eurostat

Economy-wide material flow accounts (EW-MFA)

Manual 2016

Draft version (13 September 2016) on DPO and Balancing items

1 Table F - Domestic Processed Output (DPO)

1. The indicator *domestic processed output to nature* (DPO) was developed and applied for the first time by an international team of experts in a joint effort resulting in the publication *The Weight of Nations* (Matthews *et al*. 2000). DPO indicates the mass weight (measured in 1000 tonnes) of all materials which are released from the national economy to the environment after having been used in the national economy. These flows belong to the SEEA-CF physical flow type of *residuals*. Flows of *domestic processed output* occur at the processing, manufacturing, use and final disposal stages of the economic production and consumption chain. Exported materials are not included in DPO because they do not constitute a *residual* flow but a *product* flow in the sense of SEEA-CF.

2. Table 1 shows DPO as calculated for the year 2013 by Austria and Switzerland. As can be clearly seen, emissions to air by far dominate the overall DPO level (99% and 93% in Austria and Switzerland, respectively) and CO_2 emissions dominate the emissions to air

Table 1: Domestic Processed Output (DPO) in Austria and Switzerland, 2013 (tonnes per capita)

	Austria	Switzerland
Emissions to air	11.5	6.8
of which: CO_2	*11.3*	*6.7*
Waste disposal	0	0
Disposal of waste to controlled landfills (memorandum item)	*1.1*	*0.2*
Emissions to water	0.004	0.02
Dissipative use of products	0.1	0.5
Dissipative losses	0.002	0.002
DPO	**11.5**	**7.3**

Source: Eurostat, EW-MFA 2015 data collection

3. DPO, as recorded in Table F, comprises 5 major categories:

F.1 *Emissions to air*

F.2 *Waste disposal*

F.3 *Emissions to water*

F.4 *Dissipative use of products*

F.5 *Dissipative losses*

4. The first three categories (F.1 to F.3) refer to the three gateways through which residual

materials are released to the environment, i.e. air, land, and water, commonly referred to as emissions and waste in official statistics. The remaining two categories (F.4 and F.5) are categories which are not fully attributable to a specific gateway, but are rather attributed to a type of release process.

5. Apparently there can be overlaps between a distinction according to gateways and a distinction according to dissipative uses and losses. Mainly these potential overlaps refer to a few emissions to air (see Table 3).

1.1 F.1. Emissions to air

1.1.1 Introduction

6. Emissions to air are gaseous or particulate materials released to the atmosphere from production or consumption processes in the economy. The list of emissions to air to be accounted for in DPO is provided in Table 2.

Table 2: Emissions to air (refers to category F.1 in Table F 'Domestic processed output' of the EW-MFA questionnaire)

F.1 Emissions to air		
	F.1.1 Carbon dioxide (CO_2)	
		F.1.1.1 Carbon dioxide (CO_2) from biomass combustion
		F.1.1.2 Carbon dioxide (CO_2) excluding biomass combustion
	F.1.2 Methane (CH_4)	
	F.1.3 Dinitrogen oxide (N_2O)	
	F.1.4 Nitrous oxides (NO_x)	
	F.1.5 Hydroflourcarbons (HFCs)	
	F.1.6 Perflourocarbons (PFCs)	
	F.1.7 Sulfur hexaflouride	
	F.1.8 Carbon monoxide (CO)	
	F.1.9 Non-methane volatile organic compounds (NMVOC)	
	F.1.10 Sulfur dioxide (SO_2)	
	F.1.11 Ammonia (NH_3)	
	F.1.12 Heavy metals	
	F.1.13 Persistent organic pollutants POPs	
	F.1.14 Particles (e.g. PM_{10}, Dust)	
	F.1.15 Other (e.g. Nitrogen trifluoride - NF_3)	

1.1.2 Data sources and compilation

7. Data sources for F.1 Emissions to air are air emission accounts (AEA) and air emission inventories. If a number of double counting issues did not occur, data on the first category of DPO would have been immediately obtained from the well-established and standardised AEA, which are already aligned to the residence principle.

8. However, air emissions inventories under the UN Framework Convention on Climate Change (UNFCCC) and the UNECE Convention on Long Range Transboundary Air Pollutants (CLRTAP) must be considered an important data sources in order to avoid overlaps between F.1 and other categories of DPO.

9. The following practical rules help to avoid double counting between emissions to air and other categories of DPO (see also guidance provided in Table 3):

- **emissions to air from fertiliser application, sewage sludge and compost** are not accounted for in F.1 as the related primary output of these different fertilisers spread on agricultural soil are accounted for in F.4, from F.4.1 to F.4.5;
- **emissions from dissipative use of products** are accounted for in F.4.8 *Solvents, laughing gas and other* and not in F.1 *Emissions to air*;
- **emissions stemming from automobile tyre and brake wear and road abrasion** are accounted for in F.5 *Dissipative losses*.

10. Compilers, most commonly in cases when both AEA and MFA compilers work in close contact, are recommended to extracts from the AEA the emission flows that shall not be accounted for in F.1. This extraction can be usually carried out at a stage of the calculation where the information on the activity from the inventories is still available, i.e. at least when data by NACE and by inventory code are available. Table 3 shows the Nomenclature for Reporting (NFR) and Common reporting format (CRF) codes of the CLRTAP and UNFCCC inventories respectively, which either have to be excluded from DPO or have not to be allocated in F.1.

Table 3: NFR and CRF codes of the air emission inventories which have not to be accounted for in F.1.

NFR/CRF code	NFR label	CRF label	Pollutant/ gas	Reporting in EW-MFA Table F
3	*Agriculture*	*Agriculture* (sub-sectors **3B** to **3I**)	**NFR**: NOx, NMVOC, NH_3, PM **CRF**: CH_4, CO_2, N_2O	not to be included in DPO (double counting with **F.4.1** and **F.4.2**)
5B	*Biological treatment of waste – Composting* (**5B1**) *Biological treatment of waste - Anaerobic digestion at biogas facilities* (**5B2**)	*Biological treatment of solid waste*	**NFR**: NMVOC, NH_3 **CRF**: CH_4, N_2O	not to be included in DPO (double counting with **F.4.3** and **F.4.4**)
2D[+]	*Solvent and other product use*	*Non-energy products from fuels and solvent use*	**NFR**: NMVOC, PM, PAH **CRF**:CO_2	**F.4.8**
2F5[+]	-	*Solvents*	HFCs	**F.4.8**
2G[+]	*Other product use*	*N_2O from product uses* (**2G3**) and *Other* (**2G4**)	**NFR**: NMVOC **CRF**: N_2O	**F.4.8**
1A3bvi*	*Road transport: Automobile tyre and brake wear*	-	Particulate matter (TSP); heavy metals	**F.5**
1A3bvii*	*Road transport: Automobile road abrasion*	-	Particulate matter (TSP); heavy metals	**F.5**

[+] see the detailed list of NFR/CFR codes in § 56-63;

* If particulate matter and heavy metal emissions in the sector 1A3 are split into exhaust and non-exhaust, all non-exhaust emissions have to be accounted for in F.5.

1.1.3 Conventions

11. **System boundaries:** In defining the system boundary for emissions to air it is important to ensure that this definition for the output side is consistent with the definition for the input side and with the definition of societal stocks. As a general rule the category *emissions to air* indicates the total weight of materials which are released to the air by national resident units on the national economic territory and abroad. Moreover, all the gases listed under G.2 (**output balancing items**) are not included in DPO

12. Emissions from fuel for use on ships or aircraft engaged in international transport (international

bunkers) have to be included in DPO. If AEA are used as a source, these emissions are already included. Otherwise, compilers that start from inventories have to add them in order to respect the **residence principle**, i.e. transport emissions from emission inventories have to be replaced by transport emissions respecting the residence principle (see the AEA manual).

1.2 F.2. Waste disposal

1.2.1 Introduction

13. By legal definition, waste refers to materials which are of no further use to the generator for purpose of production, transformation or consumption. The generator discards, intends or is required to discard these materials. Wastes may be generated during the extraction of raw materials, during the processing of raw materials to intermediate and final products, during the consumption of final products, and in the context of other activities.

14. In Europe, the majority of waste residuals stay in the economy i.e. in controlled landfills. Only a small fraction of the waste generated is illegally discharged into the natural environment.

15. Waste constitutes a residual material flow according to SEEA-CF (see SEEA-CF 3.2.4). However, controlled and managed landfill sites are considered to be as part of the produced assets of the national economy. Therefore, flows of residuals into these facilities are regarded as flows within the economy rather than as flows to the environment and for this reason not accounted for in EW-MFA.

16. The EW-MFA questionnaire distinguishes between municipal and industrial waste and accounts for both of these flows only if they are discharged to the environment (see Table 4). The EW-MFA questionnaire also includes disposal of waste to controlled landfill as memorandum item (*M.2.1* and *M.2.2*).

Table 4: Domestic processed output: waste landfilled (refers to Table F.2 of the EW-MFA questionnaire)

1 digit	2 digit	3 digit
F.2 Waste disposal		
	F.2.1 Disposal of municipal waste to the environment	
	M.2.1 Disposal of municipal waste to controlled landfills	
	F.2.2 Disposal of industrial waste to the environment	
	M.2.2 Disposal of industrial waste to controlled landfills	

1.2.2 Data sources

17. First and foremost, national waste statistics should be used to acquire data for waste to uncontrolled landfills. A good overview on waste statistics data for European countries can be obtained from Eurostat's Environmental Data Centre on Waste.

1.2.3 Conventions

18. System boundaries: There are two important system boundaries to be considered when accounting for waste as part of DPO. Only waste deposited in **uncontrolled** landfills (wild dumping) is an output to nature and therefore part of DPO. Consequently, emissions from uncontrolled landfills are not considered as this would constitute double counting.

19. In contrast, **controlled**, i.e. maintained, landfills must be considered part of the socio-economic system. Therefore, waste deposited in controlled landfills is accounted for as an addition to stock and it is reported in Table F only as a memorandum item.

20. The following flows are excluded:

- Residuals directly recycled or reused at the place of generation.
- Waste materials that are directly discharged into ambient water or air. They are accounted for in emissions to air or water respectively.
- Waste that was generated by unused extraction (natural resource residuals in SEEA-CF). This refers mainly to soil excavation in constructions and to overburden from mining and quarrying.
- Waste incinerated. This flow is already accounted for in F.1 Emissions to air.

1.2.4 Data compilation

21. Only waste to uncontrolled landfills should be counted under F.2. If no specific data are available, national experts should be consulted. If no reliable information can be found on waste discharged to uncontrolled landfills, for industrialized economies, the **assumption can be made that only controlled landfills are used**.

22. European data on waste to controlled lanfills (memorandum item in the DPO classification) can be found in Eurostat's online database (Generation of waste and Municipal waste).

23. Construction and demolition waste includes rubble and other waste material arising from the construction, demolition, renovation or reconstruction of buildings or parts thereof, whether on the surface or underground. It consists mainly of building material and soil, including excavated soil. It includes waste from all origins and from all sectors of economic activity. For the requirements of EW- MFA, excavated soil has to be omitted from the figures for construction and demolition waste. Excavated soil or earth represents a material flow of the unused domestic extraction type which is not part of the direct material inputs to the economy and must therefore also be excluded from the domestic processed output of the economy.

1.3 F.3 Emissions to water

1.3.1 Introduction

24. Emissions to water are substances and materials released to natural waters by human activities after or without passing waste water treatment. Emissions to water, along with Dissipative losses, represent the smallest category of DPO. In the context of a full material balance of a national economy it is therefore sufficient to roughly estimate emissions to water.

Table 5: Domestic processed output: emissions to water (refers to Table F.3 of the EW-MFA questionnaire)

1 digit	2 digit	3 digit
F.3 Emissions to water		
	F.3.1 Nitrogen (N)	
	F.3.2 Phosphorus (P)	
	F.3.3 Heavy metals	
	F.3.4 Other substances and (organic) materials	
	F.3.5 Dumping of materials at sea	

1.3.2 Data sources

25. These flows are difficult to estimate. Statistics on emissions to water can be found on environmental reports. Moreover, the European Pollutant Release and Transfer Register (E-PRTR) can also be investigated.

26. It should be noted that statistics on water pollution commonly use a specific reporting terminology. While the inorganic pollutants nitrogen and phosphorus as well as heavy metals are commonly reported as elements, organic pollutants are reported as compounds by using various indirect aggregate indicators. Due to the minor quantitative importance of emissions to water in the overall material flow accounts, the estimation of specific balancing items is not necessary.

27. Switzerland estimates the quantity of water treated by wastewater treatment plants. This quantity is multiplied by the maximum legal limit value for diverse pollutants. The hypothesis in this methodology is that plants are respecting the law and the concentration of pollutant in water emitted is close to the legal maximum.

1.3.3 Conventions

28. **Terminology and classification:** The EW-MFA classification for emissions to water represents an aggregation of the main categories reported in the emissions statistics.

1.3.4 System boundaries

29. Emissions to water are materials which cross the boundary from the economy back into the environment with water as a gateway. Therefore, emissions to water should be accounted for at the state they are in upon discharge to the environment. Where waste water treatment occurs, this refers to the post-treatment state. Otherwise, it refers to the substances or materials directly released to the environment via water. It should be noted that statistics on water pollutants traditionally focused on the concentration of the pollutants in the water bodies. Attention must therefore be paid to including only data on *flows* of pollutants into the water bodies (normally measured in quantity per year) and not data on pollutant *concentration* in the water bodies (normally measured in quantity per volume).

1.3.5 Data compilation

F.3.1 Nitrogen (N)

30. Total nitrogen (N) stands for the sum of all nitrogen compounds. Nitrogen from agriculture is not included in the category emissions to water because it is already included in the category “dissipative use of products” as nitrogenous fertilisers (F.4.1 and F.4.2). N-emissions to water include emissions by waste water from households and industry.

F.3.2 Phosphorus (P)

31. As with nitrogen, total phosphorus (P) stands for the sum of all phosphorus compounds. P-emissions to water include emissions by waste water from households and industry and do not include emissions from agriculture, as these are again included in category “dissipative use of products” as phosphorus fertilisers.

F.3.3 Heavy metals

32. Heavy metals may come from municipal and industrial discharges.

F.3.4 Other substances and (organic) materials

33. Organic substances are commonly reported in water emission inventories as indirect summary indicators. The most commonly used are BOD (biological oxygen demand), COD (chemical oxygen demand), TOC (total organic carbon), or AOX (absorbable organic halogen compounds). **Please note!** All of these indicators measure organic substances in water by each using a different indirect method. The values reported for these indicators should therefore neither be included directly in EW-MFA nor should they be aggregated. It is necessary to:

- Make a decision as to which of the indicators to use. Our recommendation is to take TOC, if available, as it is the most comprehensive and sensitive indicator.
- Convert the reported quantity which indirectly indicates the amount of organic substances into the quantity of the organic substance itself by using a simplified stoichiometric equation.

34. Alternatively, as a rule of thumb, 5% of the item F.4.1 *Organic fertilisers* could be accounted for in F.3.4, i.e. a 5% loss of manure in water is assumed to occur.

F.3.5 Dumping of materials at sea

35. Dumping of materials at sea is not a common reporting format and data may not be available. **Please note!** Attention should be paid not to include materials which are part of the unused domestic extraction, like dredging, in order to be consistent with the material input side.

1.4 F.4. Dissipative use of products

1.4.1 Introduction

36. "Some materials are deliberately dissipated into the environment because dispersal is an inherent quality of product use or quality and cannot be avoided" (Matthews *et al*. 2000). Examples of dissipative use flows are inorganic and organic fertilizers such as manure, compost, or sewage sludge.

Table 6: Domestic processed output: dissipative use of products (refers to Table F.4 of the MFA questionnaire)

1 digit	2 digit	3 digit
F.4 Dissipative use of products		
	F.4.1 Organic fertiliser (manure)	
	F.4.2 Mineral fertiliser	
	F.4.3 Sewage sludge	
	F.4.4 Compost	
	F.4.5 Pesticides	
	F.4.6 Seeds	
	F.4.7 Salt and other thawing materials spread on roads (incl. grit)	
	F.4.8 Solvents, laughing gas and other	

37. Matthews *et al*. (2000) were the first to make an attempt to account for these flows as part of an EW-MFA. Their results for 1996 show, for example, that applied mineral fertiliser ranged from 17 kilogram per capita and year in Japan to around 110 kg/cap in Austria and Germany, spread manure from 105 kg/cap in Japan to 2 282 kg/cap in the Netherlands, sewage sludge from 4 kg/cap in the Netherlands to 13 kg/cap in Germany, pesticides from 0.4 kg/cap in Germany to 3 kg/cap in Austria, and grit materials from 26 kg/cap in Germany to 134 kg/cap in Austria.

1.4.2 Data sources

38. Data on dissipative use of products are reported in official statistics. Agricultural statistics can

be used to estimate the consumption and use of mineral fertiliser[1], pesticides[2] and seeds. Data for organic fertiliser usually have to be estimated. Data for sewage sludge, compost, and salt and other thawing materials on roads may be reported in statistics or reports on the environment or in specific studies[3]; in addition, waste statistics information on the output of compost from waste management could also be used in order to account for compost.

39. Two additional important data sources that compilers should consider are the Gross Nutrient Balance (GNB) and the background data of emission inventories (UNFCCC in particular). On the former source, the methodological guide is published by Eurostat/OECD.

1.4.3 Conventions

40. **Water content:** Organic fertiliser (manure) spread on agricultural land should be reported in dry weight. If reported with water content, an attempt should be made to convert the data to dry matter. The same holds true for sewage sludge and compost.

1.4.4 Data compilation

F.4.1 Organic fertiliser (manure)

41. Manure is organic matter, excreted by animals, which is used as a soil amendment and fertilizer.

42. Manure spread on agricultural land is usually not or not sufficiently reported in agricultural statistics and has to be estimated (see e.g. Matthews *et al*. 2000). An estimate could be based on the number of livestock by type[4] multiplied with the manure production per animal per year and a coefficient to correct for dry matter. Examples for required coefficients are given in Table 7.

Table 7: Daily manure production coefficients

	Manure production per animal per day in kg	Dry matter of manure 1= Wet weight
Dairy cows	70	0.085
Calves	17	0.05
Other bovine	28	0.085
Pigs for slaughtering	7	0.071
Pigs for breeding	26	0.028
Other pigs	8	0.071
Sheep	7	0.07

[1] Note that use manufacturing statistics on domestic sales from producing or importing units to consumers or sales organizations can also be used.
[2] Data on domestic sales of pesticides can be explored. They are expressed in terms of active ingredients and appropriate multipliers should be found in order to convert them to total mass.
[3] Further options are (estimates over) statistics of mining and quarrying industry, and fishery.
[4] Common data set of number livestock by type should be used for GNB, EW-MFA, UNFCCC and Economical account for agriculture (EAA).

Horses	7	0.07
Poultry	0.2	0.15

Source: Meissner 1994

An additional data source is the VS (Volatile Solids) set of coefficients that are used within the UNFCCC inventory. Compilers are recommended to contact emission inventory experts on this source.

F.4.2 Mineral fertiliser

43. The fertiliser industry is essentially concerned with the provision of three major plant nutrients - nitrogen, phosphorus and potassium - in plant-available forms. Nitrogen is expressed in the elemental form, N, but phosphorus and potassium may be expressed either as the oxide (P_2O_5, K_2O) or as the element (P, K). Sulphur is also supplied in large amounts, partly through the sulphates present in such products as superphosphate and ammonium sulphate.

44. Accordingly, agricultural statistics commonly report domestic consumption in agriculture of specified nitrogenous, phosphate, potash and multi-nutrient fertilizers (NP/NPK/NK/PK). Eurostat database provides the Consumption estimate of manufactured fertilizers (source: Fertilizers Europe), the Use of inorganic fertilizers and the Gross Nutrient Balance[5]; data are in tonnes of nutrient.

45. FAOSTAT reports fertilizers for the EU countries. Data refer to consumption and consumtion in nutrients of fertilisers. Moreover, the UNFCCC inventories report N (see the CRF table 3.D) and liming within sectoral background data for agriculture (see the CRF table 3.G-I).

46. In principle, the accounting of fertilisers would have to be for the total masses. Statistics, however, commonly report fertilisers in nutrient contents (e.g. N, P, K). In case coefficients to total weight are known, the account should be based on total weights[6] (coefficients can be found both at the International Fertilizers Industry Association and national seller web sites).

F.4.3 Sewage sludge

47. Sewage sludge refers to any solid, semi-solid, or liquid residue removed during the treatment of municipal waste water or domestic sewage. Although it is useful as a fertiliser and soil conditioner, sewage sludge, if applied inappropriately can also be potentially harmful to the water and soil environment and human and animal health. The application of sludge on agricultural land is therefore subject to strict regulations in many countries.

48. Sewage sludge spread on agricultural land is reported in environment statistics as well as in UNFCCC inventories within sectoral background data for agriculture (see the CRF table 3.D). Sewage sludge should be reported in dry weight. If reported in wet weight, a water content of 85% may be assumed for conversion to dry weight.

[5] Eurostat is aiming at establishing a harmonised data collection system for mineral fertiliser consumption and gross nutrient balances, based on the data coherent with the submissions to UNFCCC. At the moment not all the data are coherent.
[6] Total weight is estimated by Switzerland using two sources: i) the fertilizer statistics in nutrient content and ii) the trade statistics which is in total mass. Given that the trend of the trade flow follows the fertilizer statistics, the latter is calibrated on the weight of trade statistics.

F.4.4 Compost

49. Composting refers to a solid waste management technique that uses natural processes to convert organic materials to humus through the action of microorganisms. Compost is a mixture that consists largely of decayed organic matter and is used for fertilizing and conditioning land.

50. Compost is reported in agricultural statistics, in environment statistics as well as in UNFCCC inventories within sectoral background data for waste (see the CRF table 5.B), or in specific studies. Compost should be reported in dry weight. If reported in wet weight, a water content of 50% may be assumed for conversion to dry weight.

F.4.5 Pesticides

51. A pesticide is commonly defined as "any substance or mixture of substances intended for preventing, destroying, repelling, or mitigating any pest". A pesticide may be a chemical substance or biological agent (such as a virus or bacteria) used against pests including insects, plant pathogens, weeds, molluscs, birds, mammals, fish, nematodes (roundworms), and microbes. Pesticides are usually, but not always, poisonous to humans. An extensive list and data of pesticides is provided in the EU Pesticides Database and in the Eurostat database within Pesticide sales (aei_fm_salpest09 and aei_fm_salpest).

52. In principle, the accounting of pesticides would have to be for the total masses. Agricultural statistics commonly report quantities of pesticides used in (or sold to) the agricultural sector. Figures are generally expressed in terms of active substances (active ingredients contents). If multipliers are available, these figures should be converted to total mass.

53. The conversion to total mass can be carried out using coefficients that are available on sellers' websites. It is a rough estimate; however, if it is not applied, the underestimation could be important given that more than a half of the content is not active.

F.4.6 Seeds

54. Seeds are the encapsulated embryos of flowering plants. Seeds for agricultural production are a common position in agricultural statistics (e.g. from FAO food commodity balance sheets) or has also to be estimated in the GNB (see the methodological guide)[7].

F.4.7 Salt and other thawing materials spread on roads (incl. grit)

55. First estimations for these flows were carried out for Austria and the U.S. (Matthews *et al.* 2000). This item should not be neglected, e.g. for rigorous winter it can accounts for about 10% of F.4 in Switzerland.

F.4.8 Solvents, laughing gas and others

56. This category includes emissions from diverse dissipative use of products, e.g. use of solvents, laughing gas, road paving, N2O for anaesthesia.

[7] Switzerland uses surfaces by crop – from an equivalent of the EU FSS (Farm structure survey) and multiplies each crop surfaces by standard seed requirements by hectare. Most quantitatively important are potatoes and cereals.

57. Several compounds are involved. The data sources for these emissions are the national inventory submissions to the CLRTAP and to the UNFCCC. The codes of the classification – NFR for the CLRTAP and CRF for the UNFCCC – of the two submissions that have to be accounted for in F.4.8 *Solvents, laughing gas and others* are showed in Table 3.

58. **As regards the CLRTAP** (NFR codes 2D and 2G), emissions are related to the use of solvent in paint application, degreasing and dry cleaning, chemical products, manufacture and processing and other solvent use, including emissions from road paving with asphalt and asphalt roofing activities.

59. NMVOC emissions are estimated from all the categories of the sector; PM for polyester and polyvinylchloride processing, in the chemical product category, and for asphalt processes; PAH emissions from the preservation of wood in the other solvent use.

60. The categories included in the NFR sectors 2D and 2G are specified as follows:

- 2D3a Domestic solvent use includes emissions from the use of solvent in household cleaning and car care products as well as cosmetics;
- 2D3b Road paving with asphalt includes emissions from the production and use of asphalt for road paving;
- 2D3c Asphalt roofing includes emissions from the manufacturing of roofing products and the blowing of asphalt;
- 2D3d1 Decorative coating includes emissions from paint application for construction and buildings, domestic use and wood products;
- 2D3d2 Industrial coating includes emissions from paint application for manufacture of automobiles, car repairing, coil coating, boat building and other industrial paint application;
- 2D3e Degreasing includes emissions from the use of solvents for metal degreasing and cleaning.
- 2D3f Dry cleaning includes emissions from the use of solvent in cleaning machines;
- 2D3g Chemical products, manufacture and processing covers the emissions from the use of chemical products such as polyurethane and polystyrene foam processing, manufacture of paints, inks and glues, textile finishing and leather tanning;
- 2D3h Printing includes emissions from the use of solvent in the printing industry;
- 2D3i Other product use addresses emissions from glass wool enduction, printing industry, fat, edible and non-edible oil extraction, preservation of wood, application of glues and adhesives, vehicles dewaxing;
- 2G Other production sector includes emissions due to the use of lubricants.

61. **As regards the UNFCCC**, the CRF sub-sector 2D "Non-energy products from fuels and solvent use" comprises the following sources, where CO_2 and NMVOC emissions are involved: lubricant use, paraffin wax, and other categories which include the use of urea, asphalt roofing and paving with asphalt and solvent use.

62. Within the CRF sub-sector 2F "Emissions of fluorinated substitutes for ozone depleting substances", the category 2F5 "Solvents" have to be considered. HFCs are now used in solvent applications and occur in four main areas as follows: precision cleaning; electronics cleaning; metal cleaning; deposition applications.

63. Within the CRF sub-sector 2G "Other product manufacture and use" the following sub-applications have to considered:

- 2.G.3 – N2O from product uses (i.e. N2O emissions from the use of N2O for anaesthesia, aerosol cans, explosives and from fire extinguishers)
- 2.G.4 – Other.

1.4.5 Specific issues related to dissipative use of products

64. **Manure produced versus manure spread on fields:** Not all manure produced is actually spread on agricultural land. A part is lost from the economic system as emissions to water and air. As regards the former, the Italian National Institute of Statistics estimated this loss at 5% (Barbiero *et al*. 2003) and reported it under emissions to water. Furthermore, manure loses some of its weight during stockpiling due to emissions to air (nitrogen compounds, methane and NMVOC, partly by combination with atmospheric gases). The DPO account may be corrected for these air emission losses from manure if information is available or a feasible estimation procedure has become available.

65. **Compost in private households:** Households may compost organic materials previously purchased (i.e., biomass that was recorded on the input side). Such composting is usually not recorded in statistics. If relevant for this DPO category, an estimate would have to be added on the output side.

1.5 F.5 Dissipative losses

1.5.1 Introduction

66. Dissipative losses are unintentional outputs of materials to the environment resulting from abrasion, corrosion, and erosion at mobile and stationary sources, and from leakages or from accidents during the transport of goods.

Table 8: Domestic processed output: dissipative losses (refers to Table F5 of the MFA questionnaire)

1 digit	2 digit	3 digit
F.5. Dissipative losses (e.g. abrasion from tyres, friction products, buildings and infrastructure)		

F.5. Abrasion from tyres, friction products, buildings and infrastructures and others

67. This category includes various types of dissipative flows. Many of them have never been quantified. It is recommended to fill in only those data that can be provided with a justifiable effort.

68. The air emission submissions to CLRTAP are the most important data source on this item. The following NFR codes, which account for Total Suspended Particulate (TSP) and heavy metals, are involved and must be reported under this DPO item instead of F.1:

- 1A3bvi "Road transport: Automobile tyre and brake wear";
- 1A3bvii "Road transport: Automobile road abrasion".

Please note that if particulate matter and heavy metal emissions in the sector 1A3 are split into exhaust and non-exhaust, all non-exhaust emissions have to be accounted for in F.5.

69. Losses of materials due to corrosion, abrasion, and erosion of buildings and infrastructure are probably a quantitatively relevant position, and they appear to be relevant under environmental aspects as well. So far, there is no comprehensive approach to account of these flows. Single aspects like losses due to leachate of copper from roofing or paints from construction have been studied, though. Such studies may serve as a starting point towards more comprehensive accounts of material losses of this kind.

70. Dissipative losses may also result from the transport of goods. In German statistics, for example, the amount of chemicals irreversibly lost due to accidents during transport is reported.

71. Another position may be leakages during (natural) gas pipeline transport (if not reported as emissions to air). Data may be reported in specific studies.

2 Table G – Balancing items

2.1 Introduction

72. Some material inputs and material outputs which are part of DMI and DPO are not sufficiently counterbalanced on the respective opposite side of the material balance. For example, carbon contained in an energy carrier is combusted and the CO_2 is counted on the output side. This requires adding the O_2 on the input side to arrive at a correct balance. Or, energy carriers on the material input side contain water which is released through combustion as water vapour on the output side and needs to be added there as a balancing item.

73. These additional inputs and outputs that are needed to compile a full mass balance are significant mass flows, as can be seen from Figure 1 which shows the Swiss material balance for 2013. In EW-MFA they are called balancing items. They are reported in specific tables and are not included in the aggregate indicators. A comprehensive and accurate estimation of balancing items is instrumental when the indicator net additions to stock (NAS) is calculated as the difference between total inputs and total outputs.

Figure 1: EW-MFA material balance for Switzerland, 2013 (tonnes per capita)

Source: Eurostat, EW-MFA 2015 data collection

74. The EXCEL version of the questionnaire provides a compilation tool which gives NSIs the possibility to estimate all the balancing items within a reasonable range of accuracy based on the available data, ideally based on the data reported in the tables already anyways, otherwise provided within the tool. This was only possible based on a number of simplifying assumptions. More precise calculations, according to the procedure detailed in this chapter, are possible (and encouraged).

75. Comments and descriptions are included in the tool in order to make it clear which particular calculation steps they refer to. A more detailed background explanations on the assumptions made are provided in this chapter hereafter.

2.2 Balancing items: Input side

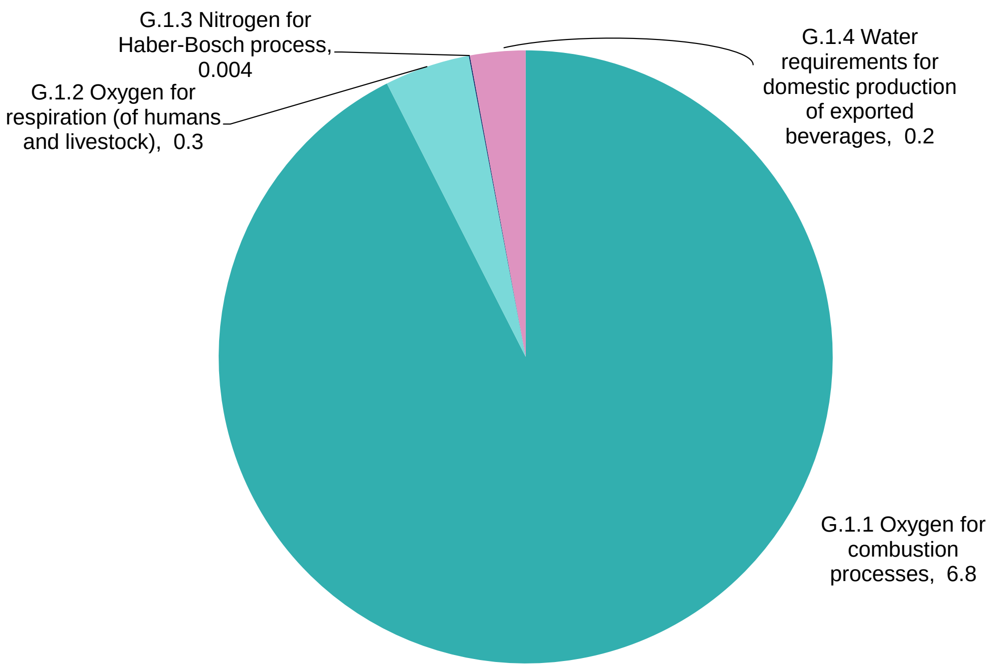
76. Table 9 presents the classification for the balancing items on the input side.

Table 9: Balancing items – Input side

G.1 Balancing items: input side
G.1.1 Oxygen for combustion processes
G.1.2 Oxygen for respiration of humans and livestock; bacterial respiration from solid waste and wastewater
G.1.3 Nitrogen for Haber-Bosch process
G.1.4 Water requirements for the domestic production of exported beverages

77. Balancing items on the input side account for those flows of air and water that are accounted for in DPO or exports, but not in DE or imports. The main processes concerned are combustion of fuels, respiration of humans and livestock, and the production of ammonia via the Haber-Bosch process and water requirements for the domestic production of exported beverages. Figure 2 shows results for the Swiss input balancing items in 2013.

Figure 2: Input balancing items for Switzerland, 2013 (tonnes per capita)



Source: Eurostat, EW-MFA 2015 data collection

2.2.1 Data compilation

78. Combustion processes require a certain amount of oxygen. For energy carriers which contain mostly C, H, O and H2O, two additional aspects must be considered: the amount of required oxygen must be set off against the oxygen content and a certain amount of H_2O (from reaction of H with O and from the moisture content) is generated. Overall, this implies the following conversion factors for the input and output side.

2.2.1.1 G.1.1 Oxygen for combustion processes

79. Total oxygen for combustion is calculated as the sum of the amount calculated in following steps, related to emissions of CO_2, CO, SO_2, N_2O and NO_2 (step 1) and to H_2O from H (step 2); then the real demand for O_2 for combustion is calculated by subtracting step 3.

- **Step 1**: Oxygen for combustion processes can be calculated stoichiometrically from respective data for emissions of CO_2, CO, SO_2, N_2O and NO_2 from combustion:
  - $C + O_2 \rightarrow CO_2$, i.e. in molar masses: 12 + 32 = 44, which implies that 0.727 tonnes of oxygen are required for one tonne of CO_2 (see also 2.3.2);
  - $C + O \rightarrow CO$, i.e. in molar masses: 12 + 16 = 28, which implies that 0.571 tonnes of oxygen are required for one tonne of CO;
  - $S + O_2 \rightarrow SO_2$, i.e. in molar masses: 32 + 32 = 64, which implies that 0.5 tonnes of oxygen are required for one tonne of SO_2;
  - $2N + O \rightarrow N_2O$, i.e. in molar masses: 28 + 16 = 44, which implies that 0.364 tonnes of oxygen are required for one tonne of N_2O;
  - $N + O_2 \rightarrow NO_2$, i.e. in molar masses: 14 + 32 = 46, which implies that 0.696 tonnes of oxygen are required for one tonne of NO_2.

  The required data for emissions from combustion should be taken from the DPO account. They are multiplied with the above factors for oxygen per substance emitted to obtain oxygen for combustion processes.

  Advanced EW-MFA compilers should also tackle the specific issues in section 2.3.

- **Step 2**: In addition, oxygen is required for combustion of the hydrogen (H) contents of energy carriers, with the resulting emission being water vapour (H_2O) (see item G.2.1 of the output side for water vapour):
  - $2H + O \rightarrow H_2O$, i.e. in molar masses: 2 + 16 = 18, which implies that 0.889 tonnes of oxygen are required for one tonne of H_2O from H.

  For this, hydrogen contents of energy carriers combusted and the resulting emissions of water vapour have to be determined. Table 10 provides exemplary values from German emission inventories for the respective oxygen demand. The following three approaches can be suggested to carry out this step.

i. The most appropriate source for energy carriers is *Table C: Physical use table of emission-relevant use of energy flows (related to fuel combustion)* of Physical energy flow accounts (PEFA).

ii. National energy balances could also be used if PEFA are not available. Note that the national account principles are not considered if this source is adopted.

Table 10: Oxygen demand for oxidation of H compound of energy carriers to H_2O

Energy carrier	Oxygen in t per t energy carrier
Sewage gas/ Biogas/ Landfill gas	1.57
Hard coal	0.37
Coke (hard coal)	0.06
Hard coal briquettes	0.33
Brown coal, crude	0.15
Dust- and dry coal	0.33
Hard brown coal	0.32
Brown coal briquettes and -coke	0.33
Mine gas	1.57
Coke oven gas	1.57
Natural gas, Crude oil gas	1.83
Gasoline	1.14
Diesel	1.06
Aviation gasoline	1.19
Fuel oil, light	1.07
Fuel oil, medium and heavy	0.93
Liquid gas	1.41
Refinery gas	1.71
Other solid fuels	0.40
Blast furnace gas	0.02

Source: Derived from Frischknecht *et al*. 1994, Kugeler *et al*. 1990, Osteroth, 1989

iii. The compilation tool proposes to use energy carriers' DMC as simple and crude approach. Compilers should be aware that this approach embodies the inconsistency among domestic extraction (natural resources) and trade tables (products).

An average composition of fuels is assumed which is unlikely to be applicable to specific combusted fuels. This is because the composition of each fuel can differ vastly depending on where it was extracted. Oil shale, in particular, is not even clearly defined chemically or geologically. NSIs are therefore encouraged to replace these composition averages with more precise national data wherever available.

It is also assumed that complete combustion takes place (i.e., the hydrocarbon reacts entirely with the available oxygen to form carbon dioxide and water vapour, and no carbon monoxide is formed). Therefore, the amount of oxygen required from the air in the combustion of fossil fuels and the amount of water (vapour) generated during combustion depend on the share of C, H, and O in the mass of the fossil fuel combusted (in 1000 metric tons as reported in the EW-MFA tables).

Note that the inclusion of fuel wood mong energy carriers (based on the data reported for the EW-MFA questionnaire) requires the assumption to be made that the item 1.3.2 of the EW-MFA classification of materials (CLAMA) mainly consists of fuel wood. In countries where this is not the case, the amounts must be adapted accordingly.

- **Step 3**: Intrinsic oxygen content of energy carriers. Since some energy carriers contain oxygen, an advanced balancing approach requires the intrinsic oxygen content of energy carriers to be determined. The intrinsic oxygen content has to be subtracted from the oxygen calculated in the previous steps in order to derive the (real) net demand for O_2 for combustion. Exemplary values for oxygen in energy carriers are shown in Table 11.

Table 11: Oxygen content of energy carriers (in % of weight)

	Oxygen content in % (wt/wt)
Sewage gas/ Biogas/ Landfill gas	14.93
Hard coal	4.94
Coke (hard coal)	1.70
Hard coal briquettes	2.78
Brown coal, crude	6.00
Dust- and dry coal	16.78
Hard brown coal	12.73
Brown coal briquettes and -coke	16.78
Mine gas	14.93
Coke oven gas	14.93
Natural gas, Crude oil gas	0.19
Other solid fuels	35.97
Blast furnace gas	34.35

Source: derived from Frischknecht *et al*. (1994), Kugeler *et al*. (1990), Osteroth, (1989)

Note that the three approaches described in the previous step hold true in this step.

2.2.1.2 G.1.2 Oxygen for respiration of human and livestock; bacterial respiration from solid waste and wastewater

80. Oxygen for respiration can be calculated using standard coefficients based on population numbers and livestock numbers (see Table 12). Data on livestock are available as underlying data of air emission inventories.

Table 12: Metabolic oxygen demand of humans and livestock

Oxygen demand for respiration	t O_2 per capita resp. head and per year
Humans	0.25
Cattle	2.45
Sheep	0.20
Horses	1.84
Pigs	0.25
Poultry	0.01

Source: Wuppertal Institute data base, based on Matthews *et al*. 2000

81. Oxygen for bacterial respiration from solid waste and wastewater has to be accounted for under this item as well, based on biogenic CO_2 emissions of the waste sector. The CRF codes of UNFCCC inventory concerned are: 5A "Solid waste disposal on land", 5B "Biological treatment of solid waste" and 5D "Wastewater handling". The coefficient 0.727 – as in **Step 1**, § 79 – can be used to estimate the O_2 content from CO_2 from biomass.

2.2.1.3 G.1.3 Nitrogen for Haber-Bosch process

82. The Haber-Bosch process designates the reaction of nitrogen and hydrogen to produce ammonia. Nitrogen is obtained from the air, and hydrogen is obtained from water and natural gas in steam reforming. Via this process around 500 million tonnes of artificial fertilizer are produced every year, mostly in the form of anhydrous ammonia, ammonium nitrate, and urea. Fertilizer produced in the Haber-Bosch process is responsible for sustaining 40% of the Earth's population. Roughly 1% of the world's energy supply is consumed in the manufacturing of this fertilizer (Smith 2002).

83. The nitrogen (N) and hydrogen (H) are reacted over an iron catalyst (Fe) under conditions of 250 atmospheres (atm) and 450-500°C:

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) + \Delta H \ldots$$

where ΔH is the heat of reaction or enthalpy. For the Haber process, this is -92.4 kJ/mol at 25°C. Nitrogen required as balancing item to account for the production of ammonia is derived by multiplying ammonia production in t with nitrogen requirements per tonne estimated as suggested below:

a) data for the production of nitrogen(fixed)-ammonia, e.g. from USGS;

b) the amount of nitrogen required to produce one tonne of ammonia, which is about 0.83 tonnes N for 1 tonne NH_3 (assuming conventional reforming in modern ammonia plants – UNEP/UNIDO 1998).

2.2.1.4 G.1.4 Water requirements for the domestic production of exported beverages

84. Water requirements for the domestic production of exported beverages may also be a relevant balancing item for the input side in some countries. The amount of water withdrawn from the domestic territory may be estimated based on export data.

85. Data for this item can be extracted from trade statistics: the exported quantities of fruit and vegetable juices (code CN 20.09) and beverages (CN 22) adjusted by a factor of water content.

2.3 Specific issues related to balancing items input side (and in total)

2.3.1 Combustion of energy carriers in the context of emission-relevant consumption

86. The emission-relevant consumption of energy carriers includes both energetic (combustion) and non-energetic processes. Emissions from combustion of energy carriers are usually by far dominating. Significant non-energetic emissions may, however, come from the production of blast furnace steel where the carbon stemming from coke in pig iron production is blown out as CO_2 through injection of technical oxygen. For a more comprehensive EW-MFA, this amount of oxygen for the process related emissions of CO_2 from coke should also be accounted for.

87. Advanced EW-MFA compilers may set up at first an account for the emission relevant consumption of energy carriers by type, and then account for oxygen as balancing item on the material input side. Respective energy consumption data are found in common energy statistics or energy balances.

2.3.2 Intrinsic CO_2 in materials

88. Process-related CO_2 emissions from intrinsic CO_2-contents of materials refer to cement and lime production: $CaCO_3$ + heat → CaO + CO_2. These emissions are reported in the Air emissions accounts and in the UNFCCC Common reporting format (CRF) tables (2A1 and 2A2 – Mineral industry, Cement and lime production).

89. Therefore, a further step can be carried out when compiling step 1 of G.1.1 by assuring that the resulting CO_2 stemming from cement and lime production is definitely excluded from the CO_2 value used for O_2 calculation.

2.3.3 Nitrogen for combustion as balancing item - input side

90. Emissions of nitrogen oxides (NO, NO_2) from fuel combustion in motors result at least partly from inputs of nitrogen in ambient air. This nitrogen input can in principle be calculated using standard coefficients based on emissions of NO_2.

2.4 G.2 Balancing items: Output side

91. Balancing items on the output side of the account are meant to equalise discrepancies resulting from data for material inputs. The main processes concerned are combustion of fuels and respiration of humans and livestock.

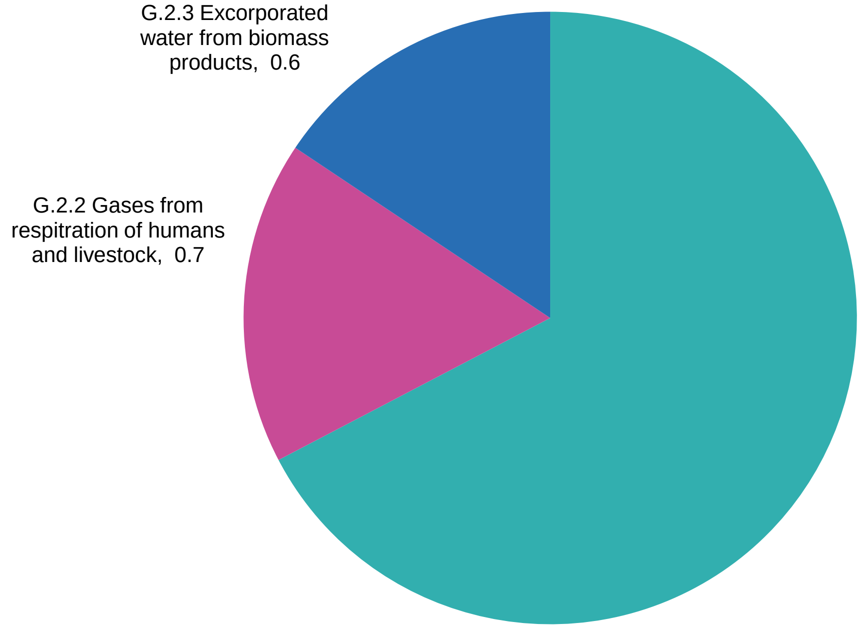
92. Table 13 presents the classification for the balancing items on the output side.

Table 13: Balancing items – Output side

G.2 Balancing items: output side		
	G.2.1 Water vapour from combustion	
		G.2.1.1 Water vapour from moisture content of fuels
		G.2.1.2 Water vapour from the oxidised hydrogen components of fuels
	G.2.2 Gases from respiration of humans and livestock (CO_2 and H_2O), and from bacterial respiration from solid waste and wastewater (H_2O)	
		G.2.2.1 Carbon dioxide (CO_2)
		G.2.2.2 Water vapour (H_2O)
	G.2.3 Excorporated water from biomass products	

93. Figure 3: Output balancing items for Switzerland, 2013 (tonnes per capita) presents results for the Swiss output balancing items in 2013.

Figure 3: Output balancing items for Switzerland, 2013 (tonnes per capita)



Source: Eurostat, EW-MFA 2015 data collection

2.4.1 Data sources

94. Data sources underlying the derivation of output balancing items are:

- for combustion: (1) data for the combustion of energy carriers to account for hydrogen contents of energy carriers resp. resulting emissions of water vapour, taken e.g. from energy balances (see also balancing items – input side) (2) similarly, data for the water contents of fuels for combustion;
- auxiliary data needed to account for CO_2 and water vapour from respiration are population numbers and livestock numbers commonly found in general statistical sources and agricultural statistics (e.g. FAOSTAT), respectively.

2.4.2 Data compilation

2.4.2.1 G.2.1.1 Water vapour from moisture content of fuels

95. In the combustion process the moisture contained in fuels is emitted as water vapour (H_2O). Resulting emissions can be estimated based on average values for water emitted per tonne energy carrier combusted. The coefficients are showed in the table below.

Table 14: Water vapour from moisture content of fuels

Energy carrier	Water vapour in t per t energy carrier
Hard coal	0.02
Coke (hard coal)	0.02
Hard coal briquettes	0.02
Brown coal, crude	0.59
Dust- and dry coal	0.11
Hard brown coal	0.18
Brown coal briquettes and -coke	0.12
Fuel oil, light	0.001
Fuel oil, medium and heavy	0.005
Other solid fuels	0.16

Source: derived from Frischknecht *et al.* (1994), Kugeler *et al.* (1990), Osteroth (1989)

2.4.2.2 G.2.1.2 Water vapour from the oxidised hydrogen components of fuels

As with the carbon component also the hydrogen component of fossil energy carriers is oxidised during combustion. The resulting water is released to the air as water vapour.

Table 15: Water vapour from oxidised hydrogen component of fossil energy carriers

Energy carrier	Water vapour in t per t energy carrier
Sewage gas/ Biogas/ Landfill gas	1.77
Hard coal	0.42
Coke (hard coal)	0.07
Hard coal briquettes	0.37
Brown coal, crude	0.17
Dust- and dry coal	0.37
Hard brown coal	0.36
Brown coal briquettes and -coke	0.37
Mine gas	1.77
Coke oven gas	1.77
Natural gas, Crude oil gas	2.05

Energy carrier	Water vapour in t per t energy carrier
Gasoline	1.28
Diesel	1.19
Aviation gasoline	1.34
Fuel oil, light	1.21
Fuel oil, medium and heavy	1.05
Liquid gas	1.59
Refinery gas	1.92
Other solid fuels	0.45
Blast furnace gas	0.02

Source: derived from Frischknecht *et al.* (1994), Kugeler *et al.* (1990), Osteroth (1989)

96. Compilers are recommended to refer to PEFA or energy balances as sources for energy carriers in the items described above *G.2.1.1 Water vapour from moisture content of fuels* and *G.2.1.2 Water vapour from the oxidised hydrogen components of fuels*, as illustrated in step 2 within the input item *G.1.1 Oxygen for combustion processes*.

97. The compilation tool suggests a method by which both the input- and the output-side balancing items of fossil fuel combustion would be calculated based on the composition by elements of the fossil fuels and the chemical reactions occurring during their combustion.

98. The composition of fossil fuels provided in the tool considers the hydrogen from C-H compounds as well has the hydrogen from moisture content (H2O) as hydrogen. Then the calculation of *G.2.1 Water vapour from combustion* could occur in just one step.

2.4.2.3 G.2.2 Gases from respiration of humans and livestock, and from bacterial respiration from solid waste and wastewater

99. CO_2 and water vapour (H_2O) from respiration can be calculated using standard coefficients based on population numbers and livestock numbers (see Table 16).

Table 16: Metabolic CO_2 and H_2O production of humans and livestock

	t CO_2 per capita resp. head and per year	t H_2O per capita resp. head and per year
Humans	0.30	0.35
Cattle	2.92	3.38
Sheep	0.24	0.27

Horses	2.19	2.53
Pigs	0.30	0.35
Poultry	0.01	0.01

Source: Wuppertal Institute data base, based on Matthews *et al.* (2000)

100. As regards bacterial respiration from solid waste and wastewater, CO_2 emissions are already accounted for in DPO. There is a definite connection between CO_2 from biomass and H_2O from bacterial respiration: waste contains hydrocarbons, thus the amount of H_2O from bacterial respiration can be determined indirectly via the CO_2 from bacterial respiration. H_2O stemming from bacterial respiration can be estimated from the CRF codes of UNFCCC inventory 5A "Solid waste disposal on land", 5B "Biological treatment of solid waste" and 5D "Wastewater handling". The coefficient 0.41 (18/44, the ratio of the molar masses of H_2O and CO_2) can be used to estimate the water vapour from CO_2 from biomass.

2.4.2.4 G.2.3 Excorporated water from biomass products

101. The item G.2.3 is symmetrical to G.1.4 Water requirements for the domestic production of exported beverages.

102. Two points need to be tackled under this item:

- **Bulk water from importation of beverages**, which is exactly the mirror image of the item G.1.4 of the input side of the balancing items. Data for this item can be extracted from trade statistics: the imported quantities of fruit and vegetable juices (code CN 20.09) and beverages (CN 22) adjusted by a factor of water content;

- **Water content of biomass products**. On the input side biomass product mainly for food are in wet weight and in the output they usually are in sewage sludge or compost in dry weight. Therefore, the water content has to be balanced. In practice, here we estimate the water content of the domestic extraction of biomass products (except wood fuel which is already included in G.2.1.1) by using production by crops (more detailed than the EW-MFA categories) and water content coefficients. The same approach holds for imports and exports (also by multiplying CN position with standard water content). Finally, domestic extraction plus Imports minus Exports provides apparent consumption. This position represents some15-20% of the balancing items of the output side for Switzerland.

  Assuming that sludge originally has 85% moisture content and compost originally has 50%, the ‘missing water’ from conversion to dry weight can be determined. However, this water only partially stems from biomass extraction. As a balancing item, water consumed through the apparent consumption of domestically extracted food crops can be estimated based on the moisture content of that food upon extraction.

  The compilation tool provides a table of the moisture content of crops at a more detailed level than the EW-MFA categories in the tool (Annex) of which NSIs with more detailed consumption data to process should make use. Average moisture content values for EW-MFA categories are proposed in the tool in order to obtain an initial estimate of the water content of consumed food.