG.MM.LIQM	**1**	**Liquid/slurry: N stored in tanks or earthen ponds outside animal confinement**
AG.MM.LSCR	2	Liquid/slurry with natural crust cover: N stored in tanks or earthen ponds outside animal confinement with natural crust
AG.MM.LSCO	2	Liquid/slurry without natural crust cover: *N stored in tanks or earthen ponds outside animal confinement with cover impermeable to water or gases
AG.MM.LAGO	**1**	**Uncovered anaerobic lagoon: N stored in lagoons**
AG.MM.PITS	2	N stored in Pits underneath slatted floors in animal confinement
AG.MM.PITB	3	Pits: *N stored in Pits underneath slatted floors in animal confinement with BAT techn to reduce NH_3-N
AG.MM.DEEP	2	Cattle and swine deep bedding: N stored with litter as deep bedding in animal confinement
AG.MM.COMP	**1**	**Composting**
AG.MM.COMPV	2	Composting – In-Vessel: N in compost piles, channels or vessels with forced aeration and continuous mixing
AG.MM.COMPP	2	Composting – Static Pile: N in compost in piles with forces aeration but no mixing
AG.MM.COMPWI	2	Composting – Intensive Windrow: N in compost in windrows with regular turning for mixing and aeration
AG.MM.COMPWP	2	Composting – Passive Windrow: N in compost in windrows with infrequent turning for mixing and aeration
AG.MM.POUL	2	Poultry manure with litter: N of poultry typically breeder flock, broilers or other meat fowl
AG.MM.POULPIT	2	Poultry manure withoug litter: N of poultry without litter usually in pit, possibly composting
AG.MM.POULBAT	3	*N of poultry with BAT tecniques in housing to reduce NH_3-N
AG.MM.LAER	2	Aerobic treatment: Aerated liquid slurry for biological oxidation

Table 6. Comparison of manure storage types used in the EMEP/EEA air pollutant emission inventory guidebook 2013 (EEA, 2013) and the IPCC (IPCC, 2006). Source: EEA, 2013, update 2014, chapter 3B, page 58.

Table A3–8 Comparison of manure storage types with those used in IPCC

Term	Definition	IPCC equivalent
Lagoons	Storage with a large surface area to depth ratio; normally shallow excavations in the soil	Liquid/slurry[1]. Manure is stored as excreted or with some minimal addition of water in either tanks or earthen ponds outside the animal housing, usually for periods less than one year.
Tanks	Storage with a low surface area to depth ratio; normally steel or concrete cylinders	
Heaps	Piles of solid manure.	Solid storage. The storage of manure, typically for a period of several months, in unconfined piles or stacks. Manure is able to be stacked due to the presence of a sufficient amount of bedding material or loss of moisture by evaporation.
In-house slurry pit	Mixture of excreta and washing water, stored within the animal house, usually below the confined animals.	Pit storage below animal confinements. Collection and storage of manure usually with little or no added water typically below a slatted floor in an enclosed animal confinement facility, usually for periods less than one year.
In-house deep litter	Mixture of excreta and bedding, accumulated on the floor of the animal house.	Cattle and pig deep bedding. As manure accumulates, bedding is continually added to absorb moisture over a production cycle and possibly for as long as 6 to 12 months. This manure management system is also known as a bedded pack manure management system.
Crust	Natural or artificial layer on the surface of slurry which reduces the diffusion of gasses to the atmosphere.	No definition given.
Cover	Rigid or flexible structure that covers the manure and is impermeable to water and gasses.	No definition given.
Composting, passive windrow	Aerobic decomposition of manure without forced ventilation.	Composting, static pile. Composting in piles with forced aeration but no mixing.
Forced-aeration composting	Aerobic decomposition of manure with forced ventilation.	Composting, in-vessel. Composting in piles with forced aeration but no mixing.

Biogas treatment	Anaerobic fermentation of slurry and/or solid	Anaerobic digester. Animal excreta with or without straw are collected and anaerobically digested in a large containment vessel or covered lagoon. Digesters are designed and operated for waste stabilization by the microbial reduction of complex organic compounds to CO_2 and CH_4, which is captured and flared or used as a fuel.
Slurry separation	The separation of the solid and liquid components of slurry.	No definition given.
Acidification	The addition of strong acid to reduce manure pH.	No definition given.

Note:
[1]In IPCC lagoons refers only to a particular type of lagoon, anaerobic lagoons, a type of liquid storage system designed and operated to combine waste stabilization and storage, storage may be for > 1 year. Lagoons referred to in this document are simply earth-banked alternatives to storage in tanks.

3.2.3 AG.MM characterization

Parameters that characterize or determine N flows in the MM pool are manyfold. As described in the EEA (2013) the annual amount of excreted manure should be calculated for livestock houses, on uncovered yards and during grazing (HOYG). This is based on the total annual N excretion (Nex) and the proportions of excreta deposited at HOUS, YARD and GRAZ, respectively. Unless better information is available, HOUS, YARD and GRAZ should equate to the proportion of the year spent at the relevant locations, and should amount to the yearly amount of manure produced. Uncovered yards and grassland in this sense is considered to be a kind of 'transitional housing' systems. With grazing the manure continues to flow from the animal husbandry pool (animal type/animal system) to the soil management pool.

In the house, animal feed can be spilled, depending on the feeding system. This mostly ends up in the manure. This flow is not mentioned in the EEA (2013) guidelines nor in IPCC's, but can add up to N in manure depending on the animal category and the housing system. In the Netherlands in dairy houses with cubicles it is estimated that 2-5% of N in feed can end up in the manure pits. For emissions this is not easily available because it is an organic compound (Norg), but it is substantial on the total flow of nitrogen for the NNB. If data on spilled feed are available it is recommended to include this in the estimation.

Another N-source which ends up in the manure is the N in litter. Litter can be either straw from the Soil Management pool, or a rest products from the Humans and Settlements pool (wood shavings, saw dust, paper etc.). The EEA (2013) guidebook gives default values for the amount of N added with straw based on the length of the housing period (Table 7).

Table 7. Default values for length of housing period, annual straw use in litter-based manure management systems and the N content of straw. Source (EEA, 2013, Chaper 3.B, Table 3.5 page 21)

Livestock class	Housing period, d	Straw, kg AAP^{-1} a^{-1}	N added in straw, kg AAP^{-1} a^{-1}
Dairy cows (100901)	180	1 500	6.00
Other cattle (100902)	180	500	2.00
Finishing pigs (100903)	365	200	0.80
Sows (100904)	365	600	2.40
Sheep and goats (100905)	30	20	0.08
Horses, etc. (100906)	180	500	2.00
Buffalos (100914)	225	1500	6.00

Not all manure comes from housing systems; some is imported from other countries, mostly dried because otherwise transport would be too expensive. Drying of manure is particularly profitable for poultry manure because of the high dry matter content of fresh excreta, and because drying prevents conversion of uric acid into ammonia. In the future manure processing may develop to produce dried and/or concentrated cattle and pig manure. This can be economically feasible when demand grows for natural fertilizers rich of P or N.

After housing (excluding grazing) the manure is directly put on the land into the AG.SM pool, or indirectly after storage. Manure imported from another country is assumed to be stored before it is applied to land. An alternative route is transfer of manure after housing or storage to an anaerobic digester (WS pool). It is assumed that no manure goes directly from the yard to the digester, but always via storage.

Two other options for manure to exit the Agricultural pool are burning manure for fuel or electricity (EF pool). Firstly, the dung cakes deposited on the grassland can be used as fuel by burning them. Secondly, dried manure from poultry houses can be transported to an electricity plant where it is burned for electricity on the grid. Here no emissions take place because the exhaust air is cleaned from NH_3 and N_2O. The next step in the EMEP/EEA guidelines is to calculate the amount of manure handled as slurry and the amount handled as solid manure. This is a logical step because they express the emissions as a fraction of TAN. The TAN fractions for liquid and solid manure are different because of additional N from litter and because other microbial processes occur in solid then in liquid manure. Additionally, the processes immobilisation of TAN into organic matter and mineralization of TAN from organic matter run to a different extend and thus fractions of TAN change. Even though it is recommended to use the TAN approach in the quantification of flows for the AG.MM pool, it is not obligatory. In case TAN-flows are used, the EMEP/EEA gives good guidance. If N-flows are used, the EMEP/EEA still give good guidance, but recalculation of TAN to N is needed. Another approach for the N-flow could be to take the IPCC guidelines as a starting point.

Table 8. Flows in the Manure management and storage N- budget. With regard to sub-pools (housing systems, HOYG, and manure management and storage systems, STOR), a disaggregation of the flows according to Table 5 is recommended.

Pool ex	Pool in	Matrix	Other info	Flow code	Level	Description/note
AG.AH	AG.MM	NFEED		AG.AH-AG.MM-NFEED	2	N from spilled feed in housing
RW	**AG.MM.STOR**	**NEXC**		**RW-AG.MM.STOR-NEXC**	**1**	**N manure imported**
AG.AH.ANIM	**AG.MM.HOYG**	**NEXC**		**AG.AH.ANIM-AG.MM.HOYG-NEXC**	**1**	**Nexcreted by animals in the different animal housing systems (as defined in the text). Note that HOUG refers to animal housing systems (HOUS) uncovered yards, and grazing (regarded as a separate, transitional 'housing' system (AG.MM.GRAZ)).**
AG.SM	AG.MM.HOUS	NLIT1		AG.SM-AG.MM.HOUS-NLIT1	2	N in Litter from crop (eg straw) added the manure in the housing systems AG.MM.HOUS
HS	AG.MM.HOUS	NLIT2		HS-AG.MM.HOUS-NLIT2	2	N in Litter from other than plant (wood shavings, saw dust, paper) added the manure in the housing systems AG.MM.HOUS
AG.MM.GRAZ	**AG.SM.LAND**	**MANG**		**AG.MM.GRAZ-AG.SM.LAND-MANG**	**1**	**N excreted during grazing from an animal husbandry sub-pool (animal type/animal system) to a soil management sub-pool (i.e. temporary grassland, GRAT, or permanent grassland, GRAS). As the 'grazing housing system' is transitional, it is: AG.AH.ANIM-AG.MM.GRAZ = AG.MM.GRAZ-AG.SM.LAND**
AG.MM.HOUS	**AG.MM.STOR**	**NMAN**		**AG.MM.HOUS-AG.MM.STOR-NMAN**	**1**	**N in manure transferred from animal housing systems to manure storage and management systems (see text for definition)**
AG.MM.HOUS	**AG.SM.LAND**	**MANA**		**AG.MM.HOUS-AG.SM.LAND-MANA**	**1**	**N in manure directly applied on land from animal housing systems**
AG.MM.YARD	**AG.MM.STOR**	**NMAN**		**AG.MM.YARD-AG.MM.STOR-NMAN**	**1**	**N in manure transferred from uncovered yards to manure storage and management systems (see text for definition)**
AG.MM.YARD	**AG.SM.LAND**	**MANA**		**AG.MM.YARD-AG.SM.LAND-MANA**	**1**	**N in manure directly applied on land from animal uncovered yard**
AG.MM.STOR	**AG.SM.LAND**	**MANA**		**AG.MM.STOR-AG.SM.LAND-MANA**	**1**	**N in manure stored/managed in manure storage and management systems and applied on land**
AG.MM.HOST	WS.ADIG	NMAN		AG.MM.HOST-WS.ADIG-NMAN	2	N for anaerobic digester from housing, uncovered yard or manure storage/management systems (HOST=HOUS+STOR)
AG.MM.GRAS	AT	NMAN	fuel	AG.MM.GRAS-AT-NMAN-fuel	2	N excreted on fields, dung cakes are burned for fuel
AG.MM.HOUS	AT	NMAN	burned	AG.MM.HOUS-AT-NMAN-burned	3	N-poultry dried in animal confinement and burned for electricity in an electricity plant
AG.MM	**RW**	**EXP**		**AG.MM-RW-EXP**	**1**	**N manure exported**
AG.MM.HOST	**AT**	**NH3**		**AG.MM.HOST-AT-NH3**	**1**	**Emission of ammonia-N to the atmosphere (for each housing and manure management/storage system)**
AG.MM.HOST	**AT**	**NITDEN**		**AG.MM.HOST-AT-NITDEN**	**1**	**Emission of N gases (N2O, NOx and N2) to the atmosphere due to (de) nitrification (for each housing and manure management/storage system)**
AG.MM.HOST	AT	N2O		AG.MM.HOST-AT-N2O	2	Emission of N2O-N to the atmosphere
AG.MM.HOST	AT	NO		AG.MM.HOST-AT-NO	2	Emission of NO-N to the atmosphere
AG.MM.HOST	AT	N2		AG.MM.HOST-AT-N2	2	Emission of N2-N to the atmosphere
AG.MM.HOST	**HY**	**Ntot**		**AG.MM.HOST-HY-Ntot**	**1**	**Loss of N to groundwater and surface water due to leakage of runoff**
AG.MM.HOST	HY	Ntot		AG.MM.HOST-HY-Ntot	2	Loss of N to groundwater due to leakage of runoff
AG.MM.HOST	HY	Ntot		AG.MM.HOST-HY-Ntot	2	Loss of N to surface water due to leakage of runoff

If manure is stored on bare soil, either in the house or outside (HOST), liquid manure or run-off can penetrate in soil and groundwater or surface water. Some countries have legislation to prevent leakage and collect this runoff.The flow of manure-N to the atmosphere should be defined for each housing type and type of manure storage.

A list of the flows to be quantified is given in Table 8.

3.2.4 Quantification of flows in the AG.MM sub-pool

3.2.4.1 Introduction

Manure is assumed to be managed as slurry or as solid. Slurry consists of excreta, some bedding material, spilt animal feed and drinking water, and water added during cleaning or to assist in handling. It is equivalent to the liquid/slurry category in IPCC (2006). Solid manure consists of excreta, spilt animal feed and drinking water and may also include bedding material. It is equivalent to the solid manure category in IPCC (2006). If detailed information on N in bedding or litter is missing, default values for straw are given in Table 7 in section 3.3.

As put forward in the EMEP/EEA emission inventory guidebook 2013 (from now on called the EEA guidebook) the calculation of the emissions of gaseous N from manure management systems based on TAN (Total Ammoniacal N) is preferred to one based on total N, as is used by IPCC to estimate emissions of N_2O. This is because gaseous N emissions arise from TAN and therefore this approach allows for more accurate estimates of the N-flows. It also allows to reflect the consequences of changes in animal diets, since the excretion of total N and TAN respond differently to such changes. So gaseous N-emissions may be affected differently depending more on TAN then on N-excretion. TAN is for the larger part urine-N, and for a smaller part formed by mineralization of the fecal organic matter. TAN can be calculated from the digestibility of the protein in the feed and the amount of fecal organic matter mineralized during storage. Default 60% of the N of cattle is excreted as TAN and 70% with pigs and poultry. Table A3-6 from the EEA guidebook can be used to recalculate N from TAN in the different subpools. The EEA guidebook compares the MMS with those in the IPCC 2006 guidebook in Table A3-8 for consistency (see Table 6).

The N-flow distinguishes storage in houses and storage outside. NH_3 emission factors are organised that way. However, in the IPCC guidelines no explicit distinction is made and N_2O-N is therefore not expressed as a percentage of N present, but as a percentage of N-excretion. To follow the flow from housing to storage the EEA guidebook gives a derivation as presented in table A3-6 in appendix A3. Note that the EEA presents this as a percentage of TAN. The derivation for N-dependant factors will follow the same structure. For the NNB TAN can be used, but the guidance focus is on N-flows because of consistency with IPCC 2006 MMS. Per MMS emission factors of NH_3-N, N_2O-N, NO-N and N_2-N can then be defined.

If emissions are expressed as a percentage of TAN and manure is managed as liquid, increase of TAN should be included because of minerilization of organic N. When no detailed information is available, 0.1 kg N per kg organic N is assumed to mineralize (Dämmgen et al. 2007)

If emissions are expressed as a percentage of TAN and manure is managed as solid, decrease of TAN should be included by immobilistaion of organic N. When no detailed information is available, 0.0067 kg N per kg organic N is assumed to immobilise (Kirchmann and Witter, 1989)

3.2.4.2 Approaches

For the quantification of N flows in a NNB, the Tier 2 approach (mass-flow approach) must be used. Tier 1 as described in IPCC 2006 and EEA (2013) are therefore not presented here. The N excreted per animal categorie must be divided over the different Manure systems, the sub pools described in chapter 3.2.2. This should be done in agreement with UNFCCC and UNECE experts and in compliance with IPCC (2006) and EEA (2013) (Figure 7).

Basic approach

Estimates of emissions from AG.MM are available in the Informative Inventory Reports (IIR) under the Convention of Long Range Transboundary Air Pollution. The distribution of manure over the various MMS present in a country (including the share of manure excreted by grazing animals) is available in CRF Table 3B(b) of the national GHG inventory. The national GHG inventory reports should also contain information on any other use of manure and/or import or export.

Tier 2

NH_3

For each sub pool, an ammonia emission factor (EF) is needed. If no country specific data are available in the Informative Inventory Report (IIR) or National Inventory Report (NIR), emission factors of Table 3.7 from the EEA guidebook can be used in agreement with UNECE experts (Table 9).

The effect of some abatement measures can be adequately described using a reduction factor, i.e. proportional reduction in emission compared with the unabated situation. For each sub pool an integrated emission factor can be calculated with the implementation factors of the available emission reducing system in a sub pool.

Table 9. Default Tier 2 NH3-N EF and associated parameters for the Tier 2 methodology for calculation of the NH3-N emissions from manure management. EF as proportion of TAN. Source EEA (2013, Chapter 3B, Table 3.7, page 27)

Table 3.7 Default Tier 2 NH_3-N EF and associated parameters for the Tier 2 methodology for calculation of the NH_3-N emissions from manure management. EF as proportion of TAN

Code	Livestock	Housing period, $d\ a^{-1}$	N_{ex}	proportion of TAN	Manure type	$EF_{housing}$	EF_{yard}	$EF_{storage}$	$EF_{spreading}$	$EF_{grazing/outdoor}$
100901	Dairy cows	180	105	0.6	slurry	0.20	[2]0.30	0.20	0.55	0.10
					solid	0.19	[2]0.30	0.27	0.79	0.10
100902	Other cattle (young cattle, beef cattle and suckling cows)	180	41	0.6	slurry	0.20	[2]0.53	0.20	0.55	0.06
					solid	0.19	[2]0.53	0.27	0.79	0.06
100903	Fattening pigs (8–110 kg)	365	12.1	0.7	slurry	0.28	[2]0.53	0.14	0.40	
					solid	0.27	[2]0.53	0.45	0.81	
100904	Sows (and piglets to 8 kg)	365	34.5	0.7	slurry	0.22	NA	0.14	0.29	
					solid	0.25	NA	0.45	0.81	
		0			outdoor	NA	NA	NA	NA	[2]0.25
100905 +100911	Sheep (and goats)	30	15.5	0.5	solid	0.22	[2]0.75	0.28	0.90	0.09
100906 +100912	Horses (and mules, asses)	180	47.5	0.6	solid	0.22	NA	0.35	[1]0.90	[2]0.35
100907	Laying hens (laying hens and parents),	365	0.77	0.7	solid, can be stacked	0.41	NA	0.14	0.69	
100907	Laying hens (laying hens and parents),	365	0.77	0.7	slurry, can be pumped	0.41	NA	0.14	0.69	
100908	Broilers (broilers and parents)	365	0.36	0.7	solid	0.28	NA	0.17	0.66	
100909	Other poultry (turkeys)	365	1.64	0.7	solid	0.35	NA	0.24	0.54	
100909	Other poultry (ducks)	365	1.26	0.7	solid	0.24	NA	0.24	0.54	
100909	Other poultry (geese)	365	[1]0.55	0.7	solid	0.57	NA	0.16	0.45	
100910	Fur animals	365	[1]0.08	0.6	solid	0.27	NA	0.09	NA	
100913	Camels[3]						NA			
	Buffalo[1]	140	[1]82.0	0.5	solid	0.20	NA	0.17	0.55	0.13

Sources: Default N excretion data were taken from Table 10.19 of IPCC chapter 10: Emissions from Livestock and Manure Management. Default EFs were taken from the work of the EAGER group

Notes:
[1]Taken from GAS-EM.
[2]Taken from NARSES

N_2O

For each sub pool a nitrous oxide emission factor is needed. If no exisiting (country specific) data are available in the IIR or NIR, emission factors of Table 10.21 of the IPCC 2006 guidebook can be used (not presented here). If not adequate, Table A3-6 from the EEA guidebook can be used. This should be done in agreement with the UNFCC and UNECE experts (Table 10).

Table 10. Derivation of default Tier 2 EF for direct N2O emissions from manure management. Appendix Table A3–7 explains how the manure storage types referred to here relate to those used by IPCC. Source EEA (2013, Chapter 3B, Table A3-67, page 55)

Table A3–6 Derivation of default Tier 2 EF for direct N_2O emissions from manure management. Appendix Table A3–7 explains how the manure storage types referred to here relate to those used by IPCC

Storage system	IPCC default EF kg N_2O-N $(kg\ N_{ex})^{-1}$	Proportion of TAN in manure at storage [(a)]	EF kg N_2O-N $(kg\ TAN\ entering\ store)^{-1}$
Cattle slurry without natural crust	0	0.50	0
Cattle slurry with natural crust	0.005	0.50	0.01
Pig slurry without natural crust	0	0.65	0
Cattle manure heaps, and solid	0.02	0.25	0.08
Pig manure heaps, and solid	0.02	0.40	0.05
Sheep and goat manure heaps, and solid	0.02	0.30	0.07
Horse (mules and asses) manure heaps, and solid	0.02	0.25	0.08
Layer manure heaps, solid	0.02	0.55	0.04
Broiler manure heaps, solid	0.02	0.65	0.03
Turkey and duck manure heaps, solid	0.02	0.60	0.03
Goose manure heaps, solid	0.02	0.60	0.03
Buffalo manure heaps, solid	0.02	0.25	0.08

Note:
[a] Based on output from the EAGER group.

NO

NO is produced in the course of nitrification and denitrification following anaerobic and aerobic circumstances respectively. The quantification of this amount is difficult to estimate and hardly measured. EMEP/EEA give default values for NO losses needed in a mass flow calculation for solid manure and slurry (Table 11)

Table 11. Default values for other losses needed in the mass-flow calculation (from Dämmgen et al. 2007). Source EEA (2013, Chapter 3B, Table A3.8, page 28)

	proportion of TAN
$EF_{storage\_slurryNO}$	0.0001
$EF_{storage\_slurryN2}$	0.0030
$EF_{storage\_solidNO}$	0.0100
$EF_{storage\_solidN2}$	0.3000

N_2

Also in the course of nitrification and denitrification, N_2 is formed. The quantification of this amount is difficult to estimate because difficult to measure since 80% of our surrounding air is N_2 (800.000 ppm). EMEP/EEA give default values for N2 losses needed in a mass flow calculation for solid manure and slurry (Table 11).

3.2.4.3 Data sources

Data sources are presented in the descriptions per gas in the above paragraphs refering to National Inventory Reports (NIR) or Informative Inventory Reports (IIR), IPCC (2006) guidelines and EEA (2013) Guidebook. For implementation of manure management systems and or reducing systems national statistics or census are advised as source.

3.2.4.4 Uncertainties

Uncertainties are large, quality of activity data are diverse between countries but also between animal categories within countries. Assessment of activity data vary from protocol measurements to expert judgements.

Uncertainties need preferably be assessed with Monte Carlo simulations rather then with propagation of error methods because of dependencies of emission in the course of the mass flow.

3.2.5 AG.MM consideration of abatement techniques

It is advised to substantiate a more sustainable agriculture by taking into account abatement techniques in the NNB. Because of the NEC directive, the Gothenborg protocol and the IED Directive, Best Available Techniques (BAT) are developed to reduce NH_3 emissions from agriculture. Bitman et al. (2014) provide an overview of NH_3 mitigation options, including livestock feeding strategy (relevant for AG.AH pool), livestock housing and manure storage (relevant for AG.MM pool) and manure and fertilizer application techniques (relevant for AG.SM pool). A lot of effort has been put into NH_3 abatement techniques during storage (covers) and application of manure (rapid incorporation, injection), but also abatement techniques in housing are developed and implemented more and more (reducing protein in feed, reducing emitting surface, air scrubbing). Present regulations do not enforce abatements of N_2O, but NH_3-emission abatement measures will affect on emissions of N_2O, NO and N_2 as well. Depending on the point of action of the abatement technique in the process of production and volatilization, more or less N_2O, NO and N_2 can be produced and emitted. It may also occur that abatement techniques induce new N-flows. For instance, air scrubbers wash the ammonia from the air, which is captured in sluice. This sluice, which will have low pH in case of chemical scrubbers, will have low emissions if applied to the field separately.

Reducing emissions from housing systems can be achieved by reducing the surface area contaminated with slurry, for instance by implementing partly slatted floors with or without sloping pit walls for pigs. For poultry reducing the dry matter content of the manure is an effective abatement measure. In dairy systems with cubicle houses, a grooved flooring system can reduce the emission of ammonia.

A breakdown of manure management systems into regular and abating systems is therefore recommended for Tier 2 budgets. This is done by using implied unit flows for manure management systems (HOUSs and STORs).

$$iuf_{HOYG} = \frac{\sum_{HOYGs}\{f_{HOYGs} \cdot Nexc_{HOYGs}\}}{\sum_{HOYGs}\{Nexc_{HOYGs}\}} \quad (8)$$

$$iuf_{STOR} = \frac{\sum_{STORs}\{f_{STORs} \cdot NMAN_{STORs}\}}{\sum_{STORs}\{NMAN_{STORs}\}} \quad (9)$$

where

HOYG: Housing system for which the implied unit flow is calculated. HOYG includes houses, yards, and grazing.

HOYGs: Sub-category of the housing system HOUS

Nexc: Manure N excreted within the housing system (incl. yards and grazing land). The total N excreted in manure in the housing sub-categories considered must be representative for the whole N excretion for the animal category: $\sum_{HOYGs}\{\boldsymbol{Nexc_{HOYGs}}\} \geq \mathbf{0.95} \cdot Nexc_{HOYG}$. Pratically, manure excreted in housing systems is quantified by animal category multiplying the AAPs for each animal category with the share of time during a year the animal is kept in the housing system, and with the manure excretion rate per year and animal place. [kg N yr^{-1}]

$iufHOYG$: Implied unit flow for housing system (HOYG) [kg N

f_{HOUSs}: Unit flow of the animal sub-category (HOYGs) [kg N (kg N)$^{-1}$]

STOR, STORs, NMAN – in analogy to HOYG, HOYGs and Nexc [kg N (kg N)$^{-1}$]

For storage, EMEP/EEA guidelines give abatement options in Table 12 (EEA, 2013, Chaper 3.B, Appendix A2, Table A2-2, page 48). This agrees with the Framework Code for Good Agricultural Practice (Bitman et al., 2014).

Table 12. Ammonia emission abatement measures for cattle and pig slurry (UNECE, 2007). Source (EEA, 2013, Chaper 3.B, Table A2-2, page 48)

Table A2–2 Ammonia emission abatement measures for cattle and pig slurry storage (UNECE, 2007)

Abatement Measure	NH_3 Emission Reduction (%)[a]	Applicability	BAT [b] available for IPPC Pig Farms?
'Tight' lid, roof or tent structure	80	Concrete or steel tanks and silos. May not be suitable on existing stores.	Yes — but decisions taken on a case by case basis
Plastic sheeting [c] (floating cover)	60	Small earth-banked lagoons.	Yes — but decisions taken on a case by case basis
Plastic sheeting [c] (floating cover)	60	Large earth-banked lagoons and concrete or steel tanks. Management and other factors may limit use of this technique.	Yes — but decisions taken on a case by case basis
'Low technology' floating covers (e.g. chopped straw, peat, bark, LECA balls, etc.) (Cat. 2)	40	Concrete or steel tanks and silos. Probably not practicable on earth-banked lagoons. Not suitable if materials likely to cause slurry management problems.	Yes — but decisions taken on a case by case basis
Natural crust (floating cover)	35–50	Higher dry matter slurries only. Not suitable on farms where it is necessary to mix and disturb the crust in order to spread slurry frequently.	Yes — but decisions taken on a case by case basis
Replacement of lagoon, etc. with covered tank or tall open tanks (H> 3 m)	30 - 60	Only new build, and subject to any planning restrictions concerning taller structures.	Not assessed
Storage bag	100	Available bag sizes may limit use on larger livestock farms.	Not assessed

Notes:
(a) Emission reductions are agreed best estimates of what might be achievable across UNECE. Reductions are expressed relative to emissions from an uncovered slurry tank/silo.
(b) BAT: Best Available Techniques.
(c) Sheeting may be a type of plastic, canvas or other suitable material.

3.3 Sub-pool Agricultural soil management (AG.SM)

3.3.1 Overall methodology and existing guidelines

The AG.SM pool is structured by land type. If possible flows to, from and within the AG.SM pool are to be estimated following the concept of the soil N-budget approach (Leip et al., 2011a). Input flows of organic and mineral fertilizers have to be quantified net of all releases of N previous to application (i.e. without the N-emissions that occured during manure management and storage), but including all N releases that occur during or after the application to arable area (e.g. volatilization of NH_3 and NO_x from the soil). According to the definition of an ideal soil budget (Eurostat, 2013), all above-ground crop residues should be included in the output flows and those that are returned to agricultural soils included in the input flows. This is of relevance (i) if a detailed assessment by crop type is made, as crop residues are used as fertilizer for the crop cultivated in the following growing period, and (ii) if the NNB is used to derive efficiency indicators.

Guidance for the AG.SM pool builds entirely on existing guidelines:

- IPCC2006 guidelines (IPCC, 2006), Volume 4 (Agriculture, Forestry and Other Land Uses, AFOLU) – Chapter 11 (N_2O emissions from managed soils, and CO_2 emissions from lime and urea application) – Section 10.5 (N_2O emissions from manure management, pages 52-70). This section of the IPCC (2006) guidelines explains the methodology for calculating direct and indirect N_2O emissions from MM as well as the coordination with emissions from manure occurring in the AG.SM pool.
- EUROSTAT (2013) Methodology and Handbook, Nutrient Budgets for EU27, NO, CH. (Eurostat, 2013).
- EMEP/EEA air pollutant emission inventory guidebook 2013. Technical guidance to prepare national emission inventories (EEA, 2013).

It is recommended to use estimates made according to (Eurostat, 2013) as a first data source as flows are available at the level of crop type. Some flows, such as N in crops harvested, are not required in UNFCCC and UNECE reporting and data are available only in the data supporting the national GNB. For each flow, (Eurostat, 2013) includes a discussion on the consistency of the GNB methodology with UNFCCC and UNECE reporting standards. This is of particular importance, as it is recommended to use data from UNFCCC reporting for the estimation of N_2O emissions and nitrogen leaching and run-off from soils, and data from UNECE reporting for the estimation of NH_3 and NO_x from soils (Chapter 3.D: Crop production and agricultural soils).

Before constructing the nitrogen budget for the AASM pool decisions according to Figure 6 shall be made. Cooperation with the experts responsible for the national GNB estimate which is submitted to Eurostat is of uttermost importance. We discourage to make own estimates that are different from the one used in the national GNB unless well justified.

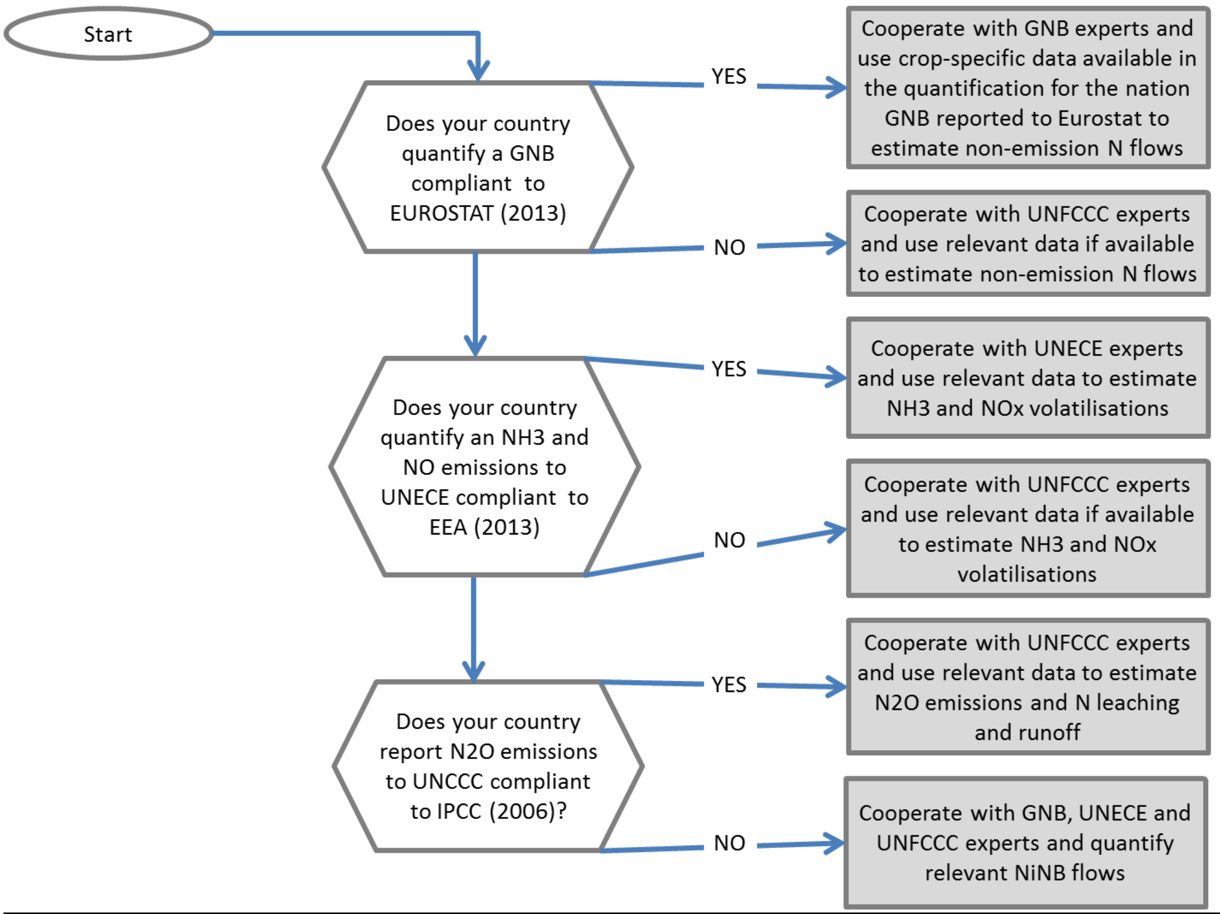

Figure 6: Decision tree to define the methodology for quantifying relevant N flows for the AG.SM pool. Details on the individual flows see below.

3.3.2 AG.SM structure

Flows in the sub-pool Soil Management are related to agricultural land management of the so-called "**agricultural area**". According to the Common Agricultural Policy of the European Union (EU, 2013, Article 4) "agricultural area" means any area taken up by **arable land** (ARAB), **permanent grassland** and **permanent pasture** (GRAS), or **permanent crops** (PERM):

- **arable land**: land cultivated for crop production or areas available for crop production but lying fallow, including areas set, irrespective of whether or not that land is under greenhouses or under fixed or mobile cover;
- **permanent crops:** non-rotational crops other than permanent grassland and permanent pasture that occupy the land for five years or more and yield repeated harvests, including nurseries and short rotation coppice;
- **permanent grassland and permanent pasture** (together referred to as **permanent grassland:** land used to grow grasses or other herbaceous forage naturally (self-seeded) or through cultivation (sown) and that has not been included in a crop rotation for five years or more; it may include other species such as shrubs and/or trees which can be grazed provided that the grasses and other herbaceous forage remain predominant.

If the distinction of these three land types is not possible, a distinction between GRAS and ARPM=ARAB+PERM could be used.

If sufficient data is available, arable land should be further sub-divided into food and other marketable crops (e.g. tobacco, fiber crops) on one hand and non marketable (fodder) crops (such as temporary grassland, fodder maize, fodder beet and other fodder crops) as given in Table 13. The distinction is important for the quantification of the flows between the AG.SM and the AG.AH pools; data on crop yield and N-content are usually available from national statistics for marketable crops, but are more uncertain for fodder crops.

Table 13. List of land use types as proposed to be used for the construction of NNBs

Land use code	Level	Tier	Land use description
AG.SM.ARPM	0		Arable land and permanent crops
AG.SM.ARAB	1		Arable land
AG.SM.FOOD	**2**	**1**	**Annual (food) crops**
AG.SM.CERE	3	2	Cereals incl. soft wheat (SWHE), durum wheat (DWHE), rye (RYEM), barley (BARL), oats (OATS), grain maize (MAIZ), rice (PARI) and other cereals (OCER)
AG.SM.PULS	3	2	Pulses incl. peas (PEAS) and other pulses (OPULS)
AG.SM.ROOT	3	2	Root crops incl. potatoes (POTA), sugar beet (SUGB), and other root crops (OROT)
AG.SM.TEXT	3	2	Industrial plants without oil seeds including tobacco (TOBA), hops (HOPS), cotton (COTT), flax (FLAX), hemp (HEMP) and other textile crops (OTEXT)
AG.SM.OILS	3	2	Oil seeds including rape and turnip (RAPE), sunflower (SUNF), soya (SOYA), linseed (LINS), and other oil seeds (OOIL)
AG.SM.OIND	3	2	Other industrial crops not mentioned elsewhere including aromatic crops (AROM)
AG.SM.VEGE	3	2	Vegetables including tomatoes (TOMA) and other vegetales (OVEG). Kitchen gardens belonging to agricultural holdings might be included here.
AG.SM.FLOW	3	2	Flowers and ornamental plants
AG.SM.FODD	**2**	**1**	**Fodder crops**
AG.SM.OFAR	3	2	Other fodder on arable land including temporary grassland (GRAT) and leguminous fodder (FLEG)
AG.SM.FNMR	3	2	Non-marketable fodder crop such as fodder maize (MAIF), fodder beet (ROOF) and other non-marketable fodder crops (OFOD)
AG.SM.FALL	3	2	Fallow land
AG.SM.OCRO	2	2	Other crops on arable land
AG.SM.PERM	**1**	**1**	**Permanent crops including fruit and berry plantations (FRUIT), nuts (NUTS), vineyards (VINE), olive plantations (OLIV), nurseries (NURS) and other permanent crops (OPERM).**
AG.SM.GRAS	**1**	**1**	**Permanent grassland and permanent meadows incl. pasture and meadow used for production, rough grazing, and grassland and meadow not used for production**
AG.SM.OTHE	**1**	**1**	**Other agricultural area not included elsewhere.**

3.3.3 AG.SM characterization

N inputs to agricultural land stem mainly from mineral fertilisers and manure. Other N inputs are from organic fertilisers else than manure (e.g. sewage sludge, compost, biomass from forests etc.), N with irrigation water, N in atmospheric deposition, and biological N fixation. N in crop residues left on the soil might are also be considered as a N input if total aboveground crop residues (left on the soil, used as feed or bedding material or used otherwise) are quantified with the total crop production in the output (see ideal GNB in Eurostat, 2013).

N outputs from agricultural land occur with crop products and crop residues, emissions to the atmosphere, losses to the hydropsphere via leaching and run-off, and soil erosion.

A list of the flows to be quantified is given in Table 14.

Often, N inputs to agricultural land are not differentiated by crop type. The IPCC2006 guidelines require information on N inputs by input type thus fertilizer application is differentiated from manure deposited by grazing animals. Accordingly, emissions of Nr and N_2 are not differentiated by land type and can be reported for AG.SM as a whole for Tier 1 budgets. Output from agricultural land with crop products and crop residues, however, needs to be estimated according to the level of disaggregation indicated in **Table 13**.

Table 14. Flows in the Soil management N- budget. With regard to sub-pools (land types, LAND), a disaggregation of the flows according to Table 13 is recommended.

Pool ex	Pool in	Matrix	Other info	Flow code	Level	Description/note
AG.SM.LAND	MP	CROP		AG.SM.LAND-MP-CROP	1	All crop products used in industry for biofuels or other industrial use. Crops used for the production of processed food are included here only exceptionally (see text). Crops used for the production of compound feed can be included here if they are not yet accounted for in the direct flow of crops to the animal husbandry pool (care not to double count). If crop products for the production of compound feed are included, they need to be included as flow from MP to AG.AH as well.
AG.SM.LAND	HS	CROP		AG.SM.LAND-HS-CROP	1	All crop products sold from the farm and not used for industrial processing (see AG.SM-MP-CROP). Note that imports or exports of crop products other than used as feed are proposed to be quantified within the HS pool, as well as stock changes or losses of crop products in the retail chain (market losses, LOSM). Thus, this flow includes crop products for human consumption (HCOM) and export (EXPT), but excludes crop products for feed (FEDM) or industrial processing (INDM).
MP	AG.SM.LAND	MINF		MP-AG.SM.LAND-MINF	1	Application of N in mineral fertilizers by land category (see text for definitions), e.g. arable land including (ARAB) or excluding (ARAC) temporary grassland and other fodder on arable land, permanent crops (PERM), and permanent grassland (GRAS). Arable land can be futher differentiated into annual food cros (AFOOD) and fodder crops (FODD): ARAB=ARAC+GRAT=AFOOD+FODD+GRAT. Total food crops are: FOOD=PERM+AFOOD

Pool ex	Pool in	Matrix	Other info	Flow code	Level	Description/note
AG.MM	**AG.SM.LAND**	**MANA**		**AG.MM-AG.SM.LAND-MANA**	**1**	**Intentionally applied manure to arable crops, permanent crops or grassland**
AG.MM	**AG.SM.LAND**	**MANG**		**AG.MM-AG.SM.LAND-MANG**	**1**	**Manure input by grazing animals**
WS	**AG.SM.LAND**	**ORGW**		**WS-AG.SM.LAND-ORGW**	**1**	**Input of N in organic waste**
WS	AG.SM.LAND	ORGC		WS-AG.SM.LAND-ORGC	2	Input of N in organic waste in the form of compost
WS	AG.SM.LAND	ORGS		WS-AG.SM.LAND-ORGS	2	Input of N in organic waste in the form of sludge
HY	**AG.SM.LAND**	Seed		**HY-AG.SM.LAND-**Seed	**1**	**Input of N by** seed
AT	**AG.SM.LAND**	**Ntot**	**DEP**	**AT-AG.SM.LAND-Ntot-DEP**	**1**	**N input by atmospheric deposition**
AT	AG.SM.LAND	Ntot	WDEP	AT-AG.SM.LAND-Ntot-WDEP	2	N input by wet atmospheric deposition
AT	AG.SM.LAND	Ntot	DDEP	AT-AG.SM.LAND-Ntot-DDEP	2	N input by dry atmospheric deposition
AT	AG.SM.LAND	Noxi	DEP	AT-AG.SM.LAND-Noxi-DEP	2	N input by atmospheric deposition of oxidized N compounds (alternative split)
AT	AG.SM.LAND	Nred	DEP	AT-AG.SM.LAND-Nred-DEP	2	N input by atmospheric deposition of reduced N compounds (alternative split)
AT	**AG.SM.LAND**	**Ntot**	**BNF**	**AT-AG.SM.LAND-Ntot-BNF**	**1**	**Biological N fixation (BNF)**
AT	AG.SM.LAND	Ntot	BNF	AT-AG.SM.LAND-Ntot-BNF	2	Biological N fixation by legumes
AT	AG.SM.LAND	Ntot	BNF	AT-AG.SM.LAND-Ntot-BNF	2	Biological N fixation by free living bacteria
AG.SM	**AG.AH.ANIM**	**FODDFRES**		**AG.SM-AG.AH.ANIM-FODDFRES**	**1**	**Net N uptake (removal by harvest from field) by fodder crops**
AG.SM	AG.AH.ANIM	FODD		AG.SM-AG.AH.ANIM-FODD	2	Total N uptake by fodder crops
AG.SM	AG.AH.ANIM	FRES		AG.SM-AG.AH.ANIM-FRES	2	N return by fodder crop residues
AG.SM	**HS**	**CROPCRES**		**AG.SM-HS-CROPCRES**	**1**	**Net N uptake (removal by harvest from field) by food crops**
AG.SM	HS	CROP		AG.SM-HS-CROP	2	Total N uptake by food crops
AG.SM	HS	CRES		AG.SM-HS-CRES	2	N return by food crop residues
AG.SM	**AS**	**NH3**		**AG.SM-AS-NH3**	**1**	**Emission of ammonia-N to the atmosphere**
AG.SM	**AS**	**N**		**AG.SM-AS-N**	**1**	**Emission of N (N2O, NOx and N2) to the atmosphere due to (de) nitrification**
AG.SM	AS	N2O		AG.SM-AS-N2O	2	Emission of N2O-N to the atmosphere
AG.SM	AS	NO		AG.SM-AS-NO	2	Emission of NO-N to the atmosphere
AG.SM	AS	N2		AG.SM-AS-N2	2	Emission of N2-N to the atmosphere
AG.SM	**HY**	**Ntot**	**ground and surface water**	**AG.SM-HY-Ntot-GWSF**	**1**	**Loss of N (NH4 and NO3 and DON) to both groundwater and surface water**
AG.SM	HY	Ntot	Ground water	AG.SM-HY-Ntot-GWAT	2	Loss of N (NH4 and NO3 and DON) to groundwater
AG.SM	HY	Ntot	Surface water	AG.SM-HY-Ntot-SWAT	2	Loss of N (NH4 and NO3 and DON) to surface water
AG.SM	**AG.SM**	**Ntot**	**soil**	**AG.SM-AG.SM-Ntot-soil**	**1**	**Change in soil N pool due to net release or accumulation of N excluding soil erosion**
AG.SM	HY	PPN	erosion	AG.SM-HY-Ntot-ERSN	2	Loss of particulate N (PPN) to surface water due to soil erosion

Note: the flows AG.SM-MP-CROP and AG.SM-HS-CROP are indicated for the whole sub pool AG.SM however a differentiation into sub-sub pools is recommended; Split of agricultural land into arable land + permanent crops and grassland: AG.SM = AG.SM.AR+AG.SM.PM; Split of arable land + permanent crops into major crop groups (acc. FSS classification).

3.3.4 *Quantification of flows in the AG.SM sub-pool*

3.3.4.1 Mineral fertiliser application

3.3.4.1.1 Introduction

Methodologies to assess fertiliser application (consumption), guidelines on practical implementation, possible data sources and coherence with UNFCCC/UNECE guidelines are given in Section 3.6 on the pages 33-35 of the Eurostat GNB handbook (Eurostat, 2013) (Version 1.02 of the Handbook from 17/05/2013)[17]. A short summary is given below.

Currently different data sources for mineral fertilizer consumption exist and are used by countries for reporting to nutrient budgets, of which the two main approaches are (i) trade/production statistics and sales data, which in general include non-agricultural uses and (ii) farmer surveys, which includes only agricultural uses. If the estimation is based on trade/production or sales statistics, it is recommended to provide corrections for non-agricultural use, stock changes, and double-counting of intermediate production.

3.3.4.1.2 Approaches

Basic approach

National inorganic nitrogenous fertilizer application is reported in Table 1.1. of the GNB reporting file[18]. Application of inorganic fertilizers on cropland and grassland are also reported in CRF table 3.D of the national GHG emission inventories. If the application of fertilizers to other land categories cannot be separately identified, this application is included here.

Other

In case some of the information is missing or appears to be incorrect, or there are conflicting data sources, it is recommended to contact the experts responsible for the GHG emission inventories or for the quantification of the national GNBs and work on improved and consistent estimates.

3.3.4.1.3 Data sources

Available data sources include:

- Data reported to UNFCCC: IPCC 2006 Guidelines propose to use country specific data, Fertilizers Europe or FAO data in the case country-specific data are not available, see also section 3.5.5.
- Data reported to UNECEC/CLTRAP: The EMEP/EEA Guidebook propose to use country specific data, and Fertilizers Europe or FAO data in the case country-specific data are not available
- Data reported to PRODCOM/COMEXT: Data on production and trade of fertilizers by type are also available in all countries from PRODCOM and COMEXT. Data on production and trade of fertilizers could be used to crosscheck estimations on fertilizer consumption.
- Other data available in countries.

[17] http://epp.eurostat.ec.europa.eu/portal/page/portal/agri_environmental_indicators/documents/Nutrient_Budgets_Handbook_(CPSA_AE_109)_corrected3.pdf

[18] Model_national_level_N_(CPSA_AE_110N)_corrected.xls from 17/05/2013

3.3.4.1.4 Uncertainties

Uncertainties are generally rather small. Oenema et al. (1999) classified the uncertainty of inputs via marketed mineral fertilizers at less than 5%, while Kros et al. (2012) assumed a coefficient of variation (CV being the standard deviation divided by the mean) of less than 10%

3.3.4.2 Manure application

3.3.4.2.1 Introduction

Methodologies to assess manure production (excretion), possible data sources and coherence with UNFCCC/UNECE guidelines are also given in Section 3.7 on the pages 35-41 of the Eurostat GNB handbook (Eurostat, 2013) while the methodologies to assess N emissions from housing systems are given in Section 3.16 on the pages 68-71. A short summary of data sources and uncertainties is given below.

Manure aplication is equal to manure excretion, calculated by multiplying animal numbers with N excretion factors in a given animal category as described in Section 4.3, corrected for N emissions from manure management systems as described in in Section 4.5

3.3.4.2.2 Approaches

<u>Basic approach</u>

Application of manure nitrogen on agricultural soils is reported in CRF table 3.D of the national GHG emission inventories. It needs to be consistent with the data used in the AG.MM pool – all managed manure is assumed to be applied on fields unless another use has been identified. Manure-N applied to agricultural soils must be corrected for N-losses in the AG.MM pool. See equation 10.34 of Chapter 4-10 in IPCC (2006, page 10.65) defining the managed manure N available for application to managed soils, feed, fuel or construction uses (N_{MMS_Avb}) and equation 11.4 of Chapter 4-11 in IPCC (2006, page 11.13) for determing the share of N applied to managed soils vs. other used (FracFEED, FracFUEL, FracCNST). Those fractions need to be reported in CRF table 3.D – Additional Information. Manure withdrawal [t N yr^{-1}] is reported in Tables 3.1. of the GNB reporting file[19].

3.3.4.2.3 Data sources

Relevant sources for the various input data are:

- Animal numbers: Annual livestock surveys, Farm structure surveys (FSS), slaughter or production statistics, Economic Accounts for Agriculture:
- Manure excretion: see Section 3.1.6
- Emission fractions: EMEP/EEA emission inventory guidebook 2013.

3.3.4.2.4 Uncertainties

Uncertainties are moderate large. Oenema and Heinen (1999) classified the uncertainty of inputs via manure production between 5% and 20%, while Kros et al. (2012) assumed a CV of 20%

[19] Model_national_level_N_(CPSA_AE_110N)_corrected.xls from 17/05/2013

3.3.4.3 Organic waste application

3.3.4.3.1 Introduction

Organic wastes are all organic fertilizers not originating from livestock excretion, including compost, sewage sludge, residues from biogas plants using crops, crops residues or grassland silage, industrial waste and other organic products containing nutrients used in agriculture as fertilizer or soil amendment. The total N input by organic wastes applied to agricultural soils is estimated by summing up the applications of different organic wastes multiplied by the N content of each organic waste fertilizer.

Methodologies to assess organic waste application, possible data sources and coherence with UNFCCC/UNECE guidelines are given in Section 3.8 on the pages 44-46 of the Eurostat GNB handbook (Eurostat, 2013). A short summary is given below.

3.3.4.3.2 Approaches

Basic approach

Application of 'other organic fertilisers' [t N yr^{-1} applied] is reported in Table 4.3 of the GNB reporting file[20]. This includes sewage sludge, urban compost, industrial waste compost, and other products. Application of organic fertilizers (other than manure) is also reported in CRF table 3.D of the national GHG emission inventories, including applied sewage sludge and other organic fertilizers applied to soils.

3.3.4.3.3 Data sources

- Data reported to the Commission under the Sewage Sludge Directive and to UNFCCC.
- Data on compost as given in the Final Report on Compost production and use in the EU from the European Compost network (ECN) by Barth et al, 2008. http://susproc.jrc.ec.europa.eu/ activities/ waste/documents/080229_EoW_final-report_v1.0.pdf
- Country data on other organic fertilizers where available.

3.3.4.3.4 Uncertainties

Uncertainties are large, quality of activity data are diverse between countries but also between waste categories within countries. Most likely the uncertainty of inputs via compost are above 20%.

3.3.4.4 Seeds and planting materials

3.3.4.4.1 Introduction

The total N input by seeds and planting material applied to agricultural soils is estimated by summing up the applications of different seeds multiplied by the N content of each seed or planting material.

Methodologies to assess N inputs by seeds and planting material, possible data sources and coherence with UNFCCC/UNECE guidelines are given in Section 3.11 on the pages 54-56 of the Eurostat GNB handbook (Eurostat, 2013). A short summary is given below.

3.3.4.4.2 Approaches

Basic approach

[20] Model_national_level_N_(CPSA_AE_110N)_corrected.xls from 17/05/2013

Seeds, coefficients, and nutrient amount [t N yr^{-1} applied] is reported in Table 6.1-6.3 of the GNB reporting file[21] (if available).

3.3.4.4.3 Data sources

As reported in the GNB handbook (Eurostat 2013), data on seeds and planting material are:

- only available for 19 countries that reported seeds in 2010/2011,
- often only available for a limited number of crops,
- often based on standard or assumed seeding rates,

Furthermore, country-specific data on nutrient contents are often not available. Default N inputs (in kg N ha^{-1} yr^{-1}) for main crops can be found in the GNB handbook, i.e. 4 for wheat, 3 for other cereals and 8 for potatoes.

3.3.4.4.4 Uncertainties

It is clear that uncertainties in seed inputs are large, but the contribution to the total N input is generally less than 2% (see GNB handbook, page 55).

3.3.4.5 Biological N fixation

3.3.4.5.1 Introduction

Nitrogen is fixed in the soil by leguminous crops, grass-legume mixtures (leguminous forage crops) and by free living soil organisms. Leguminous crops include beans, soya bean, pulses etc, and are defined in the Handbook Crop Statistics as leguminous plants grown and harvested green as the whole plant, mainly for forage. The biological N fixation (BNF) by leguminous crops is determined by multiplying the area covered by leguminous crops with an N fixation coefficient. The Tier 1a approach assumes that crop N fixation equals total crop biomass, being twice the mass of edible crop (FAO, 1990), multiplied with the N content of the N fixing crop.The estimation of BNF in forage/fodder legumes and legume-grass pastures depends on the productivity and areas of these legumes, which are difficut to assess. The BNF by free living soil organisms has been excluded in the GNB approach due to uncertain and very limited availability of estimates on this flow. Others use fixed values of 2-4 kg N ha^{-1} yr^{-1}.

Methodologies to assess biological N fixation, possible data sources and coherence with UNFCCC/UNECE guidelines are given in Section 3.9 on the pages 47-52 and in more detail in Annex 2 of the Eurostat GNB handbook (Eurostat, 2013). A short summary is given below.

3.3.4.5.2 Approaches

<u>Stock taking</u>

Detailed data on N input by biological N fixation is available in Tables 8.1-8.3 of the GNB reporting file[22]. Requested data are differentiated by leguminous crops (dried pulses, soy bean, leguminous plants (multi-annual fodder/perennial green fodder), pulses, and legume grass mixtures.

Estimates of N-input to agricultural soils by biological N fixation are not reported any more in the CRF reporter since the use of the new IPCC (2006) guidelines. However, for the estimation of N in crop

[21] Model_national_level_N_(CPSA_AE_110N)_corrected.xls from 17/05/2013
[22] Model_national_level_N_(CPSA_AE_110N)_corrected.xls from 17/05/2013

residues N from N fixation grains and pulses and N-fixing forage crops (clover, alfalfa) need to be considered. The information should therefore be included in the National Inventory Reports submitted by the countries to the UNFCCC.

3.3.4.5.3 Data sources

- Countries which do not have country-specific coefficients on the N content of the N fixing crop can use the default estimation procedure in IPCC Good Practice Guidance (Tier 1a or Tier 1b) to estimate BNF of leguminous crops, as presented in Annex 2 of the GNB handbook (Eurostat 2013).
- In case country data are available on crop production and the N content of the N fixing crop, those data should be used.

3.3.4.5.4 Uncertainties

Uncertainties are very large, especially with respect to the BNF of grass-legume mixtures. This flow is obligatory, as ignoring would lead to a significant bias, but data availability is low and default estimation procedures have not yet been established. The comparability and transparency of the estimation of BNF in forage/fodder legumes and legumegrass mixtures could be improved if a set of common guidelines on the estimation method and update frequency were established. For now the unceratainty can be estimated at more than 50%.

3.3.4.6 Atmospheric deposition

3.3.4.6.1 Introduction

Guidance for the quantification of atmospheric deposition to agricultural land (arable land and permanent crops, and grassland) is given in the Annex AT.

Methodologies to assess atmospheric deposition, possible data sources and coherence with UNFCCC/UNECE guidelines are given in Section 3.10 on the pages 52-54 of the Eurostat GNB handbook (Eurostat, 2013). A short summary is given below. An approximation of N deposited on the reference area (N deposition) can be derived by multiplying either (i) a national average deposition rate (Ndeposition_coefficient) per ha with the used agricultural area or (ii) more high resolution data, such as EMEP model 50 km x 50 km estimates, with the agricultural area in those grids and adding them up to country level.

3.3.4.6.2 Approaches

Stock taking

Data on N in atmospheric deposition available in Tables 9.1-9.3 of the GNB reporting file[23].

3.3.4.6.3 Data sources

- UNFCC: Data on atmospheric deposition of soil N emissions originating from agriculture reported to UNFCCC under the IPCC Revised 1996 Guidelines.
- The European Monitoring and Evaluation Programme (EMEP) of CLTRAP: EMEP models total N deposition at 50 km x 50 km grid level in a harmonised way for signatories of CLTRAP. EMEP makes use of national expertise and research.

[23] Model_national_level_N_(CPSA_AE_110N)_corrected.xls from 17/05/2013

- Country-specific data sources

3.3.4.6.4 Uncertainties

Uncertainties at national scale are moderate, i.e on average as large as the uncertainties in N emissions at that scale. It is most likely between 5 and 20 %.

3.3.4.7 Crop removal

3.3.4.7.1 Introduction

The N removal with crop production is estimated by summing up the crop yields of different crops multiplied by the area of crop cultivation and mutiplied by the N content of each crop.

Methodologies to assess crop N removal, possible data sources and coherence with UNFCCC/UNECE guidelines are given in Section 3.13 on the pages 44-46 of the Eurostat GNB handbook (Eurostat, 2013). A short summary is given below.

3.3.4.7.2 Approaches

<u>Basic approach</u>

Nutrient export in harvested crops and forage is available in Tables 5.1-5.3 of the GNB reporting file[24]. Requested data are at a high level of detail with regard to crop types. Data reported are total harvested crops, nitrogen coefficients [kg t^{-1}] and nitrogen export [kg N ha^{-1} yr^{-1}].

3.3.4.7.3 Data sources

Sources for the various input data are:

- Crop production and area: Eurostat Crop Statistics for data on the main crops
- Crop nutrient contents: At present there are no default values, but Eurostat will estimate coefficients for countries which do not have country-specific data available. Table 15 gives a list of default values that could be used.

Table 15. Average values for crop N contents (in g kg^{-1} fresh weight, FW) that could be used in country N balances.

Crop categories	N contents in crops (g/kg FW)
Cereals	18.1
Common wheat	18.1
Durum wheat	18.1
Barley	18.1
Rey	18.1
Oats	18.1
Maize	18.1
Other cereals	18.1
Citrus	2.7
Citrus fruits: oranges	2.7
Fodder	10.8
Fodder other	10.8
Gras	10.8
Fodder maize	10.8
Fruits	6.7
Other fruit	6.7

[24] Model_national_level_N_(CPSA_AE_110N)_corrected.xls from 17/05/2013

Crop categories	N contents in crops (g/kg FW)
Oilseeds	39.7
Sunflower	39.7
Rape and turnip rape	39.7
Soya	39.7
Fibre and oleaginous crops; cotton	39.7
Dry pulses	39.7
Other oil	39.7
Olives	20.0
Olive groves	20.0
Table olives	20.0
Rice	14.8
Rice	14.8
Roots	2.6
Sugar beet	2.6
Potatoes	2.6
Vineyard	4.6
Vineyards/table wine	4.6
Table grapes	4.6

3.3.4.7.4 Uncertainties

Uncertainties in crop N uptake are moderate. Oenema et al. (1999) classified the uncertainty of crop N uptake between 5 and 20 %, while Kros et al. (2012) assumed a CV of 20%. There is a strong need for deriving high quality data on country specific N contents in the various crops.

3.3.4.8 Fodder removal

3.3.4.8.1 Introduction

As with crop N uptake, the N removal with grass and fodder production is estimated by summing up the yields of forage and grass multiplied by the area of grass and forage cultivation and multiplied by the N content of grass and forage.

Methodologies to assess fodder production, possible data sources and coherence with UNFCCC/UNECE guidelines are given in Section 3.14 on the pages 59-65 of the Eurostat GNB handbook (Eurostat, 2013). A short summary is given below.

3.3.4.8.2 Approaches

Basic approach

Nutrient export in harvested crops and forage is available in Tables 5.1-5.3 of the GNB reporting file[25]. Requested data are at a high level of detail with regard to crop types including plants harvested green/green fodder and temporary and permanent pasture. For temporary and permanent pasture, data requested are both gross production and net production. Data reported are total harvested crops, nitrogen coefficients [kg t^{-1}] and nitrogen export [kg N ha^{-1} yr^{-1}].

3.3.4.8.3 Data sources

- Production of grasslands: currently not available from Eurostat statistics.
- Areas: available from annual Crop Statistics (Regulation (EC) No 543/2009) for temporary grasses and grazing (area under cultivation) and permanent grassland (main areas, also at regional level: NUTS2, UK and DE at NUTS1) and also from the the Farm Structure Survey.

[25] Model_national_level_N_(CPSA_AE_110N)_corrected.xls from 17/05/2013

- Grass and forage nutrient contents: At present there are no default values. Default values (in gN/kg FW) that could be used vary between 4.4-10.8 for grass and between 13.6 and 18.1 for maize.

3.3.4.8.4 Uncertainties

Uncertainties are very large, since the quality of data on grass production is very low. To improve data on grassland statistics, incl. land use, the estimation of grassland production and biological fixation, Eurostat has issued a tender on grassland statistics. This project will provide a first step towards a harmonised classification of grasslands and the estimation of grassland production and biological fixation. For now the unceratainty can be estimated at more than 50%.

3.3.4.9 Crop residues outputs

3.3.4.9.1 Introduction

The N removal of crop residues from the field either by removal or burning can be estimated by summing up the N removals of crop residues for different crops, which in turn are estimated by multiplying the amount of crop residues removed with the residue N content. The amount of crop residues for a crop is estimated by multiplying data on the main production of the crop with a harvest factor (ratio between main crop and residue). The fraction of crop residues removed from the field is subsequently estimated by multiplying the total crop residues with the recovery rate. In principle data on all (net) crop residue removals should be included, but a minimum requirement is the removal of crop residues of cereal crops, rapeseed, soybean and sugar beet.

Methodologies to assess crop residues outputs, possible data sources and coherence with UNFCCC/UNECE guidelines are given in Section 3.15 on the pages 65-68 of the Eurostat GNB handbook (Eurostat, 2013). A short summary is given below.

The Eurostat guidebook distinguishes the *ideal* estimation of the GNB and the *practical* estimation, which differs considerably with regard to crop residues. In the *ideal* N budget all crop residues are included in the output term – this includes crop residues left on the field, crop residues removed from the field, and crop residues burned. The input term quantifies crop residues left on the field, crop residues harvest but returned to the field (e.g. in bedding material, thus care must be taken to avoid double counting), or N in ashes. For the practical implementation, crop residues are not considered in the input terms, but in the output term: crop residues removed and not returned, and N in crop residues burned and not remaining in the ashes.

The difference between the ideal and the practical implementation of the N budget is important in case N use efficiency indicators are calculated. There is no difference though in terms of the N balance, which is identical for both implementations.

3.3.4.9.2 Approaches

<u>Basic approach</u>

Nutrient export in crop residues is available in Tables 7.1-7.3 of the GNB reporting file[26]. Requested data are at a high level of detail and include head leaves and stems (potatoes, sugar and fodder beet,

[26] Model_national_level_N_(CPSA_AE_110N)_corrected.xls from 17/05/2013

other fodder roots), straw (cereals), and other crop residues (rape and turnip rape, soy bean). Data reported are total crop residues, nitrogen coefficients [kg t^{-1}] and nitrogen export [kg N ha^{-1} yr^{-1}].

3.3.4.9.3 Data sources

Annex 5 of the Eurostat GNB handbook (Eurostat, 2013) summarizes international guidelines to assess crop residues outputs. Data sources include:

- default values to be used for the harvest factor (ratio between main crop and residue) and N content in the residues of major crops: Revised IPCC 1996 Guidelines
- Main production of crops: Eurostat Crop Statistics.
- Data on harvested crop residues are also be available from the Economic Accounts for Agriculture.

3.3.4.9.4 Uncertainties

Uncertainties are large, since the quality of activity data are diverse between countries, but the contribution to the N balance is likely small.

3.3.4.10 Ammonia soil emissions

3.3.4.10.1 Introduction

Ammonia (NH_3) soil emissions occur due to manure application, grazing (manure dropped on pastures), application of mineral fertilizers, and application of other organic fertilizers, crop residues and field burning of agricultural wastes. NH_3 emissions are equal to the N amounts that are applied by these N source multiplied by NH_3 emission factors for each source.

Methodologies to assess ammonia (NH_3) soil emissions, possible data sources and coherence with UNFCCC/UNECE guidelines are given in Section 3.16 on the pages 68-71 of the Eurostat GNB handbook (Eurostat, 2013). A short summary is given below.

3.3.4.10.2 Approaches

NH_3 emission factors for each source are available in IPCC (2006) and EMEP/EEA 2013 Guidebook.

3.3.4.10.3 Uncertainties

Uncertainties are relatively large, especially due to uncertainties in NH_3 emission factors for each source and are likely more than 20 % (see Oenema and Heinen, 1999).

3.3.4.11 Other soil N emissions (or denitrification)

3.3.4.11.1 Introduction

Other soil N emissions include emissions of N_2O, NO, NO_2 and N_2 which are emitted during denitrification processes. Emissions of these N compounds are equal to the N amounts that are applied by these N source multiplied by emission factors of each N compounds for each source. For N_2, no data are given. An option to quantify denitrification is to assess N leaching and runoff on the basis of a default set of N runoff and N leaching fractions, depending on soil, slope, hydrology etc. (e.g. Velthof et al., 2009) and assume that denitification equals the N surplus minus N runoff and N leaching.

Methodologies to assess other soil N emissions, possible data sources and coherence with UNFCCC/UNECE guidelines are also given in Section 3.16 on the pages 68-71 of the Eurostat GNB handbook (Eurostat, 2013) as far as N_2O and NO is concerned. For N_2, no data are given in this guidebook. A short summary is given below.

3.3.4.11.2 Data sources

Data sources on N_2O and NO emission factors for each source are given in the IPCC guidebook and EMEP/EEA 2013 Guidebook. Data on N runoff and N leaching fractions, depending on soil, slope, hydrology etc are given in Velthof et al. (2009).

3.3.4.11.3 Uncertainties

Uncertainties in N_2O and NO emission are large and in N_2 emissions very large because they can not be measured. Estimations are based on all the inputs and outputs of N thus containting the unceratianty of each estimate. Uncertainty can easily be more than 50% (see e.g. Kros et al., 2012).

3.3.4.12 Soil nitrogen stock changes

3.3.4.12.1 Soil stock changes

Soil stock changes occur when the equilibrium between mineralization of soil organic matter on one hand and the formation or addition of new organic matter is out of balance and thus the content of organic matter (and thus organic nitrogen) in soils decreases or increases. Soil stock changes are important flows for the AG.SM pool (Hutton et al., nd; Leip et al., 2011a; Eurostat, 2013; Ozbek and Leip, 2015), however data are difficult to obtain and are so far not included in any of above-mentioned guidelines. It is recommended to make some efforts to obtain an estimate on soil stock changes. An option would be to derive them from long term monitoring programmes, or to estimate N stock changes, either using process-based modelling (see for example Leip et al., 2011b) or on basis of regression assumptions (see for example Hutton et al., nd; Ozbek and Leip, 2015).

3.3.5 Crop specific assessment and consideration of mitigation techniquese in AG.SM

Crop production statistics are usually available at a higher level of disaggregaton than other data required to characterize an AG.SM.LAND pool; therefore an area-weighted implied unit flow for crop production must be calculated:

$$\boldsymbol{iuf_{LAND}} = \frac{\sum_{\boldsymbol{LANDs}}\{\boldsymbol{f_{LANDs}} \cdot \boldsymbol{A_{LANDs}}\}}{\sum_{\boldsymbol{LANDs}}\{\boldsymbol{A_{LANDs}}\}} \quad (10)$$

$$\boldsymbol{f_{LANDs}} = \boldsymbol{Y_{LANDs}} \cdot \boldsymbol{\chi_{LANDs}} \quad (11)$$

where

LAND:	Land type for which the implied unit flow is calculated
LANDs:	More detailed land use types for which information on crop and crop residues output is available.
f_{LANDs}	The crop or fodder output (CROP, FODD) and crop or fodder residues (CRES, FRES) Unit: kg N ha^{-1} yr^{-1}
Y_{LANDs}	Yield of land use LANDs in kg crop dry matter ha^{-1} yr^{-1} and/or kg residue dry matter ha^{-1} yr^{-1}
χ^N_{LANDs}	Nitrogen content of crop or residue for land type LANDs in kg N (kg crop or residue dry matter)$^{-1}$
A_{LANDs}:	Area cultivated with land type LANDs, ha
iuf_{LAND}:	Implied unit flow for land typ LAND, kg N ha^{-1} yr^{-1}

In case that data on the application of mitigation measures/techniques, the use of precision farming, or agronomic differences are available, it is recommended to calculate implied unit flows. Mitigation technologies are often aimed at reducing losses of nitrogen to the environment and/or improving the nitrogen use efficiency of the crop. It is important to assess the effect of the different technologies on all output flows and determine the share of total input flows $\boldsymbol{f_{LAND,t}}$ used for the specific technologies applied to the land type in order to not bias the soil-budget of the land types.

$$\boldsymbol{iuf_{LAND}} = \frac{\sum_t \{\boldsymbol{f_{LAND,t}} \cdot \boldsymbol{A_{LAND,t}}\}}{\sum_t \{\boldsymbol{A_{LAND,t}}\}} \quad 12$$

where

LAND:	Land type for which the implied unit flow is calculated
t	Technology: mitigation measure/technique, precision farming technology etc.
f_{LAND}	The crop or fodder output (CROP, FODD) and crop or fodder residues (CRES, FRES) Unit [kg N ha^{-1} yr^{-1}]
A_{LAND}:	Area cultivated with land type LANDs [ha]
iuf_{LAND}:	Implied unit flow for land typ LAND [kg N ha^{-1} yr^{-1}]

In case data is available it is important to first perform a screening of the different technologies to assess whether the additional detail will provide added value to the NNB according to the criteria set in the general annex and in Section 3.1.2. The selection of the proper level of disaggregation so that the resources invested in the quantification of the flows is used most efficiently.

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5 Document version

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Annex 4 – Forest and semi-natural vegetation

1 Introduction

1.1 Purpose of this Annex

This annex defines the pool "forest and semi-natural vegetation" to the "Guidance document on national nitrogen budgets" (UN ECE 2013). It describes the relevant nitrogen sub-pools (i.e. forest, wetland and Other Land) of the compartment forest and semi-natural vegetation, encompassing vegetation and soil, as well as the relevant nitrogen transformation processes. In addition, it provides guidance on how to calculate the relevant internal flows as well as the flows across given system boundaries (chapter 4) and also stock changes (chapter 5), by presenting calculation methods and possible data sources. Moreover, tables and references are presented in chapters 6 and 7, respectively.

Basically, this guidance document relates to existing national nitrogen budgets (NNB) such as the Swiss N budget (Heldstab 2010), the German N budget (Umweltbundesamt 2009), and the European N budget (Leip et al., 2011). The Guidance document is taking advantage of the IPCC guideline for National Greenhouse Gas Inventories (2006) in order to use existing structure and appropriate information.

2 Overview over the Forest and Semi-natural vegetation (FS) pool

2.1 The FS pool and corresponding pools

The pool forest and semi-natural vegetation (FS) comprises all natural and semi-natural terrestrial ecosystems (i.e. forest and Other Lands including their soils), as well as wetlands. The main N flows between FS and other pools are presented in figure 1. The spatial boundary of the NNB system is given through the national border.

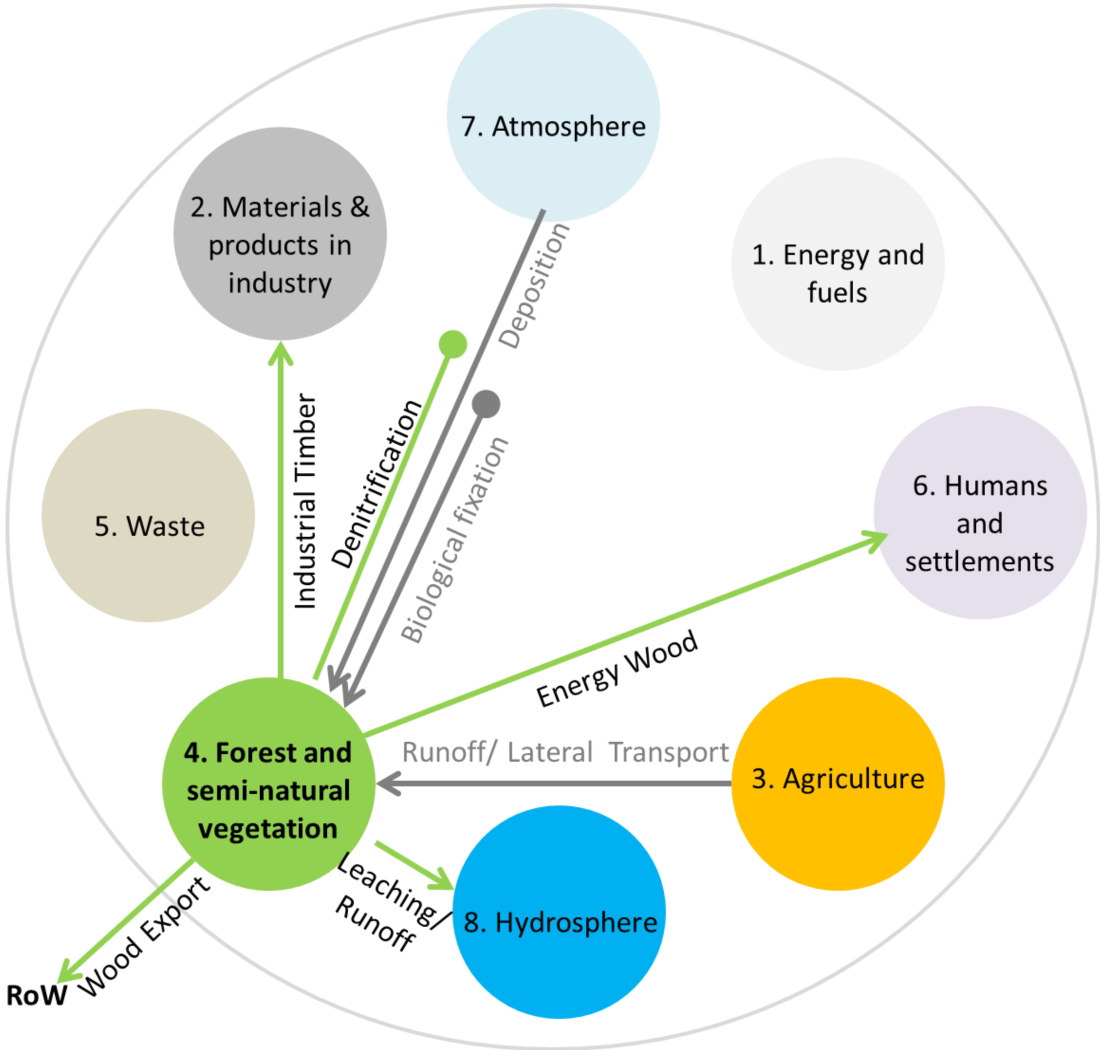

Figure 4: Most relevant N flows connecting neighbouring pools with the pool Forest and semi-natural vegetation.

The runoff and interflow (lateral transport, including groundwater) water from agriculture pools and hydrosphere pools represents the biggest N sources to the wetland sub-pool of the FS pool. Also, an indirect linkage is given between agriculture and FS pool via atmospheric N deposition processes. There are no direct flow connections to the waste pool. The FS pool is also linked to the rest of the world (RW) through the export of wood products.

2.2 Nitrogen species

Table 4 of Annex 0 provides a descriptive overview of all potential nitrogen species involved. Dissolved organic N is not included even though organic N may constitute an important fraction of deposition and/or leaching of nitrogen in some systems (Neff et al., 2002; Cape et al., 2012).

2.3 Nitrogen processes in the FS pool

Inflows

The most significant inflows of nitrogen occur from the atmosphere to the biosphere (Leip et al., 2011). Such nitrogen inputs include atmospheric ***deposition*** as well as ***biological fixation*** of elementary nitrogen (N_2) (by microbes in a symbiotic association with the roots of higher plants and soil heterotrophic microorganisms).

N transformation processes and retention

Nitrogen undergoes various transformation processes in the FS pool (e.g. Butterbach Bahl et al., 2013). To our current knowledge, the most relevant processes are:

- ***Ammonification (mineralization)***: During the decomposition of litter and soil organic matter, different organic nitrogen compounds are mineralized to ammonium (NH_4^+).
- ***Nitrification***: Under aerobic conditions Ammonium (NH_4^+) is oxidized by microbes to nitrite (NO_2^-) and further to nitrate (NO_3^-).

The inorganic N species, ammonium (NH_4^+) and nitrate (NO_3^-) can either be taken up by plants (***uptake***) or immobilized by soil microorganisms in the form of organic nitrogen compounds (***immobilisation)***. Moreover, ammonium can also be adsorbed on clay minerals and so precluded from further transformation (***adsorption)***. Hence uptake, immobilisation and adsorption ensure for the ***N retention*** within the pool.

Outflows

In contrast to ammonium (NH_4^+), nitrate (NO_3^-) is easily soluble in soil water and may not be completely consumed by plants and microorganisms so that it is leached to water bodies such as streams, lakes and groundwater. Apart from leaching, N can also be emitted to the atmosphere by two major processes:

- ***Denitrification***: Under anoxic condition nitrate (NO_3^-) and nitrite (NO_2^-) are transformed into gaseous compounds such as nitrogen oxide (NO), nitrous oxide (N_2O) and elementary nitrogen (N_2) and are emitted back to the atmosphere.

  Anammox (Anaerobic ammonium oxidation)*:* Also under anoxic condition nitrite (NO_2^-) and ammonium (NH_4^+) can be converted into dinitrogen (N_2), which again is emitted.

Leaching of nitrate (NO_3^-) into the hydrosphere and ***emission*** of gaseous denitrification products (NO, N_2O, N_2) and anammox products (N_2O, N_2) to the atmosphere represent the most significant outflows from the FS pool. In addition to these, biomass losses through the ***tree harvest*** and subsequent transformation in wood products lead to changes in the N stocks and thus contribute to the N output. ***Natural disturbances*** (e.g. insect outbreaks, diseases, windfall, fire) may cause additional losses.

2.4 Level of Detail

In general, calculations for N flows are based on the Tier approaches (1-2), where each successive tier requires more detail resources than the previous one.
For Tier 1 basically default values from international sources will be applied, while for Tier 2 the national-specific data should be used if available.

Only quantitatively significant N flows (at least **100 t N per million inhabitants and year [10^{-2} Gg (10^6 capita)$^{-1}$× a^{-1}]**) are considered for the nation nitrogen budgets (see Annex 0).

3 Internal structure

The FS pool is divided into 3 sub-pools, namely forest, Other Land, and wetland. Each sub-pool involves two main components, namely plant biomass (includes above- and belowground biomass) and soil.

Figure 2 shows the internal structure of the pool and their specific connections to neighbouring pools.

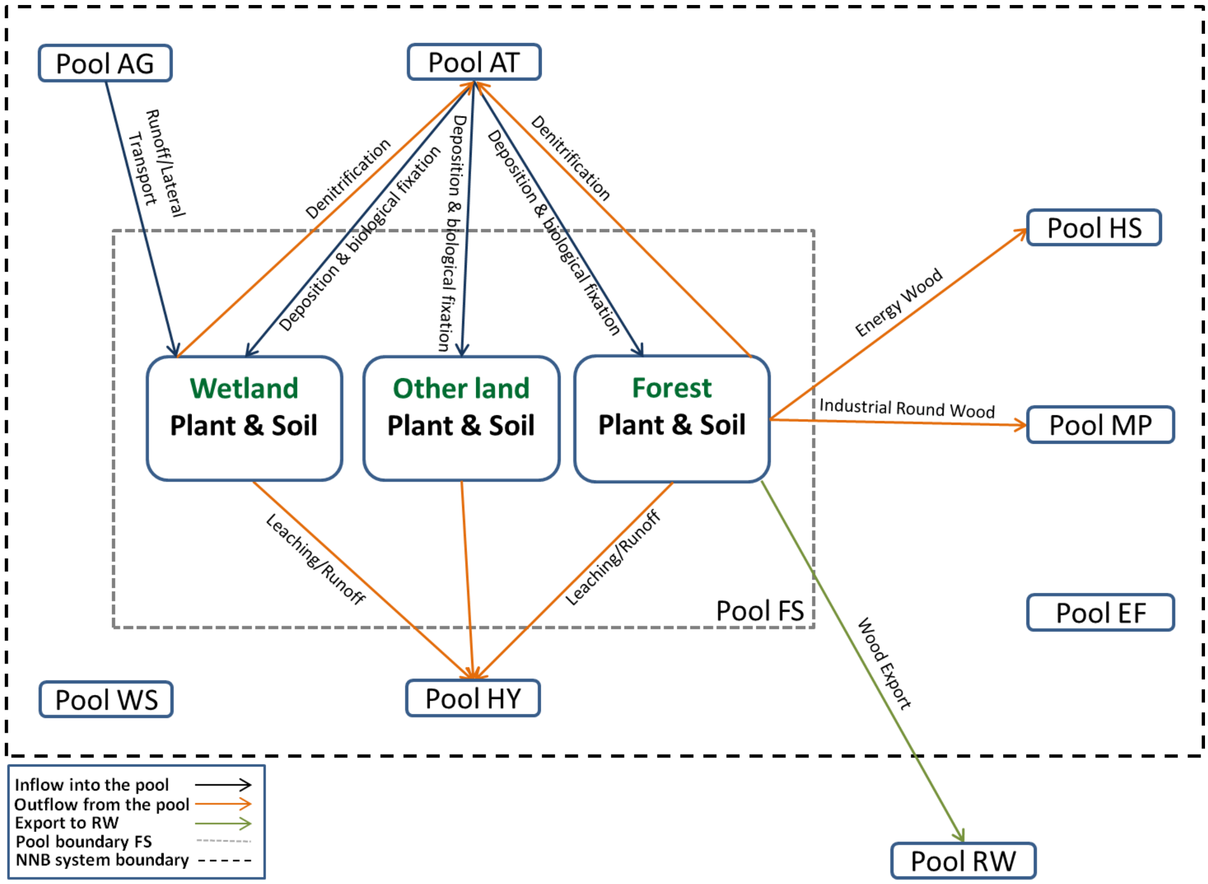

Figure 2: Internal structure of the FS pool. For "Pool" references see Figure 1.

Table 1: Sub-pools of the tree FS pools (Forest and Semi-natural vegetation)

ID	Code	Full name of the sub-pool
4A	FS.FO	Forest and Semi-natural vegetation - Forest (Plant and Soil)
4B	FS.OL	Forest and Semi-natural vegetation - Other Land (Plant and Soil)
4C	FS.WL	Forest and Semi-natural vegetation - Wetland (Plant and Soil)

3.1 Sub-pool Forest (FS.FO)

Forest land is per definition a land with an area more than 0.5 hectare, and a canopy cover of more than 5--10 % that has been under forest for over 20 years (IPCC, 2006). Atmospheric deposition and biological N_2 fixation constitute the ***inflows*** of N into the system, while harvested biomass, leaching, and denitrification account for the relevant ***outflows***. Natural disturbances such as fire may cause additional losses; however no significant flows are probable and therefore were not taken into further consideration.

If only vertical percolation of precipitation to the groundwater is considered the changes in N budget can be calculated as:

$$\Delta_{Nbudget} = \boldsymbol{Deposition + biological\ N\ Fixation - Harvesting - Denitrification - Leaching = Stock\ changes} \quad 1.0$$

3.2 Sub-pool Other Land (FS.OL)

The sub-pool "Other Land" encompasses bare land (i.e. as a result of development of settlements), rock and ice (IPCC, 2006). The atmospheric deposition is the main ***inflow*** to the sub-pool “Other Land”, while the leaching/runoff represent the most relevant ***outflow***. Other Land is always unmanaged, and in that case changes in N stocks as well as biological N_2 fixation and denitrification were assumed to be very small and were thus neglected (J. Heldstab, personal communication).

Based on these assumptions the change in the N budget can be calculated as:

$$\Delta_{Nbudget} = \boldsymbol{Deposition - Leaching} \quad 2.0$$

Only in case of land conversion to Other Land important stock changes can be expected. Otherwise, no significant flows are likely between the sub-pools "Other Land", forest and wetland and therefore were not taken into further consideration.

3.3 Sub-pool Wetland (FS.WL)

In the IPCC Guidelines for National Greenhouse Gas Inventories (2006) wetlands are defined as any lands that are covered or saturated by water for all or part of the year, and do not fall into the Forest Land, Cropland, or Grassland categories. Numerous environmental factors (i.e. water table depth, water flow, nutrient availability) form a diverse picture of wetland types with various vegetation communities and biogeochemical cycles (Smith et al., 2007, Frazier 1999). This diversity challenges the inclusion of wetlands in national N budget calculations.

N inflow pathways into wetlands are complex and include N deposition, biological N_2 fixation and N ***inflow*** via surface water inflow (here "Runon"), pipe and tile drainage from neighbouring agricultural fields, interflow, young oxic and anoxic groundwater, old anoxic groundwater from a deeper aquifer and river water inflow (Trepel & Kluge, 2004). N retention within the wetland is governed by plant N uptake (and sedimentation) (Saunders & Kalff, 2001; Jordan et al. 2011). N ***outflows*** also include a number of processes, whereupon the most relevant are denitrification, forest/grass harvest and N leaching via saturated overland flow, ditch outflow, overbank flow due to flooding, subsurface discharge and river flow (Trepel & Kluge, 2004).

$$\Delta_{Nbudget} = \boldsymbol{Runon + Deposition + biological\ N\ Fixation - Denitrifikation - -Leaching - Forst/Grass\ Harvest)} \quad 3.0$$

Where Δ = accumulation (+) or loss (-).

4 Flows: Calculation guidance

This section describes calculation methods and data sources to derive all relevant N flows in and out of the pool Forest and Semi-Natural Vegetation and Soil. Table 2 gives an overview on the flows considered.

Table 2: Overview on relevant N flows in and out of the Forest and Semi-natural vegetation and soil pools.

$Pool_{ex}$	$Pool_{in}$	Matrix*	Other info	Total code	Annex where guidance is given	Description
AT	FS.FO	Atmospheric N		AT-FS.FO-AtmN	7	Deposition of N from atmosphere to forest
AT	FS.FO	N_2		AT-FS.FO-N_2	7	Biological N fixation of N_2 from atmosphere to forest
AT	FS.OL	Atmospheric N		AT-FS.OL-AtmN	7	Deposition of N from atmosphere to Other Land
AT	FS.WL	Atmospheric N		AT-FS.WL-AtmN	7	Deposition of N from atmosphere to wetland
AT	FS.WL	N_2		AT-FS.WL-N_2	7	Biological N fixation of N_2 from atmosphere to wetland
AG	FS.WL	NO_3	Runoff in surface water	AG-FS.WL-SURFW-NO_3	3	Surface water runoff NO3-N losses to the wetlands from agricultural soil
FS.FO	AT	Gas N	Denitrification	FS.FO-AT-GasN	4	Gaseous N emission to the atmosphere from forest soil
FS.FO	HS.MW	Wood N	Wood	FS.FO-HS.MW-WoodN	4	Energy wood export to humans and settlements sub-pool material world
FS.FO	MP.OP	Wood N	Wood	FS.FO-MP-WoodN	4	Industrial round wood export to the pool material and products in industry
FS.FO	RW	Wood N	Wood	FS.FO-RW-WoodN	4	Wood export from the country to the rest of the world
FS.FO	HY.SW	NO_3	Leaching and runoff	FS.FO-HY.SW-NO_3	4	NO_3-N leaching and surface water runoff into the hydrosphere from forest soil
FS.OL	HY.SW	NO_3	Leaching and runoff	FS.OL-HY.SW-NO_3	4	NO_3-N leaching and surface water runoff into the hydrosphere from the Other Land soil
FS.WL	HY.SW	NO_3	Leaching and runoff	FS.WL-HY.SW-NO_3	4	NO3-N leaching and surface water runoff into the hydrosphere from wetland soil
FS.WL	AT	N_2O	Denitrification	FS.WL-AT-N_2O	4	N_2O emission to the atmosphere from wetland soil

4.1 Forest

Table 3: Overview on forest related N-flows in/out of the FS pool (from table 2)

Flow Code	Flow Description	Pool ex	Pool in	Matrix
AT-FS.FO-AtmN	Deposition of N2O-N form atmosphere to forest	AT	FS.FO	AtmN
AT-FS.FO-N2	Biological N fixation of N2 from atmosphere to forest	AT	FS.FO	N2
FS.FO-AT-GasN	Gaseous N emission to the atmosphere from forest soil	FS.FO	AT	GasN
FS.FO-HY.SW-NO3	NO3-N leaching & surface water runoff into the hydrosphere from forest soil	FS.FO	HY.SW	NO3
FS.FO-MP-WoodN	Industrial round wood export to the pool material and products in industry within the country	FS.FO	MP	WoodN
FS.FO-HS.MW-WoodN	Energy wood export to humans and settlements sub-pool material world within the country	FS.FO	HS.MW	WoodN
FS.FO-RW-WoodN	Wood export (industrial round wood and fuel wood) from the country to the rest of the world	FS.FO	RW	WoodN

4.1.1 Atmospheric N deposition (AT-FS.FO-AtmN)

Information on atmospheric N deposition is provided in annex 7 – atmosphere of the guidance document on national N budgets. The total N deposition varies considerably between forest types, mostly depending on leaf surface, tree species composition (de Vries et al., 2007) and structure such as forest edges (Beier & Gundersen, 1989). Only total N deposition is reported in large-scale deposition models (e.g. EMEP/MSC-W model), which include uptake processes for nitrogen occurring in the canopy but not measured in the throughfall. Nitrogen in throughfall is a good indicator of N leaching with the seepage water (Gundersen et al., 2006) and for gaseous emission losses (see section 5.1.4). Therefore, a conversion procedure is needed that quantifies throughfall deposition for a given region. N throughfall deposition is however not easily available. Several approaches to quantify total deposition and throughfall are described below.

Tier 1

Tier 1 approach is used for the countries without throughfall measurements. The throughfall deposition can be estimated by an inferential approach:

$$\textit{Throughfall: } \boldsymbol{TF = TD - CU} \qquad 1.1$$

$$\boldsymbol{TD = WD + \sum (vdep_i \times conc_i)} \qquad 1.1.1$$

Where: **TF** = throughfall [kg N ha^{-1} y^{-1}]
TD= total deposition in forested area [kg N ha^{-1} y^{-1}]
CU= canopy uptake [kg N ha^{-1} y^{-1}], see Table 4
WD = wet deposition [kg N ha^{-1} y^{-1}]; WD data can be obtained by multiplying concentration of N in precipitation (bulk deposition = BD) with precipitation amounts from the mean annual precipitation. If BD is sampled by funnel – type collectors, then provided concentrations have to be corrected with the average wet-only to bulk ratios given in the literature (Draaijers et al., 1998). EMEP provides modelled data on WD.
Vdep_i = deposition velocity of N species for coniferous and broad-leaved forests [mm s^{-1}]. Averaged over the altitude ranges: default values 3.3 for both forest types (Source: Thimonier et al., 2005)
Conc_i = concentration of the N species in the air [µg N m^{-3}]; from EMEP

As an alternative to the inferential approach, the N in throughfall could also be estimated by using a conversion factor describing the general relationship between throughfall and deposition. From the site-based data on non-forest bulk deposition and throughfall given in ICP Forests a conversion factor could be calculated for specific forest types and regions. Regionalisation can then be done with the modelled total N deposition at non-forested areas coming from the EMEP database. Since such an assessment is in progress but not yet finished (pers. comm. Meesenburg), calculations have yet to be done with national ICP Forests and ICP Integrated Monitoring data.

Under the framework of ICP Forests and ICP Integrated Monitoring the throughfall deposition has been monitored at several hundred-forest plots for more than 15 years with a precision of ±30% (95% significance level). The mean annual inorganic nitrogen (NH_4^+-N and NO_3^--N) throughfall depositions [kg N ha^{-1} y^{-1}] from these are reported in Waldner at al., 2014 and the same data can be obtained from the programme centre of ICP Integrated Monitoring.

Tier 2

In forest deposition monitoring at the plot scale, the total deposition of inorganic nitrogen (NH_4^+ and NO_3^-), taking into account all deposition pathways and canopy exchange, can be calculated by using the canopy budget model developed by Ulrich (1983) and synthesized by Adriaenssens (2013). Also an improved canopy budget model based on forest edge and throughfall measurements is available (Beier et al. 1992).

4.1.1.1 Uncertainty and other comments

- → Levels of uncertainty are provided in Annex 0, Table 5
- → Uncertainties here originate form spatial and temporal variability of measured fluxes and parameterisation uncertainties when up scaling to the ecosystem level.
- → If EMEP wet deposition (WD) data are used then the differences between modelled and measured WD values should be taken in consideration for uncertainty estimations (see e.g. Simpson et al., 2006).
- → Estimated uncertainty: level 2.

4.1.1.2 Suggested Data sources

- CORINE land cover contains information on the coverage and land use all over Europe, www.eea.europa.eu/data-and-maps/data/corine-land-cover
- Spatial distribution of nitrogen depositions are available at EMEP at the following link: http://www.emep.int/mscw/SR_data/sr_tables.html
- Deposition monitoring in the ICP Forests Level II plots; http://icp-forests.net/page/data-requests
- Deposition monitoring in the ICP Integrated Monitoring plots: www.syke.fi/nature/icpim
- National GHG inventory

4.1.2 Biological N fixation (AT-FS.FO-N2)

Tier 1

For a rough estimation of biological N_2 fixation (BNF), the N fixation rates for several biome types are provided in Cleveland et al. (1999) (see Table 5). Given these data, the N fixation rates for specific forests and biomes can be obtained by relating these default values to the national forest area

In case the stock changes (i.e. wood growth) are negligible, the biological N_2 fixation can also be estimated as a difference between output (leaching, gaseous loss) and input (deposition).

$$\text{Biological N fixation } \boldsymbol{BNF} = (\boldsymbol{FS1} + \boldsymbol{FS2}) - \boldsymbol{A1} \qquad 1.2$$

Where:

BNF = N_2 fixed [t N/year]
FS1= outflow of N from denitrification [t N/year], see 4.1.3
FS2= outflow of N from leaching [t N/year], see 4.1.4
A1 = inflow of N from atmospheric deposition [t N/year], see 4.1.1.

Tier 2

For Tier 2 approach country-specific data on BNF shall be used.

4.1.2.1 Uncertainty and other comments

→ Levels of uncertainty are provided in Annex 0, Table 5
→ Default values in the table 5 have a very high spread. It is suggested, however, if relying on data reported in Cleveland et al. (1999), to use the lower percent cover values of symbiotic N fixers over the landscape (i.e. 1.5 in case of 1.5-2).
→ In case the reverse calculation, interpretation should be with caution since both the deposition and leaching data are associated with high uncertainties and also N accumulation may occur owing to increased availability of N.
→ Estimated uncertainty: level 2.

4.1.2.2 Suggested data sources

- Cleveland et al. (1999)
- The European Nitrogen Assessment; *Nitrogen process in terrestrial ecosystems*. Sutton et al., 2011. Cambridge University Press.

4.1.3 Nitrogen emissions (FS.FO-AT-GasN)

Denitrification is defined as the dissimilatory reduction of nitrate (NO_3^-) to nitrite (NO_2^-), nitric oxide (NO), nitrous oxide (N_2O) and N_2 by microbes. Besides microbial denitrification as the main pathway of N losses, several other processes have been identified covering soil N emissions (Sutton et al. 2011). Despite decades of research on this topic, continuous year-round measurements of N_2O, NO and N_2 emissions from forest soils are still lacking and hence robust mean annual fluxes of N_2O, NO and N_2 emissions and national estimates derived thereof are scarce and highly uncertain (Sutton et al. 2011). N_2-emissions to the atmosphere are not relevant for the NNB, as it is not a reactive N flow. However, the N_2 measurements are necessary for the calculation of N_2:N_2O ratios. Moreover, different measurement methods complicate the combined analysis of measurement from different studies (Butterbach-Bahl et al. 2013).

We note here that fire is not considered in the guideline even though it could be of importance for some countries.

Tier 1

For the EU states plus Switzerland and Norway total simulated N_2O-N and NO-N emissions from forest soils are listed in Table 6 (source: Kesik et al., 2005). For other states, average N_2O-N and NO-N emissions from forest soils can be adopted from the same data source by selecting data from a country showing comparable environmental characteristics and multiply with the forested area of the respective states. More straightforward, Kesik et al. (2005) reported measured mean daily N_2O-N and NO-N emissions of 4.2 g N ha^{-1} day^{-1} and 11.7 g N ha^{-1} day^{-1} from 11 European forest sites covering a wide gradient of site characteristics and N deposition. For annual estimates these values have to be multiplied by 365 and by the forested area of the respective state.

To estimate N_2-N emissions, a mean N_2:N_2O ratio of 19.5 (+/- 26.8) has been calculated from studies of forest ecosystems (n = 6; for temperate beech and spruce forests in Germany) listed in the electronic supplementary attached to Butterbach-Bahl et al. (2013).

Tier 2

Pilegaard et al. (2006) presented linear regression models between N_2O-N and NO-N emissions and selected forcing factors (i.e. N deposition, vegetation type, C/N-ratio, age). Resulting linear regressions models and associated regressions coefficients are listed in Table 7. A number of process based models (e.g. DayCent, Coup Model, Landscape DNDC, Orchidee etc.) for N emissions but also for leaching can be used at the national scales with available empirical data. A qualitative comparison of currently available models is given in Cameron et al. (2013).

4.1.3.1 Uncertainty and other comments

→ Levels of uncertainty are provided in Annex 0, Table 5
→ The estimation of denitrification to N2 remains highly uncertain, due to difficulties in measurement and a high degree of temporal and spatial variability.
→ Estimated uncertainty: level 2.

4.1.3.2 Suggested data sources

- Spatial distribution of nitrogen depositions are available at EMEP at the following link: http://www.emep.int/mscw/SR_data/sr_tables.html
- CORINE land cover contains information on the coverage and land use all over Europe: www.eea.europa.eu; www.eea.europa.eu/data-and-maps/data/corine-land-cover
- National forest inventories (C/N-ratios, stand age)

4.1.4 Leaching (FS.FO-HY.SW-NO$_3$)

Nitrate leaching to the groundwater occurs when N deposition (input) and net mineralization (status) exceed plant demand (Gundersen et al., 2006).

Tier 1

In cases where no measurements are available, several indicators can be used as proxies for nitrate leaching. Nitrate leaching is strongly dependent on the amount of N deposited in throughfall (see section 4.1.1). No significant NO_3^- leaching could be expected when the throughfall fluxes are less than 8 kg N ha^{-1} y^{-1}, while above 25 kg N ha^{-1} y^{-1} N leaching is very probable (Dise et al., 2009; Gundersen et al., 2006). Predicted rates of N leaching related to throughfall N (95% confidence intervals are ± 10 kg N ha^{-1} y^{-1}) for soils with C:N ratios higher or lower than 25 are given in the Table 8.

Also, a significant relationship was found between organic soil C:N ratios and leaching (Cools et al., 2014). Elevated nitrate leaching tends to occur at C:N ratio <25 and hence this threshold shall be used as a default. In order to evaluate the risk for nitrate leaching from the forest status of the soil, mean

C:N ratios are given according to tree species occurrence and the soil type in the table 9 (Cools et al., 2014).

Likewise, foliage N content as well as N density (total aboveground N input to the soil i.e. throughfall + litterfall, excluding belowground root litter input) can be used as a proxy for the nitrate leaching (Gundersen et al., 2006) – see Table 10. Finally, the N status of the system (limited vs. saturated) will also determine its retention capacity. Basically, N-poor systems have a higher retention than N-rich systems. Therefore, the forest type specific empirical Critical Load is a measure of the sensitivity of ecosystems to nitrate leaching (Holmberg et al., 2013).

Tier 2

Measured soil water nitrogen concentration, e.g. from ICP Forests or ICP Integrated Monitoring sites, can be used to improve estimated leaching rates. At the plot level, leaching fluxes should be calculated by multiplying the measured soil solution concentrations with measured or simulated water fluxes. Water fluxes can be estimated with a number of different models, such as the monthly water balance WATBAL model (Starr, 1999) or with a daily water balance Richard's model (van der Salm et al., 2007). At the regional scale water drainage fluxes can be estimated from annual means of precipitation and temperature. The manual for modelling and mapping Critical Loads gives detailed guidance on the relevant procedure (CLRTAP 2014).

4.1.4.1 Uncertainty and other comments

- → Levels of uncertainty are provided in Annex 0, Table 5
- → Estimated uncertainty: level 2.

4.1.4.2 Suggested data sources

- IFEF, Indicators of Forest Ecosystem Functioning, Dise et al. (1998b); contains data on input-output budgets published in scientific papers over the last decades for 250 forest sites.

- Level II database, expanded from De Vries et al. (2006); contains input-output budgets derived from UN-ECE/EC intensive monitoring plots for the period 1995-2000 for approximately 110 forest sites.

- Homberg et al. (2013) contains input-output budgets for ICP Integrated Monitoring sites across Europe.

- National forest inventory

- National soil inventory provides information on floor C:N ratio

- CLRTAP (2014). Mapping critical loads on ecosystems, Chapter V of Manual on methodologies and criteria for modelling and mapping critical loads and levels and air pollution effects, risks and trends. UNECE Convention on Long-range Transboundary Air Pollution, www.icpmapping.org.

4.1.5 Forest products

Removal of wood by exploitation is an important flux in the N balance of forest ecosystems. In general, the total wood removal can be calculated as:

$$H_{total} = H_{industrial\,round\,wood} + H_{fuel\,wood} + H_{wood\,export} \qquad 1.3$$

Where:

H_{total}= annual wood removal for domestic use as well as for export to the rest of the world
$H_{industrial\ round\ wood}$ = annual industrial round wood removals for domestic use
$H_{fuel\ wood}$ = annual fuel wood removals for domestic use
$H_{wood\ export}$= annual wood export of industrial round wood and fuel wood to the rest of the world

The amount of N export depends on tree species, growth, and nutrient contents in different tree compartments. For the estimation of nitrogen losses due to biomass removals the following calculation can be applied:

$$N_{biomass-removals} = H \times D \times N_F \qquad 1.4$$

Where:

$L_{biomass-removals}$ = annual N loss due to biomass removals [t N y^{-1}]
H = annual wood removals [1000 $m^3 yr^{-1}$], see Tables 11, 12 for industrial round wood and Tables 13, 14 for fuel wood
D = basic wood density [oven-dry t (moist m^{-3})], see Table 15
N_F = content of N in tree compartments [mg g^{-1}], see Table 16

4.1.6 Industrial round wood (FS.FO-MP-WoodN)

Industrial round wood comprises all wood obtained from removals (i.e. saw-logs and veneer logs; pulpwood, round and split; and other industrial round wood) except wood fuel (UNECE/FAO Forestry and Timber Section). Removals, however, refer to the volume of all trees, living or dead, that are felled and removed from the forest and other wooded land. It includes removals of stem and non-stem wood (i.e. harvest) and removal of trees killed or damaged by natural causes (i.e. natural losses). It is reported in cubic meters solid volume under bark (i.e. excluding bark).

In terms of classification, caution should be paid to the definition of round wood removals, which encompasses all wood removed with or without bark as well as wood fuel, charcoal and industrial round wood (IPCC, 2006).

Tier 1

The estimation of nitrogen losses due to removal of industrial round wood is based on the equation 1.4 . Data on industrial round wood removals could be found for the period of 2007-2011 in Table 11. For the wood density the mean value shall be used (Table 15), while for the content of N in tree compartment the values for "whole tree" shall be used.

Tier 2

Tier 2 requires more precise categorisation of tree types and tree compartment. In general, for Tier 2 approach country-specific data shall be used. However, the wood density for different tree types as well as nitrogen contents of tree compartments can be found in Tables 15 and 16, respectively.

4.1.6.1 Uncertainty and other comments

→ Levels of uncertainty are provided in Annex 0, Table 5.

→ Estimated uncertainty: level 2.

4.1.6.2 Suggested data sources

- National statistics
- UNECE Forestry and Timber Section database: http://www.unece.org/forests/fpm/onlinedata.html
- FAOSTAT: http://faostat3.fao.org/browse/F/*/E
- EUROSTAT database: http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/search_database

4.1.7 Fuel wood (FS.FO-HS.MW-WoodN)

According to the UNECE/FAO classification the fuel wood refers to round wood that is used as fuel for purposes such as cooking, heating or power production. It includes wood harvested from main stems, branches and other parts of trees (where these are harvested for fuel) and wood that will be used for charcoal production (e.g. in pit kilns and portable ovens) but excludes wood charcoal. It also includes wood chips to be used for fuel that are made directly (i.e. in the forest) from round wood. It is reported in cubic meters solid volume under bark (i.e. excluding bark).

Tier 1

The estimation of nitrogen losses due to removal of fuel wood is also based on the equation 1.4. Data on fuel wood removals could be found for the period of 2007-2011 in Table 13. For the wood density the mean value shall be used (Table 15), while for the content of N in tree compartment the values for "whole tree" shall be used.

Tier 2

Tier 2 requires more precise categorisation of tree types and tree compartment. In general, for Tier 2 approach country-specific data shall be used. However, the wood density for different tree types as well as nitrogen contents of tree compartments can be found in Tables 15 and 16, respectively.

4.1.7.1 Uncertainty and other comments

→ Levels of uncertainty are provided in Annex 0, Table 5.

→ Estimated uncertainty: level 2.

4.1.7.2 Suggested data sources

- National statistics
- UNECE Forestry and Timber Section database: http://www.unece.org/forests/fpm/onlinedata.html
- FAOSTAT: http://faostat3.fao.org/browse/F/*/E
- EUROSTAT database: http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/search_database

4.1.8 Wood export (FS.FO-RW-WoodN)

Wood export involves forest products of domestic origin exported from the country. It is reported in cubic meters of solid volume or metric tons.

Tier 1

The estimation of nitrogen losses due to wood export is also based on the equation 1.4. Data on wood exports can be found for the period of 2007-2011 in the Table 12 for round wood and in Table 14 for fuel wood. For the wood density the mean value shall be used (Table 15), while for the content of N in tree compartment the values for "whole tree" shall be used.

Tier 2

Tier 2 requires more precise categorisation of tree types and tree compartment. In general, for Tier 2 approach country-specific data shall be used. However, the wood density for different tree types as well as nitrogen contents of tree compartments can be found in Tables 15 and 16, respectively.

4.1.8.1 Uncertainty and other comments

→ Levels of uncertainty are provided in Annex 0, Table 5.

→ Estimated uncertainty: level 2.

4.1.8.2 Suggested data sources

- National statistics
- FAOSTAT: http://faostat3.fao.org/browse/F/*/E
- FAOSTAT forestry database: http://faostat3.fao.org/download, are available from year 1961
- OECD database: http://www.oecd.org/statistics/, provides information on growing stock in forest, forest land area and exports of forestry products
- UNECE Forestry and Timber Section database: http://www.unece.org/forests/fpm/onlinedata.html

4.2 Other Land (FS.OL)

Table 17: Overview on N-flows in/out the FS.OL pool

Flow Code	Flow Description	Pool ex	Pool in	Matrix
AT-FS.OL-AtmN	Deposition of N_2O-N from atmosphere to Other Land	AT	FS.OL	AtmN
FS.OL-HY.SW-NO3	NO_3-N leaching & surface water runoff into the hydrosphere from Other Land soil	FS.OL	HY.SW	NO3

Assuming that biological N_2 fixation as well as denitrification is negligibly in this pool, N budgets can be calculated as a difference between deposition and leaching.

4.2.1 *Atmospheric N deposition (AT-FS.OL-AtmN)*

Tier 1

For N deposition data are available in EMEP. In case that data are not offered for certain countries in the EMEP database, it could be assumed that the atmospheric deposition in semi-natural vegetation is homogenous within a country (Heldstab, 2010). Starting from this assumption, the total N deposition in Other Land can be computed by multiplying atmospheric N deposition in non-forested area by the percentage of land.

Tier 2

Tier 2 approaches involve the use of country-specific data.

4.2.1.1 Uncertainty and other comments

- → Levels of uncertainty are provided in Annex 0, Table 5.
- → Estimated uncertainty: level 2.

4.2.1.2 Suggested data sources

- CORINE land cover, contains information of the coverage and land use all over the Europe: www.eea.europa.eu/data-and-maps/data/corine-land-cover also FAO – www.fao.org
- EMEP MSC-W chemical transport model provides data on atmospheric deposition to semi-natural vegetation (non-forested area)
- National GHG inventory

4.2.2 *Leaching (FS.OL-HY.SW-NO3)*

Tier 1

In N limited ecosystems it can be assumed that N deposited from the atmosphere will stay in soil (i.e. zero leaching), while in the N rich areas N will be leached. If no data on nitrate leaching from Other Lands are available then the nitrate leaching can be estimated by using default values or proxies (e.g. 2-10 kt N y^{-1} proposed in the Swiss N budget). For areas with periods of soil frost and snow, the N deposition associated with snow will mostly run off with snowmelt and not be accumulated in the soil. If no data on runoff are available then it can be assumed that all deposition via snow equals runoff.

Tier 2

Tier 2 approaches involve the use of national specific data.

4.2.2.1 Uncertainty and other comments

- → Levels of uncertainty are provided in Annex 0, Table 5.
- → Estimated uncertainty: level 2.

4.2.2.2 Suggested data sources

- National meteorological stations shall provide data on N-deposition with snow
- The proxy values could be obtained through the expert judgement (i.e. national environmental agency)

4.3 Wetlands

Table 18: Overview on N-flows in/out the FS.WL pool

Flow Code	Flow Description	Pool ex	Pool in	Matrix
AT-FS.WL-AtmN	Deposition of N form atmosphere to wetland	AT	FS.WL	AtmN
AT-SL.WL-N2	Biological N fixation of N_2 from atmosphere to wetland	AT	FS.WL	N2
FS.WL-AT-NH3	NH_3 emission to the atmosphere from wetland soil	FS.WL	AT	NH3
AG-FS.WL-NO3-SURFW	Surface water runon NO3-N losses to the wetlands from agricultural soil	AG	FS.WL	NO3
FS.WL-HY.SW-NO3	NO_3-N leaching & surface water runoff into the hydrosphere from wetland soil	FS.WL	HY.SW	NO3

As stated above, the inclusion of the diverse wetland types covering large environmental gradients and the corresponding insufficient data challenge wetlands in national N budget calculations. Hence, a robust quantification of N flows in wetlands that can be used as general reference will be difficult and more research is necessary in this topic. Overall, the flow-path-oriented approach in WETTRANS (Trepel & Kluge, 2004) presents a promising method to quantify the N retention ability of riparian peatlands in particular and in modified form for wetlands in general. Consequently, in this chapter we will give some hints on how N-flows for Tier 1 approach could be estimated.

4.3.1 Atmospheric N deposition (AT-FS.WL-AtmN)

Tier 1

Classification of vegetation composition in forest and non-forest determines the approach of atmospheric N deposition calculation to the respective wetland. If classified as forests, atmospheric N deposition is calculated corresponding to Chapter 4.1.1. If classified as non-forest, it can be assumed that N deposition equals atmospheric N deposition on non-forested area.

4.3.1.1 Uncertainty and other comments

- → Levels of uncertainty are provided in Annex 0, Table 5.
- → Estimated uncertainty: level 2.

4.3.1.2 Suggested data sources

- CORINE land cover, contains information of the coverage and forest type all over the Europe: www.eea.europa.eu/data-and-maps/data/corine-land-cover, FAO – www.fao.org, aerial /satellite photo
- EMEP MSC-W chemical transport model provides data on atmospheric deposition to semi-natural vegetation (non-forested area)
- International and national wetland databases (Ramsar, etc.)
- National GHG inventory

4.3.2 Biological N_2 fixation (AT-SL.WL-N2)

As molecular nitrogen does not constitute a reactive N form, this flow may be considered source rather than transfer from the atmosphere – which does not alter the need of quantification.

Tier 1

For some wetland types the default values of biological N_2 fixation are provided in Table 19. If none of those wetland types are representative for the given country, then a mean value of 45 shall be used.

Tier 2

If national data are available these should be used.

4.3.2.1 Uncertainty and other comments

- → Levels of uncertainty are provided in Annex 0, Table 5.
- → Estimated uncertainty: level 2.

4.3.2.2 Suggested data sources

- Reddy and DeLaune (2008)

4.3.3 Runoff (AG-FS.WL-NO3-SURFW)

As stated above, N inflow pathways from upland ecosystems include N inflow via surface runon, pipe and tile drainage from neighbouring agricultural fields, interflow, young oxic groundwater, young anoxic groundwater, old anoxic groundwater from a deeper aquifer and river water (Trepel & Kluge, 2004). Information on N inputs from surface runon from adjacent agricultural, groundwater and open water shall be provided in annexe 3 (for agriculture - AG). However, a possible approach to estimate the N runon is presented below.

Tier 1

Quantification of N input with surface runoff from adjacent agricultural areas can be done by the widely used Runoff Curve number approach implemented with relevant digital GIS layers (Weng 2001) and data on concentrations of N in surface runoff of different land use classes (Trepel & Kluge 2004). Alternatively, N input to wetlands with surface runon from surrounding agriculture can be quantified through a spatial intersection of the digital wetland layer with the resulting digital GIS layer of annual amounts of N in surface runoff.

Similar, the N input with groundwater can be estimated through a spatial intersection of the digital wetland layer with spatial national groundwater data on nitrate concentrations in groundwater.

Finally, the N input with adjacent open waters (i.e. rivers, lakes, oceans) can be estimated through the N load of this open water.

4.3.3.1 Uncertainty and other comments

- → Levels of uncertainty are provided in Annex 0, Table 5.
- → Estimated uncertainty: level 2.

4.3.3.2 Suggested data sources

- RAMSAR database, contains information on wetlands area (ha) designed as RAMSAR sites all over the world (https://rsis.ramsar.org/)
- CORINE land cover, contains information of the coverage and land use all over the Europe: www.eea.europa.eu/data-and-maps/data/corine-land-cover, FAO – www.fao.org
- Groundwater/surface water data on N concentrations
- Digital elevation model
- National meteorological data
- National soil inventory data on soil texture

4.3.4 Emissions (FS.WL-AT-N2O)

The groundwater table level and nitrogen content of organic matter and nutrient status have been found to affect N_2O emissions from wetland soils (Martikainen et al. 1993, Regina et al. 1996, Marjainen et al. 2010, Klemedtson et al. 2005). Therefore, the IPCC Guidelines for National Greenhouse Gas Inventories (2006) proposed a stratification of managed peatlands in boreal and temperate climate according to nutrient status for the determination of N_2O emission factors from managed wetlands.

Tier 1

A classification of the national wetlands according to nutrient status is provided in Table 20. The N_2O-N emission from soils with C:N ratios > 25 are insignificant (Klemedtson et al., 2005) or very low (e.g. <0.01 kg N_2O-N ha^{-2} in case of undrained ombrotrophic peatlands; Maljanen et al., 2010) so that N_2O emissions from wetlands with medium, poor or very poor nutrient status can be considered as negligible.

For wetland types with higher nutrient status, Table 21 provides a number of annual N_2O emission rates from relevant studies.

4.3.4.1 Uncertainty and other comments

- → Levels of uncertainty are provided in Annex 0, Table 5.
- → The robust quantifications of N_2O emissions for specific wetland types are highly uncertain due to the low number of available studies. The emission fluxes are highly variable depending on changes in the anoxic conditions and no studies are available providing simple ways to their calculation.
- → Estimated uncertainty: level 2.

4.3.4.2 Suggested data sources

- RAMSAR database, contains information on wetlands area (ha) designed as RAMSA sites all over the world (https://rsis.ramsar.org/)
- National wetland database (if available)
- Wetland inventories

4.3.5 Leaching and surface water runoff (FS.WL-HY.SW-NO3)

Nitrogen leaching and runoff occurs via saturated overland flow, ditch outflow, overbank flow due to flooding, subsurface discharge and river flow (Trepel & Kluge, 2004).

Tier 1

In general, the N leaching can be estimated from the N load (sections 4.3.1-4.3.3) to and N removal (section 4.3.4) from the wetland:

$$N_{leaching} = N_{load} - N_{removal} \qquad 3.1$$

A very robust relationship was found between the reactive N load to the system and the N removal from the system based on observation of 190 datasets with sufficient information for spatially and temporally normalized input-output models of reactive N reduction by wetlands (Jordan et al. 2011). Accordingly, N leaching can be estimated as:

$$log10_{(N\ removal)} = -0.033 + 0.943 \times log10_{(Nload)} \quad 3.2$$

4.3.5.1 Uncertainty and other comments

→ Levels of uncertainty are provided in Annex 0, Table 5.
→ Estimated uncertainty: level 2.

4.3.5.2 Suggested data sources

- CORINE land cover, contains information of the coverage and forest type all over the Europe: www.eea.europa.eu/data-and-maps/data/corine-land-cover, FAO – www.fao.org, aerial /satellite photo
- EMEP MSC-W chemical transport model provides data on atmospheric deposition to semi-natural vegetation (non-forested area)
- Default values for N fixation see Table 19
- RAMSAR database, contains information on wetlands area (ha) designed as RAMSA sites all over the world (https://rsis.ramsar.org/)
- Groundwater/surface water data on N concentrations

5 Stocks & Stock Changes

Calculations of stocks and stock changes are provided as a means to validate the mass balance estimates. Nitrogen stocks in biomass and soil may change over time as a result in the difference between inflows and outflows of nitrogen. When losses exceed gains, the stock decreases, and the pool acts as a source; when gains exceed losses, the pools accumulate nitrogen, and the pools act as a sink. We follow the approach used by IPCC reporting guidelines and distinguish between plant biomass, dead organic matter (dead wood + litter) and soil stocks (IPCC, 2006).

5.1 Stock changes in forest land

5.1.1 Biomass stock changes (ΔN_B)

Biomass stock changes of nitrogen are related to plant growth, human activities (e.g. harvest, management practices), and natural losses due to disturbances (e.g. windstorms, insect outbreaks, and diseases).

Tier 1

Estimation of N stock changes in biomass can be derived based on default methods (Tier 1) as:

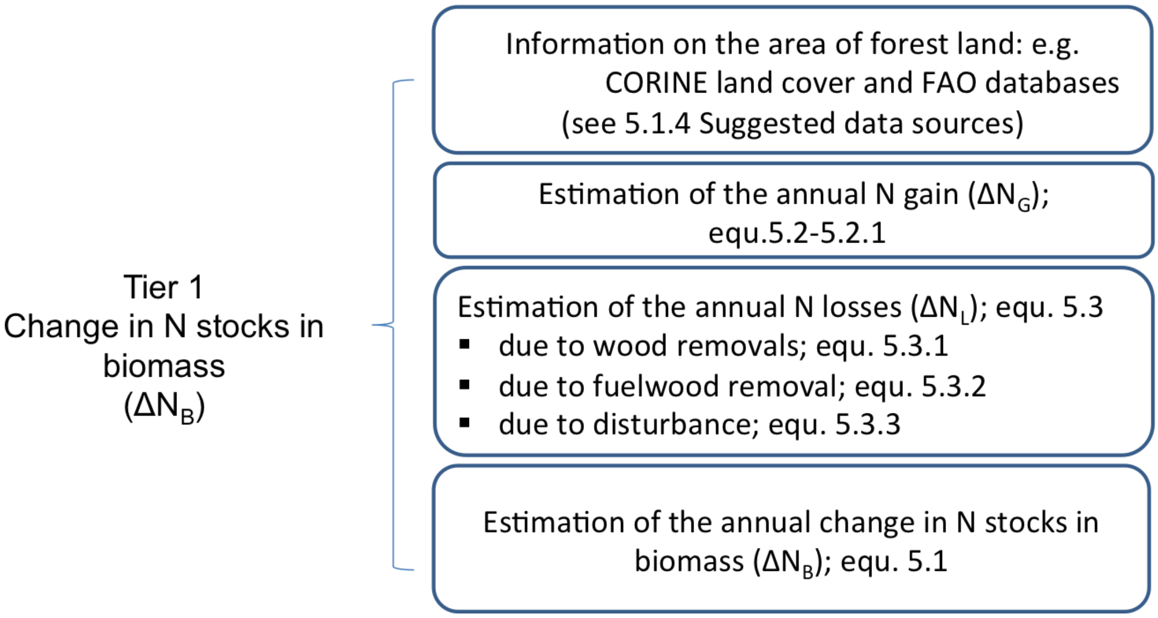

Figure 3: Schematic diagram for estimating biomass N stocks changes for the level Tier 1. Details on the individual calculations see below.

Annual changes in N stocks in biomass are calculated according to the *Gain -Loss Method*:

$$\textit{Changes in N stocks in biomass:}\quad \Delta \boldsymbol{N_B} = \Delta \boldsymbol{N_G} - \Delta \boldsymbol{N_L} \qquad 5.1$$

Where:

ΔN_B = annual change in N stocks in biomass, considering total area [t N y^{-1}]
ΔN_G= annual increase in N stocks due to biomass growth, considering total area [t N y^{-1}] (eq. 5.2)
ΔN_L = annual decrease in N stocks due to biomass loss, considering total area [t N y^{-1}] (eq. 5.3)

Annual increase in biomass N stocks due to biomass increment (ΔN_G) in eq. 5.1 is calculated:

$$\textit{Annual increase in biomass:}\ \Delta \boldsymbol{N_G} = \sum_{i,j}(\boldsymbol{A_{i,j}} \times \boldsymbol{GTOTAL_{i,j}} \times \boldsymbol{NF_{i,j}}) \qquad 5.2$$

Where:

ΔN_G = annual increase in biomass N stocks due to biomass growth [t N yr^{-1}]
A= area of land [ha]
G_{TOTAL} = mean annual biomass growth [t d. m. ha^{-1} yr^{-1}] (calculated according to eq. 5.2.1)
i = ecological zone (i=1 to n); see for this IPCC Guideline for National Greenhouse Gas Inventories 2006 Table 4.1.
j = climate domain (j =1 to m); see for this IPCC Guideline for National Greenhouse Gas Inventories 2006 Table 4.1.
NF = nitrogen fraction of dry matter [t N $(t\ d.m.)^{-1}$], see Table 16. Caution: values in the table are in g kg^{-1}; divide by 1000 in order to get the ratio.

The ***average annual increment in biomass*** (G_{TOTAL}) in eq. 5.2 is calculated:

To estimate average annual biomass growth above and belowground, the biomass increment data of forest inventories (dry matter) can be used directly.

$$\textit{Average annual increment in biomass:}\ \boldsymbol{G_{TOTAL}} = \sum\{\boldsymbol{G_W} \times (\mathbf{1} + \boldsymbol{R})\} \qquad 5.2.1$$

Where:

G_{TOTAL} = average annual biomass growth above and belowground [t N d.m. $ha^{-1}yr^{-1}$]
GW = average annual aboveground biomass growth for a specific woody vegetation type [t N d.m. $ha^{-1}yr^{-1}$]; see *Table 22*. For land converted to forest land see *Table 23*
R = ratio of belowground biomass to above ground biomass for a specific vegetation type tonne d.m. belowground biomass (tonne d.m. aboveground biomass)$^{-1}$. R must be set to zero if assuming no changes of belowground biomass allocation patterns; see *Table 24* with reference to *Table 25* for above ground biomass. For land converted to forest land see *Table 26*

Tier 2

For the higher tiers also, net annual increment data can be used to estimate average annual aboveground biomass growth by applying a biomass conversion and expansion factor.

$$\text{Average annual biomass growth } \boldsymbol{G_{TOTAL}} = \sum\{\boldsymbol{I_V} \times \boldsymbol{BCEF_I} \times (\boldsymbol{1} + \boldsymbol{R})\} \quad 5.2.2$$

Where:

G_{TOTAL} = average annual biomass growth above and belowground [t N d.m. $ha^{-1}y^{-1}$]
R = ratio of belowground biomass to above ground biomass for a specific vegetation type, tonne d.m. belowground biomass (tonne d.m. aboveground biomass)$^{-1}$. R must be set to zero if assuming no changes of belowground biomass allocation patterns; see Table 24, with reference to Table 25 for above ground biomass. For land converted to forest land see Table 26
I_V = average net annual increment for specific vegetation type [m^3 ha^{-1} yr^{-1}]
$BCEF_I$ = biomass conversion and expansion factor for conversion of net annual increment in volume (including bark) to aboveground biomass growth for specific vegetation type, t aboveground biomass growth [m^3 net annual increment]$^{-1}$, see Table 27.

If $BCEF_I$ values are not available and if the biomass expansion factor (BEF) and basic wood density (D) values are separately estimated, then the following conversion can be used:

$$\text{Biomass conversion and expansion factor } \boldsymbol{BCEF_I} = \boldsymbol{BEF_I} \times \boldsymbol{D} \quad 5.2.3$$

Where:

$BCEF_I$ = biomass conversion and expansion factor for conversion on net annual increment in volume (including bark) to aboveground biomass growth for specific vegetation type, t aboveground biomass growth [m^3 net annual increment]$^{-1}$, see Table 27.
BEF_I = biomass expansion factor
D = basic wood density [oven-dry t (moist m^{-3})], see Table 15

Biomass loss (ΔN_L) in eq. 5.3 is a sum of annual loss due to wood removals ($L_{wood\text{-}removals}$), fuel wood gathering ($L_{fuelwood}$) and disturbance ($L_{disturbance}$) (eq. 5.3.1-5.3.3).

$$\text{Annual decrease in biomass } \Delta \boldsymbol{N_L} = \boldsymbol{L_{wood-removals}} + \boldsymbol{L_{fuelwood}} + \boldsymbol{L_{disturbance}} \quad 5.3$$

Where:

ΔN_L = annual decrease in nitrogen stocks due to biomass loss in land remaining in the same land-use category, [t N yr^{-1}]
$L_{wood\text{-}removals}$ = annual N loss due to wood removals [t N yr^{-1}]
$L_{fuelwood}$ = annual biomass N loss due to fuel wood removals, [t N yr^{-1}]
$L_{disturbance}$ = annual N losses due to disturbances, [t N yr^{-1}]

Where *the annual N losses due to wood removals* ($L_{wood\text{-}removals}$) are calculated as:

$$\boldsymbol{L_{wood-removals}} = \{\boldsymbol{H} \times \boldsymbol{BCEF_R} \times (\boldsymbol{1} + \boldsymbol{R}) \times \boldsymbol{NF}\} \quad 5.3.1$$

Where:

$L_{wood\text{-}removals}$ = annual N loss due to biomass removals [t N y^{-1}]
H = annual wood removals, roundwood [m^3 y^{-1}]
R = ratio of belowground biomass to above ground biomass, in tonne d.m. belowground biomass (tonne d.m. aboveground biomass)$^{-1}$. R must be set to zero if assuming no changes of belowground biomass allocation patterns (Tier 1); see Table 24, with reference to Table 25 for above ground biomass. For land converted to forest land see Table 26
NF = Nitrogen fraction of dry matter [tonne N (t d.m.)$^{-1}$], see Table 16
$BCEF_R$ = biomass conversion and expansion factor for conversion of removals in merchantable volume to total biomass removals (including bark), t biomass removal [m^3 of removals]$^{-1}$, see Table 27. However, if $BCEF_I$ values are not available and if the biomass expansion factor (BEF) and basic wood density (D) values are separately estimated, then the following conversion can be used: $BCEF_R = BEF_R \times D$

The annual N losses due to fuelwood removal ($L_{fuelwood}$) are calculated as:

$$L_{fuelwood} = [\{FG_{trees} \times BCEF_R \times (1 + R) + FG_{part} \times D\} \times NF \quad (5.3.2)$$

Where:

$L_{fuelwood}$= annual N loss due to fuelwood removals [t N yr^{-1}]
FG_{trees} = annual volume of fuelwood removal of whole trees [m^3 yr^{-1}]
FG_{part} = annual volume of fuelwood removal as tree parts [m^3 yr^{-1}]
R = ratio of belowground biomass to above ground biomass, in tonne d.m. belowground biomass (tonne d.m. aboveground biomass)$^{-1}$. R must be set to zero if assuming no changes of belowground biomass allocation patterns (Tier 1); see Table 24, with reference to Table 25 for above ground biomass. For land converted to forest land see Table 26
NF = Nitrogen fraction of dry matter [tonne N (t d.m.)$^{-1}$], see Table 16
D = basic wood density [tonne d.m. (m)$^{-3}$], see Table 15
$BCEF_R$ = biomass conversion and expansion factor for conversion of removals in merchantable volume to biomass removals (including bark), t biomass removal [m^3 of removals]$^{-1}$, see Table 27. However, if $BCEF_I$ values are not available and if the biomass expansion factor for wood removals (BEF_R) and basic wood density (D) values are separately estimated, then the following conversion can be used: $BCEF_R = BEF_R \times D$

The annual N losses due to disturbances ($L_{disturbances}$) are calculated as:

$$L_{disturbance} = \{A_{disturbance} \times B_W \times (1 + R) \times NF \times fd\} \quad (5.3.3)$$

Where:

$L_{disturbance}$= annual other loss of N [t N yr^{-1}]
$A_{disturbances}$ = area affected by disturbances [ha yr^{-1}]
B_W = average aboveground biomass of land areas affected by disturbances [tonne N d.m. ha^{-1}]
R = ratio of belowground biomass to above ground biomass, in tonne d.m. belowground biomass (tonne d.m. aboveground biomass)$^{-1}$. R must be set to zero if no changes of belowground biomass are assumed (Tier 1); see Table 24, with reference to Table 25 for above ground biomass. For land converted to forest land see Table 26
NF = Nitrogen fraction of dry matter [tonne N (t d.m.)$^{-1}$]; see Table 16
fd = fraction of biomass lost in disturbance
Note: The parameter fd defines the proportion of biomass that is lost from the biomass pool: as stand-replacing disturbance will kill all (fd =1) biomass while an insect disturbance may only remove a portion (e.g. fd =0.3) of the average biomass N density. The Tier 1 assumption is that all of $L_{disturbances}$ is leached or emitted in the year of disturbances. Higher Tier methods assume that some of this N is leached or emitted immediately and some is added to the dead organic matter pools (dead wood, litter) or harvested wood products.

Tier 2

Tier 2 approach for biomass N stock change estimation can be used in countries with detailed national forest inventories (www.efi.int), which are required for the stock-difference method.

Annual changes in N stocks in biomass according to the *Stock-Difference Method* can be calculated as:

$$\Delta \boldsymbol{N_B} = \frac{(N_{t2} - N_{t1})}{(t2 - t1)} \qquad 5.3.4$$

$$\boldsymbol{N_{tn}} = \sum_{i,j} \{A_{i,j} \times V_{i,j} \times BCEFs_{i,j} \times (1 + R_{i,j}) \times NF_{i,j}\} \qquad 5.3.5$$

Where:

ΔN_B = annual change in nitrogen stocks in biomass [t N y^{-1}]
N_{t2} = total N in biomass at time t_2 [t N]
N_{t1} = total N in biomass at time t_1 [t N]
N_{tn} = total N in biomass for time t_1 and t_2
A = area of land [ha]
V = merchantable growing stock volume [m^3 ha^{-1}]
i = ecological zone (i = 1 t n); see for this IPCC Guideline for National Greenhouse Gas Inventories 2006 Table 4.1.
j = climate domain (j = 1 t m); see for this IPCC Guideline for National Greenhouse Gas Inventories 2006 Table 4.1.

R = ratio of belowground biomass to aboveground biomass; see Table 24, with reference to Table 25 for above ground biomass. For land converted to forest land see Table 26
NF = nitrogen fraction of dry matter, [t N (t d.m.)$^{-1}$]; see Table 16
$BCEF_S$ = biomass conversion and expansion factor for expansion of merchantable growing stock volume to aboveground biomass; see Table 27. $BCEF_S$ transforms merchantable volume of growing stock directly into its aboveground biomass. $BCEF_S$ values are more convenient because they can be applied directly to volume-based forest inventory data and operational records, without the need of having to resort to basic wood densities (D). They provide best results, when they have been derived locally and based directly on merchantable volume. However, if $BCEF_S$ values are not available and if the biomass expansion factor (BEF_S) and basic wood density (D) values are separately estimated, then the following conversion can be used: $BCEF_S = BEF_S \times D$

5.1.2 Land conversion

In general, N stock changes can also be expected when land-use change occurs. According to the definition in the IPCC report (2006) the land converted to forest land (LF) should have a transition time of 20 years.

Tier 1

If the data in previous land uses are not available, it will be assumed that there is no change in initial biomass N stocks due to conversion. Categorisation for the Tier 1 can be obtained by use of approach 1 or 2 in Chapter 3 of IPCC report 2006.

Tier 2

Tier 2 requires more precise categorisation of converted land, which should be derived from national sources. Estimation of N stock changes in biomass can then be maintained as according to the following procedure:

Figure 4: Schematic diagram for estimating biomass N stocks changes due to land conversion for the higher Tier levels. Details on the individual calculations see below.

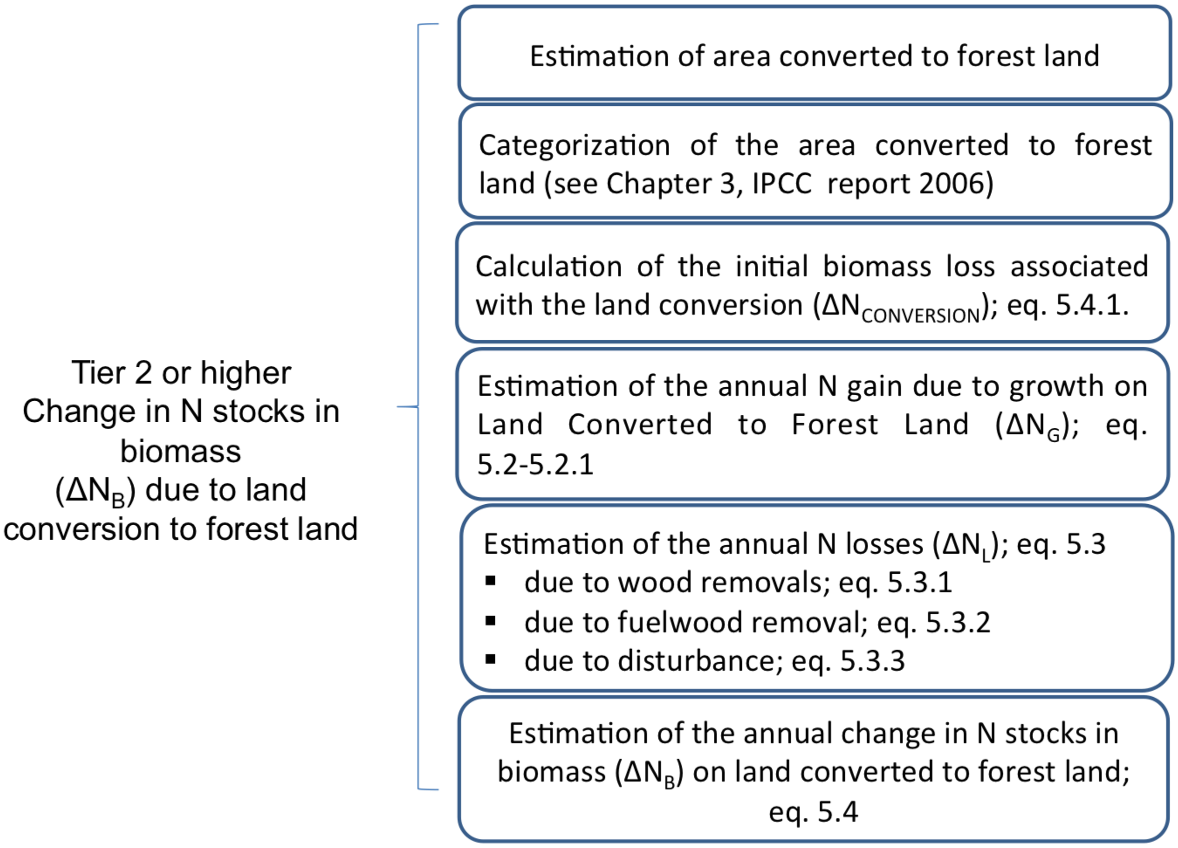

Figure 4: Schematic diagram for estimating biomass N stocks changes due to conversion to forest land for Tier 2 or higher levels.

Then annual change in biomass N stocks on land converted to forest land can be calculated as:

$$\textit{Annual change in biomass N stocks } \Delta \boldsymbol{N_B} = \Delta \boldsymbol{N_G} + \Delta \boldsymbol{N_{CONVERSION}} - \Delta \boldsymbol{N_L} \qquad 5.4$$

Where:

ΔN_B= annual change in N stocks in biomass on land converted to other land-use category [t N yr^{-1}]
ΔN_G= annual increase in N stocks in biomass due to growth on land converted to another land-use category [t N y^{-1}]
$\Delta N_{CONVERSION}$ =initial change in N stocks in biomass on land converted to Other Land-use category [t N yr^{-1}]; see eq.5.4.1
ΔN_L = annual decrease in biomass N stocks due to losses from harvesting, fuel wood gathering and disturbances on land converted to other land-use category [t N yr^{-1}]

$$\Delta \boldsymbol{N_{CONVERSION}} = \sum_i \{(\boldsymbol{B_{AFTERi}} - \boldsymbol{B_{BEFOREi}}) \times \boldsymbol{D}\} \times \Delta \boldsymbol{A_{TO\_OTHERSi}}\} \times \boldsymbol{NF} \qquad 5.4.1$$

Where:

$\Delta N_{CONVERSION}$= initial change in biomass N stocks on land converted to another land-use category [t N yr^{-1}]
B_{AFTERi}= biomass stocks on land type i immediately after the conversion, [t d.m. ha^{-1}]
$B_{BEFOREi}$ =biomass stocks on land type i before the conversion, [t d.m. ha^{-1}]
$\Delta A_{TO\_OTHERSi}$ = area of land use I converted to another land-use category in a certain year [ha yr^{-1}]
NF = nitrogen fraction of dry matter, [tonne N (t d.m.)$^{-1}$]; see Table 16
i = type of land use converted to another land-use category

5.1.3 Changes in nitrogen stock in Dead Organic Matter (ΔN_{DM})

Changes in N stocks in dead organic matter are related to the changes in litter and dead wood. The dead wood contains nitrogen in coarse woody debris, dead coarse roots, standing dead trees, and other dead material not included in the litter or soil nitrogen pools. The litter pool contains nitrogen in dead leaves, twigs and small branches (up to a diameter limit of 10 cm), fruits, flowers, roots, and bark (IPCC, 2006).

Both harvest (residuals) and natural disturbances add biomass to dead wood and litter pools, while fire and other management practices remove N from these. This means that for the estimation of N stock changes information on harvest inputs and outputs and disturbance related inputs and losses are required and have to be calculated separately for dead wood and litter pool.

Tier 1

Tier 1 methods assume that the nitrogen stock remain the same in DM pools and N leaching/emission from those pools are zero if the land remains within the same land-use category.

Tier 2

Tier 2 and higher tiers methods need data from field measurements and models for their implementation.

Basically, a forest inventory may provide annual data on dead wood mass, which will significantly depend on the forest management type. A rough estimation for annual litter input amounts to 0.15% (Robert Jandl personal communication).

If annual data on transfer into and out of N_{DM} stocks are available, then estimation of N stock changes in dead organic matter can be maintained based on Gain-Loss method as:

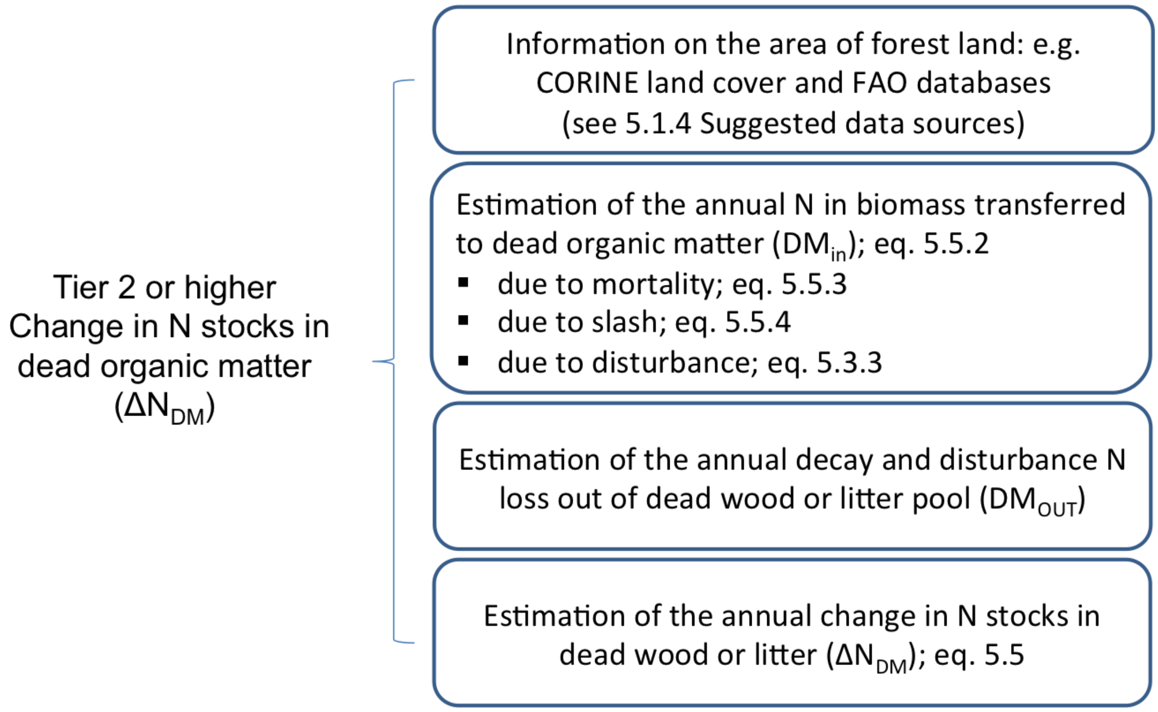

Figure 5: Schematic diagram for estimating N stocks changes in dead organic matter for the higher tier levels. Details on the individual calculations see below.

The annual change in N_{DM} can be expressed as:

$$The\ annual\ change\ in\ N\ stocks\ in\ dead\ wood\ or\ litter\ \Delta \boldsymbol{N_{DM}} = \Delta \boldsymbol{N_{DW}} + \Delta \boldsymbol{N_{LT}} \quad 5.5$$

Where:

ΔN_{DM} = annual change in N stocks in dead organic matter [t N y^{-1}]; eq. 5.5.1
ΔN_{DW} = changes in N stocks in dead wood [t N y^{-1}]
ΔN_{LT} = changes in N stocks in litter [t N y^{-1}]

The annual change in N stocks in dead wood or litter can be computed as:

$$\Delta \boldsymbol{N_{DM}} = \boldsymbol{A} \times (\boldsymbol{DM_{in}} - \boldsymbol{DM_{out}}) \times \boldsymbol{C} \quad 5.5.1$$

Where:

ΔN_{DM} = annual change in N stocks in dead wood/litter pool [t N yr^{-1}]
A = area of managed land [ha]
DM_{in} = average annual transfer of biomass into the dead wood /litter pool due to annual processes and disturbances [t d.m. ha^{-1} yr^{-1}].
DM_{out} = average annual decay and disturbance N loss out the dead wood /litter pool [t d.m. ha^{-1} y^{-r1}]
NF = nitrogen fraction of dry matter [t N (t d.dm)$^{-1}$]; see Table 16

Annual N increment in biomass transferred to dead organic matter (DM_{in}) in eq. 5.5.1 is calculated as:

$$\boldsymbol{DM_{in}} = \{\boldsymbol{L_{mortality}} + \boldsymbol{L_{slash}} + (\boldsymbol{L_{disturbance}} \times \boldsymbol{f_{BLol}})\} \quad 5.5.2$$

Where:

DM_{in} = total nitrogen in biomass transferred to dead organic matter [t N yr^{-1}]
$L_{mortality}$ = annual biomass nitrogen transfer to DOM due to mortality [t N yr^{-1}], see equation 5.5.3
L_{slash}= annual biomass nitrogen transfer to DOM as slash [t N yr^{-1}], see equation 5.5.4
$L_{disturbances}$ = annual biomass nitrogen loss resulting from disturbances [t N yr^{-1}], see equation 5.3.3
f_{BLol} = fraction of biomass left to decay on the ground from loss due to disturbance; default value for average fraction of dead wood left to decay after burning is 0.4 (Source: UNFCC/CCNUC Executive Board 41, Annex 14). When national data are incomplete, IPCC Chapter 2 provides default values of combustion factor (Table 2.6) and of biomass removals (Table 2.4).

Annual N biomass loss due to mortality in eq. 5.5.2 is calculated as:

$$\boldsymbol{L_{mortality}} = (\boldsymbol{A} \times \boldsymbol{G_W} \times \boldsymbol{NF} \times \boldsymbol{m}) \quad 5.5.3.$$

Where:

$L_{mortality}$ = annual biomass nitrogen loss due to mortality [t N yr^{-1}]
A = area of land remaining in the same land use [ha]
G_W= aboveground biomass growth [t d.m. ha^{-1} yr^{-1}], see *Table 22*. For land converted to forest land see *Table 23*.
NF = nitrogen fraction of dry matter, [t N (t d.m.)$^{-1}$], see Table 16
m = mortality rate expressed as a fraction of aboveground biomass growth

Annual N transfer to slash in eq. 5.5.2 is calculated as:

$$\boldsymbol{L_{slash}} = [\{\boldsymbol{H} \times \boldsymbol{BCEF_R} \times (\boldsymbol{1} + \boldsymbol{R})\} - \{\boldsymbol{H} \times \boldsymbol{D}\}] \times \boldsymbol{NF} \quad 5.5.4$$

Where:

L_{slash} = annual nitrogen transfer from aboveground biomass to slash, including dead roots [t N yr^{-1}]
H = annual wood harvest (roundwood or fuelwood removal) [m^3 yr^{-1}]
$BCEF_R$= biomass conversion and expansion factors applicable to wood removals, which transform merchantable volume of wood removal into aboveground biomass removals [t biomass removal (m^3 of removals)$^{-1}$]. If $BCEF_R$

values are not available and if BEF and density values are separately estimated then the following conversion can be used: $BCEF_R = BEF_R$ x D; where D is basic wood density [t d.m. m^{-3}] and biomass expansion factors (BEF_R) expand merchantable wood removals to total aboveground biomass volume to account for non-merchantable components of the tree, stand and forest. BEF_R is dimensionless.
R = ratio of below ground biomass to above –ground biomass [t d.m. belowground biomass (t d.m. aboveground biomass)$^{-1}$]. R must be set zero if root biomass increment is not included in Tier 1; see Table 24, with reference to Table 25 for above ground biomass. For land converted to forest land see Table 26
NF = nitrogen fraction of dry matter [tonne N (t d.m)$^{-1}$], see Table 16

If data on N_{DM} is available at two periods of time then estimation of N stock changes in dead organic matter or litter can also be maintained based on the Stock-Difference method:

$$\text{Annual change in N stocks in dead wood } \Delta \boldsymbol{N_{DM}} = \left[\boldsymbol{A} \times \frac{(\boldsymbol{DM_{t2}} - \boldsymbol{DM_{t1}})}{\boldsymbol{T}}\right] \times \boldsymbol{NF} \qquad 5.5.5$$

Where:

ΔN_{DM} = annual change in N stocks in dead wood or litter [t N yr^{-1}]
A = area of managed land [ha]
DM_{t1}= dead wood/litter stock at t1 for managed land [t d.m. ha^{-1}]
DM_{t2}= dead wood/litter stock at t2 for managed land [t d.m. ha^{-1}]
T = (t_2-t_1) = time period between time of the second stock estimate and the first stock estimate [yr]
NF = nitrogen fraction of dry matter (default= 0.37 for litter) [tonne N (t d.m.)$^{-1}$]; see Table 16

In case of land conversion to a new land-use category, the annual change in N_{DM} stock can be calculated as:

$$\Delta \boldsymbol{N_{DM}} = \frac{(\boldsymbol{N_n} - \boldsymbol{N_o}) \times \boldsymbol{A_{on}}}{\boldsymbol{T_{on}}} \qquad 5.5.6$$

Where:

ΔN_{DM} = annual change in N stocks in dead wood or litter [t N yr^{-1}]
N_o = dead wood/litter stock, under the old land-use category [t N ha^{-1}]
N_n = dead wood/litter stock, under the new land-use category [t N ha^{-1}]
A_{on} = area undergoing conversion from old to new land-use category [ha]
T_{on} = time period of the transition from old to new land-use category [yr]. The Tier 1 default is 20 years for N stock increases and 1 year for N losses.

5.1.4 Soil stock changes

The soil nitrogen stock changes are largely determined by the forest productivity (driving both the production of litter as well as the transfer of N from the soil to the plant biomass), the decomposition of litter (driving the incorporation of nitrogen into the mineral soil) and loss of nitrogen through mineralization and subsequent leaching and gaseous volatilization. In general, N stock changes are difficult to measure directly over short time steps (<10 years) because of small changes and large variation. Moreover, data availability is still scarce so that soil N stock changes are often not included in budget calculation (see Swiss national N budget).

Tier 1

For Tier 1 level it is assumed that soil C stocks do not change for mineral soils. In case of organic soils only drainage of the organic soils are addressed in Tier 1. Hence, in case of land conversion to forest-land on organic soils, the annual N loss can be estimated as:

$$\text{Annual N loss through land conversion on organic soil } L_{organic} = \sum_{c} (A \times EF)c \quad (5.6)$$

Where:

$L_{organic}$ = annual N loss from drained organic soils, [t N yr^{-1}]
A = land area of drained organic soils in climate *c*, [ha]
EF = emission factor for annual losses of N_2O_N under climate type c, [kg N ha^{-1} yr^{-1}]; EF =8 for temperate organic crop and grassland soils, EF =0.6 and 0.1 for temperate and boreal organic nutrient rich and nutrient poor forest soils, respectively. For tier 1 these default the emission factors are used, while for tier 2 emission factors shall be derived from country or region-specific data.

Tier 2

If national data are available annual changes in N stocks in mineral soils can be estimated as:

$$\Delta \boldsymbol{N}_{S\_mineral} = \frac{(SON_0 - SON_{(0-T)})}{(D)} \quad (5.6.1)$$

$$SON = \sum_{c,s,i} (SON_{REF\ c,s,i} \times F_{LUc,s,i} \times F_{MGc,s,i} \times F_{Ic,s,i} \times A_{c,s,i} \quad (5.6.2)$$

Where:

$\Delta N_{S\_mineral}$ = annual change in N stocks in mineral soils, [t N yr^{-1}]
SON_0 = soil organic N stock in the last year of an inventory time period, [t N]
$SON_{(0-T)}$ = soil organic N stock at the beginning of the inventory time period, [t N]
T = number of years over a single inventory time period, [yr]
D = Time dependence of stock change factors which is the default time period for transition between equilibrium **SON** values, yr. Commonly 20 years, but depends on assumptions made in computing the factors F_{LU}, F_{MG}, L_I. If T exceeds D, use the value for T to obtain an annual rate of change over the inventory time period (0-T years)
c = represents the climate zones, *s* the soil types, and *i* the set of management systems that are present in a country
SON_{REF} = the reference N stock, [t N ha^{-1}], from national soil inventory
F_{LU} = stock change factor for land-use systems or sub-system for a particular land-use. Note: F_{ND} is substituted for **F_{LU}** in forest soil N calculation to estimate the influence of natural disturbance; For default values see IPCC 2006 Volume 4 (Table 5.5. and Table 6.2.)
F_{MG} =stock change factor for management regime
F_I =stock change factor for input of organic matter
A = land area, [ha]

For the organic soil, the same basic equation will be used as in Tier 1 (eq. 5.6) but with country-specific information.

5.2 Stock changes in Other Lands

Nitrogen stock changes in Other Lands are assumed to be small and depend on the land cover.

Tier 1

For areas without soil, such as bare rock, changes in N stocks can be neglected. For areas with soils and vegetation nitrogen stock changes will mainly occur in the soil. For calculation of the changes in soil N stocks see equations 5.6.

In case of land conversion from forest land, cropland, grassland, wetlands, and settlements to Other Land, respectively it is assumed that the dominant vegetation is removed entirely, resulting in no N remaining in biomass after conversion. To estimate changes in biomass N stocks equation 5.1 can be applied. In this case, B_{AFTER} in equation 5.4.1 is set to zero. In case of Tier 1 B_{BEFORE} is estimated by multiplying average N content of above ground biomass by the area converted annually to Other Land (see Tables 24, 25, 22, 23).

For the calculation of N stock changes in dead organic matter after conversion to the Other Land Tier 1 assumes that there is no accumulation in DM stocks and hence it is not estimated.

N stock changes in organic soils are assumed to be minimal and very unlikely in other-lands. In case of conversion of wetland to Other Land the annual N loss can be estimated according the equation 5.1.

Tier 2

For Tier 2 country-specific data on N stocks in aboveground biomass are used. Removed biomass can be partially used as wood products or as fuel wood. Nitrogen losses due to biomass removals can be estimated according the equation 5.3.1. No stock changes in dead organic matter after conversion are assumed and therefore will be not computed. To estimate changes in N stocks for the mineral soils after the conversion equation 5.6.1 can be applied.

5.3 Stock changes in wetlands

Wetlands differ substantially in their above- and belowground properties, spanning from riverine forests to sphagnum peatland. In order to minimise this complexity and by taking into account potential data sources, the calculation of biomass stock changes is mainly based on the classification of the aboveground vegetation as forest or non-forest. This differentiation can be done with national and international wetland data bases and (if not available) by aerial photographs and/or satellite images. If classified as forest, biomass stock changes can be estimated by means of the equation 5.1. If the vegetation is dominated by shrubs and grasses, biomass stock changes are considered to be negligible.

Tier 1

Wetland soils generally accumulate nitrogen in undecomposed organic matter. Several studies (Yu 2012, Bridgham et al., 2006) present approaches and data for the calculation of northern peatland carbon stocks and dynamics, which can be adopted for the calculation of soil N stock changes in wetlands. For example, the change in the carbon pool can be used as a “tracer” for nitrogen by using C:N ratios of the organic matter. Hereby N-retention can be estimated as:

$$N_{retention} = C_{SOM_{accumulation}} \times C{:}N_{SOM} \qquad 5.7$$

The global average carbon soil organic matter (SOM) accumulation is around 118 g C $m^{-2}y^{-1}$ (range 20-140; Mitsch et al., 2012) and C:N ratio of SOM in wetland is around 30 (range 22-42; Maljanen et al., 2010.

For **Tier 2**, the same equation is used as in Tier 1 (eq. 5.7) but, more wetland classes are included and country specific C:N ratio are incorporated.

5.4 Suggested data sources

- CORINE land cover, contains information of the coverage and land use all over Europe: www.eea.europa.eu/data-and-maps/data/corine-land-cover; also FAO – www.fao.org

- IPCC 2006 guidelines (www.ipcc.ch) as well as EFDB (www.ipcc-nggip.iges.or.jp) provide information on biomass and SON stocks, growth rates of N pools, biomass conversion and expansion factors, wood density.
- National GHG inventory reports: http://unfeccc.int/national-reports/items/1408.php.
- National forest inventories: compiled at the European Forest Institute (EFI) - www.efi.int
- National monitoring data on forest management, national soil and climate data, vegetation inventories (e.g. Austrian Forest Inventory, Austrian Soil Condition Inventory).

6 Tables

Table 4: Canopy uptake; source Thimonier et al., 2005

Forest type	*Canopy N uptake (kg NH_4-N ha^{-1} a^{-1})*	*Canopy N uptake (kg NO_3-N ha^{-1} a^{-1})*
Coniferous	1.5	0.3
Deciduous	3.7	0.7
Forest Overall	2.8	0.5

Table 5: Reported ranges for biological N_2 fixation in natural ecosystems (source: Butterbach-Bahl et al. in Sutton et al., 2011).

Ecosystem Type	***N fixation rate (kg N ha^{-1} yr-^{1})***	***Source***
Boreal forests and boreal woodland	1.5-2	Cleveland et al., 1999
Temperate forests and forested foodplains	6.5-26.6	Cleveland et al., 1999
Natural grasslands	2.3-3.1	Cleveland et al., 1999
Mediterranean shrublands	1.5-3.5	Cleveland et al., 1999

Table 6: Average and total simulated N_2O and NO emissions from forest soils for individual European countries using meteorology for the years 1990, 1995 and 2000 (Source: Kesik et al. 2005)

Country	*Forested Area km²*	*1990*				*1995*				*2000*			
		N_2O		*NO*		*N_2O*		*NO*		*N_2O*		*NO*	
		kg N ha^{-1} yr^{-1}	*ktN yr^{-1}*	*kg N ha^{-1} yr^{-1}*	*ktN yr^{-1}*	*kg N ha^{-1} yr^{-1}*	*ktN yr^{-1}*	*kg N ha^{-1} yr^{-1}*	*ktN yr^{-1}*	*kg N ha^{-1} yr^{-1}*	*ktN yr^{-1}*	*kg N ha^{-1} yr^{-1}*	*ktN yr^{-1}*
Andorra	232	0.70	1.6×10^{-2}	1.04	0.02	0.20	5.0×10^{-3}	0.28	6.6×10^{-3}	0.23	5.3×10^{-3}	0.36	8.4×10^{-3}
Austria	24 032	0.86	2.08	0.72	1.73	0.60	1.44	0.48	1.14	0.64	1.53	0.62	1.50
Belgium	7 699	0.76	0.58	1.56	1.20	0.61	0.47	1.26	0.97	0.94	0.72	1.96	1.51
Bulgaria	28 494	0.95	2.71	0.80	2.27	0.58	1.64	0.64	1.82	0.70	1.99	0.56	1.61
Croatia	12 574	0.86	1.08	0.93	1.16	0.58	0.73	0.72	0.91	0.60	0.76	0.69	0.87
Czech. Republic	20 406	0.60	1.23	1.05	2.13	0.52	1.07	0.80	1.63	0.68	1.38	1.09	2.23
Denmark	18 608	0.58	1.08	0.85	1.58	0.48	0.90	0.68	1.26	0.70	1.30	0.94	1.75
Estonia	18 341	0.51	0.93	0.49	0.90	0.70	1.28	0.60	1.11	0.57	1.05	0.72	1.32
Finland	159 676	0.77	12.35	0.56	8.88	0.74	11.79	0.64	10.25	0.65	10.30	0.58	9.32
France	132 395	0.57	7.60	0.67	8.84	0.46	6.07	0.53	7.07	0.55	7.26	0.72	9.58
Germany	117 848	0.72	8.48	1.16	13.70	0.58	6.84	0.93	10.93	0.77	9.09	1.30	15.28
Gibraltar	0.43	0.55	2.4×10^{-5}	0.07	3.0×10^{-6}	0.54	2.3×10^{-5}	0.03	1.3×10^{-6}	0.55	2.4×10^{-6}	0.05	2.2×10^{-6}
Greece	30 676	0.68	2.09	0.45	1.38	0.53	1.64	0.36	1.11	0.55	1.68	0.35	1.07
Hungary	21 181	0.57	1.21	0.49	1.03	0.57	1.22	0.49	1.03	0.75	1.59	0.49	1.04
Irish Republic	5 523	0.17	0.09	0.34	0.19	0.14	0.08	0.25	0.14	0.18	0.10	0.37	0.20
Italy	59 834	0.91	5.43	0.78	4.68	0.60	3.57	0.64	3.84	0.59	3.56	0.63	3.78
Latvia	28 229	0.42	1.19	0.72	2.04	0.74	2.08	0.74	2.08	0.73	2.07	0.79	2.24
Liechtenstein	89	0.87	7.7×10^{-3}	0.39	3.4×10^{-3}	0.97	8.6×10^{-3}	0.23	2.1×10^{-3}	0.77	6.8×10^{-3}	0.27	2.4×10^{-3}
Lithuania	18 843	0.63	0.55	0.43	0.82	0.43	0.81	0.42	0.79	0.53	1.01	0.52	0.98
Luxembourg	1 032	0.29	0.07	0.98	0.10	0.53	0.05	0.84	0.09	0.64	0.07	1.09	0.11
Monaco	0.21	0.21	4.3×10^{-6}	0.12	2.5×10^{-6}	0.26	5.4×10^{-6}	0.22	4.7×10^{-6}	0.26	5.5×10^{-6}	0.16	3.3×10^{-6}
Netherlands	8 271	0.99	0.82	2.39	1.98	0.77	0.64	1.84	1.52	1.26	1.04	3.01	2.49
Norway	159 482	0.19	2.99	0.05	0.86	0.23	3.62	0.04	0.63	0.17	2.69	0.05	0.72
Poland	76 358	0.52	4.00	1.10	8.37	0.50	3.79	0.87	6.65	0.59	4.53	1.06	8.06
Portugal	32 713	0.39	1.26	0.20	0.66	0.38	1.26	0.13	0.42	0.36	1.18	0.10	0.33
Romania	41 284	0.85	3.50	0.76	3.13	0.60	2.49	0.68	2.80	0.96	3.95	0.70	2.88
San Marino	0.35	0.27	9.4×10^{-6}	0.31	1.1×10^{-5}	0.28	9.8×10^{-6}	0.31	1.1×10^{-5}	0.30	1.0×10^{-5}	0.26	9.1×10^{-6}
Slovakia	9 162	0.70	0.64	0.83	0.76	0.74	0.67	0.67	0.61	0.94	0.86	0.87	0.80
Slovenia	7 881	1.14	0.90	1.30	1.02	0.67	0.52	0.87	0.69	0.82	0.65	1.10	0.87
Spain	138 484	0.65	8.97	0.37	5.19	0.60	8.36	0.29	3.98	0.57	7.94	0.27	3.80

Sweden	196 236	0.68	13.43	1.14	22.33	0.68	13.34	1.03	20.20	0.61	11.94	1.19	23.27
Switzerland	12 407	0.81	1.01	0.54	0.67	0.54	0.67	0.33	0.41	0.60	0.75	0.47	0.58
United Kingdom	22 481	0.22	0.49	0.33	0.75	0.24	0.53	0.35	0.80	0.27	0.60	0.44	0.99
Sum	1 410 477		86.78		98.37		77.59		84.89		81.59		99.20
Average		0.62		0.70		0.55		0.60		0.58		0.70	

Table 7: Linear regression models and associated regressions coefficients between N_2O-N and NO-N (Source: Pilegaard et al., 2006)

	Parameter	*Coefficient*
NO emission all (r^2=0.71)	intercept	-3.29
	N deposition	19.45
	type (deciduous)	-22.45
NO emission coniferous (r^2=0.82)	intercept	-13.93
	N deposition	25.52
NO emission deciduous (r^2=0.004)	intercept	3.52
	N deposition	0.37
N_2O emission all (r^2=0.67)	intercept	26.47
	C/N	-0.67
	age	-0.07
N_2O emission C/N<20 (r^2=0.25)	Intercept	31.76
	C/N	-1.5
ln(N_2O emission) all (r^2=0.87)	Intercept	4.82
	C/N	-0.14
	Age	-0.01
N_2O emission all (r^2=0.03)	Intercept	9.6
	N deposition	-0.33

Table 8: Predicted rates of NO_3^- leaching from forest (source: MacDonald et al., 2002)

Throughfall N (kg ha-1 y-1)	*C: N ratio organic layer*	*Leached N (low/high 95% CI)*
10	≤25	3 (0-11)
10	>25	2 (0-11)
20	≤25	8 (0-18)
20	>25	4 (0-14)
30	≤25	15 (5-25)
30	>25	9 (0-18)

Table 9: Mean C:N ratios of the tops soil (0-10cm) with their 95% confidence interval (in brackets) grouped by WRB reference soil groups for the eight most frequently recorded main tree species on ICP Forests (Source: Cools et al., 2014)

Mean tree specie *Reference soil group*	*Scote pine*	*Norway spruce*	*Common beach*	*Silver birch*	*Pedunculate oak*	*Holm oak*	*Maritime pine*	*Aleppo pine*
Arenosols	20.9 (20.4;21.4)	20.8 (19.0;22.4)		17.6 (16.0;20.2)	19.4 (17.7;21.9)	14.4 (12.9;16.0)	27.9 (23.0;32.8)	
Cambisols	20.3 (19.3;21.5)	18.3 (17.8;18.8)	15.7 (15.2;16.2)	16.6 (15.4;18.4)	15.3 (14.7;15.9)		24.6 (21.6;30.1)	13.3 (10.3;15.2)
Gleysols	20.9 (18.7;23.4)	18.3 (16.5;20.4)		17.2 (14.7;21.5)				
Histosols	30.7 (29.2;32.2)	26.4 (24.4;30.8)		16.7 (15.1;18.4)				
Leptosols	20.2 (18.6;22.0)	18.4 (17.4;19.5)	15.8 (14.7;17.6)			13.5 (12.6;14.6)		17.0 (14.3;20.0)
Luvisols	16.4 (14.4;18.2)	14.9 (13.9;15.8)	14.9 (14.2;15.7)		15.1 (14.2;16.1)			
Phaeozems	18.2 (16.6;20.3)	17.2 (16.3;18.5)	14.9 (14.0;16.2)					
Podzols	23.6 (22.9;24.5)	20.8 (20.1;21.6)		22.0 (19.4;25.4)			30.5 (26.6;34.5)	
Regosols	21.5 (20.8;22.2)	19.4 (18.8;20.0)	16.6 (14.9;18.5)	21.0 (18.3;24.2)		13.7 (12.2;15.5)	23.8 (20.8;26.2)	15.1 (11.3;20.2)

Stagnosols	21.3 (19.8;22.9)	19.3 (18.0;20.7)	17.5 (16.0;20.2)		16.4 (14.7;18.2)			
Umbrisosl	16.1 (14.4;17.9)	18.0 (16.7;19.2)	18.0 (16.7;19.2)				20.0 (18.0;22.0)	

Table 10: An overview of ranges in N leaching as a function of the N status of the ecosystem (Source Gundersen et al., 2006) Predicted rates of NO_3^- leaching from forest (source: MacDonald et al., 2002)

Nitrogen status	*Low status (N-limited)*	*Intermediate*	*High N status (N-saturated)*
Input [kg N ha-1y-1]	0-15	15-40	40-100
Needle N (in spruce) [%]	<1.4	1.4-1.7	1.7-2.5
C:N ratio	>30	25-30	<25
Soil flux density proxy (litterfall + throughfall) [kg N ha-1y-1]	<60	60-80	>80
Proportion of input leached	**<10**	**0-60**	**30-100**

Table 11: Coniferous and non-coniferous industrial round wood removals (1000 m^3), adapted in accordance to the UNECE/FAO database

	Coniferous					Non- Coniferous				
	2007	2008	2009	2010	2011	2007	2008	2009	2010	2011
Albania	30.67	30.67	30.67	30.67	30.67	49.33	49.33	49.33	49.33	49.33
Austria	15569.62	15722.44	11343.93	12542.29	12783.58	951.35	1049.30	799.95	739.16	846.96
Belgium	3275.00	3060.00	2800.00	3138.67	3231.25	1000.00	940.00	870.00	975.23	1004.00
Bosnia and Herzegovina	1581.00	1715.00	1393.53	1575.00	1732.00	832.00	856.00	706.00	780.00	803.00
Bulgaria	1800.00	1979.00	1077.00	1682.00	2005.00	1370.00	1400.00	1147.00	1329.00	1359.00
Croatia	642.00	643.00	607.00	591.00	678.00	2807.00	3063.00	2773.00	2830.00	3158.00
Cyprus	11.68	12.39	4.93	5.03	4.63	0.27	0.74	1.23	0.30	0.32
Czech Republic	15868.00	13487.00	12888.00	13729.00	12291.00	870.00	820.00	881.00	1042.00	1176.00
Denmark	1299.00	1299.00	1299.00	1210.62	1117.74	161.00	381.00	408.00	379.31	350.21
Estonia	2376.00	2497.50	2758.50	3564.00	3699.00	1134.00	1210.50	1345.50	1692.00	1755.00
Finland	44591.67	38612.20	30543.32	38758.41	38354.77	6814.06	7353.05	6157.52	7218.27	7171.41
France	19634.18	18051.42	20918.67	21263.50	19585.10	10182.48	9673.03	8162.10	8370.75	8802.05
Germany	59159.00	38277.00	32531.04	37941.62	36443.37	8870.00	8529.00	6455.62	7446.21	8914.85
Greece	801.42	801.42	801.42	801.42	801.42	146.66	146.66	146.66	146.66	146.66
Hungary	631.00	505.00	579.00	624.01	648.57	2130.00	2210.00	1785.70	2122.28	2273.19

	Coniferous					Non- Coniferous				
Iceland	-	-	-	-	-	-	-	-	-	-
Ireland	2671.00	2179.00	2258.55	2436.61	2431.07	7.00	1.00	2.95	0.36	1.41
Israel	23.46	23.46	23.46	23.46	23.00	1.50	1.50	1.50	1.50	2.00
Italy	1439.82	1370.47	1406.04	1399.09	1253.06	1551.29	1623.21	1322.04	1248.14	409.37
Latvia	7117.80	5830.53	6635.63	6991.11	8445.20	4027.10	2376.80	2070.40	3230.71	3203.91
Liechtenstein	8.50	9.35	9.00	8.00	7.00	3.50	4.20	1.00	1.00	1.00
Lithuania	2940.00	2274.89	2123.03	3153.27	3332.00	1950.00	1937.68	1553.69	2000.59	2014.00
Luxembourg	96.86	96.86	113.03	113.41	107.16	173.39	235.39	144.25	144.74	136.75
Malta	-	-	-	-	-	-	-	-	-	-
Montenegro	83.00	275.00	177.00	177.00	177.00	109.00	54.00	31.00	31.00	31.00
Netherlands	515.24	566.13	488.77	532.16	470.88	216.81	260.97	237.36	258.43	217.07
Norway	8138.25	7982.42	6528.21	8248.94	8467.60	73.67	88.36	102.62	73.49	38.69
Poland	25479.52	23570.69	23420.10	24460.71	24968.83	6981.44	6898.90	7055.15	6882.29	7231.38
Portugal	3636.98	3115.67	3419.45	3451.60	3257.61	6585.90	6453.08	5544.62	5596.76	5282.20
Romania	5934.00	4693.80	4228.10	4728.58	5107.85	5638.00	4823.50	4359.20	5819.47	5236.61
Serbia	232.00	267.00	243.00	252.00	228.00	1195.00	1348.00	1116.00	1161.00	1133.00
Slovakia	4794.55	5903.70	5924.13	6089.63	5124.05	2920.31	2810.35	2576.77	2999.55	3445.87

	Coniferous					Non- Coniferous				
Slovenia	1662.32	1616.24	1468.41	1419.34	1582.24	431.05	445.53	479.21	422.06	469.46
Spain	6612.00	7270.93	5348.58	5285.22	4615.72	5934.00	7156.44	6551.46	5684.18	6912.05
Sweden	68290.00	61550.00	56150.00	62390.00	62333.33	4010.00	3350.00	3050.00	3910.00	3870.00
Switzerland	3687.26	3222.88	2848.37	2967.48	2840.40	610.78	532.59	438.74	471.91	481.69
The fYR of Macedonia	65.00	95.00	45.00	40.00	55.00	90.00	98.00	64.00	61.00	66.00
Turkey	8501.00	9042.00	8676.00	9521.00	10147.00	5173.00	5420.00	5576.00	6174.00	6276.00
United Kingdom	8439.00	7744.84	7516.43	8218.75	8664.59	123.00	114.52	118.90	118.41	123.08
Armenia	-	-	-	-	-	6.00	2.00	2.00	1.00	1.00
Azerbaijan	-	-	-	-	-	3.30	3.30	3.30	3.30	3.30
Belarus	5386.00	5386.00	4490.50	5428.00	5428.00	2025.10	2025.10	2227.50	2644.60	2644.60
Georgia	31.87	31.87	31.87	31.87	31.87	73.13	73.13	73.13	73.13	73.13
Kazakhstan	170.20	170.20	50.00	55.00	55.00	27.70	27.70	24.00	18.00	18.00
Kyrgyzstan	2.79	2.79	2.79	2.79	2.79	6.51	6.51	6.51	6.51	6.51
Republic of Moldova	-	-	-	-	-	43.00	43.00	43.00	43.00	43.00
Russian Federation	120100.00	101200.00	85300.00	103464.32	116471.26	41900.00	35500.00	27600.00	32611.76	36711.53
Ukraine	4749.70	4749.70	4297.59	5138.69	5540.63	2614.70	2614.70	1884.01	2397.31	2448.77
Uzbekistan	-	-	-	-	-	9.00	8.00	8.00	8.00	8.00

Table 12: Coniferous and non-coniferous round wood exports (1000 m^3), adapted in accordance to the UNECE/FAO database

	Coniferous					Non- Coniferous				
	2007	2008	2009	2010	2011	2007	2008	2009	2010	2011
Albania	0.03	0.03	0.03	0.03	0.03	0.43	0.43	0.43	0.43	0.43
Austria	719.00	849.00	648.43	856.15	919.57	157.00	125.00	80.35	98.72	97.86
Belgium	575.86	588.72	432.22	505.55	595.30	238.13	511.89	232.56	349.46	418.49
Bosnia and Herzegovina	67.79	36.70	86.99	92.09	86.72	51.41	85.00	35.43	125.32	141.69
Bulgaria	100.87	98.68	91.84	172.12	164.00	687.55	240.02	113.24	312.85	344.00
Croatia	29.00	32.00	17.00	5.00	16.00	492.00	455.00	423.00	573.00	580.00
Cyprus	-	-	-	-	-	0.00	-	-	-	-
Czech Republic	2300.00	1825.00	2514.00	1658.00	3100.00	84.00	81.00	82.00	85.00	387.20
Denmark	768.32	745.07	536.58	646.14	563.82	77.87	217.32	541.44	128.49	113.29
Estonia	662.33	671.68	581.17	1142.25	1468.89	840.10	796.87	499.21	1108.24	1140.74
Finland	605.67	664.47	504.90	473.54	654.45	40.83	45.16	28.83	9.58	22.88
France	2148.06	1944.95	3496.49	4953.47	4765.73	1817.89	1601.76	1550.88	1711.08	1614.46
Germany	6117.00	5606.00	3017.26	2783.12	2440.46	1557.00	1431.00	839.42	942.50	1112.40
Greece	23.30	23.20	23.20	23.20	23.20	7.08	7.08	7.08	7.08	7.08
Hungary	351.00	213.70	311.89	292.20	264.21	703.00	447.20	372.40	580.87	612.74

	Coniferous					Non- Coniferous				
Iceland	-	-	-	0.01	-	-	-	-	-	-
Ireland	295.00	247.03	270.82	338.74	298.18	13.00	10.58	9.79	11.20	12.88
Israel	-	0.97	2.30	0.59	0.59	-	0.06	-	-	-
Italy	6.00	22.62	18.10	29.54	59.00	10.70	10.58	8.46	17.00	46.00
Latvia	1712.06	1606.44	1335.42	1841.96	2218.49	1977.56	1586.14	1167.17	2315.82	2182.18
Liechtenstein	6.00	6.00	6.00	4.00	4.00	2.00	2.00	1.00	1.00	-
Lithuania	865.40	558.12	399.59	851.15	1172.06	805.38	613.31	273.54	478.34	671.92
Luxembourg	257.12	257.95	201.65	87.82	149.22	41.42	121.46	29.71	1.94	2.95
Malta	-	-	-	-	-	-	-	-	-	-
Montenegro	44.32	36.60	14.46	14.46	14.46	2.86	36.60	14.46	14.46	14.46
Netherlands	563.20	391.80	323.40	409.00	295.76	98.20	96.90	64.60	68.30	109.60
Norway	939.94	867.57	842.66	843.07	924.85	9.50	29.43	25.24	21.73	13.88
Poland	266.81	279.57	899.41	1450.22	1607.32	69.19	89.06	71.55	134.31	195.72
Portugal	115.00	17.58	19.88	3.92	15.95	1411.00	1327.14	582.49	996.95	1016.89
Romania	18.00	77.90	42.24	151.17	403.23	137.00	131.96	125.06	169.89	294.31
Serbia	2.00	16.00	1.00	15.00	3.00	68.00	29.00	12.00	18.00	29.00
Slovakia	923.00	1755.88	2116.30	2074.53	1987.72	534.00	436.21	421.99	359.38	545.17

	Coniferous					Non- Coniferous				
Slovenia	308.57	274.15	306.09	337.48	512.89	197.18	201.38	200.78	228.14	295.40
Spain	161.56	135.74	208.07	383.39	448.00	203.00	878.53	598.67	948.62	1518.52
Sweden	3794.00	2334.09	1165.00	1205.95	826.21	14.00	15.09	12.00	10.62	20.08
Switzerland	1026.62	776.21	575.03	527.05	674.93	978.77	378.96	-	268.59	250.70
The fYR of Macedonia	-	0.67	0.17	0.05	1.29	15.00	1.56	0.58	1.24	0.53
Turkey	3.00	0.60	1.00	5.80	3.20	8.00	4.26	12.00	1.60	0.60
United Kingdom	745.57	719.49	341.08	458.21	574.67	12.43	7.04	3.72	3.63	3.63
Armenia	-	-	-	-	-	2.62	-	0.70	0.01	0.01
Azerbaijan	-	-	-	-	-	0.01	0.01	0.01	0.01	0.01
Belarus	1151.20	1151.20	553.60	978.00	1119.07	291.80	291.80	921.50	1239.30	1390.07
Georgia	-	-	-	-	-	0.94	0.94	0.94	0.94	0.94
Kazakhstan	-	-	-	0.06	0.06	-	-	-	0.02	0.02
Kyrgyzstan	-	-	-	-	-	0.30	0.30	-	-	-
Republic of Moldova	-	-	-	-	-	2.55	2.55	2.55	2.55	2.55
Russian Federation	35100.00	25034.00	18300.00	16482.43	16284.00	14000.00	11750.00	3400.00	4500.08	4144.94
Ukraine	1348.00	1348.00	1348.00	2143.90	2217.28	1234.20	1234.20	1234.20	788.30	790.80
Uzbekistan	2.06	2.06	2.06	2.06	2.06	2.06	2.06	2.06	2.06	2.06

Table 13: Coniferous and non-coniferous wood fuel removals (1000 m³), adapted in accordance to the UNECE/FAO database

	Coniferous					Non- Coniferous				
	2007	2008	2009	2010	2011	2007	2008	2009	2010	2011
Albania	-	-	-	-	-	350,00	350,00	350,00	350,00	1100,00
Austria	3056.78	3162.04	2735.01	2754.36	2943.69	1739.60	1861.65	1848.54	1795.16	2121.45
Belgium	50.00	50.00	50.00	49.21	61.57	690.00	650.00	675.00	664.32	831.18
Bosnia and Herzegovina	11.00	8.00	2.00	2.00	2.00	1328.00	1432.00	1327.00	1258.00	1312.00
Bulgaria	267.00	302.00	223.00	278.00	305.00	2259.00	2390.00	2152.00	2379.00	2536.00
Croatia	15.00	12.00	14.00	22.00	29.00	746.00	751.00	848.00	1034.00	1393.00
Cyprus	6.94	5.96	2.90	3.19	2.94	0.79	0.75	0.82	0.43	0.61
Czech Republic	1410.00	1390.00	1159.00	1337.00	1049.00	360.00	490.00	574.00	628.00	865.00
Denmark	825.00	825.00	825.00	805.24	832.02	281.00	281.00	281.00	274.27	283.39
Estonia	360.00	432.00	495.00	720.00	747.00	630.00	720.00	801.00	1224.00	1269.00
Finland	2580.86	1775.62	1775.62	1775.62	1775.44	2625.60	2929.59	3176.69	3199.23	3465.14
France	2476.59	2503.21	2536.64	2617.36	2665.34	22289.30	22528.91	22829.78	23556.21	23988.06
Germany	4454.00	4476.00	4518.81	4498.78	5266.39	4245.00	4085.00	4567.81	4531.74	5516.97
Greece	113.80	113.80	113.80	113.80	113.80	681.04	681.04	681.04	681.04	681.04
Hungary	129.00	75.60	141.50	96.86	113.65	2750.00	2485.40	2737.80	2897.13	3038.06

	Coniferous					Non- Coniferous				
Ireland	12.00	24.00	87.27	77.73	73.77	20.00	28.00	80.00	103.29	120.77
Israel	1.54	1.54	1.54	1.54	1.50	0.50	0.50	0.50	0.50	0.50
Italy	445.33	492.37	581.10	674.51	633.55	4688.53	5180.97	4771.16	4522.05	4009.76
Latvia	617.00	257.31	801.36	994.16	558.41	411.00	341.11	934.92	1317.84	625.98
Liechtenstein	9.00	4.80	4.00	5.00	6.00	4.00	9.90	11.00	11.00	12.00
Lithuania	540.00	434.32	611.52	647.67	552.00	765.00	947.49	1171.29	1295.33	1106.00
Luxembourg	2.73	2.73	3.78	3.85	4.01	17.84	17.84	12.73	12.95	13.51
Montenegro	40.00	8.00	7.00	7.00	7.00	225.00	148.00	149.00	700.00	700.00
Netherlands	50.00	50.00	50.00	50.00	50.00	240.00	240.00	240.00	240.00	240.00
Norway	762.11	762.11	762.11	772.03	588.96	1490.66	1490.66	1490.66	1348.62	1195.77
Poland	1789.67	1906.69	2072.96	2068.30	2460.24	1683.94	1897.14	2080.96	2056.11	2519.53
Portugal	200.00	200.00	200.00	200.00	200.00	400.00	400.00	400.00	400.00	400.00
Romania	733.00	838.50	694.00	411.18	749.78	3036.00	3311.20	3275.20	2152.41	3264.40
Serbia	81.00	68.00	72.00	103.00	124.00	1473.00	1503.00	1706.00	6120.00	6221.00
Slovakia	230.59	320.85	351.54	293.05	324.80	186.04	233.67	234.56	216.84	318.20
Slovenia	126.30	130.54	113.76	136.38	176.67	661.98	797.75	868.84	967.66	1159.50
Spain	259.00	600.00	580.00	620.00	620.00	1723.00	2000.00	1500.00	4500.00	4500.00

	Coniferous					Non- Coniferous				
Sweden	2950.00	2950.00	2950.00	2950.00	2950.00	2950.00	2950.00	2950.00	2950.00	2950.00
Switzerland	430.15	424.26	434.08	461.26	477.52	791.83	770.63	980.58	1037.39	1061.39
The fYR of Macedonia	1.00	4.00	7.00	7.00	1.00	478.00	512.00	523.00	523.00	475.00
Turkey	1753.00	1922.00	2049.00	1976.00	1962.00	2892.00	3036.00	2999.00	2926.00	2654.00
United Kingdom	196.00	294.60	638.30	1031.10	883.80	263.00	262.50	350.00	350.00	350.00
Armenia	-	-	-	-	-	40.00	1368.00	1500.00	1750.00	2074.00
Azerbaijan	-	-	-	-	-	3.20	3.20	3.20	3.20	3.20
Belarus	431.30	431.30	671.42	734.85	734.85	913.70	913.70	1422.38	1556.75	1556.75
Georgia	146.60	146.60	146.60	146.60	146.60	586.40	586.40	586.40	586.40	586.40
Kazakhstan	40.80	40.80	199.89	223.74	223.74	8.80	8.80	43.11	48.26	48.26
Kyrgyzstan	5.40	5.40	8.55	10.98	10.98	12.60	12.60	19.95	25.62	25.62
Republic of Moldova	2.50	2.50	2.50	2.50	2.50	306.30	306.30	306.30	306.30	306.30
Russian Federation	17900.00	17500.00	15100.00	22535.68	25368.74	27100.00	27200.00	23400.00	16388.24	18448.47
Tajikistan	45.00	45.00	45.00	45.00	45.00	45.00	45.00	45.00	45.00	45.00
Turkmenistan	-	-	-	-	-	10.00	10.00	10.00	10.00	10.00
Ukraine	3807.49	3807.49	5589.45	5870.76	6492.16	5712.41	5712.41	2450.35	2738.84	3028.74
Uzbekistan	-	-	-	-	-	23.00	22.00	22.00	22.00	22.00

Table 14: Fuel wood exports (1000 m^3), adapted in accordance to the UNECE/FAO database

	Removals					Exports				
	2007	2008	2009	2010	2011	2007	2008	2009	2010	2011
Albania	350.00	350.00	350.00	350.00	1100.00	56.30	56.30	56.30	56.30	56.30
Austria	4796.38	5023.69	4583.55	4549.51	5065.14	45.00	39.00	76.62	75.76	64.40
Belgium	740.00	700.00	725.00	713.53	892.75	6.59	6.14	18.20	17.48	16.80
Bosnia and Herzegovina	1339.00	1440.00	1329.00	1260.00	1314.00	289.80	434.01	463.81	488.69	596.92
Bulgaria	2526.00	2692.00	2375.00	2657.00	2841.00	104.22	74.38	73.14	194.40	411.53
Croatia	761.00	763.00	862.00	1056.00	1422.00	314.00	241.00	312.00	247.00	484.00
Cyprus	7.73	6.70	3.72	3.63	3.55	-	-	-	-	-
Czech Republic	1770.00	1880.00	1733.00	1965.00	1914.00	127.00	100.00	133.61	96.00	112.00
Denmark	1106.00	1106.00	1106.00	1079.51	1115.41	32.64	31.57	53.29	77.26	115.45
Estonia	990.00	1152.00	1296.00	1944.00	2016.00	41.32	87.28	194.80	202.65	188.98
Finland	5206.45	4705.21	4952.30	4974.85	5240.58	9.31	6.67	5.77	18.82	53.36
France	24765.89	25032.12	25366.43	26173.57	26653.39	501.32	456.27	589.98	813.77	848.15
Germany	8699.00	8561.00	9086.61	9030.52	10783.35	83.00	144.00	153.16	133.07	99.36
Greece	794.84	794.84	794.84	794.84	794.84	5.41	5.41	5.41	5.41	5.41
Hungary	2879.00	2561.00	2879.30	2993.98	3151.71	220.00	166.10	227.76	246.05	398.66

	Removals					Exports				
Iceland	-	-	-	-	-	-	-	-	-	0.00
Ireland	32.00	52.00	167.27	181.02	194.54	0.01	4.54	4.71	0.04	0.07
Israel	2.04	2.04	2.04	2.04	2.00	-	-	-	-	-
Italy	5133.86	5673.34	5352.26	5196.56	4643.30	0.75	0.66	0.53	1.00	0.83
Latvia	1028.00	598.42	1736.28	2312.00	1184.38	450.02	470.85	1046.30	1329.09	863.68
Liechtenstein	13.00	14.70	15.00	16.00	18.00	-	1.00	1.00	1.00	1.00
Lithuania	1305.00	1381.81	1782.81	1943.00	1658.00	47.47	62.69	103.12	112.47	145.96
Luxembourg	20.57	20.57	16.51	16.80	17.52	3.06	0.02	0.04	12.40	20.40
Montenegro	265.00	156.00	156.00	707.00	707.00	29.60	3.45	6.62	6.62	6.62
Netherlands	290.00	290.00	290.00	290.00	290.00	44.10	41.30	52.20	31.80	25.10
Norway	2252.77	2252.77	2252.77	2120.65	1784.74	2.61	2.31	4.82	19.06	24.27
Poland	3473.60	3803.83	4153.92	4124.42	4979.78	51.47	67.31	118.29	149.01	101.21
Portugal	600.00	600.00	600.00	600.00	600.00	9.00	2.19	14.41	2.09	1.26
Romania	3769.00	4149.70	3969.20	2563.59	4014.18	24.00	47.19	57.42	108.22	134.31
Serbia	1554.00	1571.00	1778.00	6223.00	6345.00	2.00	3.00	-	3.00	12.00
Slovakia	416.62	554.52	586.10	509.89	643.00	76.00	97.24	147.41	129.79	150.71
Slovenia	788.28	928.29	982.60	1104.05	1336.17	199.99	248.84	260.08	278.40	334.15

	Removals					Exports				
Spain	1982.00	2600.00	2080.00	5120.00	5120.00	171.03	153.17	60.94	59.23	77.24
Sweden	5900.00	5900.00	5900.00	5900.00	5900.00	78.00	103.91	31.65	39.47	45.94
Switzerland	1221.98	1194.89	1414.66	1498.65	1538.92	22.11	23.73	25.19	24.67	18.15
The fYR of Macedonia	479.00	516.00	530.00	530.00	476.00	5.00	2.64	0.02	0.05	0.32
Turkey	4645.00	4958.00	5048.00	4902.00	4616.00	-	-	0.02	0.01	-
United Kingdom	459.00	557.10	988.30	1381.10	1233.80	164.90	106.00	65.14	159.92	146.16
Armenia	40.00	1368.00	1500.00	1750.00	2074.00	-	-	-	-	-
Azerbaijan	3.20	3.20	3.20	3.20	3.20	-	-	-	-	-
Belarus	1345.00	1345.00	2093.80	2291.60	2291.60	74.55	74.55	4.39	4.62	10.88
Georgia	733.00	733.00	733.00	733.00	733.00	-	-	-	-	-
Kazakhstan	49.60	49.60	243.00	272.00	272.00	-	0.04	-	-	-
Kyrgyzstan	18.00	18.00	28.50	36.60	36.60	-	0.30	0.16	0.16	0.16
Republic of Moldova	308.80	308.80	308.80	308.80	308.80	-	-	-	-	-
Russian Federation	45000.00	44700.00	38500.00	38923.92	43817.21	200.00	274.61	589.36	193.32	270.90
Tajikistan	90.00	90.00	90.00	90.00	90.00	-	-	-	-	-
Turkmenistan	10.00	10.00	10.00	10.00	10.00	-	-	-	-	-
Ukraine	9519.90	9519.90	8039.80	8609.60	9520.90	814.24	814.24	814.24	738.40	1143.78
Uzbekistan	23.00	22.00	22.00	22.00	22.00	-	-	-	-	-

Table 15: Basic wood density (D) of selected temperate and boreal tree taxa; source IPCC, 2006

Taxon	*D [oven-dry t (moist m^{-3})]*	*Source*
Abies spp.	0.4	2
Acer spp.	0.52	2
Alnus spp.	0.45	2
Betula spp.	0.51	2
Fagus sylvatica	0.58	2
Fraxinus spp.	0.57	2
Larix decidua	0.46	2
Picea abies	0.4	2
Picea sitchensis	0.4	3
Pinus pinaster	0.44	4
Pinus radiata	0.38 (0.33-0.45)	1
Pinus strobus	0.32	2
Pinus sylvestris	0.42	2
Populus spp.	0.35	2
Prunus spp.	0.49	2
Pseudotsuga menziesii	0.45	2
Quercus spp.	0.58	2
Salix spp.	0.45	2
Tilia spp.	0.43	2
Average	**0.45**	

1 = Beets et al., 2001
2 = Dietz, 1975
3 = Knigge and Schulz, 1966
4= Rijsijk and Laming, 1994

Table 16: Nitrogen fraction of aboveground forest biomass (NF).

Tree types	*Compartment*	*Nitrogen fraction (NF) (g kg^{-1})*	*References*
Evergreens (*Pinus sylvestris, Pinus nigra, Picea abies, Abies alba, Pseudotsuga menziesii*)	foliage	13.2 ± 3.0 (n=77)	Jacobsen, 2002 Meerts, 2002 Cole, 1981 Genenger, 2003 Kram, 1997 Bauer, 1997
	branches	4.5 ± 1.9 (n=71)	
	stems	1.2 ± 0.5 (n=62)	
	coarse roots	3.0 ± 2.7 (n=27)	
	fine roots	10.0 ± 3.7 (n=23)	
	whole tree (Sweden + Finland, Pinus/Picea)	3.4 ± 1.5	
	whole tree (Austria + Germany, Picea)	2.8 ± 1.2	
	whole tree (Ireland, Picea)	2.7 ± 1.2	
	whole tree (Spain, Pinus/Abies)	2.9 ± 1.5	
Broadleaves (*Fagus silvestris, Quercus Petraea, Quercus robur, Fraxinus excelsior, Betula sp.*)	foliage	26.0 ± 3.2 (n=48)	Jacobsen, 2002 Hagen-Thorn, 2004 Witthaker, 1979 Bauer, 1997 Meerts, 2002 Cole, 1981 Andre, 2003
	branches	4.6 ± 1.6 (n=24)	
	stems	1.4 ± 0.5 (n=36)	
	coarse roots	3.6 ± 1.6 (n=16)	
	fine roots	9.3 ± 3.6 (n=13)	
	whole tree (Sweden + Finland, mixed broadleaves)	4.3 ± 1.2	
	whole tree (Austria + Germany, Fagus)	2.8 ± 0.9	
	whole tree (Spain, Quercus p./Populus)	2.9 ± 1.0	
Mediterranean broadleaves (*Quercus ilex*)	foliage	13.3 (n=1)	Cole, 1981
	branches	5.0 (n=1)	
	stems	2.2 (n=1)	
	coarse roots	-	
	fine roots	-	
Larix kaempferi	foliage	27.0 (n=1)	Jacobsen, 2002
	branches	6.2 ± 1.3 (n=2)	
	stems	1.2 ± 0.4 (n=3)	
	coarse roots	2.8 (n=1)	
	fine roots	-	

Table 19: Biological N_2 fixation in the wetlands (Source: Reddy and DeLaune, 2008)

Wetland type	*Biological N_2 fixation (kg N ha^{-1} $year^{-1}$)*	
	Minimum	*Maximum*
Rice paddies	7	175
Coastal wetlands	4	460
Freshwater marshes	0	58
Cypress swamps	4	29
Peat bog	0	22
Flax Pond mud flats	7	0
Estuaries	1	18
Oligotrophic lakes	0	18
Mesotrophic lakes	0	1
Eutrophic lakes	2	91

Table 20: Enhanced Wetland Classification class crosswalk to inferred nutrient classes (Source: Smith et al., 2007)

Nutrient Class			***Enhanced Wetland Classification Classes***
		Main categories	Examples
High	**Very Rich**	Marsh	Emergent Marsh, Mudflats, Meadow Marsh
Dissolved available nutrients	**Rich**	Swamp, Fen	Mixedwood Swamp, Hardwood Swamp, Shrub Swamp, Shrubby Rich Fen, Graminoid Rich Fen, Treed Rich Fen
	Medium	Swamp	Conifer Swamp, Tamarack Swamp
	Poor	Fen	Treed poor Fen, Shrubby Poor Fen, Graminoid Poor Fen
Low	**Very Poor**	Bog	Open Bog, Shrubby Bog, Treed Bog

Table 21: Nitrous dioxide fluxes from different wetland soils. Table adapted from Moseman-Valtierra (2012) and Chen et al. (2010).

Nutrient class[1]	Wetland type	Location	N_2O-N flux ($kg\ N_2O$-$N\ ha^{-2}\ y^{-1}$)	References
Rich - very rich	Marsh (permanently inundated)	Sanjiang Experimental Station of Wetland Ecology	1.24	Song et al. 2009
Rich - very rich	Marsh (seasonally inundated)		1.1	
Rich - very rich	Swamp (shrub swamp)		2.8	
Medium	Marsh (freshwater marsh)	Sanjiang Mire Wetland Experimental Station	2.6	Jiang et al. 2009
-	Marsh	Nature Reserve of Yellow River Delta	0.71	Sun et al. 2014
-	Swamp (peat swamp forest)	Central Kalimantan Province, Indonesia	0.56	Jauhiainen et al. 2012
Very poor	Mire (forested)	Harz Mountain (central Germany)	0.4	Tauchnitz et al. 2008
Very poor	Mire (non-forested)	Harz Mountain (central Germany)	0.2	
Very poor	Swamp (forested)	Asa Experimental Forest, Southern Sweden	0.63	Von Arnold et al. 2005

[1]Classified (as far as possible) using the classes proposed in the table 20 based on chemical parameters presented in the respective studies.

Table 22: Aboveground net biomass growth in natural forests. Source IPCC, 2006

Domain	*Ecological zone*	*Continent*	*Aboveground biomass growth (t d.m. $ha^{-1}\ yr^{-1}$)*	*Reference*
Temperate	Temperate oceanic forest	Europe	2.3	
		North America	15 (1.2-105)	Hessl *et al.*, 2004
		New Zealand	3.5 (3.2-3.8)	Coomes *et al.*, 2002
		South America	2.4-8.9	Echevarria and Lara, 2004
	Temperate continental forest	Asia, Europe, North America (≤20 y)	4.0 (0.5-8.0)	IPCC, 2003
		Asia, Europe, North America (>20 y)	4.0 (0.5-7.5)	IPCC, 2003
	Temperate mountain systems	Asia, Europe, North America	3.0 (0.5-6.0)	IPCC, 2003
Boreal	Boreal coniferous forest	Asia, Europe, North America	0.1-2.1	Gower *et al.*, 2001
	Boreal tundra woodland	Asia, Europe, North America	0.4 (0.2-0.5)	IPCC, 2003
	Boreal mountain systems	Asia, Europe, North America (≤20 y)	1.0-1.1	IPCC, 2003
		Asia, Europe, North America (>20 y)	1.1-1.5	IPCC, 2003

Table 23: Tier 1 estimated biomass values from tables 25,22,15. Values are approximate, use only for Tier 1. Source IPCC, 2006.

Climate domain	*Ecological zone*	*Aboveground biomass in natural forests (t d.m. ha^{-1})*	*Aboveground biomass in forest plantations (t d.m. ha^{-1})*	*Aboveground net biomass growth in natural forests (t d.m. ha^{-1} yr^{-1})*	*Aboveground net biomass growth in forest plantations (t d.m. ha^{-1} yr^{-1}*
Temperate	Temperate oceanic forest	180	160	4.4	4.4
	Temperate continental forest	120	10 0	4.0	4.0
	Temperate mountain systems	100	100	3.0	3.0
Boreal	Boreal coniferous forest	50	40	1.0	1.0
	Boreal tundra woodland	15	15	0.4	0.4
	Boreal mountain systems	30	30	1.0	1.0

Table 24: Ratio of belowground biomass to aboveground biomass (R). Source IPCC, 2006. Note, for Tier 1 the R is set to zero if no change of belowground biomass is assumed (Tier 1).

Domain	*Ecological zone*	*Aboveground biomass*	*R [tonne root d.m. (t shoot d.m.)$^{-1}$]*	*References*
Temperate	Temperate oceanic forest, Temperate continental forest, Temperate mountain systems	conifers aboveground biomass < 50 t ha^{-1}	0.40 (0.21-1.06)	Mokany *et al.*, 2006
		conifers aboveground biomass 50-150 t ha-1	0.29 (0.24-0.50)	Mokany *et al.*, 2006
		conifers aboveground biomass >150 t ha-1	0.20 (0.12-0.49)	Mokany *et al.*, 2006
		Quercus spp. above ground biomass >70 t ha^{-1}	0.30 (0.20-1.16)	Mokany *et al.*, 2006
		Eucalyptus spp. above ground biomass <50 t ha^{-1}	0.44 (0.29-0.81)	Mokany *et al.*, 2006
		Eucalyptus spp. aboveground biomass 50-150 t ha^{-1}	0.28 (0.15-0.81)	Mokany *et al.*, 2006
		Eucalyptus spp. aboveground biomass >150 t ha^{-1}	0.20 (0.10-0.33)	Mokany *et al.*, 2006
		other broadleaf aboveground biomass <75 t ha^{-1}	0.46 (0.12-0.93)	Mokany et al., 2006
		other broadleaf aboveground biomass 75-150 t ha^{-1}	0.23 (0.13-0.37)	Mokany et al., 2006
		other broadleaf aboveground biomass >150 t ha^{-1}	0.24 (0.17-0.44)	Mokany et al., 2006
Boreal	Boreal coniferous forest, Boreal tundra woodland, Boreal mountain systems	aboveground biomass <75 t ha^{-1}	0.39 (0.23-0.96)	Li *et al.*, 2003; Mokany *et al.*, 2006
		aboveground biomass >75 t ha^{-1}	0.24 (0.15-0.37)	Li *et al.*, 2003; Mokany *et al.*, 2006

Table 25: Aboveground biomass in forests (Bw). Source IPCC, 2006.

Domain	Ecological zone	Continent	Aboveground biomass (t d.m. ha^{-1})	References
Temperate	Temperate oceanic forest	Europa	120	-
		North America	660 (80-1200)	Hessl *et al.*, 2004; Smithwick *et al.*, 2002
		New Zealand	360 (210-430)	Hall *et al.*, 2001
		South America	180 (90-310)	Gayoso and Schlegel, 2003; Battles *et al.*, 2002
		Asia, Europe (≤20 y)	20	IPCC, 2003
	Temperate continental forest	Asia, Europe (>20 y)	120 (20-320)	IPCC, 2003
		North and South America (≤20 y)	60 (10-130)	IPCC, 2003
		North and South America (>20 y)	130 (50-200)	IPCC, 2003
		Asia, Europe (≤20 y)	100 (20-180)	IPCC, 2003
	Temperate mountain systems	Asia, Europe (>20 y)	130 (20-600)	IPCC, 2003
		North and South America (≤20 y)	50 (20-110)	IPCC, 2003
		North and South America (>20 y)	130 (40-280)	IPCC, 2003
		Asia, Europe, North America	10-90	Gower *et al.*, 2001
Boreal	Boreal coniferous forest	Asia, Europe, North America (≤20 y)	3-4	IPCC, 2003
	Boreal tundra woodland	Asia, Europe, North America (>20 y)	15-20	IPCC, 2003
		Asia, Europe, North America (≤20 y)	12-15	IPCC, 2003
	Boreal mountain systems	Asia, Europe, North America (>20 y)	40-50	IPCC, 2003

Table 26: Aboveground biomass in forest plantation used for land converted to forest land (eq.5.4). Source IPCC, 2006.

Domain	*Ecological zone*	*Continent*	*Aboveground biomass (t d.m. ha^{-1})*	*References*
Temperate	Temperate oceanic forest	Asia, Europe, broadleaf >	200	IPCC, 2003
		Asia, Europe, broadleaf ≤	30	IPCC, 2003
		Asia, Europe, coniferous >	150-	IPCC, 2003
		Asia, Europe, coniferous ≤	40	IPCC, 2003
		North America	50-300	IPCC, 2003
		New Zealand	150-350	Hinds and Reid, 1957; Hall and Hollinger, 1997; Hall,
		South America	90-120	IPCC, 2003
	Temperate continental forest and mountain systems	Asia, Europe, broadleaf >	200	IPCC, 2003
		Asia, Europe, broadleaf ≤	15	IPCC, 2003
		Asia, Europe, coniferous >	150-	IPCC, 2003
		Asia, Europe, coniferous ≤	25-	IPCC, 2003
		North America	50-300	IPCC, 2003
		South America	90-120	IPCC, 2003
Boreal	Boreal coniferous forest and mountain systems	Asia, Europe > 20 y	40	IPCC, 2003
		Asia, Europe ≤ 20 y	5	IPCC, 2003
		North America	40-50	IPCC, 2003
	Boreal tundra woodland	Asia, Europe > 20 y	25	IPCC, 2003
		Asia, Europe ≤ 20 y	5	IPCC, 2003
		North America	25	IPCC, 2003

Table 27: Default biomass conversion and expansion factors (BCEF). BCEF for expansion of merchantable growing stock volume to aboveground biomass (BCEFS), for conversion of net annual increment (BCEFI) and for conversion of wood and fuelwood removal volume to aboveground biomass removal (BCEFR) in t biomass (m^3 of wood volume)$^{-1}$. Source IPCC, 2006.

Climatic	*Forest type*	*BCEF*	*Growing stock level (m^3)*				
Boreal			<20	21-50	51-100	>100	
	pines	BCEFS BCEFI BCEFR	**1.2** (0.85-1.3) 0.47 1.33	**0.68** (0.5-0.72) 0.46 0.75	**0.57** (0.52-0.65) 0.46 0.63	**0.5** (0.45-0.58) 0.463 0.55	
	larch	BCEFS BCEFI BCEFR	**1.22** (0.9-1.5) 0.9 1.35	**0.78** (0.7-0.8) 0.75 0.87	**0.77** (0.7-0.85) 0.77 0.85	**0.77** (0.7-0.85) 0.77 0.85	
	firs and spruces	BCEFS BCEFI BCEFR	**1.16** (0.8-1.5) 0.55 1.29	**0.66** (0.55-0.75) 0.47 0.73	**0.58** (0.5-0.65) 0.47 0.64	**0.53** (0.45-0.605) 0.464 0.59	
	hardwoods	BCEFS BCEFI BCEFR	**0.9** (0.7-1.2) 0.65 1.0	**0.7** (0.6-0.75) 0.54 0.77	**0.62** (0.53-0.7) 0.52 0.69	**0.55** (0.5-0.65) 0.505 0.61	
Temperate			<20	21-40	41-100	100 -200	>200
	hardwoods	BCEFS BCEFI BCEFR	**3.0** (0.8-4.5) 1.5 3.33	**1.7** (0.8-2.6) 1.3 1.89	**1.4** (0.7-1.9) 0.9 1.55	**1.05** (0.6-1.4) 0.6 1.17	**0.8** (0.55-1.1) 0.48 0.89
	pines	BCEFS BCEFI BCEFR	**1.8** (0.6 -2.4) 1.5 2.0	**1.0** (0.65 -1.5) 1.75 1.11	**0.75** (0.6-1.0) 0.6 0.83	**0.7** (0.4-1.0) 0.67 0.77	**0.7** (0.4-1.0) 0.69 0.77
	other conifers	BCEFS BCEFI BCEFR	**3.0** (0.7-4.0) 1.0 3.33	**1.4** (0.5-2.5) 0,83 1.55	**1.0** (0.5-1.4) 0,57 1.11	**0.75** (0.4-1.2) 0.53 0.83	**0.7** (0.35-0.9) 0.60 0.77
Mediterranean, dry tropical, subtropical			<20	21-40	41-80	>80	
	hardwoods	BCEFS BCEFI BCEFR	**5.0** (2.0-8.0) 1.5 5.55	**1.9** (1.0-2.6) 0.5 2.11	**0.8** (0.6-1.4) 0.55 0.89	**0.66** (0.4-0.9) 0.66 0.73	
	conifers	BCEFS BCEFI BCEFR	**6.0** (3.0-8.0) 1.5 6.67	**1.2** (0.5-2.0) 0.4 1.33	**0.6** (0.4-0.9) 0.45 0.67	**0.55** (0.4-0.7) 0.54 0.61	

Note: Lower values of the ranges for BCEFS apply if growing stock definition includes branches, stem tops and cull trees; upper values apply if branches and tops are not part of growing stock, minimum top diameters in the definition of growing stock are large, inventoried volume falls near the lower category limit or basic wood densities are relatively high.

Continuous graphs, functional forms and updates with new studies can be found at the forest- and climate- change website at: http://www.fao.org/forestry/

Average BCEF for inhomogeneous forests should be derived as far as possible as weighted averages. It is good practice to justify the factors chosen. To apply BCEFI, an estimate of the current average growing stock is necessary. It can be derived from FRA 2005 at http://www.fao.org/forestry/

BCEFR values are derived by dividing BCEFs

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8 Document version

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Annex 5 - Waste

Unfinished manuscript – not publicly available yet

Annex 6 - Humans and Settlements

1 Introduction

This document is an annex to the "Guidance document on national nitrogen budgets" (UN ECE 2013) supplementing it with detailed information on how to establish national nitrogen budgets for Humans and Settlements. In the guidance document and the general annex, eight essential pools are defined: 1) Energy and fuels (EF), 2) Material and products in industry (MP), 3) Agriculture (AG), 4) Forest and semi-natural vegetation including soils (FS), 5) Waste (WS), 6) Humans and settlements (HS), 7) Atmosphere (AT), and 8) Hydrosphere (HY). In addition, the pool "Rest of the World" (RW) is included for the quantification of imports and exports. For general information and definitions, please refer to the guidance document and the general annex.

This annex defines the pool "humans and settlements" (HS) and outlines its internal structure. It provides specific guidance on how to calculate relevant nitrogen flows related to the pool HS, presenting calculation methods and suggesting possible data sources. Furthermore, it points to information that needs to be provided by and coordinated with other pools. For the pool HS, following other pools are of particular relevance: Agriculture, Material and Products in Industry, Waste.

The pool humans and settlements (HS) is dominated by individual human behaviour (in terms of consumption, utilization efficiency and waste separation). Product flows are characterized by high material heterogeneity. Uncertainties are generally high due to insufficient data, as the pool is not necessarily characterized by economic activities, which typically are accessible by statistical information. Rather, the focus in this pool is on (domestic) consumption. By definition from the guidance document (UN ECE 2013), four main sub-pools are encompassed by the pool HS: i) the human body, ii) the material world, iii) the organic world, and iv) pets (non-agricultural animals).

Domestic inflows into the pool stem from food products from agriculture, as well as from material products from industry. Imports and forests and semi-natural vegetation do also play a role. On the other end, N is lost via diffuse release pathways.

This document is organized as follows: Chapter 2 gives an overview on the activities and flows encompassed by the pool. Chapter 3 provides insight in the internal structure of the pool, delineating and characterizing the four sub-pools with their relevant flows. Finally, in chapters 4 and 5, specific calculation methods are presented and possible data sources for individual flows are suggested. Chapter 6 contains some general deliberations on the uncertainties related to this assessment. Additional tables and references can be found in chapters 7 and 8, respectively.

2 Definitions

2.1 Activities and Flows encompassed by the pool

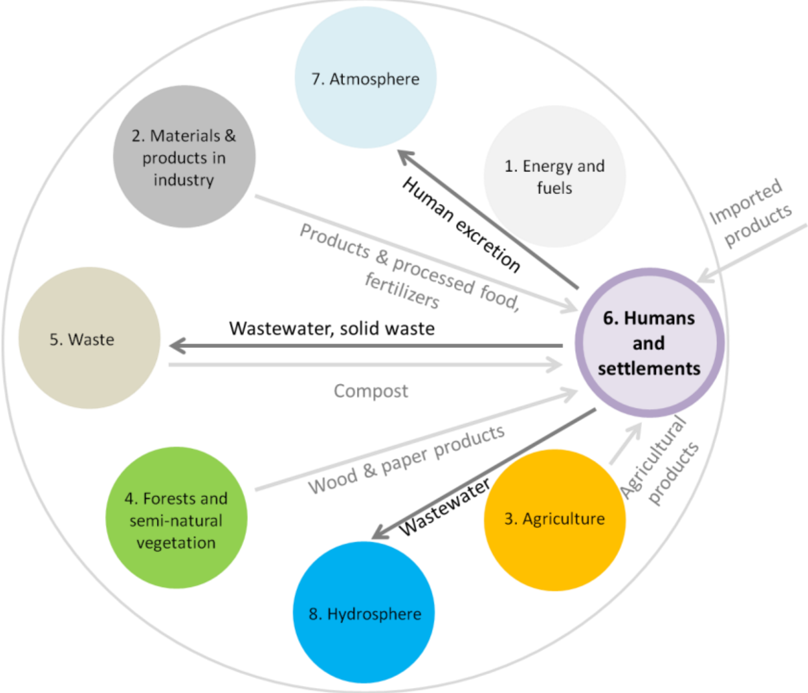

Figure 1: Flows connecting neighboring pools with „Humans and settlements“.

Figure 1 presents the main N flows between HS and other pools. The pool is also connected to the rest of the world (RW) via imports of both food and non-food products. Exports, in contrast, do not occur directly from HS, but are rather related to the respective production pools (i.e. agriculture and material and products in industry). Depending on the data sources available, it might not be possible to report imports from the rest of the world separately, as they might just be included in overall consumption statistics. Ideally, these products and related N flows should be reported in the pools "Agriculture" and "Materials and Products in Industry".

2.2 Tier 1 approach

A range of substances consumed in the HS is relevant in terms of Nr. The most relevant flows that should be included in a NNB in any case are the following:

Inflows

- Food for human nutrition from agriculture, industry and imports (agricultural products and processed food)
- Pet food from agriculture and industry
- Industrial fertilizers and compost for use in private gardens and public green spaces
- N embedded in materials and products

Outflows

- Food waste
- Human excretion and pet excretion to waste management and hydrosphere
- Human body emissions to atmosphere (not considering population dynamics, see section 3.5 below)
- N embedded in solid waste from materials and products

In general, fully unreactive forms of N (e.g., N in polymer fibres) need not be considered for a national nitrogen budget (see general annex). N embedded in industrial products is less critical with regard to impacts and societal costs than for instance N from combustion processes or agricultural production. However, the amount of N embedded in industrial materials and products that end up with final consumers can be substantial. According to Leip et al. (2011), more than 50% of the Nr that is available for consumers apparently serves other purposes than nutrition. To account for these aspects, a rough estimation is proposed for the tier 1 approach, and a more detailed approximation is included in the tier 2 approach.

There are several N flows due to activities of HS which spatially overlap with activities of other pools. In particular, this concerns the following flows that should be covered by the pool "energy & fuels":

- Road, Aviation, Railways, Navigation
- Electricity and Heating

2.3 Tier 2 approach

- In addition to including all other tier 1 inflows and outflows, tier 2 provides a more detailed assessment of N embedded in materials and products, as well as solid material waste. Specifically, the inflow of N embedded in materials and products is distributed to: Wood & paper products
- Synthetic polymers for product use (textiles, machineries, electronics, buildings, rubber and plastic products etc.)
- Textiles, wearing apparel & leather
- Detergents / surfactants

3 Internal structure

Figure 2 shows the internal structure of the pool, including its four sub-pools and their specific connections to neighbouring pools.

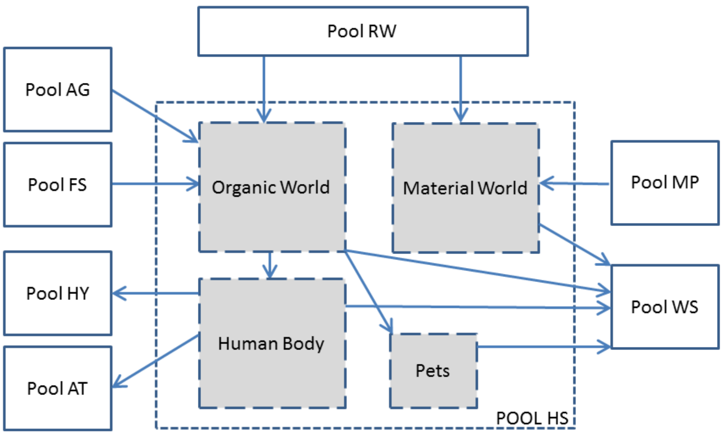

Figure 2: Internal structure of the pool HS

Table 1: Sub-pools of the pool HS

ID	Code	Full name of the sub-pool
6A	HS.OW	Organic World

6B	HS.HB	Human Body
6C	HS.MW	Material World
6D	HS.PE	Pets (Non-agricultural animals)

3.1 Sub-pool Organic World (HS.OW)

The sub-pool organic world serves as an entry-point and distribution hub for all kinds of organic material. Via this sub-pool, food and feed is allocated to the "human body" as well as to "pets".

Relevant **inflows** are mainly food products from domestic agriculture and imports, as well as non-agricultural fertilizer use for private gardens and public green spaces. If food (or other products) is conceptually separated between agriculture and industry, inflows might also come from industry (e.g. convenience food). Food inputs from private gardens can be neglected as an input flow, as they are likely to be small and are usually not covered statistically.

A large share of the **outflows** temporarily remains within the pool HS, as it is all food and feed consumed by humans and pets and thus is distributed to the respective sub-pools. Other outflows come from gardening in human settlements. Conceptually, outflows in a certain period stem partly from current inflows and partly from existing storage from previous periods within the sub-pool. However, this aspect is not of primary importance for a NNB, and does not have to be accounted for. Furthermore, some outflows go directly to the waste pool: food waste and non-consumed food (from households/final consumers as well as from supermarkets and food service etc.).

3.2 Sub-pool Human Body (HS.HB)

Inflows to the human body come from the organic world as food. Highly processed products such as flavour enhancers, pharmaceuticals and dietary supplements are not considered.

Outflows from human body are mainly excrements going to the sewage system, or directly to the hydrosphere, if households are not connected to the sewage system. Furthermore, emissions of NH_3 due to sweating and breathing can be quantified (Sutton et al. 2000). For practical reasons renewed skin, hair and nails are implicitly covered by the excrement flow as well. It is assumed that adults do not accumulate significant amounts of Nr in their body (i.e. all Nr that is taken in is excreted as well). Children, in contrast, do still accumulate some N, but are not considered separately. Food waste is not included as an outflow here, as it is assumed to go directly from the organic world to the waste pool.

3.3 Sub-pool Material World (HS.MW)

The sub-pool material world is only relevant for the tier 2 approach. This sub-pool includes products used in private households, such as furniture, packaging devices, clothes and electronic equipment. Materials such as those used in buildings and cars, for instance, are included here. Wood and paper products and natural polymers are explicitly assigned to the material world, rather than the organic world.

Inflows to this pool are mainly dominated by manufactured goods containing N in various forms (bound in synthetic or natural polymers; ionic forms in surfactants).

Major **outflows** of N occur to the waste sector. N species in solid form are released after usage in identical form as the N inflows (e.g. synthetic or natural polymers), thus the transformation by burning processes or biological degradation etc. occurs only in the pool waste (WS). Other significant outflows of N are transported by exported goods, which need to be quantified directly by the pool "material and products in industry".

3.4 Sub-pool Non-agricultural animals (pets) (HS.PE)

Non-agricultural animals, or pets, are non-productive animals, (mostly) kept without economic reasons. This includes popular pets like cats and dogs as well as sport animals such as racing horses or bulls for fighting and working animals like sniffer dogs. Productive livestock, clearly belonging to agricultural activities, such as cattle, pigs, etc. are considered in the pool agriculture.

Similarly to the sub-pool human body, only N from food is covered here as an **inflow.**

Outflows are mainly excrements. Animal hair and fur is also relevant in terms of N, but is difficult to report separately. As with humans, population dynamics are not considered.

3.5 Stocks & Stock Changes

Nitrogen stocks and their changes are generally not quantified for the pool HS. Among other reasons, this is because of inherent difficulties with data availability. In general, stock changes are simply the difference between inflows and outflows. But due to the lack of data, many inflows in the pool HS cannot be quantified independently and have to be assumed equal to the respective outflows (or vice versa). This makes the idea of stock changes obsolete. Consequently, there is no further detailed guidance on stock changes in this document. However, stock changes might be of relevance for some purposes. This section gives some general ideas on the kind of stock changes that might be interesting.

Organic world: Conceptually, stock changes might come for example from food that is stored in households or supermarkets for more than one year.

Human body: Stock changes in this sub-pool are related to population dynamics. They could be estimated by using the net change in population (birth and deaths, as well as immigration and emigration) for a given year and combining it with an average value for the amount of N contained in a person (ideally considering the differences in N weight between adults and children). If this is done, additional inflows and outflows would have to be included as well. (For example, outflows related to human corpses could be split into exhaust fumes from crematories (NO_x) and N outflows to the soil due to biological decomposition processes on cemeteries.)

Pets: In analogy to the human body, stock changes are related to the dynamics of pet population.

Material world: Stock changes in the material world are particularly interesting. In contrast to food, material world products are usually not used up immediately, but accumulate in the pool HS (e.g., furniture, electronic devices, or entire buildings). It has been estimated that more than 25% of inflows of industrial products accumulate in settlements, as they tend to have rather long service lives (Gu et al. 2013). If good data on related waste streams are available, stock changes might be quantified. However, the sub-pool material world is generally characterized by rather uncertain data.

4 Flows: Calculation guidance Tier 1

This section describes the calculation methods and data sources that are suggested to derive the basic N flows concerning the pool HS. The flows related to food supply should be provided by the pools AG and MP. Still, a simplified alternative way of estimation is proposed here in addition. This could be used for a fast approximation and/or to compare the respective results.

Table 2: Overview on flows Tier 1

$Pool_{ex}$	$Pool_{in}$	Matrix*	Other info	Total code	Annex where guidance is given	Description
AG	HS.OW	FOOD	Incl. various sub-flows	AG-HS.OW-FOOD	3, (6)	Food from domestic agriculture
RW	HS.OW	FOOD	Incl. various sub-flows	RW-HS.OW-FOOD	3, (6)	Food from imports
HS.OW	HS.HB	FOOD	Incl. various sub-flows	HS.OW-HS.HB-FOOD	6	Food consumed by humans
HS.OW	WS	FOWS	Incl. various sub-flows	HS.OW-WS-FOWS	6	Food waste by consumers
AG / RW	HS.OW	PFOD		AG-HS.OW-PFOD	6	Pet food supply
HS.OW	HS.PE	PFOD		HS.OW-HS.PE-PFOD	6	Consumed pet food
HS.PE	WS	Ntot		HS.PE-WS-Ntot	6	Waste & excretion from pets
MP	HS.OW	FERT		MP-HS.OW-FERT	(2), 6	Mineral fertilizer inputs to private gardens & public green spaces
WS	HS.OW	COMP		WS-HS.OW-COMP	5, (6)	Compost inputs to private gardens & public green spaces
HS.OW	WS	GRWS		HS.OW-WS-GRWS	6	Green waste & garden waste
MP	HS.MW	Ntot		MP-HS.MW-Ntot	6	Materials and products
HS.HB	WS	Ntot		HS.HB-WS-Ntot	6	Human excretion to sewage system
HS.HB	HY	Ntot		HS.HB-HY-Ntot	6	Human excretion to hydrosphere
HS.HB	AT	NH3		HS.HB-AT-NH3	6	Atmospheric emissions from human body
HS.MW	WS	SOWS		HS.MW-WS-SOWS	6	Solid material waste

4.1 Food supply

The N flows related to food supply should be provided in detail by the pools AG and MP. Still, a simplified alternative way of estimation is proposed here in addition. This can be used for a fast approximation and/or to compare the respective results.

Food supply N is all N contained in the food available for (domestic) human consumption. Most of the food is assumed to come either from domestic agriculture or imports. Furthermore, plant and animal N should be distinguished for both domestic food supply and imports. Although tobacco is no food product, it is consumed by humans and is therefore included here. As it is probably too small to be depicted separately, it can simply be added to the flow “food supply”.

Processed food products (including convenience food) that are actually entering the HS pool from food industries are not accounted for separately due to data limitations. However, if information is provided by the pool MP, processed food products can be accounted for separately.

Table 3: Overview on food supply flows

Flow Code	Flow Description	Pool ex	Pool in	Matrix
AG-HS.OW-FOOD (“Food domestic”)	Food supply from domestic agriculture (total)	AG	HS.OW	FOOD

RW-HS.OW-FOOD (“Food imported”)	Food supply from imports (total)	RW	HS.OW	FOOD

4.1.1 AG-HS.OW-FOOD & RW-HS.OW-FOOD: Food from domestic agriculture & imports

Protein supply data (e.g. from the FAOSTAT database) can be used to derive food N flows from domestic agriculture and imports for a set of food categories.

$$\text{AG-HS.OW-FOOD} = \sum_{i=1}^{k}(\boldsymbol{ps\_domestic_i} * \mathbf{0.16}) = \sum_{i=1}^{k}\boldsymbol{fs1_i} \quad (0.1)$$

$$\text{RW-HS.OW-FOOD} = \sum_{i=1}^{k}(\boldsymbol{ps\_import_i} * \mathbf{0.16}) + \boldsymbol{tob} = \sum_{i=1}^{k}\boldsymbol{fs2_i} + \boldsymbol{tob} \quad (0.2)$$

$$\boldsymbol{tob} = \boldsymbol{amount\ of\ tobacco\ consumed} * \mathbf{0.04} \quad (0.3)$$

Where:

AG-HS.OW-FOOD = total inflow of food N from domestic agriculture [t N/year]
RW-HS.OW-FOOD = total inflow of food N from imports [t N/year]
ps_i = protein supply for food category *i* [t/year], either domestic or from imports
tob = N from tobacco products [t N/year], N content 4%, see section “Tables”.
$fs1_i$ = inflow of food N from domestic agriculture, food category *i* [t N/year]
$fs2_i$ = inflow of food N from imports, food category *i* [t N/year]

Instead of the protein supply data, food N flows can also be derived from production and trade statistics. However, in these statistics only product quantities are reported, which means that additional robust information on N contents of different food categories is required.

$$\text{AG-HS.OW-FOOD} = \sum_{i=1}^{k}(\boldsymbol{food\_domestic_i} * \boldsymbol{N_i^{coeff}}) \quad (0.4)$$

$$\text{RW-HS.OW-FOOD} = \sum_{i=1}^{k}(\boldsymbol{food\_imports_i} * \boldsymbol{N_i^{coeff}}) + \boldsymbol{tob} \quad (0.5)$$

Where:

AG-HS.OW-FOOD = total inflow of food N from domestic agriculture [t N/year]
RW-HS.OW-FOOD = total inflow of food N from imports [t N/year]
$food\_domestic_i$ = food supply for food category *i* from domestic production [t/year]
$food\_imports_i$ = food supply for food category *i* from imports [t/year]
N_i^{coeff} = estimated average content of N in in food category *i* [share]
tob = N from tobacco products [t N/year]

4.1.2 Suggested Data sources

- The **FAOSTAT database** (http://faostat3.fao.org/home) provides easily accessible and consistent information on protein supply from different food categories (in g/cap/year) for a wide range of countries. Protein supply is reported as primary equivalents, and thus includes all the raw materials for processed food products as well. The FAO Commodity Balances - Crops Primary Equivalent (http://faostat3.fao.org/faostat-gateway/go/to/download/FB/BC/E) also provide information on tobacco production and supply.
- Attention must be paid to avoid double counting, for instance when the meat used to produce sausages is also accounted for as raw meat. In general, data on primary equivalents is preferable.
- Information on imported food and domestic production can also be found in the FAOSTAT database (food balance sheets). This information can also be gathered directly from **national statistics**.
- **N contents** of different food categories are frequently available from existing nitrogen budgets, e.g. Heldstab et al. (2010). In addition, reference texts such as Souci et al. (2008) provide a good source of information. Table 12 provides an overview on the N content of food categories according to FAO’s

classification. This classification is based on primary equivalents, which prevents the risk of double-counting.

4.2 Food consumption & waste

Not all food that is theoretically available for consumption is actually consumed by humans, as there are usually significant amounts of food waste. As a consequence, food waste has to be subtracted from the food supply to derive food consumption.

The approach presented here does not distinguish between food consumed at home and at restaurants/canteens etc. If national data allow for such a distinction, it is recommended to do so.

Table 4: Overview on food consumption and waste flows

Flow Code	Flow Description	Pool ex	Pool in	Matrix
HS.OW-HS.HB-FOOD ("Food consumed")	Food consumed by humans (total)	HS.OW	HS.HB	FOOD
HS.OW-WS-FOWS ("Food waste")	Food waste by consumers (total)	HS.OW	WS	FOWS

4.2.1 HS.OW-HS.HB-FOOD: Food consumed by humans

Food N that is actually consumed by humans (HS.OW-HS.HB-FOOD) is calculated by means of the known flows of food supply (AG-HS.OW-FOOD & RW-HS.OW-FOOD), and food waste (HS.OW-WS-FOWS). There might be some storage of food as well. Although this storage is assumed to be rather short-term (i.e., less than a year, which is the typical time horizon for a NNB), it is conceptually included in the calculation below. Usually, this term is set at zero, unless specific data on long-term food storage are available. Optionally, HS.OW-HS.HB-FOOD can also be split up to distinguish between animal food and plant food.

$$\text{HS.OW-HS.HB-FOOD} = (\text{AG-HS.OW-FOOD} + \text{RW-HS.OW-FOOD}) - \text{HS.OW-WS-FOWS} - \mathbf{N}_{\textbf{longterm storage}} \quad 0.6$$

Where:

HS.OW-HS.HB-FOOD = N in food consumed by humans [t N/year]
AG-HS.OW-FOOD = total inflow of food N from domestic agriculture [t N/year], see 4.1.1
RW-HS.OW-FOOD = total inflow of food N from imports [t N/year], see **Fehler! Verweisquelle konnte nicht gefunden werden.**
HS.OW-WS-FOWS = N in food waste [t N/year], see **Fehler! Verweisquelle konnte nicht gefunden werden.**
$N_{longterm\_storage}$ = N contained in food that is stored for more than a year [t N/year]

4.2.2 HS.OW-WS-FOWS: Food waste

Food waste on the consumption side is a crucial issue, particularly in rich and developed nations. It is defined here as waste occurring in the retail/distribution phase (e.g. supermarkets), as well as direct waste from consumers in households and in the food service industry. Estimation of the amounts of food wasted is rather difficult, as there is hardly any data available. If there are no specific national statistics or reports available, it is suggested to rely on Gustavsson et al. (2011) for a rough estimation of waste percentages. With regard to tobacco, no wastage needs to be considered.

$$\text{HS.OW-WS-FOWS} = \sum_{i=1}^{k} (\boldsymbol{fs1} + \boldsymbol{fs2})_i * \boldsymbol{waste_i} \quad 0.7$$

Where:

HS.OW-WS-FOWS = N in food waste [t N/year]
$fs1_i$ = inflow of food N from domestic agriculture, food category *i* [t N/year], see **Fehler! Verweisquelle konnte nicht gefunden werden.**
$fs2_i$ = inflow of food N from imports, food category *i* [t N/year], see **Fehler! Verweisquelle konnte nicht gefunden werden.**
$waste_i$ = percentage of food supply that is wasted, for food category *i* [%]

4.2.3 Suggested Data sources

- FAOSTAT Database: http://faostat3.fao.org/home
- Gustavsson et al. (2011) for wood waste percentages – see also Table 11 in this document

4.3 Non-agricultural animals (pets)

It is suggested to use cats, dogs and small mammals (including hamsters, mice, rabbits…) as the main pet categories. Other pets (such as ornamental birds, ornamental fish, and reptiles) should be included depending on the available data on protein intake and animal numbers in a specific country. If appropriate for a certain country and if respective data are available, non-agricultural horses (including racing horses and police horses, for instance) or fighting bulls might also be considered. Animals in laboratories, circuses or zoos are neglected in the analysis.

Table 5: Overview on pet food and waste flows

Flow Code	Flow Description	Pool ex	Pool in	Matrix
AG-HS.OW-PFOD ("Pet food supply")	Pet food supply	AG	HS.OW	PFOD
HS.OW-HS.PE-PFOD („Pet food consumed")	Consumed pet food	HS.OW	HS.PE	PFOD
HS.PE-WS-Ntot ("Pet excretion")	Waste & excretion from pets	HS.PE	WS	Ntot

4.3.1 AG-HS.OW-PFOD: Pet food supply

The supply of pet food is difficult to trace. While some part is explicitly produced and sold as pet food, another part comes from food that is actually meant for human consumption, or from various other sources. As these flows cannot be defined exactly, the simple way is to set the pet food supply equal to the consumed pet food and treat it as an additional inflow to the organic world. This is probably an overestimation of the flow, but can be accepted due to the low absolute value.

$$\text{AG-HS.OW-PFOD} = \text{HS.OW-HS.PE-PFOD} \quad (0.8)$$

Where:
AG-HS.OW-PFOD = N supplied as pet food [t N/year]
HS.OW-HS.PE-PFOD = N consumed as food by pets [t N/year]

4.3.2 HS.OW-HS.PE-PFOD: Consumed pet food

To approximate the N in food consumed by pets, it is suggested to use the average recommended protein intake per pet group. This is only a rough estimation, but represents the best data commonly available.

0.9

$$\text{HS.OW-HS.PE-PFOD} = \frac{\sum_{i=1}^{k} number\ of\ animals_i * p\_intake_i * 0.16}{1000}$$

Where:

HS.OW-HS.PE-PFOD = N consumed as food by pets [t N/year]
number of $animals_i$ = number of animals from group *i*
p_intake_i = recommended protein intake per animal from group *i* per year [kg/year]

4.3.3 *HS.PE-WS-Ntot: Waste & excretion from pets*

In analogy to humans, it is assumed that all N consumed by pets is excreted in one form or another, and thus HS.PE-WS-Ntot = HS.OW-HS.PE-PFOD. Conceptually, this flow can be split up into N emitted to the atmosphere (e.g., NH_3-N from excreta), and to the waste sector (e.g., N contained in hair and fur). Sutton et al. (2000) report average yearly total N excretion and ammonia emission rates for cats, dogs, and horses that should be used for this purpose.

$$\text{HS.PE-WS-Ntot} = \text{HS.OW-HS.PE-PFOD} \qquad 0.10$$

Where:

HS.PE-WS-Ntot = N waste and excretion from pets [t N/year]
HS.OW-HS.PE-PFOD = N consumed as food by pets [t N/year]

4.3.4 *Suggested data sources*

- With regard to the number of pets in different European countries, the European Pet Food Industry provides comprehensive data (FEDIAF 2012). It is recommended to use this source if no other more appropriate national statistics are available. If estimates are available, straying and not-registered pets can also be included.
- Recommended average protein and N intake can be compiled from a range of different sources (see for instance Table 18).
- NH_3 volatilization rates for horses, cats and dogs can be found in Sutton et al. (2000), and are also summarized in Table 19.

4.4 Private gardens & public green spaces

With regard to private gardens and public green spaces, the main N inflow comes from fertilizers and compost, and outflows are useful (food) products, green waste & garden waste, as well as NH_3 emissions from the fertilizers used. However, non-agricultural fertilizer use is usually not accounted for separately in fertilizer statistics, as it is minor compared to the agricultural use. The same is true for (food) products from private gardens. These are directly consumed by private individuals and never enter any market. Consequently, no statistics capture these goods and thus the related N flows cannot be quantified here.

Table 6: Overview on garden-related flows

Flow Code	Flow Description	Pool ex	Pool in	Matrix
MP-HS.OW-FERT (“Fertilizer_HS”)	Mineral fertilizer inputs to private gardens & public green spaces	MP	HS.OW	FERT
WS-HS.OW-COMP (“Compost_HS”)	Compost inputs to private gardens & public green spaces	WS	HS.OW	COMP
HS.OW-WS-GRWS (“Greenwaste_HS”)	Green waste & garden waste	HS.OW	WS	GRWS

4.4.1 MP-HS.OW-FERT: Fertilizer for private gardens & public green spaces

Only about 1-3% of total mineral fertilizer use is dedicated to private gardens and public green spaces, while the rest is consumed by agriculture (estimate for Austria, Egle et al. 2014). It is suggested to use the mean value of 2%, or adapt this value if possible (i.e., if more appropriate national estimates are available).

$$\text{MP-HS.OW-FERT} = \textit{total N consumed as mineral fertilizer} * 0.02 \qquad 0.11$$

Where:

MP-HS.OW-FERT = Mineral N fertilizer for private gardens & public green spaces [t N/year]

4.4.2 WS-HS.OW-COMP: Compost for private gardens & public green spaces

With regard to compost, Egle et al. (2014) estimate that 20% of the available compost is applied as fertilizer in gardens. Total N contents of compost range from 0.6 to 2.3% dry matter (BMLFUW 2010).

$$\text{WS-HS.OW-COMP} = \textit{total N consumed as compost} * 0.2 \qquad 0.12$$

Where:

WS-HS.OW-COMP = Compost N for private gardens & public green spaces [t N/year]

4.4.3 HS.OW-WS-GRWS: Green waste & garden waste

Green waste and garden waste are the main outflows from private gardens and public green spaces that can be quantified. The amount of green waste and garden waste can be estimated from national waste statistics. The N content of fresh green waste has been estimated as roughly 0.8% (Vaughan et al. 2011, Kumar et al. 2010). This flow has a very high level of uncertainty. In particular the direct use of private garden waste for home composting cannot be captured statistically.

$$\text{HS.OW-WS-GRWS} = \textit{Green waste \& garden waste} * 0.008 \qquad 0.13$$

Where:

HS.OW-WS-GRWS = N from green waste & garden waste [t N/year]

4.4.4 Suggested data sources

- Data on total mineral fertilizer use is frequently available from national statistical reports, or can be derived in coordination with the pool "Agriculture". In addition, the International Fertilizer Industry Association provides statistics for many countries online at www.fertilizer.org
- Total use of compost can be derived from national agricultural statistics. Some information might also be available from the European Compost Network (ECN, http://www.compostnetwork.info/) and their country reports.
- Data on green waste & garden waste should be estimated from national waste statistics, such as the federal waste management plan in Austria.

4.5 Material flows

Material flows of N are rather difficult to assess in terms of nitrogen. There is a vast range of products that are made of a combination of many different materials. As a consequence, it is challenging to determine N contents of these products that are aggregated into broad categories. For the tier 1 approach, the magnitude of these N flows can be roughly approximated based on Pierer et al. (2015).

Table 7: Overview on material flows

Flow Code	Flow Description	Pool ex	Pool in	Matrix
MP-HS.MW-Ntot (“Materials”)	Materials and products	MP	HS.MW	Ntot
HS.MW-WS-SOWS (“Waste_HS”)	Solid material waste	HS.MW	WS	SOWS

4.5.1 *MP-HS.MW-Ntot : Materials and products*

Following Pierer et al. (2015), the order of magnitude of the N inflows embedded in materials and products is 40% of all other inflows. This has to be considered a very rough approximation. If possible, the tier 2 approach should be used.

$$\text{MP-HS.MW-Ntot} = (\text{AG-HS.OW-FOOD} + \text{RW-HS.OW-FOOD} + \text{AG-HS.OW-PFOD} + \text{MP-HS.OW-FERT} + \text{WS-HS.OW-COMP}) * 0.40 = sum\ of\ all\ other\ inflows * 0.40 \quad (0.14)$$

Where:

MP-HS.MW-Ntot = N from materials and products [t N/year]
AG-HS.OW-FOOD = N in food from domestic agriculture [t N/year]
RW-HS.OW-FOOD = N in food from imports [t N/year]
AG-HS.OW-PFOD = N in pet food supply [t N/year]
MP-HS.OW-FERT = Mineral N fertilizer for private gardens & public green spaces [t N/year]WS-HS.OW-COMP = Compost N for private gardens & public green spaces [t N/year]

4.5.2 *HS.MW-WS-SOWS: Solid material waste*

Following Pierer et al. (2015), the order of magnitude of the N outflows embedded in solid material waste that can be quantified is 7% of all other outflows. This has to be considered a very rough approximation. If possible, the tier 2 approach should be used.

$$\text{HS.MW-WS-SOWS} = (\text{HS.OW-WS-FOWS} + \text{HS.PE-WS-Ntot} + \text{HS.OW-WS-GRWS} + \text{HS.HB-WS-Ntot} + \text{HS.HB-HY-Ntot} + \text{HS.HB-AT-NH3}) * 0.07 = sum\ of\ all\ other\ outflows * 0.07 \quad (0.15)$$

HS.OW-WS-FOWS = N in food waste by consumers [t N/year]
HS.PE-WS-Ntot = N in waste & excretion from pets [t N/year]
HS.OW-WS-GRWS = N in green waste & garden waste [t N/year]
HS.HB-WS-Ntot = Human excretion to sewage system [t N/year]
HS.HB-HY-Ntot = Human excretion to hydrosphere [t N/year]
HS.HB-AT-NH3 = Atmospheric emissions from human body [t N/year]

4.6 Human body emissions

It is assumed that the N consumed by humans as food and drinks does not accumulate in the human body in relevant amounts, and is thus an outflow in some form. The main challenge is to distribute this total amount of N outflow to the different channels (i.e., sewage system, atmosphere, and hydrosphere).

Table 8: Overview on human body emissions

Flow Code	Flow Description	Pool ex	Pool in	Matrix
HS.HB-WS-Ntot ("HS_sewage")	Human excretion to sewage system	HS.HB	WS	Ntot
HS.HB-HY-Ntot ("HS_hydro")	Human excretion to hydrosphere	HS.HB	HY	Ntot
HS.HB-AT-NH3 ("HS_atmo")	Atmospheric emissions from human body (including sweat, breath, infant nappies, cigarette smoking)	HS.HB	AT	NH3

4.6.1 HS.HB-WS-Ntot : Human excretion to the sewage system

It is assumed that all the N intake that is not excreted as ammonia (see section **Fehler! Verweisquelle konnte nicht gefunden werden.**) either goes to the sewage system (where a certain percentage of it is denitrified), or, if a household is not connected to the sewage system, directly to the hydrosphere (see **Fehler! Verweisquelle konnte nicht gefunden werden.**).

HS.HB-WS-Ntot = (HS.OW-HS.HB-FOOD – HS.HB-AT-NH3) * sewage_connection 0.16

Where:

HS.HB-WS-Ntot = Human N excretion to the sewage system [t N/year]
HS.OW-HS.HB-FOOD = N in food consumed by humans [t N/year], see section **Fehler! Verweisquelle konnte nicht gefunden werden.**
HS.HB-AT-NH3 = Atmospheric N emissions from human body [t N/year], see section **Fehler! Verweisquelle konnte nicht gefunden werden.**sewage_connection = national connection rate to the sewage system [%]

4.6.2 HS.HB-HY-Ntot: Human excretion to the hydrosphere

This flow entails the human excrements from households that are not connected to the sewage system.

HS.HB-HY-Ntot = (HS.OW-HS.HB-FOOD – HS.HB-AT-NH3) * (1 - sewage_connection) 0.17

Where:

HS.HB-HY-Ntot = Human N excretion to the hydrosphere [t N/year]
HS.OW-HS.HB-FOOD = N in food consumed by humans [t N/year], see section **Fehler! Verweisquelle konnte nicht gefunden werden.**
HS.HB-AT-NH3 = Atmospheric N emissions from human body [t N/year], see section **Fehler! Verweisquelle konnte nicht gefunden werden.**
sewage_connection = national connection rate to the sewage system [%]

4.6.3 HS.HB-AT-NH3: Atmospheric emissions from Human body

Sutton et al. (2000) list breath, sweat, and infant excretion as main sources of direct NH_3 emissions from humans. While NO_x emissions from tobacco smoke seem to be minor (3g NO_x per ton tobacco smoked – EMEP and EEA 2009), Sutton et al. (2000) report more relevant amounts of NH_3. Consequently, it is recommended to include these sources of NH_3 in flow HS.HB-AT-NH3 (See Table 20).

HS.HB-AT-NH3 = 1.7*10^{-5}*pop_{total} + 1.17*10^{-5}*$pop_{under1y}$ + 1,46*10^{-5}*$pop_{1\text{-}3y}$ + 3.4*10^{-9} *cig	0.18

Where:

HS.HB-AT-NH3 = Atmospheric N emissions from human body [t N/year]
Pop_{total} = average total national population
$Pop_{under1y}$ = average national population of children aged <1 year
$Pop_{1\text{-}3y}$ = average national population of children aged 1-3 years
Cig = average amount of cigarettes smoked per year

4.6.4 *Suggested data sources*

- Connection rates to the sewage system can usually be found in national statistics on water and/or wastewater, as well as in Eurostat water statistics (e.g., http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Water_statistics)
- To calculate the atmospheric NH_3 emissions, it is recommended to use the data from Sutton et al. (2000; information also compiled in Table 20) unless a more appropriate source is available.

5 Flows: Calculation guidance Tier 2

Apart from the flows covered by the basic tier 1 approach, tier 2 includes additional flows related to N embedded in material products:

Table 9: Overview on additional flows Tier 2

$Pool_{ex}$	$Pool_{in}$	Matrix*	Other info	Total code	Annex where guidance is given	Description
MP	HS.MW	POLY	Incl. various sub-flows	MP-HS.MW-POLY	2	Synthetic polymers for product use
MP	HS.MW	DETG		MP-HS.MW-DETG	2	Detergents / surfactants
MP	HS.MW	TEXT		MP-HS.MW-TEXT	2	Textiles, wearing apparel and leather products
MP / FS	HS.MW	WOOD		MP-HS.MW-WOOD	4 (2)	Wood & paper and products thereof
HS.MW	WS	SOWS	Incl. various sub-flows	HS.MW-WS-SOWS	6	Solid material waste

5.1 Material Flows

Material flows of N are rather difficult to assess in terms of nitrogen. There is a vast range of products that are made of a combination of many different materials. As a consequence, it is challenging to determine N contents of these products that are aggregated into broad categories.

Thus, the calculation should be based on production and foreign trade statistics, and assumed N contents of different product classes. As a minimum requirement, the basic substances that are components of the final products should be estimated. Production itself is available from the description in the MP pool. Imports and exports (even if not fully compatible in terminology) need to be added here.

Table 10: Overview on material flows

Flow Code	Flow Description	Pool ex	Pool in	Matrix
MP-HS.MW-POLY ("Polymer_HS")	Synthetic polymers for product use	MP	HS.MW	POLY

MP-HS.MW-DETG (“Detergents_HS”)	Detergents / surfactants	MP	HS.MW	DETG
MP-HS.MW-TEXT (“Textiles_HS”)	Textiles, wearing apparel and leather products	MP	HS.MW	TEXT
MP-HS.MW-WOOD (“Wood_HS”)	Wood & paper and products thereof	MP	HS.MW	WOOD
HS.MW-WS-SOWS (“Waste_HS”)	Solid material waste	HS.MW	WS	SOWS

5.1.1 MP-HS.MW-POLY: Synthetic polymers for product use

With production of synthetic polymers defined in Annex 2 (MP) already, only imports and exports still need to be assigned. This follows the same principles as for production: as there is an uncountable number of individual products, it is good practice to estimate substances instead. Substances to be accounted for are Polyurethanes, Polyamides and Melamine-based resins.

The approach suggested in MP for Tier 1 already points to consumption directly. There is no need to specifically focus on trade here. Trade statistics are not fully compatible with production statistics. Thus a Tier 2 approach will require detailed study of available information, based on respective national data.

5.1.2 MP-HS.MW-DETG: Detergents and Washing preparations
MP-HS.MW-TEXT: Textiles, Wearing apparel and Leather products
MP-HS.MW-WOOD: Wood & Paper and Products thereof

For all of these flows, the “apparent consumption” is derived from imports minus exports plus sold domestic production (as from the MP pool). MP-HS.MW-DETG in particular might not be above the boundary of significance and could be aggregated in many countries.

$$\boldsymbol{c(product) = Import(product) - Export(product) + sold\ domestic\ production(product)} \qquad 0.19$$

Where:

c(product) = apparent annual consumption of one product category (cT&W, cLP or cW&P) [t/yr]

5.1.3 HS.MW-WS-SOWS – Waste from material world

At the end of their lifetime, material products are disposed of and enter the pool waste. Some products, such as packaging materials, are usually discarded immediately or at least within the one-year timeframe of a NNB. Other goods (consumer durables) are used for longer periods before they are disposed of. It is difficult to determine what share of inflows for a given year accumulates in the pool, and what share is disposed of. As an approximation, the estimate by Gu et al. (2013) can be used: according to them, roughly 25% of industrial products accumulate in settlements. Consequently, it can be assumed that 75% are discarded readily.

HS.MW-WS-SOWS = (MP-HS.MW-POLY + MP-HS.MW-DETG + MP-HS.MW-TEXT + MP-HS.MW-WOOD) * 0.75 0.20

Where:

HS.MW-WS-SOWS = N in material waste [t N/year]

An alternative approach to calculate the waste flow from material world is to look at national waste statistics and assess the amount of N contained in (separately) collected waste fractions. In addition, it is recommended to separate the flow HS.MW-WS-SOWS into the different waste management streams, such as recycling, waste incineration or landfills. This needs to be done in close cooperation with the pool “waste” and requires detailed national data.

5.1.4 Suggested data sources

N contents

N content factors are given in Table 16. Estimated factors are based on calculations of the molecular (monomeric) formula of the respective component. Note that synthetic polymers have high variances in their molecular structure and composition. This applies in particular to polyurethanes (PU), polyimides, and nitrile butadiene rubbers (NBR).

Consumption data - Flow MP-HS.MW-POLY

As with production data (see Annex 2) industry associations may be a good source for consumption data:

- Plastics Europe (European trade association): Annual reports, such as “Plastics – the Facts 2012. An analysis of European plastics production, demand and waste data for 2011.” www.plasticseurope.org
- ISOPA (European trade association for producers of diisocyanates and polyols), specialized on PUs. www.isopa.org
- PCI Nylon (market research consultancy focused on the global nylon and polyamide industry) www.pcinylon.com
- www.plastemart.com
- Detailed market reports (e.g. CAS World consumption reports; chemical economics handbook)

Consumption data - Flows MP-HS.MW-DETG; MP-HS.MW-TEXT; MP-HS.MW-WOOD

Potentially useful sources and industry reports include:

- National import/export statistics (based on Prodcom) referring to CN or SITC.
- National business cycle statistics (based on Prodcom), providing data on sold goods referring to CPA 2008 classes. Note: Usually these statistics do not provide any information about the origin of used resources (imported or domestic).

6 Uncertainties

This section specifies a general approach to assess uncertainties in the utilized data sets. The uncertainties related with the pool HS are generally high, due to a lack of established and reliable data sources. Many flows have to be determined as residuals from other flows within the pool, and quantifications are frequently based on assumptions (see Pierer et al., 2015). Treatment of uncertainties is covered in detail in Annex 0 (Table 5).

For some flows, uncertainties are already implicitly included in the calculation description (e.g. emissions from human body – data used by Sutton et al. (2000) have a low estimate, high estimate, and best estimate). In these cases, the UF that fits best to the given uncertainty interval should be chosen.

7 Tables

Table 11: Estimated/assumed food waste percentages (source: Gustavsson et al. 2011).

Estimated/assumed waste percentages for food commodity groups for the last two steps in the Food Supply Chain (FSC)				
Europe incl. Russia				
	Distribution: Supermarket Retail	**Consumption**	**Distribution + Consumption**	**Assigned categories**
Cereals	2.0%	25.0%	26.50%	wheat, rice, alcoholic beverages
Roots & Tubers	7.0%	17.0%	22.81%	potatoes, starchy roots
Oilseeds & Pulses	1.0%	4.0%	4.96%	vegetable oils, nuts
Fruit & Vegetables	10.0%	19.0%	27.10%	fruits, vegetables, stimulants, spices, sugar & sweeteners
Meat	4.0%	11.0%	14.56%	poultry meat, pigmeat, bovine meat, eggs, animal fats, offals, other meat, mutton & goat meat
Fish & Seafood	9.0%	11.0%	19.01%	fish & seafood
Milk	0.5%	7.0%	7.47%	milk, cheese

Table 12: N content of food groups according to FAO classification (FAOSTAT 2014; N contents from Heldstab et al. 2010, Souci et al. 2008)

Crops – Primary Equivalent			
Item Code	**Item Name**	**% N**	**Definition – Default composition**
2617	Apples	0.1%	515 Apples, 518 Juice, apple, single strength, 519 Juice, apple, concentrated
2615	Bananas	0.2%	486 Bananas
2513	Barley	1.7%	44 Barley, 45 Barley, pot, 46 Barley, pearled, 49 Malt, 50 Malt extract; nutrient data only: 47 Bran, barley, 48 Flour, barley and grits
2546	Beans	3.6%	176 Beans, dry
2656	Beer	0.1%	51 Beer of barley
2658	Beverages. Alcoholic	0.0%	634 Beverages, distilled alcoholic
2657	Beverages. Fermented	0.0%	26 Beverages, fermented wheat, 39 Beverages, fermented rice, 66 Beer of maize, 82 Beer of millet, 86 Beer of sorghum, 517 Cider etc
2532	Cassava	0.2%	125 Cassava, 126 Flour, cassava, 127 Tapioca, cassava, 128 Cassava dried, 129 Starch, cassava
2520	Cereals. Other	1.5%	68 Popcorn, 89 Buckwheat, 90 Flour, buckwheat, 92 Quinoa, 94 Fonio, 95 Flour, fonio, 97 Triticale, 98 Flour, triticale, 101 Canary seed, 103 Grain, mixed, 104 Flour, mixed grain, 108 Cereals, nes, 111 Flour, cereals, 113 Cereal preparations, nes; nutrient data only: 91 Bran, buckwheat, 96 Bran, fonio, 99 Bran, triticale, 105 Bran, mixed grains, 112 Bran, cereals nes
2614	Citrus. Other	0.1%	512 Fruit, citrus nes, 513 Juice, citrus, single strength, 514 Juice, citrus, concentrated
2642	Cloves	1.8%	698 Cloves
2633	Cocoa Beans	3.2%	661 Cocoa, beans, 662 Cocoa, paste, 665 Cocoa, powder and cake, 666 Chocolate products nes
2560	Coconuts - Incl Copra	0.7%	249 Coconuts, 250 Coconuts, desiccated, 251 Copra
2630	Coffee	1.8%	656 Coffee, green, 657 Coffee, roasted, 659 Coffee, extracts
2619	Dates	0.3%	577 Dates
2625	Fruits. Other	0.1%	521 Pears, 523 Quinces, 526 Apricots, 527 Apricots, dry, 530 Cherries, sour, 531 Cherries, 534 Peaches and nectarines, 536 Plums and sloes, 537 Plums dried (prunes), 538 Juice, plum, single strength, 539 Juice, plum, concentrated, 541 Fruit, stone nes, 542 Fruit, pome nes, 544 Strawberries, 547 Raspberries, 549 Gooseberries, 550 Currants, 552 Blueberries, 554 Cranberries, 558 Berries nes, 567 Watermelons, 568 Melons, other (inc.cantaloupes), 569 Figs, 570 Figs dried, 571 Mangoes, mangosteens, guavas, 572 Avocados, 583 Juice, mango, 587 Persimmons, 591 Cashewapple, 592 Kiwi fruit, 600 Papayas, 603 Fruit, tropical fresh nes, 604 Fruit, tropical dried nes, 619 Fruit, fresh nes, 620 Fruit, dried nes, 622 Juice, fruit nes, 623 Fruit, prepared nes, 624 Flour, fruit, 625 Fruits, nuts, peel, sugar preserved, 626 Fruit, cooked, homogenized preparations
2613	Grapefruit	0.1%	507 Grapefruit (inc. pomelos), 509 Juice, grapefruit, 510 Juice, grapefruit, concentrated
2620	Grapes	0.1%	560 Grapes, 561 Raisins, 562 Juice, grape, 563 Grapes, must
2556	Groundnuts (Shelled Eq)	4.8%	242 Groundnuts, with shell, 243 Groundnuts, shelled, 246 Groundnuts, prepared, 247 Peanut butter
2612	Lemons. Limes	0.1%	497 Lemons and limes, 498 Juice, lemon, single strength, 499 Juice, lemon, concentrated

2514	Maize	1.3%	56 Maize, 58 Flour, maize, 64 Starch, maize, 846 Feed and meal, gluten; nutrient data only: 57 Germ, maize, 59 Bran, maize, 63 Gluten, maize
2517	Millet	1.5%	79 Millet, 80 Flour, millet; nutrient data only: 81 Bran, millet
2544	Molasses	1.4%	
2551	Nuts	3.2%	216 Brazil nuts, with shell, 217 Cashew nuts, with shell, 220 Chestnut, 221 Almonds, with shell, 222 Walnuts, with shell, 223 Pistachios, 224 Kola nuts, 225 Hazelnuts, with shell, 226 Areca nuts, 229 Brazil nuts, shelled, 230 Cashew nuts, shelled, 231 Almonds shelled, 232 Walnuts, shelled, 233 Hazelnuts, shelled, 234 Nuts, nes, 235 Nuts, prepared (exc. groundnuts)
2516	Oats	1.8%	75 Oats, 76 Oats rolled; nutrient data only: 77 Bran, oats
2570	Oilcrops. Other	3.9%	263 Karite nuts (sheanuts), 265 Castor oil seed, 275 Tung nuts, 277 Jojoba seed, 280 Safflower seed, 296 Poppy seed, 299 Melonseed, 305 Tallowtree seed, 310 Kapok fruit, 311 Kapokseed in shell, 312 Kapokseed shelled, 333 Linseed, 336 Hempseed, 339 Oilseeds nes, 343 Flour, oilseeds
2563	Olives	0.2%	260 Olives, 262 Olives preserved
2602	Onions	0.2%	403 Onions, dry
2611	Oranges. Mandarines	0.1%	490 Oranges, 491 Juice, orange, single strength, 492 Juice, orange, concentrated, 495 Tangerines, mandarins, clementines, satsumas, 496 Juice, tangerine
2547	Peas	3.6%	187 Peas, dry
2640	Pepper	1.8%	687 Pepper (piper spp.)
2641	Pimento	1.8%	689 Chillies and peppers, dry
2618	Pineapples	0.1%	574 Pineapples, 575 Pineapples canned, 576 Juice, pineapple, 580 Juice, pineapple, concentrated
2531	Potatoes	0.3%	116 Potatoes, 117 Flour, potatoes, 118 Potatoes, frozen, 119 Starch, potatoes, 121 Tapioca, potatoes
2549	Pulses. Other	3.6%	181 Broad beans, horse beans, dry, 191 Chick peas, 195 Cow peas, dry, 197 Pigeon peas, 201 Lentils, 203 Bambara beans, 205 Vetches, 210 Lupins, 211 Pulses, nes, 212 Flour, pulses; nutrient data only: 213 Bran, pulses
2805	Rice (Milled Eq.)	1.2%	27 Rice, paddy, 28 Rice, husked, 29 Rice, milled/husked, 31 Rice, milled, 32 Rice, broken, 34 Starch, rice, 38 Flour, rice; nutrient data only: 33 Gluten, rice, 35 Bran, rice
2804	Rice (Paddy Eq.)	1.2%	
2534	Roots. Other	0.3%	135 Yautia (cocoyam), 136 Taro (cocoyam), 149 Roots and tubers, nes, 150 Flour, roots and tubers nes, 151 Roots and tubers dried
2515	Rye	1.7%	71 Rye, 72 Flour, rye; nutrient data only: 73 Bran, rye
2561	Sesameseed	3.9%	289 Sesame seed
2518	Sorghum	1.5%	83 Sorghum, 84 Flour, sorghum; nutrient data only: 85 Bran, sorghum
2555	Soyabeans	6.0%	236 Soybeans, 239 Soya sauce, 240 Soya paste, 241 Soya curd
2645	Spices. Other	1.8%	692 Vanilla, 693 Cinnamon (canella), 702 Nutmeg, mace and cardamoms, 711 Anise, badian, fennel, coriander, 720 Ginger, 723 Spices, nes
2557	Sunflowerseed	3.4%	267 Sunflower seed
2533	Sweet Potatoes	0.3%	122 Sweet potatoes
2635	Tea	1.8%	667 Tea, 671 MatÃ©, 672 Tea, mate extracts
2601	Tomatoes	0.2%	388 Tomatoes, 389 Juice, tomato, concentrated, 390 Juice, tomato, 391 Tomatoes, paste, 392 Tomatoes, peeled
2605	Vegetables. Other	0.3%	358 Cabbages and other brassicas, 366 Artichokes, 367 Asparagus, 372 Lettuce and chicory, 373 Spinach, 378 Cassava leaves, 393 Cauliflowers and broccoli, 394 Pumpkins, squash and gourds, 397 Cucumbers and gherkins, 399 Eggplants (aubergines), 401 Chillies and peppers, green, 402 Onions, shallots, green, 406 Garlic, 407 Leeks, other alliaceous vegetables, 414 Beans, green, 417 Peas, green, 420 Vegetables, leguminous nes,

			423 String beans, 426 Carrots and turnips, 430 Okra, 446 Maize, green, 447 Sweet corn frozen, 448 Sweet corn prep or preserved, 449 Mushrooms and truffles, 450 Mushrooms, dried, 451 Mushrooms, canned, 459 Chicory roots, 461 Carobs, 463 Vegetables, fresh nes, 464 Vegetables, dried nes, 465 Vegetables, canned nes, 466 Juice, vegetables nes, 469 Vegetables, dehydrated, 471 Vegetables in vinegar, 472 Vegetables, preserved nes, 473 Vegetables, frozen, 474 Vegetables, temporarily preserved, 475 Vegetables, preserved, frozen, 476 Vegetables, homogenized preparations, 567 Watermelons, 568 Melons, other (inc.cantaloupes), 658 Coffee, substitutes containing coffee
2511	Wheat	2.3%	15 Wheat, 16 Flour, wheat, 18 Macaroni, 20 Bread, 21 Bulgur, 22 Pastry, 23 Starch, wheat, 41 Cereals, breakfast, 110 Wafers; nutrient data only: 17 Bran, wheat, 19 Germ, wheat, 24 Gluten, wheat, 114 Mixes and doughs, 115 Food preparations, flour, malt extract
2655	Wine	0.0%	564 Wine, 565 Vermouths and similar
2535	Yams	0.3%	137 Yams
	Sugars & Sweeteners	0.0%	2542 Sugar (raw equivalent), 2537 Sugar Beet, 2536 Sugar Cane, 2541 Sugar Non-Centrifugal, 2827 Sugar Raw Eq., 2818 Sugar Refined Eq., 2543 Sweeteners – other
	Oils	0.0%	2578 Coconut Oil, 2575 Cottonseed Oil, 2572 Groundnut Oil, 2582 Maize Germ Oil, 2586 Oilcrops Oil – other, 2580 Olive Oil, 2576 Palmkernel Oil, 2577 Palm Oil, 2574 Rape and Mustard Oil, 2581 Ricebran Oil, 2579 Sesameseed Oil, 2571 Soyabean Oil, 2573 Sunflowerseed Oil, etc.

Livestock and Fish – Primary Equivalent

Item Code	**Item Name**	**% N**	**Definition – Default composition**
Item Code	**Item Name**		**Definition**
2769	Aquatic Animals. Others	2.8%	1587 Aqutc Anim F, 1588 Aq A Cured, 1589 Aquatic Animals Meals, 1590 Aq A Prep Ns
2775	Aquatic Plants	40.0%	1594 Aquatic plants, fresh, 1595 Aquatic plants, dried, 1596 Aquatic plants, other preparations
2731	Bovine Meat	2.5%	867 Meat, cattle, 870 Meat, cattle, boneless (beef and veal), 872 Meat, beef, dried, salted, smoked, 873 Meat, extracts, 874 Meat, beef and veal sausages, 875 Meat, beef, preparations, 876 Meat, beef, canned, 877 Meat, homogenized preparations, 947 Meat, buffalo
2740	Butter. Ghee	0.1%	886 Butter, cow milk, 887 Ghee, butteroil of cow milk, 952 Butter, buffalo milk, 953 Ghee, of buffalo milk, 983 Butter and ghee, sheep milk, 1022 Butter of goat mlk
2766	Cephalopods	2.8%	1570 Cephlp Fresh, 1571 Cphlp Frozen, 1572 Cphlp Cured, 1573 Cphlp Canned, 1574 Cphlp Pr nes, 1575 Cphlp Meals
2741	Cheese	4.2%	
2743	Cream	0.5%	885 Cream fresh
2765	Crustaceans	2.8%	1553 Crstaceans F, 1554 Crstc Frozen, 1555 Crstc Cured, 1556 Crstc Canned, 1557 Crstc Pr nes, 1558 Crstc Meals
2762	Demersal Fish	2.8%	1514 Dmrsl Fresh, 1515 Dmrsl Fz Whl, 1516 Dmrsl Fillet, 1517 Dmrsl Fz Flt, 1518 Dmrsl Cured, 1519 Dmrsl Canned, 1520 Dmrsl Pr nes, 1521 Dmrsl Meals
2744	Eggs	1.9%	1062 Eggs, hen, in shell, 1063 Eggs, liquid, 1064 Eggs, dried, 1091 Eggs, other bird, in shell; nutrient data only: 916 Egg albumine
2855	Fish Meal	10.7%	
2761	Freshwater Fish	2.8%	1501 Frwtr Diad F, 1502 Frwtr Fz Whl, 1503 Frwtr Fillet, 1504 Frwtr Fz Flt, 1505 Frwtr Cured, 1506 Frwtr Canned, 1507 Frwtr Pr nes, 1508 Frwtr Meals
2748	Hides & Skins	5.2%	

2745	Honey	0.1%	1182 Honey, natural
2764	Marine Fish. Other	2.8%	1540 Marine nes F, 1541 Marin Fz Whl, 1542 Marin Fillet, 1543 Marin Fz Flt, 1544 Marin Cured, 1545 Marin Canned, 1546 Marin Pr nes, 1547 Marin Meals
2749	Meat Meal	10.7%	
2735	Meat. Other	2.5%	1089 Meat, bird nes, 1097 Meat, horse, 1108 Meat, ass, 1111 Meat, mule, 1127 Meat, camel, 1141 Meat, rabbit, 1151 Meat, other rodents, 1158 Meat, other camelids, 1163 Meat, game, 1164 Meat, dried nes, 1166 Meat, nes, 1172 Meat, nes, preparations, 1176 Snails, not sea
2848	Milk - Excluding Butter	2.1%	882 Milk, whole fresh cow, 888 Milk, skimmed cow, 889 Milk, whole condensed, 890 Whey, condensed, 891 Yoghurt, 892 Yoghurt, concentrated or not, 893 Buttermilk, curdled, acidified milk, 894 Milk, whole evaporated, 895 Milk, skimmed evaporated, 896 Milk, skimmed condensed, 897 Milk, whole dried, 898 Milk, skimmed dried, 899 Milk, dry buttermilk, 900 Whey, dry, 901 Cheese, whole cow milk, 904 Cheese, skimmed cow milk, 905 Whey, cheese, 907 Cheese, processed, 908 Milk, reconstituted, 917 Casein, 951 Milk, whole fresh buffalo, 954 Milk, skimmed buffalo, 955 Cheese, buffalo milk, 982 Milk, whole fresh sheep, 984 Cheese, sheep milk, 985 Milk, skimmed sheep, 1020 Milk, whole fresh goat, 1021 Cheese of goat mlk, 1023 Milk, skimmed goat, 1130 Milk, whole fresh camel; nutrient data only: 903 Whey, fresh, 909 Milk, products of natural constituents nes, 910 Ice cream and edible ice
2738	Milk. Whole	0.5%	
2767	Molluscs. Other	2.8%	1562 Mlluscs Frsh, 1563 Molsc Frozen, 1564 Molsc Cured, 1565 Molsc Canned, 1566 Molsc Meals
2732	Mutton & Goat Meat	2.5%	977 Meat, sheep, 1017 Meat, goat
2736	Offals. Edible	2.5%	868 Offals, edible, cattle, 878 Liver prep., 948 Offals, edible, buffaloes, 978 Offals, sheep,edible, 1018 Offals, edible, goats, 1036 Offals, pigs, edible, 1059 Offals, liver chicken, 1074 Offals, liver geese, 1075 Offals, liver duck, 1081 Offals, liver turkeys, 1098 Offals, horses, 1128 Offals, edible, camels, 1159 Offals, other camelids, 1167 Offals, nes
2763	Pelagic Fish	2.8%	1527 Pelagic Frsh, 1528 Pelgc Fz Whl, 1529 Pelgc Fillet, 1530 Pelgc Fz Flt, 1531 Pelgc Cured, 1532 Pelgc Canned, 1533 Pelgc Pr nes, 1534 Pelgc Meals
2733	Pigmeat	2.2%	1035 Meat, pig, 1038 Meat, pork, 1039 Bacon and ham, 1041 Meat, pig sausages, 1042 Meat, pig, preparations
2734	Poultry Meat	2.6%	1058 Meat, chicken, 1060 Fat, liver prepared (foie gras), 1061 Meat, chicken, canned, 1069 Meat, duck, 1073 Meat, goose and guinea fowl, 1080 Meat, turkey
2742	Whey (dry)	2.0%	
	Fats & Oils	0.0%	2737 Fats, Animals, Raw, 2781 Fish, Body Oil, 2782 Fish, Liver Oil

Table 13: N content and application of potentially relevant synthetic polymers

synthetic polymers	chemical structure	Mr [g/mol]	m(N) [g/mol]	N [m%]	explanatory notes referring to N content	applications
Polyamides (PA)						
Perlon (PA 6)	$(C_6H_{11}NO)_n$	113	14	**12**	calculated	fibres (clothes, carpets), films (packaging), automotive and electronic industry
Nylon (PA 66)	$(C_{12}H_{22}N_2O_2)_n$	226	28	**12**	calculated	
Polyurethane (PU)	high variance in monomeric composition			**10**	estimated	insulating foams, matresses, automotive parts, building and construction
Melamine/Urea Formaldehyde Resins (MF, MUF, UF)						
MF (melamine formaldehyde)	$(C_7H_{12}N_6)_n$	180	84	**47**	calculated (N in pure melamine: 66.6 m%)	woody panels, surface coatings for cars, dishes, flame retardants
UF (urea formaldehyde)	$(C_4H_8N_2O)_n$	100	28	**28**	calculated	Woody panels
Others						
PAN (polyacrylonitrile)	$(C_3H_3N)_n$	53	14	**26**	calculated	textiles
ABS (acrylonitrile butadiene styrene)	$(C_8H_8{\cdot}C_4H_6{\cdot}C_3H_3N)_n$	198	14	**7.1**	calculated	automotive and electronic industry
NBR (nitrile butadiene rubber)	$(C_4H_6)_n(C_3H_3N)_m$	107	14	**13**	estimated (acrylonitrile amount: 18-50 m%)	sealings, gloves
Polyimide	high variance in monomeric composition			**10**	estimated	electronic industry, coatings
Chitosan	$(C_6H_{13}O_5N)_n$	203	14	**6.9**	calculated	medical applications, food packaging

Table 14: N content and application of potentially relevant natural polymers

natural polymers	protein [m%]	N [m%]	explanatory notes referring to N content	applications
silk (fibroin, sericin)	>95	**15**	N contents of natural polymers are estimated on the base of 95 m% protein content. N [m%] = protein [m%] * 0.16 Other substances, usually beyond 5 m%, can be carbohydrates, lipids, natural dyes and water.	textiles, wearing apparels
wool, cashmere (keratin)				textiles, wearing apparels
leather (collagen)				textiles, wearing apparels
fur (keratin, collagen)				textiles, wearing apparels
gelatine				coating (color printing papers, photo-papers), pharmaceuticals
collagen				cosmetics
casein				dyes, adhesives
horn, plumes (keratin)				bedding, decoration, trophies, musical instruments

Table 15: N content and application of surfactants

tensides (+ enzymes)		Protein [%]	N [m%]	explanatory notes referring to N content	applications
enyzmes (lipases/proteases/cellulases)	Protein	>95	**15**		cleaning agents
ammonium salts esterquats, betain, EDTA…	ionic	-	**2.2**[27]		cleaning agents, surfactants in general

[27] mass weight representative calculated basing on an esterquat (quaternary ammonium cations with a relative molecular weight of 648 g/mol).

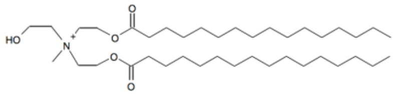

Table 16: N content factors for products referring to CPA 2008 Codes and CN Classes.

CN Chapter	CPA 2008 Code C	Description MANUFACTURED PRODUCTS	N [%]	UL
24	12	**Tobacco products**		
		sum of positions	4.0	3
50 - 67	13, 14	**Textiles and Wearing apparel**		
		Positions outlined to be made of crop fibres[28]	0.2	2
		Positions outlined to be made of animal hair or animal fibres[29]	15	1
		Positions outlined to be made of Polyamides[30] are included in MP-HS.MW-POLY (Synthetic polymers for product use)	12	2
41, 42, 43	15	**Leather and related products**		
		Sum of positions	15	1
44, 45, 46	16	**Wood, products of wood and cork, except furniture; articles of straw and plaiting materials** Sum of positions, excluding: firewood, wood chips, briquettes, pellets, sawdust and charcoal.	0.2	2
47, 48, 49	17	**Paper and paper products**		
		Sum of positions	0.2	2
34	20	**Chemicals and chemical products** (covered by the pool „Industry“)		
3402	20.41.32	**Detergents and Washing Preparations**		
34021200	20.41.32	cationic surfactants[31]	2.1	4
39, 40 and others	22	**Rubber and plastic products** Included in MP-HS.MW-POLY (Synthetic polymers for product use)		
94	31	**Furniture**		
		Positions outlined to be made of wood	0.2	2
		PU for mattresses or other foams, melamine for coatings and other relevant components in this class are included in MP-HS.MW-POLY (Synthetic polymers for product use).		

[28] Crop fibres: cotton, cellulose, flax, plush, velvet, fleece, chenille. Some positions are outlined to have a content of < 85% plant fibres which is neglected. Neglects are taken into account, since there is no information about the other part of the material (> 15%), which can be of animal, plant or synthetic origin.

[29] Animal hair/ fibres: wool, silk, cashmere, fur, grége, felt. Some positions are outlined to have a content of < 85% of animal fibres, which is neglected. Neglects are taken into account, since there is no information about the other part of the material (> 15%), which can be of animal, plant or synthetic origin.

[30] nylon, PA 66, perlon, PA 6, aramid

[31] mass weight representative calculated basing on an esterquat (quaternary ammonium cations with a relative molecular weight of 648 g/mol).

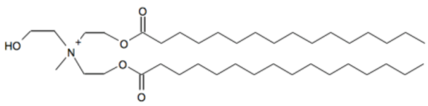

Table 17: Polyurethane (PU), Polyamide (PA), and Melamine use per sector (sources: IHS 2010; ISOPA 2003; OCI Nitrogen 2011; Plastemart 2007a,b;)

PU		PA		Melamine	
Sector	**%**	**Sector**	**%**	**Sector**	**%**
Construction	24	Fibres (textiles and other filaments)	57	Wood-panel industry	75
Automotive	21	Engineering Thermoplastics (cars and electrical, electronics)	36	Coating resins	7
Furniture	22	Films	7	Moulding compounds	8
Electrical, electronics	11			Flame retardants	5
Footwear	8			Others	5
Others (e.g. packaging, engineering, sporting goods)	14				

Table 18: Average protein and N intake of pets

	Average feed intake per day (g/animal/day or % of body weight)	**average feed intake per year** (kg)	**Protein content in feed**	**Protein intake per year** (kg)	**N intake per year** (kg)
Mouse	5g	1.8	13% [a]	0.24	0.04
Rat	15 - 20g	6.4	13% [a]	0.83	0.13
Hamster	8 - 12g	3.7	13% [a]	0.47	0.08
Guinea pig	35 - 70g	19.2	10%	1.92	0.31
Rabbit	200 - 300g	91.3	16%	14.60	2.34
average small mammals		24.5		3.61	0.58
Cat[b]	5%	73.0	26%	18.98	3.04
Dog[c]	3%	164.3	18%	29.57	4.73
Ornamental birds[d]	n.a	n.a.	10-15%	0.06	0.009
Ornamental fish (Goldfish)	4g	1.5	40%	0.58	0.09
Source	Weiss et al. 2003, Mette 2011	calculated	Hand et al. 2002; Methling & Unshelm 2002, Rühle 2013; Mette 2011; Knauer 2013	Calculated; Knauer 2013	calculated

[a] calculated as average from guinea pig and rabbit
[b] Assumed average weight of cats: 4 kg
[c] Assumed average weight of dogs: 15 kg
[d] Assumed average weight of ornamental birds: 50 g

Table 19: Average urinary & faecal N excretion and NH_3 volatilization of non-agricultural animals (source: Sutton et al. 2000).

	Best estimate	Low estimate	High estimate	Unit
Pleasure riding horses N volatilization	10	5	20	kg NH_3-N / horse/year
Race horses N excretion	137			kg N /horse/ year
Race horses N volatilization	33.7	15	40	kg NH_3-N / horse/year
Dogs N excretion	2.6			kg available N /dog/year
Dogs N volatilization	0.61	0.3	0.93	kg NH_3-N/dog/year
Cats N excretion	0.91			kg urinary N /cat/year
Cats N volatilization	0.11	0.05	0.16	kg NH_3-N / cat/year
Source	Sutton et al. 2000			

Table 20: NH_3-N emission factors of human sweat, breath, infant nappies and cigarette smoke (source: Sutton et al. 2000).

	Best estimate	Low estimate	High estimate	Unit
Sweat NH_3 emission	14.04	2.08	74.99	g N / person / year
Breath emissions	3.0	1.0	7.7	g NH_3-N / person / year
Estimated NH_3 emissions < 1 year old infant	11.7	2.4	54.2	g NH_3-N / child / year
Estimated NH_3 emissions 1-3 year old infant	14.6	3.0	67.8	g NH_3-N / child / year
Cigarette smoke	3.4	1.7	6.2	mg NH_3-N / cigarette
Source	Sutton et al. 2000			

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9 Document version

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Annex 7 – Atmosphere

1 Introduction

The atmosphere in terms of N-budgets mainly functions as a transport medium, as it serves to collect, to deposit and to transport reactive nitrogen under various chemical forms in the troposphere. Even though most of the available nitrogen consists in the form of inert molecular N_2, only the fraction present as Nr or being converted to or from Nr has to be quantified. The quantification of conversions between compounds of different possible atmospheric sub-pools (e.g., oxidized or reduces Nr-species) is not required, except for N_2 fixation to NO_X due to lightning, which is considered as an input flow. Main input flows are atmospheric import of Nr, and emissions from all other pools in a National Nitrogen Budget (NNB). Output flows are biological and technical N-fixation, export of Nr by atmospheric transport and Nr-deposition to land-based pools. N fixation is not considered in the atmosphere pool but is treated and described in Agriculture pool.

2 Definitions

2.1 Flow connection scheme

In figure 1 the N budget scheme for the pool 'Atmosphere' is reported. To be noted that the scheme of the atmosphere is simplified, skipping the all tropopause description, neglecting fluxes between different layers, just focusing on lower layer troposphere.

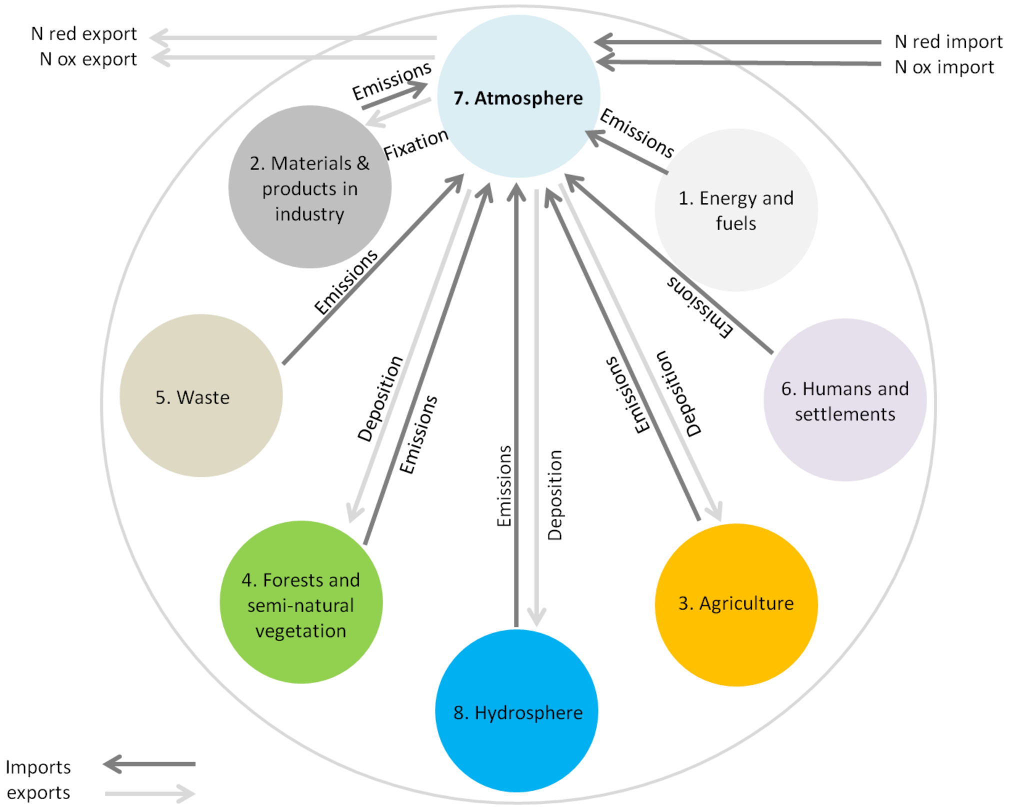

Figure 1 – N budget scheme for the Atmosphere pool.

The input flows are the N fluxes (as tons of N emitted) from all other pools ('Energy and Fuels', 'Waste', 'Forest and Semi-natural Vegetation', 'Materials and Products', 'Agriculture', 'Humans and

Settlements', 'Hydrosphere') and N (reduced and oxidized) by transboundary transport. Output flows are N deposition to national ecosystem (hydro and terrestrial) and exported to neighboring countries.

2.2 Definition of atmospheric nitrogen pollutants

The pollutant emissions to be considered in this pool are ammonia (NH_3), nitrogen oxides (NO_X) and (nitrous oxide) N_2O. Even if properties of individual species may differ (e.g. N in NH_3, N in N_2O), N budgets refer only to total Nr.

Nitrogen oxides (NO_X) are a generic term for mono-nitrogen oxides (nitric oxide, NO, and nitrogen dioxide, NO_2) and are mainly emitted during fuel combustion especially at high temperature. The main emitting sectors are industrial facilities and road transport.

The vast majority of NH_3 comes from the agricultural sector in connection with activities and practices such as manure storage, slurry spreading and the use of synthetic nitrogenous fertilizers.

Nitrous oxide (N_2O) is a powerful greenhouse gas produced both naturally and via human activities. N_2O gives rise to NO on reaction with oxygen atoms and this NO then reacts with ozone. So it is the main naturally occurring regulator of stratospheric ozone (Ravishankara et al., 2009), by its depleting ozone activity. Following IPCC (2007) it has a global warming potential (GWP) 298 times than carbon dioxide (CO_2). The main human sources of N_2O are agriculture, and especially soil cultivation with nitrogen fertilizers, and livestock production.

The NH_3, NO_X and N_2O input emission to the Atmosphere should be quantified from the output of the subpools "Energy and Fuels", "Agriculture" considering emissions from livestock and nitrogen fertilizers, "Humans and Settlements" and "Waste" sectors and natural emissions.

Emissions are usually quantified as tons of the emitted pollutant, while in a nitrogen budget emissions have to be reported in tons of Nitrogen emitted. To convert pollution emissions in N emissions the coefficient to be used is linked to the atomic weights of the different substances, as reported in table 1.

Table 1 – Stoichiometric coefficient to convert air pollution emitted (NH_3, NO_x, N_2O) in N emissions.

from Substance	to N emissions	Conversion coefficient
NH_3 (weight 17)	N (weight 14)	0.824
NO_x (as NO_2 emissions: weight 46)	N (weight 14)	0.304
N_2O (weight 44)	N_2 (weight 28)	0.636

Looking at the conversion coefficient, this means that from 1 ton of NH_3 more N is emitted in the atmosphere than through the emission of NO_x or N_2O.

Another important NO_x source is lightning in the middle and upper troposphere. The knowledge of the lightning-induced nitrogen oxides (LNO_x) source is important for understanding and predicting the nitrogen oxides and ozone distributions in the troposphere and their trends, the oxidizing capacity of the atmosphere, and the lifetime of trace gases destroyed by reactions with OH (Schumann and Huntrieser, 2007). In the middle and upper troposphere, where NO_x is long-lived and typically at more dilute concentrations, LNO_x is a particularly significant source (Ridley et al., 1996; Huntrieser et al., 1998; Pickering et al., 1998; Zhang et al., 2000; Bond et al., 2001, 2005). Lightning is a transient, high-current electric discharge over a path length of several kilometers in the atmosphere (Uman, 1987). The majority of lightning in the Earth's atmosphere is associated with convective thunderstorms (MacGorman and Rust, 1998; Rakov and Uman, 2003). Lightning forms from the breakdown of charge separation in thunderstorms.

The global LNO_x source is one of the largest natural sources of NO_x in the atmosphere (Galloway et al., 2004) and certainly the largest source of NO_x in the upper troposphere (see below for more detailed quantification).

2.3 Definition of transboundary nitrogen flows

Nitrogen deposition is the term used to describe the removal of atmospheric trace constituents due to uptake on the earth's surface. Most concern has addressed the impacts of nitrogen deposition to terrestrial ecosystems, but impacts may also occur in the marine environment. The pollutants that contribute to nitrogen deposition derive mainly from nitrogen oxides (NO_X) and ammonia (NH_3) emissions. In the atmosphere NO_X is transformed to a range of secondary pollutants, including nitric acid (HNO_3), nitrates (NO_3^-) and organic compounds, such as peroxyacetyle nitrate (PAN), while NH_3 is transformed to ammonium (NH_4^+). Both the primary and secondary pollutants are removed by wet deposition (scavenging of gases and aerosols by precipitation) and by dry deposition (direct turbulent deposition of gases and aerosols) (Hornung and Williams, 1994).

Transboundary air pollution is an important Nr-flow for Nr-components that are not easily removed from the atmosphere, i.e. have considerable residence time in the atmosphere. These are cross boundary pollutants that can be generated in one country and transported to other countries; Transboundary air pollutants can remain in the atmosphere sufficiently long to be transported thousands of kilometres and thus to spread over the whole of Europe, across national borders, far from the original sources of polluting emissions, causing eutrophication and acidification.

Transboundary nitrogen deposition for a single country is considered like the balance between nitrogen input from other countries and nitrogen output towards other countries. This balance is very sensitive to climate conditions and to geographical position (Posch, 2002).

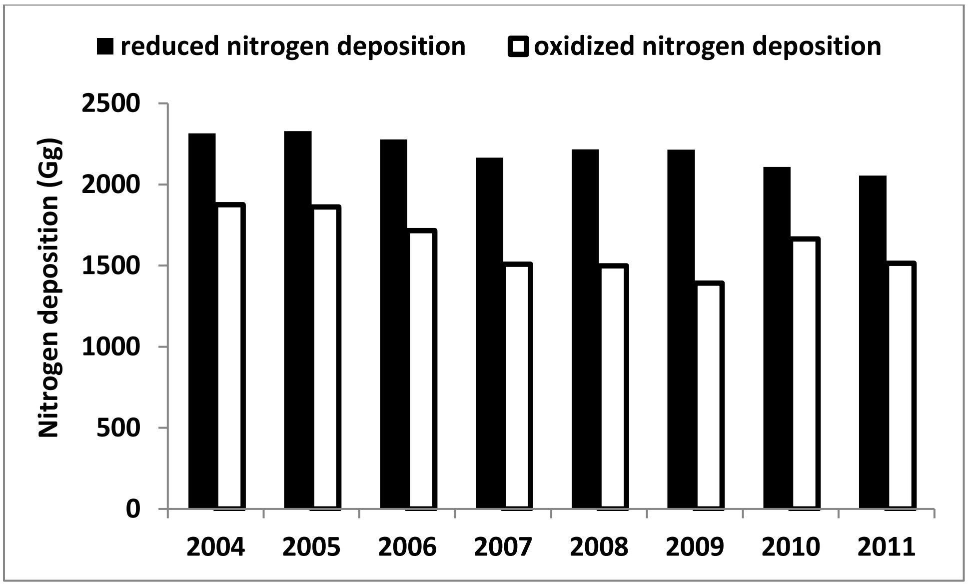

Figure 2. Time trend for reduced and oxidized nitrogen deposition in comparison with total nitrogen deposition in Europe, source EMEP (EEA, 2013a).

In Figure 2 time trends for reduced and oxidized nitrogen deposition for Europe are presented. The trend is generally decreasing for total nitrogen and oxidized nitrogen deposition, whilst is more or less stable for reduced nitrogen. This is linked, as will be more detailed described later, to the emission from agricultural sector, which is the main responsible for reduced nitrogen deposition.

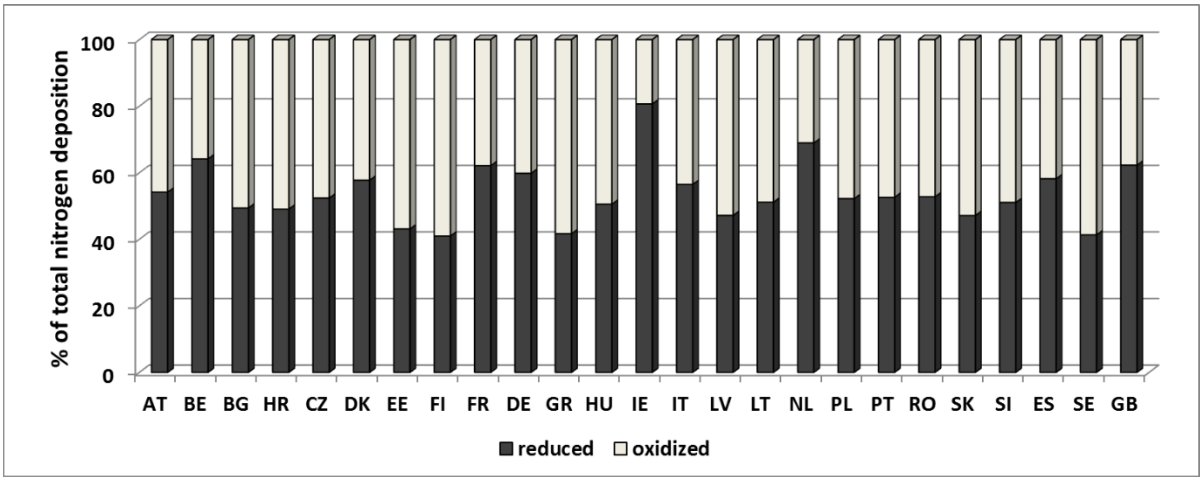

Figure 3. Percentage of Nitrogen reduced (black bars) or Nitrogen oxidized (white bars) deposition respect to the total deposition (year 2010).

Figure 3 focus on the different composition of nitrogen deposition in terms of oxidized or reduced components in the year 2010 for the European countries. Some countries show higher levels of the reduced component of nitrogen deposition, that reach a value ranging between 80% in Ireland (IE) or 70% in The Netherlands (NL).

2.4 Separate consideration of chemical species

For assessment of effects it has been assumed that nitrogen originating from NH_3 or NO_X has the same ecological effect (Sutton et al. 1993, Hornung and Williams, 1994). This assumption is now being challenged, as both UK wide survey work (Stevens et al, 2010) and manipulation studies (Sheppard et al 2011) have found stronger correlations between detrimental effects on semi-natural plant species, particularly among lower plants, and the concentration or dose of reduced N. However, it is clear that NO_X emissions are much more widely dispersed than NH_3, with the latter often deposited in high quantities to semi-natural vegetation in intensive agricultural areas. Reduced N (Nred) is primarily emitted from intensive animal units and more recently vehicles with the introduction of catalytic converters. Thus effects of NH_3 are most common close to urban highway and roadside verges, and within 100 - 500m of the point source depending on the size of the source of the source. Aerosols of ammonia, by comparison, are carried much further and contribute to wet deposition. The loading of N in wet deposition will depend on the amount of precipitation and the amount of N. In the east, N concentrations can be quite high due to the low rainfall, whereas in the west the rainfall is much higher but the concentrations tend to be lower.

3 Inflows and outflows

3.1 Emissions

In a National Nitrogen Budget, the main input flows to the Atmosphere pool are the emissions from all other pools and the atmospheric import of Nr. Considerable detailed guidance to describing methods for assessing flows of N compounds to the atmosphere has been given by EMEP/EEA (2013), and, for N_2O, by IPCC (2006). Hence, this section describes the generic methods for estimating the amount of various N inputs to the Atmosphere pool only, and refers to the details contained in the respective external guidance documents.

In EU27 NO_X emissions have dropped considerably since 1990 and a reduction of 48% in 2011 has been observed (EEA, 2013b). Main reductions have been taken place in the electricity/energy generation sectors as a result of technical measures and fuel switching from coal to gas.

NH_3 emissions decreased considerably (-28%) from 1990 to 2011 as a result of improved manure management. In recent years, however, the trend in emissions is quite stable (EEA, 2013b).

All detailed data are available at the following link

http://www.eea.europa.eu/publications/emep-eea-guidebook-2013 (EMEP/EEA, 2013))

http://webdab.umweltbundesamt.at/official_country_year.html?cgiproxy_skip=1

http://www.eea.europa.eu/data-and-maps/data/national-emissions-reported-to-the-convention-on-long-range-transboundary-air-pollution-lrtap-convention-7

For NO_x, the main emitting sources are the energy and transport sectors. The road transport sectors represent the largest source of NO_x emissions, accounting for 40 % of total EU-27 emissions in 2011 (EEA, 2013c).

For NH_3, the agricultural sector is responsible for the 93% of total EU-27 emissions in 2011 (EEA, 2013c).

Nitrous oxide is naturally present in the atmosphere as part of the Earth's nitrogen cycle, and has a variety of natural sources. However, human activities such as agriculture, fossil fuel combustion, wastewater management, and industrial processes are increasing the amount of N_2O in the atmosphere. Nitrous oxide molecules stay in the atmosphere for an average of 120 years before being removed by a sink or destroyed through chemical reactions. The impact of 1 kg of N_2O on warming the atmosphere is about298 times that of 1 kg of carbon dioxide.

In EU-27, N_2O emissions decreased by 36% in 2011 respect to the year 1990 (EEA, 2013d). Detailed data for each Member States could be downloaded at the following link http://www.eea.europa.eu/data-and-maps/data/national-emissions-reported-to-the-unfccc-and-to-the-eu-greenhouse-gas-monitoring-mechanism-7

Lightning and corona discharge during thunderstorm events cause atmospheric chemical reactions to take place at high voltages and high temperatures. These reactions cause the production of NOx in the atmosphere. Global NOx production by lightning has been estimated in the range of 3–5 Tg N/yr (Levy et al., 1996). The methodology to estimate emissions from lightning could be found in the last version of the EMEP/EEA air pollutant emission inventory guidebook 2013 (EEA, 2013e) and on the web site www.euclid.org.

3.1.1 Suggested Data Sources

Anthropogenic and natural emission sources of NO_X and NH_3 can be estimated from the EMEP/EEA air pollutant emission inventory guidebook (http://webdab.umweltbundesamt.at/official_country_year.html?cgiproxy_skip=1).

At the link of the Center on Emission Inventories and Projections, http://www.ceip.at/, emission data officially submitted by the Parties to the Convention on Long-Range Transboundary Air Pollution (CLRTAP) can be downloaded.

The quantification of anthropogenic N_2O emissions can be estimated from the IPCC guidelines for National Greenhouse Gas Inventories (IPCC, 2006). From the UNFCCC site it is possible to download emission data, http://unfccc.int/ghg_data/items/3800.php

Data can be downloaded for Europe on the European Environmental Agency link: http://www.eea.europa.eu/data-and-maps#tab-datasets

It is recommended to nitrogen budget experts to liaise with national experts providing data for UNFCCC and for UNECE.

3.2 Nitrogen deposition and in and outflow of Nr of NNB-domain

Air dispersion models are used to provide an estimate of a concentration or deposition of a pollutant emitted from an industrial process (point source) or a road (line source). Output from dispersion models are often used to predict the contribution of a new or existing process, to level of pollutants at specified points. The modeled outputs of concentrations and depositions can then be compared with environmental limits (e.g. Critical Loads) and air quality limits related to human health. There are numerous models that are used for both short-range local scale modeling (<20 km), and long-range, regional/trans-boundary, air pollution (>50km). Between these model the so-called Chemical Transport Models (CTM) take into account the strength of anthropogenic and biogenic emissions, their diffusion in the atmosphere, the transport of air masses, and the chemical interactions of all the substances being observed. With the help of CTM it is possible to generate a wide-area forecast of pollutant load. A precondition for forecasting air quality is knowing the meteorological situation. A weather forecast for the ensuing three days is necessary with the help of the Weather Research and Forecast (WRF) model. In contrast to weather models, CTMs take into account the chemical interactions between all atmospheric trace substances known to be relevant.

One of the most accessible tool to obtain pollution database over Europe is the EMEP unified model. The new unified modelling system has been designed to provide a common core to all MSC-W modelling activities, building upon one Eulerian model structure. the model has covered all of Europe with a resolution of about 50 km × 50 km, and extending vertically from ground level to the tropopause (100 hPa). The model has changed extensively over the last ten years, however, with flexible processing of chemical schemes, meteorological inputs, and with nesting capability: the code is now applied on scales ranging from local (ca. 5 km grid size) to global (with 1 degree resolution) (Simpson et al., 2012)

Transboundary nitrogen deposition is evaluated according to the country to country source-receptor matrices. The matrices are available in EMEP at the following link:

http://www.emep.int/mscw/SR_data/sr_tables.html

Nitrogen deposition per ecosystem type (cropland or forestland), as requested by the nitrogen budget excel sheet, can be determined following the distribution of ecosystems that can be found in CORINAIR landcover, containing information of the coverage and land use all over Europe (www.eea.europa.eu).

3.2.1 Suggested Data Sources

Deposition data and landcover data are available for download on the internet. When using the deposition data in more detail – which may be needed when differentiating to specific ecosystems, i.e. identifying fluxes to specific NNB pools – liaising with EMEP experts is recommended.

http://www.emep.int/mscw/index_mscw.html
http://www.eea.europa.eu/data-and-maps/data/corine-land-cover

4 Uncertainties

Overall, the European Environment Agency assesses the uncertainty in emissions for NO_x and NH_3 as ±20% and ±30% respectively (Pouliot et al., 2015).

Nitrogen oxide emission estimates in Europe are thought to have an uncertainty of about ±20% (EMEP, 2011), as the NO_x emitted comes both from the fuel burnt and the combustion air and so cannot be estimated accurately from fuel nitrogen alone. However, because of the need for interpolation to account for missing data, the complete data set used will have higher uncertainty.

Ammonia emissions are relatively uncertain. NH_3 emission estimates in Europe are more uncertain than those for NO_x or SO_2 due largely to the diverse nature of agricultural sources – which account for the vast majority of NH_3 emissions. It is estimated that they are around ±30% (EMEP, 2011). The trend is likely to be more accurate than the individual absolute annual values – the annual values are not independent of each other.

Major uncertainties in emission estimates seem to be related to activity data or emission factor knowledge. National inventory report usually contains an estimation of emission uncertainties (EEA, 2015).

As highlighted in the previous paragraphs, the LNO_x source rate is considered to be the least known one within the total atmospheric NO_x budget. The global LNO_x amount cannot be measured directly, and is difficult to determine. In the last years many progresses have been made which allow reducing the uncertainty of the global LNO_x value, for example satellite observations of global, satellite observations of NO_2 column distributions, improved global models.

About N deposition modeling, the uncertainties are linked to the model itself and on the quality of data that feed the model. Generally the uncertainties are strictly linked to the selected model resolution, thus a national based model is to be preferred to a European one.

The uncertainties in models may arise from model parameters, or from structural uncertainties as some processes in the climate and air quality system are not fully understood or are impossible to resolve because of computational constraints. Additionally, when projecting on a regional scale, due to the model size and complexity, the GCM models must have inevitably omitted some factors that affect regional climate. Thus, projection data with less uncertainty at a higher spatial resolution may be more valuable (Madaniyazia et al., 2015).

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Annex 8 – Hydrosphere

1 Introduction

The Convention on Long-range Transboundary Air Pollution adopted a guidance document to assist in the calculation of national nitrogen budgets (NNB) (ECE/EB.AIR/119). According to the guidelines, the NNB must include eight pools that exchange nitrogen or store it in stocks, notably Atmosphere, Energy and fuels, Humans and settlements, Agriculture, Forest and semi-natural vegetation, Waste, Material and products, and Hydrosphere (ECE/EB.AIR/119 IV). Exchanges outside national boundaries are considered as flows from/to the pool Rest of the world.

This document describes the pool Hydrosphere and provides methodologies for the computation of the major nitrogen flows to the other pools of the NNB. In addition, the document discusses inherent uncertainties and limitations in the estimation of nitrogen flows and stock changes in the pool.

2 Definition

2.1 Activities and flows encompassed by the pool

The pool Hydrosphere consists of all national water bodies that are part of the liquid phase of the (natural) hydrological cycle[32]. This includes: groundwater, rivers, lakes, estuaries, coastal and marine waters.

The nitrogen flows between the Hydrosphere and the other pools of the National Nitrogen Budget and the Rest of the world are represented in Figure 1, and will be described in details in Section 4 of this document.

[32] For the definition of the *hydrological cycle* see the IPCC Fifth Assessment Report, Climate Change 2014: Synthesis Report, Annex II Glossary, available at http://www.ipcc.ch/pdf/assessment-report/ar5/syr/AR5_SYR_FINAL_Annexes.pdf (accessed on 23/03/2015) "*Hydrological cycle*: the cycle in which water evaporates from the oceans and the land surface, is carried over the Earth in atmospheric circulation as water vapour, condenses to form clouds, precipitates over ocean and land as rain or snow, which on land can be intercepted by trees and vegetation, provides runoff on the land surface, infiltrates into soils, recharges groundwater, discharges into streams and ultimately flows out into the oceans, from which it will eventually evaporate again. The various systems involved in the hydrological cycle are usually referred to as hydrological systems".

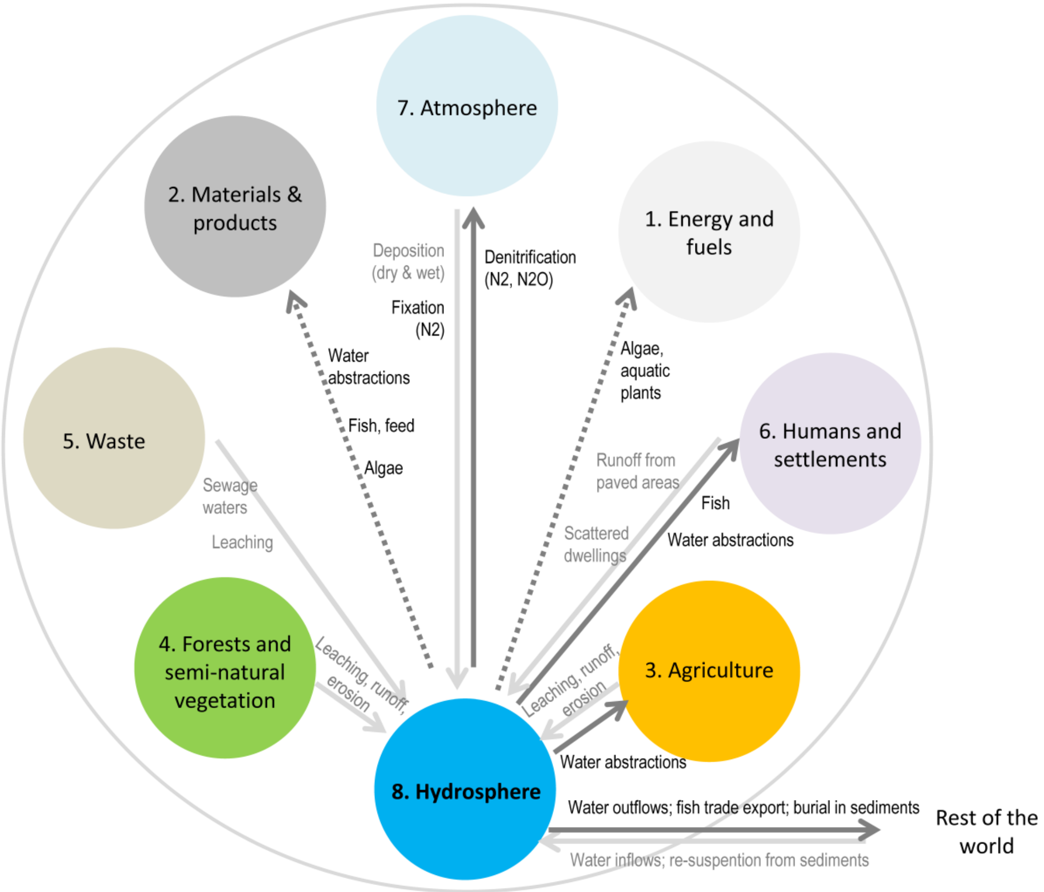

Figure 1 – Nitrogen flows between the Hydrosphere and the other pools of the National Nitrogen Budget (including the pool "Rest of the world"). Light grey arrows represent nitrogen flows entering the Hydrosphere from the other pools; dark grey arrows show nitrogen flows from the Hydrosphere to the other pools. Pointed arrows indicate that nitrogen flows is not quantified in the present document.

2.2 Definition of boundaries

For the inherent difficulty in establishing the boundaries of some water bodies (for example groundwater bodies, or the water exchange between territorial and international sea water), for the scope of the NNB we propose the conceptual simplification of the Hydrosphere in three main compartments: 1) groundwater, 2) surface water and 3) coastal water (including transitional, coastal and marine water).

For the definition of *groundwater* and *surface water* we refer to the EU Directive 2000/60/EC (Water Framework Directive, WFD). In the definition of *coastal water* we include the transitional and coastal water, as defined by the EU Directive 2000/60/EC, and the marine waters, as defined in the EU Directive 2008/56/EC (Marine Strategy Framework Directive, MSFD). The definitions are reported in Table 1.

Besides the physical boundaries of water bodies, the river basin delineates the natural geographical area relevant for inland water, as it is "the area of land from which all surface run-off flows through a sequence of streams, rivers and, possibly, lakes into the sea at a single river mouth, estuary or delta" (Directive 2000/60/EC Article 2(13)).

The boundary of the Hydrosphere with the Rest of the world might be complex for several reasons. First, the hydrological cycle follows the natural boundaries rather than the national boundaries; this means that water flow between transboundary aquifers, rivers or lakes can be present. Second, the extent and feature of aquifers are known only partially. Third, although the limit of territorial waters and international waters is defined spatially[33], the water and nitrogen fluxes between sea's areas are very complex to be accounted, as no physical boundaries are present. For these reasons the computation of the nitrogen national budget is not completely closed for the Hydrosphere, and river basin outlets (or the coastal line) seem the possible location where computing meaningful water nitrogen budgets.

Nitrogen processes and water exchanges at the interfaces, such as river-coastal zone, river-aquifer or water body-bottom sediments, are complex and difficult to be quantified. Sediments in surface and marine waters are not part of the Hydrosphere pool, but they are in the national territory. Considering the geological times, the permanent burial of nitrogen in sediments of water bodies could be considered as an export towards the Rest of the world. However, when there is the possibility of re-suspension of nitrogen then sediments should be better considered as a temporal stock change (accumulation in sediments that can be released to the Hydrosphere). In addition, in the first layers of sediments anoxic conditions can foster the process of denitrification producing nitrogen losses towards the atmosphere.

[33] According to the UNCLOS (United Nations Convention on the Law of the Sea, 1982), every state has the right to establish the breadth of its **territorial sea** up to a limit not exceeding 12 nautical miles, measured from baselines, which is the low-water line along the coast. The **Exclusive Economic Zone** is an area beyond and adjacent to the territorial sea, that extends beyond 200 nautical miles from the baselines from which the breadth of the territorial sea is measured. Over this zone the state has sovereign rights for the purpose of exploring and exploiting, conserving and managing the natural resources, whether living or non-living, of the waters superjacent to the seabed and of the seabed and its subsoil, and with regard to other activities for the economic exploitation and exploration of the zone, such as the production of energy from the water, currents and winds, subject to the legal regime of the UNCLOS.

Table 1 – Definition of the simplified conceptual compartments considered in the Hydrosphere pool (based on the definition of water bodies from EU Directives 2000/60/EC and 2008/56/EC).

Hydrosphere (this annex)	Definition (from EU legislation)
Groundwater (GW)	**Groundwater** means all water which is below the surface of the ground in the saturation zone and in direct contact with the ground or subsoil (*Directive 2000/60/EC Article 2(2)*).
Surface water (SW)	**Surface water** means inland waters, except groundwater; transitional waters and coastal waters (*Directive 2000/60/EC Article 2(1)*). **Inland water** means all standing or flowing water on the surface of the land, and all groundwater on the landward side of the baseline from which the breadth of territorial waters is measured (*Directive 2000/60/EC Article 2(3)*).
Coastal water (CW)	**Transitional waters** are bodies of surface water in the vicinity of river mouths which are partly saline in character as a result of their proximity to coastal waters but which are substantially influenced by freshwater flows (*Directive 2000/60/EC Article 2(6)*). **Coastal water** means surface water on the landward side of a line, every point of which is at a distance of one nautical mile on the seaward side from the nearest point of the baseline from which the breadth of territorial waters is measured, extending where appropriate up to the outer limit of transitional waters (*Directive 2000/60/EC Article 2(7)*). **Marine waters** means: (a) waters, the seabed and subsoil on the seaward side of the baseline from which the extent of territorial waters is measured extending to the outmost reach of the area where a Member State has and/or exercises jurisdictional rights, in accordance with the Unclos[34], with the exception of waters adjacent to the countries and territories mentioned in Annex II to the Treaty and the French Overseas Departments and Collectivities; and (b) coastal waters as defined by Directive 2000/60/EC, their seabed and their subsoil, in so far as particular aspects of the environmental status of the marine environment are not already addressed through that Directive or other Community legislation (*Directive 2008/56/EC Article 3(1)*).

[34] United Nations Convention on the Law of the Sea
http://www.un.org/depts/los/convention_agreements/convention_overview_convention.htm (accessed on 18-12-2014)

2.3 Nitrogen species involved

Water is the medium of most of the nitrogen fluxes between the Hydrosphere and the other pools. In water nitrogen can be present in different forms, including nitrate (NO_3^-), nitrite (NO_2^-), ammonium (NH_4^+), and organic nitrogen compounds[35] (N_{org}) (Durand et al, 2011), as reported in Table 2. Nitrogen can be embedded in the organic matter of living organisms (phytoplankton, zooplankton, benthos, fishes, macrophytes, plants, bacteria, fungi, etc.) and detritus. In the exchanges between Hydrosphere and Atmosphere, the gaseous forms of nitrogen are involved, such as N_2, N_2O, NO_x and NH_3 (Table 2).

For the computation of the national nitrogen budget we consider the flows of total nitrogen (N_{tot}), which is the sum of all nitrogen forms in water ($N_{tot}=NO_3^-+NO_2^-+NH_4^+$+DON+PON, Table 2), and nitrogen in proteins of fish and fish products.

However, we have to acknowledge that often only data on NO_3^- or dissolved inorganic nitrogen (NO_3^- $+NO_2^-+NH_4^+$) are available. For a summary of nitrogen (and other nutrients) forms involved in different processes in the aquatic system see Bouwman et al. (2013).

Table 2 – Form of nitrogen present in the pool Hydrosphere.

Nitrogen forms	Acronym	Chemical formula	N content [%]	State	description
Nitrate	NO_3^-	NO_3^-	22	in aqueous solution	
Nitrite	NO_2^-	NO_2^-	30	in aqueous solution	
Ammonium	NH_4^+	NH_4^+	77.8	in aqueous solution	
Organic Nitrogen[4]	N_{org}	variable	variable	in aqueous solution	Dissolved organic nitrogen and nitrogen in organic matter, small living and dead organisms, and fragments of organisms
Nitrogen	N_2	N_2	100	Gas	
Nitrous oxide	N_2O	N_2O	63.64	Gas	
Ammonia	NH_3	NH_3	82.35	Gas	
Nitrogen oxides	NO_x	NO_x	30.43	Gas	
Nitrogen in proteins of living organisms			16	in proteins of living organisms	

[35] Organic nitrogen can be distinguished in dissolved organic nitrogen (DON) and particulate organic nitrogen (PON). Operationally, the total organic nitrogen is computed by subtracting NH_3/NH_4^+ from the Total Kjeldahl Nitrogen (TKN), which is determined by the Kjeldahl method (which consists in N digestion with persulphate solution).

3 Internal structure

The Hydrosphere is composed by a number of water bodies connected by the hydrological cycle. Schematically, it can be subdivided in three sub-pools[36]: groundwater (GW), surface water (SW) and coastal water (CW) (Figure 2). The definition of the sub-pools' boundaries is provided in Table 1. The division in sub-pools is related to the location of water bodies in the river basin (above/below soil surface) and the salinity (freshwater versus salt water). Within surface waters, sub sub-pools could be distinguished on the basis of the water residence time into lentic (lakes) and lotic (rivers) water systems[37]. Location, physicochemical characteristics and water residence time have a great influence on the nitrogen's processes in water bodies.

In the river basin, surface water moves from the land to the sea according to the topographic slope, but the direction of exchanges between groundwater and surface waters can vary locally and temporarily. The boundaries of rivers and lakes are defined (although they are subject to seasonal or temporal local variations), while the extent of aquifers and the temporal variation of the water table are not always known. Also, the limits of territorial and international waters are set legally but do not exist physically. Except for the nitrogen load at the river basin outlet, nitrogen flows between sub-pools cannot be measured in practice (unless specific monitoring network are in place). Therefore the internal flows will not be described by these guidelines. However, as the processes related to nitrogen and their intensity vary greatly in the different water bodies, mainly as a consequences of diverse water residence times, in the computation of nitrogen flows when possible we distinguish between the sub-pools.

In addition, within surface water bodies nitrogen moves continuously through the trophic chain of the aquatic ecosystem, as described by the nutrient spiralling concept (Newbold et al., 1981; Howard William, 1985), cycling through dissolved forms, living organisms (indicated as "biota" in Figure 2) and detritus (in these guidelines sediments are considered part of the pool Rest of the world). Due to the complexity of these processes and the lack of data, these internal flows of nitrogen are not computed in the budget.

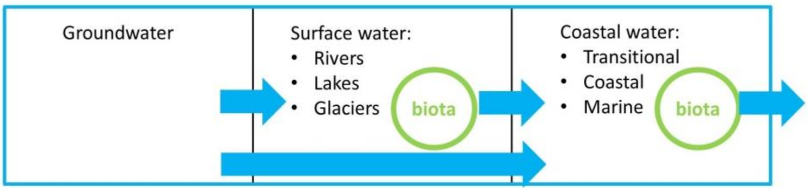

Figure 2 – Schematic representation of the sub-pools of the Hydrosphere.

[36] Sub-pools of the Hydrosphere pool: (also presented in Annex 0)

ID	Acronym	Sub-pool
8A	GW	Groundwater
8B	SW	Surface waters
8C	CW	Coastal waters (open to the rest of the world)

[37] Glaciers are not considered in these guidelines

4 Description of flows

4.1 Overview of the nitrogen flows

This section describes the major flows between the Hydrosphere pool and the other pools (see Annex 0) of the NNB and the suggested method of computation, specifying when possible the flows per sub-pool. Several flows are not estimated due to the lack of information. Differently from the other pools of the NNB, the nitrogen flows estimated in the Hydrosphere are those for which information are available independently from the magnitude of the flow.

Since the flows can be described only partially and in an aggregated form, they are all considered as Tier 1 approach.

The emissions of nitrogen toward the Atmosphere are in the form of N_2 and N_2O, volatilisation being in the form of NH_3 (in the fish farms placed in rivers and coastal waters the NH_3 flow can be high, Bouwman et al. 2013a); the exchanges in the water medium are expressed as total nitrogen. With regard to flows involving organic matter, we consider that nitrogen is contained in proteins and constitutes 16% in content (FAO 2003, http://www.fao.org/docrep/006/y5022e/y5022e03.htm accessed in March 2015).

The overview of the N flows between the Hydrosphere and the other pools of the NNB is presented in Table 3.

Table 3 – Nitrogen flows between the Hydrosphere and the other pools of the NNB. (* indicates that the flow is not estimated).

Flow name	$Pool_{ex}$	$Pool_{in}$	Process	Major N forms	Sub-pools involved	Description	Annex describing the method
ATHYdep	AT	HY	Deposition	NO_x, NH_3	SW, CW	Dry and wet deposition	Annex AT
ATHYfix	AT	HY	Fixation	N_2	SW, CW		Annex HY
HYATden	HY	AT	Denitrification	N_2, N_2O	GW, SW, CW		Annex HY
HSHYsd	HS	HY	Emissions from scattered dwellings	urea, NH_4^+; N_{org}	GW, (SW), (CW)	Emissions not connected to the sewage system	Annex HS
HSHYurb*	HS	HY	Runoff from paved areas	NO_3^-, NH_4^+, N_{org}	SW, (CW)		Annex HS*
HYHSabs*	HY	HS	Water abstraction	All forms	GW, SW		Annex HY*
HYHSfish	HY	HS	Fish landing	N in fish proteins	SW, CW	N in fish proteins	Annex HY
AGHYleach	AG	HY	N leaching	NO_3^-	GW		Annex AG
AGHYrun	AG	HY	N runoff	NO_3^-, N_{org}; NH_4^+	SW, (CW)	water and sediment transport	Annex AG
HYAGabs*	HY	AG	Water abstractions	All forms	GW, SW	Water abstractions for irrigation and animal drinking	Annex HY*
FSHYleach	FS	HY	N leaching	NO_3^-	GW	Natural background emissions	Annex FS
FSHYrun	FS	HY	N runoff	NO_3^-, N_{org}	SW, (CW)	Natural background emissions (ex. leaves) water and sediment transport	Annex FS
WSHYsew	WS	HY	Sewage waters	All forms	SW, (CW)	Treated or untreated sewage waters (& waste from ships)	Annex WS
WSHYleach	WS	HY	Leaching	NO_3^-; N_{org}	GW	Leaching from solid waste	Annex WS
HYMP*	HY	MP	Fish, algae (water abstractions)	N in proteins (all forms)	SW, CW	Fish, algae for food & cosmetics gels	Annex HY*
HYEF*	HY	EF	(water abstractions)	N in proteins (all forms)	SW, CW	Algae and aquatic plants used for energy production	Annex HY*
RWHYin	RW	HY	Water inflows	All forms	GW, SW	Transboundary rivers, lakes, aquifers & artificial transfers	Annex HY
RWHYsed*	RW	HY	Re-suspension from sediments	All forms	SW, CW		Annex HY*
RWHYsea*	RW	HY	Import from the open sea	All forms	CW		Annex HY*
HYRWout	HY	RW	Water outflows	All forms	GW, SW	Transboundary rivers, lakes, aquifers & artificial transfers	Annex HY
HYRWsed*	HY	RW	Burial in sediments	All forms	SW, CW		Annex HY*
HYRWsea*	HY	RW	Export to the open sea	All forms	CW		Annex HY*

Theoretically, the nitrogen budget of the Hydrosphere pool should be closed. However, in practice there are missing information, unaccounted flows, errors or inconsistent data (ECE/EB.AIR/119), and most of all it is impossible to account for the nitrogen budget in the sea at the national level.

According to the ideal balance equation, the sum of the net nitrogen flows between the Hydrosphere and the other pools (HYnet, kgN/yr) and the change in stock (ΔStock, kgN/yr) should be equal to zero:

$$\mathbf{HYnet + \Delta Stock = 0} \qquad (1)$$

In the Hydrosphere the change in stock is represented by changes in the biota (living organisms, fish stock, aquatic plants) and in the concentration of different nitrogen forms in water, linked by microbial processes converting nitrogen compounds from one pool into the other. Sediments are not part of the Hydrosphere in these guidelines (they were defined as Rest of the World), but can constitute an important buffer, from which N can be resuspended.

HYnet is defined as the sum of the net nitrogen flow between Hydrosphere and each of the other pools:

$$\mathbf{HYnet = HYATnet + HYHSnet + HYAGnet + HYFSnet + HYWSnet + HYRWnet} \qquad (2)$$

The terms of the Eq.2 (expressed in kgN/yr) represent the net N flows between the Hydrosphere and the other pools of the budget. They are described in the following paragraphs (the pools EF and MP are not included in the equation for simplification, as they are not estimated in this document).

Equation 1 and 2 are also valid for any sub-pools and individual water bodies of the Hydrosphere, where Equation 2 may simplify when some of the terms do not occur.

4.2 Exchanges with the pool Atmosphere (HYAT)

The net nitrogen flow between the Hydrosphere and the Atmosphere pool (HYATnet) is defined as:

$$\mathbf{HYATnet = ATHYdep + ATHYfix - HYATden} \qquad (3)$$

ATHYdep, ATHYfix, HYATden are the N flows related to the processes of atmospheric deposition, fixation and denitrification, respectively (Table 3), and can be computed as follows:

Flow name	Method of computation	Suggested data sources
ATHYdep	Annex AT	
ATHYfix	Not estimated	
HYATden	To be developed. At this stage and at for a large scale estimation we can consider a range of N elimination (mostly denitrification) of 20-45 %, associated to a coefficient for N_2O emission of 1-20 % (depending on controlling factors, including the lack of knowledge in modelling water fluxes at the interfaces).	

In the computation of HYATden, it would be useful to distinguish between N_2 emission, which is inert, and N_2O emission, which acts as greenhouse gas.

In-stream N retention of N loading:

- 7-45% (studies reported by Howarth et al. 1996);
- 5-20% (estimated by Howarth et al. 1996);
- 30% (estimated by Bouwman et al. 2005 and Van Drecht et al. 2003);
- Regression equation Saunders and Kalff (2001);
- Retention in lakes and reservoirs (Harrison et al. 2009);
- Retention in drainage network (Billen and Garnier 1999).

Studies on denitrification:

- Review of processes and global estimates (Seitzinger et al. 2006);
- Review of methods (Boyer et al. 2006);
- Modelling and global estimations (Bouwman et al. 2013; Galloway et al. 2004);
- Meta-analysis (Pina-Ochoa and Cobelas 2009);
- Other studies (Alexander et al., 2007; Mulholland et al., 2008; Voss et al., 2013, Thouvenot-Korppoo et al. 2009)

Link to the IPCC Guidelines:

According to the IPCC Guidelines (2006) the annual amount of N_2O–N (kg N_2O–N/yr) produced from leaching and runoff (of N additions to managed soils in regions where leaching/runoff occurs) is estimated by multiplying the amount of N in leaching and runoff by the emission factor EF5 (emission factor for N_2O emissions from N leaching and runoff (kg N_2O–N/kg N leached and runoff)), whose default value is 0.0075 and uncertainty range 0.0005-0.0025 (from Chapter 11 Table 11.3 IPCC Guidelines 2006).

A further N flow from the Hydrosphere to the Atmosphere, which is not described here and can be develop in future, is represented by the ammonia emission in mariculture and fish farms (Bouwman et al. 2013a).

4.3 Exchanges with the pool Humans and settlements (HYHS)

The net nitrogen flow between the Hydrosphere and the Humans and settlements pool (HYHSnet) is defined as:

$$\textbf{HYHSnet = HSHYsd + HSHYurb - HYHSabs - HYHSfish} \quad (4)$$

HSHYsd are the N emissions from scattered dwellings not connected to the sewage system, HSHYurb is the N flux associated with the runoff from paved and urban areas, HYHSabs is the N load in water abstractions for public supply, and HYHSfish is the N flux related to fish production (we assume that all the production enters the HS pool, where part is consumed by humans and part is exported) (Table 3).

These fluxes can be estimated as follows:

Flow name	Method of computation	Suggested data sources
HSHYsd	Annex HS	
HSHYurb	Annex HS	
HYHSabs	Not estimated	
HYHSfish	FAO Fish production * Fish protein fraction *0.16→kg N	FAO food balance sheet http://faostat3.fao.org/download/FB/FBS/E (accessed in March 2015) FAO Items aggregated: Fish, Seafood FAO Yearbook of Fishery Statistics Summary tables (Food Balance Sheet 2011) ftp://ftp.fao.org/FI/STAT/summary/FBS_bycontinent.pdf (accessed in March 2015)

In the computation of N fluxes related to food consumption we adopt two assumptions (FAO, 2003): nitrogen in the diet is present as amino acids in proteins and the average nitrogen content in proteins is 16%. The FAO food balance sheets (http://faostat3.fao.org/download/FB/FBS/E accessed in March 2015) provide data on fish and fishery products, including production, imports, exports and food supply. Within the group Fish, Seafood, the FAO database distinguishes between seven items: Freshwater Fish, Demersal Fish, Pelagic Fish, Marine Fish Other, Crustaceans, Cephalopods and Molluscs Other. The protein content of most fish is between 15-20% (FAO 2014, http://www.fao.org/fishery/topic/12319/en accessed on 17-12-2014 accessed in March 2015). The FAO Food Balance Sheet provides the total food supply (tonnes), the population and the protein supply quantity (g/capita/day). From these data is possible to compute the average fraction of proteins in fish and fishery products per country. For a more detailed calculation, the fish and fishery products from inland and coastal waters can be distinguished and their consumption multiplied by the respective protein contents.

The USDA National Nutrient Database for Standard Reference (Release 27) provides detailed protein contents for different food groups, including 267 finfish and shellfish products (USDA 2014, http://ndb.nal.usda.gov/ndb/ accessed December 2014). Similarly, FAO information on protein content in different fish types can be found at http://www.fao.org/wairdocs/tan/x5916e/x5916e01.htm

4.4 Exchanges with the pool Agriculture (HYAG)

The net nitrogen flow between the Hydrosphere and the Agriculture pool (HYAGnet) is defined as:

$$\textbf{HYAGnet = AGHYleach + AGHYrun - HYAGabs} \qquad (5)$$

AGHYleach and AGHYrun are the nitrogen emissions from agriculture to water through leaching and runoff respectively, while HYAGabs is the N load in water abstracted for irrigation, and is not estimated in these guidelines (Table 3).

Flow name	Method of computation	Suggested data sources
AGHYleach	Annex AG	
AGHYrun	Annex AG	
HYAGabs	Not estimated	

4.5 Exchanges with the Forest and semi-natural vegetation (HYFS)

The net nitrogen flow between the Hydrosphere and the Forest and semi-natural vegetation including soils pool (HYFSnet) is defined as:

$$\textbf{HYFSnet = FSHYleach + FSHYrun} \qquad (6)$$

FSHYleach and FSHYrun are the nitrogen emissions from the Forest and semi-natural vegetation to water through leaching and runoff respectively (Table 3).

Flow name	Method of computation	Suggested data sources
FSHYleach	Annex FS	
FSHYrun	Annex FS	

4.6 Exchanges with the pool Waste (HYWS)

The net nitrogen flow between the Hydrosphere and the Waste pool (HYWSnet) is defined as:

$$\textbf{HYWSnet = WSHYsew + WSHYleach} \qquad (7)$$

WSHYsew is the N flow from waste water waters collected by the sewage system and discharged into the surface water treated and untreated. WSHYleach is the N leaching from the waste disposal sites (Table 3).

Flow name	Method of computation	Suggested data sources
WSHYsew	Annex WS	
WSHYleach	Annex WS	

4.7 Exchanges with the pool Rest of the world (HYRW)

The net nitrogen flow between the Hydrosphere and the Rest of the world pool (HYRWnet) is defined as:

HYRWnet = RWHYin - HYRWout + (RWHYsea-HYRWsea) + (RWHYsed-HYRWsed) (8)

RWHYin and HYRWout are the N flows associated with the water inflow and outflow at the land national borders respectively. Losses and gains of waters across borders can occur in aquifers, rivers, lakes and coastal waters, but only the flows of rivers is usually measured. The N flow in the sea (RWHYsea-HYRWsea) is not estimated.

(RWHYsed-HYRWsed) is the N losses/gains due to net sedimentation. This process varies greatly with the water body type. N losses in coastal sediments and reservoirs can be significant.

The terms of Eq.8 (also summarised in Table 3) can be computed as follows:

Flow name	Method of computation	Suggested data sources
RWHYin	Rivers: River discharge in transboundary*N concentration→ kg N gained	Data reported under transboundary river basin conventions, or national statistics
HYRWout	Rivers: River discharge in transboundary*N concentration→ kg N lost	Data reported under transboundary river basin conventions, or national statistics
RWHYsed-HYRWsed	Not estimated	
RWHYsea-HYRWsea	Not estimated	

4.8 Nitrogen flows that can be computed

Overall, from the description of nitrogen flows between the Hydrosphere and the other pools it is clear that most of the flows cannot be computed, due to the lack of data and the inner complexity of the water system. (For a description of the nutrient dynamic in the river continuum see Billen et al. 1991; Billen et al. 2007; Bouwman et al. 2013b).

The nitrogen flows that can be possibly computed are the following:

1. Sum of the N inputs (from all the other pools) to the Hydrosphere
   ∑ N input = ATHYdep+HSHYsd+AGHYleach+AGHYrun+FSHYleach+FSHYrun+WSHYsew+WSHYleach+(RWHYin-RWHYout)
2. N load from rivers to coastal water (using measurements or coarse estimation)
   The delivery of riverine N to the sea can be computed using annual load measured at the outlet of major river basin in the country or assuming that the N retention in the river system is around 30% (Van Drecht et al. 2003: Bouwman et al. 2005).
3. N flows from the sea to the HS pool with fish landings
   See HYHSfish in Paragraph 4.3

5 Uncertainties

Main uncertainties related to the quantification of NNB in the Hydrosphere are related to:

- the nature of the pool's boundaries, that follow basin rather than national borders, and the difficulty or even the impossibility to measure the N stock and flow within and across the water bodies, such as aquifers, large lakes, coastal water and open sea;

- the complexity of quantifying nitrogen processes and water fluxes at the interfaces (such as river-coastal zone, river-aquifer or water body-sediments);
- the complexity of the nitrogen cycling within the aquatic ecosystem, where nitrogen continuously moves between water (where it is present in different chemical forms) and living organisms through the trophic chain and microbial processes;
- the spatial and temporal variability of the processes involved in the N exchanges with the other pools, such as denitrification, fixation, sedimentation, which depends on local physic-chemical conditions and are mediated by microbial activities;
- the spatial location of nitrogen loading to the water system and the spatial connectivity of the elements of the river continuum, which influence the magnitude of the retention (in this respect the way the wetlands are represented in the NNB might not be appropriate); clearly the other pools can be easily simplified to one-dimensional balances, while this simplification does not hold for the hydrosphere.
- the natural water cycle, which affects the fate and transport of nitrogen determining different water residence time, that can accelerate or delay the flow of nitrogen in the different water bodies, making it difficult to measure the variation of nitrogen over time (for example the lag time observed in aquifers);
- the lack of measurements of water flow and nitrogen concentration in aquifers, rivers and water abstractions.
- the way aquaculture (freshwater aquaculture/mariculture) is accounted (at the moment it is under the pool AG, but this representation might not be optimal for mariculture). In addition fish production from the pool HY is assigned to HS, although the origin of the fish could be from the country's sea Exclusive Economic Zone or even beyond).

When looking at all these sources of uncertainty, it appears that closing the nitrogen budget of the Hydrosphere is not possible and that several aspects still have to be developed or improved. However, quantifying nitrogen flows into/from the water system is extremely relevant for monitoring purposes and for raising awareness on unaccounted nitrogen flows. In fact, water is a final and important receptor of nitrogen pollution. The excess nitrogen can impair the quality of water resources and alter the functioning of aquatic ecosystems. Quantifying the few possible nitrogen flows would reveal the contribution of different sources to the impacts and offer an early warning on possible accumulation of nitrogen in the water system.

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