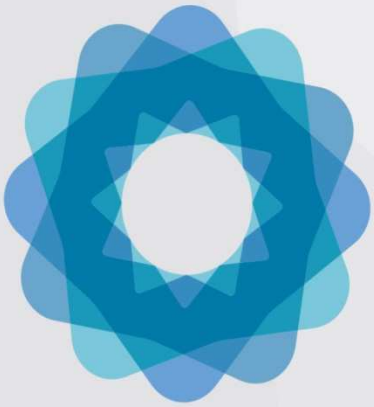

System of Environmental Economic Accounting

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SEEA TECHNICAL NOTE: ECONOMY-WIDE MATERIAL FLOW ACCOUNTS

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This note is a part of a series of Technical Notes prepared to support the development of data based on the System of Environmental Economic Accounts (SEEA) Central Framework, the first international standard in environmental economic accounting. Since SEEA is not a single account but a series of modules, the accounts in each of the various modules can be developed separately in accordance with the priorities and the resource availability in each country.

The series of Technical Notes is comprised of one note addressing general issues that cut across domains focusing on processes and operational aspects that encourage efficient implementation of the standard and associated data compilation exercises and a number of notes on specific topics. It is recommended that those wishing to develop data related to any of these specific topics should read the general process note in conjunction with the note on the specific topic to be developed.

The notes on modules summarize the data requirements and other operational considerations designed to provide sufficient guidance to initiate the development of the accounts. The notes also provide reference information for additional publications that will support the full development of the accounts and provide information on extensions and linkages that can be exploited once the accounts and tables are in place.

Table of Contents

1. Introduction

1. Natural resources and other inputs from the environment, as well as the capacity of the environment to act as a sink to absorb residuals and unwanted by-products from economic production, are necessary considerations for sustainable development. Measuring the flows of natural inputs into and releases of residuals from the economy in physical terms can therefore support related policy.

2. The economy-wide material flow accounts (EW-MFA) provide a physical measurement of the relationship between the economy and the environment through an aggregate overview, in tonnes, of the material inputs and outputs of an economy, including inputs from the environment, flows of materials back to the environment, and the physical amounts of imports and exports. Through the measurement of these flows, the EW-MFA and associated balances constitute the basis for a summary overview based on the derivation of a variety of material flow-based indicators.

3. This technical note provides an overview of economy-wide material flow accounting according to the System of Environmental Economic Accounting 2012 Central Framework (SEEA CF), which was adopted by the United Nations Statistical Commission in 2012 as the international statistical standard for environmental-economic accounts.

4. A full description of EW-MFA accounting and the associated indicators can be found in Economy-wide Material Flow Accounts and Derived Indicators: A Methodological Guide (European Commission and Eurostat, 2001) and the Eurostat Economy-wide material flow accounts compilation guide (2013). Useful background information may also be found in the OECD publication entitled "Measuring material flows and resource productivity: OECD guidance manual" and Vol. II: "A theoretical framework for material flow accounts and their applications at national level" (OECD, 2008).

5. The general purpose of SEEA Technical Notes is to summarize the key features of accounting for a given module to support countries in the implementation of the SEEA, and describe what might be a minimum set of information to guide initial efforts in compilation. This Technical Note will describe the main features of the SEEA accounts for economy-wide material flows, and present a core account and a combined presentation, which comprises an adapted version of the SEEA Central Framework account to focus and guide initial compilation.

6. The core account represents a minimum set of information, which countries should aim to compile and report, explicitly identifying the most important data items for the module at hand. While the core accounts represent a minimum set, countries may often wish to extend the information based on national policy needs. The Technical Notes provide highlights of such possible extensions in the explanatory text.

7. In addition to the core account, this technical note presents a combined presentation, which provides countries with a template to present and disseminate an aggregated set of key monetary and physical information from a range of sources (including the SEEA and SNA). The information included in the combined presentation is very relevant to policy makers and, in combination, can be used to derive important indicators (including the SDG indicators).

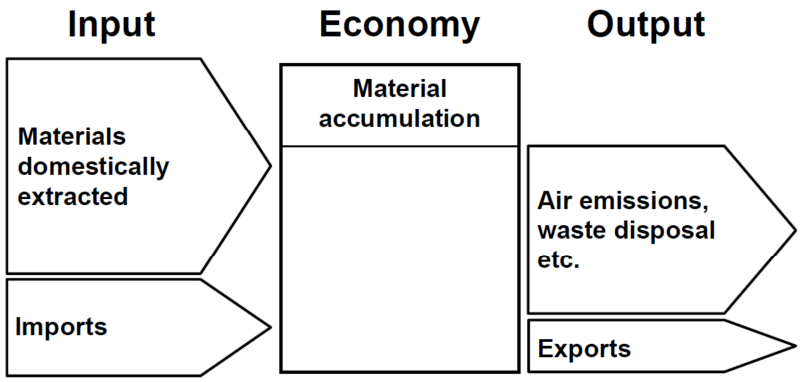
8. The development of core accounts was requested by the UN Statistical Commission at its 44th session in February 2013. The core account for material flows, along with other core accounts such as those for energy, land, and others, constitutes a starting point in the development of common reporting tables in close coordination with international agencies. They will be submitted to the UNCEEA after extensive consultations with experts, including the London Group on Environmental Accounting, international organizations and national statistical offices.

9. This note is organized as follows. Section II briefly discusses accounting for economy-wide material flows and presents the core account. Section III describes the combined presentation for economy-wide material flows. Section IV deals with the data sets required to produce the material flow data including the main concepts, data sources and compilation methods. Section V describes how the SEEA accounts and related datasets may be extended to address broader issues and linked to other data sets. Section VI provides references and links to supporting material.

2. SEEA CF Accounts for Economy-wide Material Flows

10. The general purpose of economy-wide material flow accounts is to describe in terms of material flows the interaction between the national economy, the natural environment, and the rest of the world economy. Only those flows crossing the system boundary of the national economy, either on the input side or on the output side, are counted. Material flows within the economy are not represented in EW-MFA. Figure 1 provides an illustration of the flows recorded in the accounts.

Figure 1: Scope of economy-wide material flow accounts (EW-MFA)



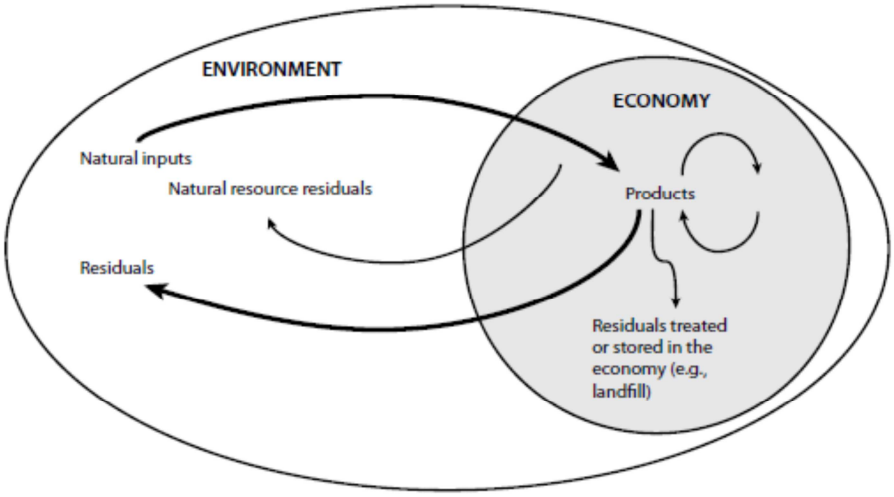
11. EW-MFA account for the flow of materials excluding bulk flows of water and air into and out of the economy. The economy is demarcated by the conventions of the System of National Accounts (including resident units).

12. EW-MFA follow the SEEA Central Framework's standard approach to physical flow accounting, which lays out a set of accounting principles and boundaries within which all types of physical flows relating to economic activities can be consistently recorded. This accounting approach is described briefly in the following section.

2.1 Physical flow accounting in the SEEA Central Framework

13. The SEEA CF defines three generic types of physical flows as depicted in Figure 2, namely natural inputs, products and residuals. While the definition of products aligns to the national accounts' definition[1], natural inputs and residuals are concepts which do not exist in national accounts. They are included in the SEEA CF in order to account for the physical inter-relations between the national economy and the natural environment. Each of these flows is described below;

Figure 2: Natural inputs, products, and residuals: types of physical flow in relation to the production boundary of the economy



Source: SEEA CF (UN et al. 2012, p. 40))

14. ***Natural inputs*** refer to physical flows from the environment into the economy. Natural inputs include all physical inputs that are moved from their location in the environment as a part of economic production processes, or are directly used in production.[2] The SEEA CF separates natural inputs into three sub-types;

- *Natural resource inputs* are material resource extractions from the natural environment. They include materials actually used in production as well as natural resource residuals. These are natural resource inputs that do not subsequently become products but instead immediately return to the environment.
- *Natural inputs from renewable energy* sources include, for example, solar energy captured by economic units (often non-material, rather energy flows).

[1] Being those goods and services created through a production process and have economic value (SEEA CF §1.40; see also SNA 2008 §§ 6.26-48 for the definition of the production boundary).
[2] It is important not to confuse *natural inputs* with *products*; for example, in the case of mining activities natural inputs such as gross ore are input flows to the mining industry. In contrast, products, such as processed ore and concentrates, are outputs of the mining industry.

- *Other natural inputs* include, for example, inputs from soil (e.g. soil nutrients) and inputs from air (e.g. oxygen taken up in combustion processes, or CO_2 absorbed by cultivated plants).

15. ***Products*** are goods and services that result from a process of production in the economy[3]. Generally products are evidenced by a transaction of positive monetary value between two economic units (SEEA CF §2.91). Products are relevant for EW-MFA in as much as they constitute physical trade flows (imports and exports). Product flows within the economy are not recorded in EW-MFA.

16. ***Residuals*** refer to flows of solid, liquid and gaseous materials and energy that are discarded, discharged or emitted to the environment (e.g., emissions to air and water) through economic processes of production, consumption or accumulation (SEEA CF § 3.73, and table 3.4).[4]

Physical supply and use tables (PSUT) - the framework

17. Physical supply and use tables (PSUT) provide an accounting framework to completely and consistently record physical flows[5] related to a national economy, including 1) flows from the environment into the economy, 2) flows within the economy, and 3) flows from the economy to the environment. Physical flows within the environment, such as natural flows of materials and water, are out of the scope of the PSUT and by extension the EW-MFA.

18. The PSUT framework is illustrated in figure 3. It consists of a pair of tables with the same structure. Row-wise, the two tables show the various types of physical flows (namely natural inputs, products, and residuals). Column-wise they show the various origins and destinations supplying and using these flows, namely industries (i.e. production activities), households (i.e. consumption activities), accumulation (i.e. changes in stocks of produced assets and product inventories), rest of the world, and environment. The physical supply table shows physical flows by origin. The physical use table shows physical flows by destination.

Economy-wide material flow accounts and the PSUT framework

19. The SEEA CF notes that the general PSUT framework shown in Figure 3 may be articulated fully or only partly. In the case of EW-MFA, it is only partly articulated. Figure 3 highlights those cells which are recorded in EW-MFA in pale blue.

[3] They are defined consistently with the definition of *products* in national accounts.
[4] Residuals can also stay as flows within the economy, as is the case when, for example, solid waste (i.e. a residual) is collected (SEEA CF §2.92) and recycled to new products. These within-economy flows are not recorded as part of the EW-MFA.
[5] Physical flows could constitute, for example, flows of water, energy, materials, etc.

Figure 3: Physical supply and use tables (PSUT) and the economy-wide material flow accounts (EW-MFA)

PHYSICAL SUPPLY TABLE						
	Production; Generation of residuals		Accumulation	Flows from the rest of the world	Flows from the environment	**TOTAL SUPPLY**
	Production; Generation of residuals by industries (incl. household production on own account) - classified by ISIC	Generation of residuals by households	Industries - classified by ISIC			
Natural inputs					**A. Flows from the environment (incl. natural resource residuals)**	Total Supply of Natural Inputs (TSNI)
Products	C. Output (incl. sale of recycled and reused products)			**D. Imports of products**		Total Supply of Products (TSP)
Residuals	I1. Residuals generated by industry (incl. natural resource residuals)	J. Residuals generated by household final consumption	K1. Residuals from scrapping and demolition of produced assets	L. Residuals received from rest of the world	M. Residuals recovered from the environment	Total Supply of Residuals (TSR)
	I2. Residuals generated following treatment		K2. Emissions from controlled landfill sites			
TOTAL SUPPLY						

PHYSICAL USE TABLE						
	Intermediate consumption of products; Use of natural inputs; Collection of residuals	Final consumption*	Accumulation	Flows to the rest of the world	Flows to the environment	**TOTAL USE**
	Industries - classified by ISIC	Households	Industries - classified by ISIC			
Natural inputs	B. Extraction of natural inputs					Total Use of Natural Inputs (TUNI)
	B1. Extraction used in production					
	B2. Natural resource residuals					
Products	E. Intermediate consumption (incl. purchase of recycled and reused products)	F. Household final consumption (incl. purchase of recycled and reused products)	**G. Gross Capital Formation (incl. fixed assets and inventories)**	**H. Exports of products**		Total Use of Products (TUP)
Residuals	N. Collection and treatment of residuals (excl accumulation in controlled landfill sites)		O. Accumulation of waste in controlled landfill sites	P. Residuals sent to the rest of the word	**Q. Residual flows to the environment**	Total Use of Residuals (TUR)
					Q1. Direct from industry and households (incl. natural resource residuals & landfill emissions)	
					Q2.Following treatment	
TOTAL USE						

20. The cells captured in EW-MFA are described as follows:

- Sub-matrix A presents the supply of natural inputs from the natural environment to the economy. This is termed domestic extraction in EW-MFA. The use-side of these natural inputs is recorded in submatrix B, which captures the use of natural inputs by the economy.
- Sub-matrix D presents the physical imports of products; i.e. the supply of products by the rest of the world[6].
- Sub-matrix G presents the net change of product inventories and the additions to produced assets (i.e. gross capital formation). The net change of man-made stocks is indirectly derivable in EW-MFA.

[6] Note that imports also include "Waste imported for final treatment and disposal", which partially corresponds to the sub-matrix L.

- Sub-matrix H presents the physical export of products; i.e. the supply to the rest of the world[7].
- Sub-matrix Q presents the use, i.e. reception or up-take, of residuals (which originate in the economy) by the environment. This is termed domestic processed output in EW-MFA. The supply-side of these residuals is recorded in sub-matrix I, which captures the supply of residuals flowing from the economy to the environment.

2.2 Core Account for EW-MFA

21. The core account for Economy-wide material flows is presented in Table 1. The core account only contains information on domestic extraction, imports and exports (cells A, B, D and H). This information suffices to derive a number of key indicators used in policy, and sufficiently informs the combined presentation laid out Section III. It is recommended countries begin compilation with the input side and exports, such that domestic extraction, imports and exports are compiled in the first stage. This can then be completed on the output side to also include residuals with Domestic Processed Output and Accumulation[8] (cells G, Q and I) being compiled in a second stage.

22. As shown in Table 1, the natural inputs and products are sub-divided into high-level categories, but can be further disaggregated according to national policy concerns[9]. Each row is described in turn below.

23. ***Domestic Extraction (DE)*** is the amount of material inputs from the environment to the economy. In SEEA CF terms it equals natural inputs minus natural resource residuals. Domestic extraction includes the *used* extraction of material; that is material extracted from the environment by humans and further processed in the economy. Domestic extraction as defined in EW-MFA excludes *unused* extraction (termed natural resource residuals in SEEA CF)[10]. Domestic extraction can be broken down into the following four categories:

- ***Biomass*** in general comprises organic non-fossil material of biological origin. Not all generated biomass is considered domestic extraction, but the following two major types of creation of biomass can be identified; 1) biomass generated within the environment by a natural process which is outside human control, such like non-cultivated forests or the growth of wild animals, and 2) biomass generated by a cultivation process which takes place more or less under human control, like production of agricultural crops and plants, cultivated animals and their products, and cultivated aquatic products. For calculation purposes, biomass generated by a

[7] Note that exports also comprise "Waste exported for final treatment and disposal", which partially corresponds to the sub-matrix P.
[8] These concepts are defined in detail later in this section
[9] For more information on further disaggregation of these categories, refer to the Eurostat Economy-wide material flow accounts compilation guide (2013).
[10] Examples of unused extraction are; soil and rock excavated during construction or overburden from mining, the unused parts of felling in forestry, the unused by-catch in fishery, the unused parts of the straw harvest in agriculture, or natural gas flared or vented.

cultivation process is treated differently in EW-MFA compared to the SEEA conceptual framework (refer to Section II.3 for a more detailed explanation).

- ***Metal Ores*** are recorded in terms of gross ore (also known as crude ore), based on their chemical classification as a metal in the periodic table of elements.

- ***Non-metallic minerals*** include flows of minerals that are non-metallic based on their chemical classification, such as marble, limestone, sand and gravel. It is important to keep in mind that this does not include the extraction of gases from the atmosphere for industrial purposes[11].

- ***Fossil energy materials/carriers*** include flows of natural inputs of fossil energy, such as coal, peat, petroleum, and natural gas[12]. Whereas energy statistics/balances show a comprehensive picture of the supply and use of all energy carriers, the domestic extraction of energy materials/carriers in EW-MFA is limited to the extraction of fossil energy carriers only[13].

24. ***Imports and Exports*** (in physical terms) are recorded based on categories that, to the greatest extent possible, mirror the main categories used for domestic extraction. EW-MFA estimates of physical flows of imports and exports are typically based on international trade data. Imports and exports exclude goods in transit through a country, which is consistent with the SNA and the SEEA.

25. It should be noted that it is necessary to consider the treatment of goods for processing, goods for repair, and for merchanting. Transactions in national accounts are based on the change of ownership principle which, in the cases mentioned here, can often differ from a physical flow basis. Adjustments should be made from the economic transaction to a physical flow basis in these cases. The residency principle used for the PSUT will also require adjustments when data inputs are based on alternate concepts. This can be particularly challenging for some transportation related cases such as for bunker fuels outside of the economy[14].

[11] One such example would be extraction of nitrogen for the Haber-Bosch process. These flows, if quantitatively important, are accounted for as balancing items.
[12] The breakdown of substances used in Eurostat's EW-MFA and Eurostat's energy statistics/balances is slightly different (refer to the Eurostat manuals for concordances).
[13] Not included are primary renewable energy carriers, like hydro, wind, solar and geothermal energy. The domestic extraction of biomass which might be used for energy purposes is reported under *biomass*. The domestic extraction of the energy carrier uranium is reported under *metals*.
[14] Refer to the SEEA Central Framework and Eurostat EW-MFA Compilation Guide for more details.

Table 1: Core account for economy-wide material flow accounts (EW-MFA)

PHYSICAL SUPPLY TABLE	Total Economy	Rest of the world	Flows from the environment	TOTAL SUPPLY
Natural inputs (tonnes)			Domestic Extraction	
Biomass				
Metal ores (gross ores)				
Non-metallic minerals				
Fossil energy materials/carriers				
TOTAL				
Products (tonnes)		Imports		
Biomass and biomass products				
Metal ores and concentrates, raw and processed				
Non-metallic minerals, raw and processed				
Fossil energy materials/carriers, raw and processed				
Other products				
Waste imported for final treatment and disposal				
TOTAL				
TOTAL SUPPLY				
PHYSICAL USE TABLE	Total Economy	Rest of the world	Flows to the environment	**TOTAL USE**
Natural inputs (tonnes)	Domestic Extraction			
Biomass				
Metal ores (gross ores)				
Non-metallic minerals				
Fossil energy materials/carriers				
TOTAL				
Products (tonnes)		Exports		
Biomass and biomass products				
Metal ores and concentrates, raw and processed				
Non-metallic minerals, raw and processed				
Fossil energy materials/carriers, raw and processed				
Other products				
Waste imported for final treatment and disposal				
TOTAL				
TOTAL USE				

Possible Extensions to the Core Account

26. In order to complete the PSUT structure, countries may wish to include residuals and accumulation as an extension of table 1. Domestic Processed Output can be recorded as illustrated in submatrix I and Q of figure 3 by adding rows for the main categories of residuals in the supply and use tables

27. ***Domestic processed output (DPO)*** is the amount of material that flows from the economy into the environment corresponding to domestic extraction. In SEEA CF terms it equals residuals (including waste flowing to uncontrolled landfills) minus natural resource residuals. These flows can be broken down into five main categories:

- Emissions to air, as recorded in air emissions accounts;

- Emissions to water, as recorded in the water emissions account;
- Waste that is dumped into uncontrolled sites, i.e. into the environment;
- Dissipative use of products, i.e. dispersion of materials as a consequence of product use on agricultural land or roads (e.g. fertilizers and manure spread on fields, or salt, sand and other thawing materials spread on roads); and
- Dissipative losses, i.e. dispersion of materials as a consequence of the corrosion and abrasion of products and infrastructures, leakages, etc. (e.g. rubber worn away from car tires, particles worn from friction products such as brakes, abrasion from roads, losses due to evaporation of e.g. water or other solvents used in paints or other coatings).

28. The core account could also be extended to accommodate accumulation by adding an additional column for accumulation, as illustrated in submatrix G and K of figure 3. Accumulation would be recorded as Net Additions to Stock.

29. ***Net additions to stock (NAS)*** is a measure for the 'physical growth of the economy'. Materials in the form of buildings, infrastructures, durable goods such as cars, industry machinery, or household appliances are added to the economy's material stock each year (gross additions), and old materials are removed from stock as buildings are demolished, and durable goods are disposed of (removals). NAS can be calculated as;

- NAS = gross additions – removals

30. Net Additions to Stock (NAS) is difficult to measure statistically according to the above equation. Hardly any statistics are available on gross additions to and removals from physical stock. NAS can be approximated using the following equation;

- NAS = (DE + Imports[15] + balancing items input side) – (DPO + balancing items output side)

31. Where special balancing items include two groupings;

- Balancing items to be added to material inputs such as oxygen for combustion processes and respiration, and nitrogen.
- Balancing items to be added to material outputs such as water vapour from combustion, and gases from respiration.

2.3 Differences in treatment between EW-MFA and PSUT

32. The EW-MFA and (conceptual) SEEA framework differ in their treatment of biological resources. It is very difficult to measure the uptake of nutrients, water and carbon dioxide by cultivated crops as they grow, which is when these natural inputs conceptually enter the economy according to the SEEA CF. In EW-MFA, the natural inputs to the growing of cultivated crops, trees and other plants are approximated by the amounts harvested. In effect, by

[15] Where DE + Imports is equal to Domestic Material Input (DMI)

recording the amount harvested rather than the natural input flows from the soil and the atmosphere, EW-MFA assumes that the quantities harvested embody all of the different natural inputs. Since the harvested amounts can be more easily measured at an aggregate level, this proxy method is used for EW-MFA purposes.

33. Because of the treatment of cultivated plant resources, many natural inputs are not directly recorded in the EW-MFA. However, some inputs from air are recorded in relation to the respiration of livestock and the inputs absorbed during combustion. These inputs are referred to as 'input balancing items' in EW-MFA.

34. The treatment of natural biological resources (both plants and animals) is the same in EW-MFA as in the SEEA CF PSUT; all wild plants and animals are recorded as entering the economy at the point of harvest.

35. Another difference in treatment is that the SEEA CF defines a sub-type of residuals: 'natural resource residuals' which denote material resource extractions which physically do not enter the production process (e.g. overburden in mining), and are currently not included in EW-MFA. This means that the recorded natural inputs and residuals[16] are net of these flows.

2.4 Indicators derived from EW-MFA

36. Three particularly important indicators can be derived based on the information provided in the core account.

37. ***Direct material input (DMI)*** represents all materials (excl. bulk flows of water and air) actually available for the national economy's production system. Note that parts of the production system's output are exported;

- DMI = DE + imports

38. ***Domestic material consumption (DMC)*** measures the total amount of materials (excl. bulk flows of water and air) that are directly/actually used in a national economy, i.e. by resident units;

- DMC = DMI – exports

39. ***Physical trade balance (PTB)*** measures the physical trade surplus (positive value) or physical trade deficit (negative value) of a given national economy;

- PTB = imports – exports

2.5 Accounting identities inherent to EW-MFA

40. The above components and derived variables are linked by accounting identities. One important identity is the 'direct material input and use account'. Domestic extraction (DE) plus

[16] It should be noted that in some EW-MFAs as currently published waste going to controlled landfills is also included in residuals. Care should be taken when comparing across economies.

imports form the direct material input (DMI). The use of DMI is composed of domestic material consumption (DMC) and exports:

- DE + imports = DMI = DMC + exports

41. Another important accounting identity is the material input-output balance for the national economy: direct material inputs (DMI) plus some balancing items equal direct processed outputs (DPO) plus/minus net additions to stock plus some balancing items

- DMI + balancing items = DPO ± NAS + balancing items

3. Combined Presentation and Indicators for EW-MFA

42. Table 2 is the combined presentation for EW-MFA and presents the aggregates and indicators discussed above, from which a range of policy relevant information can be derived. For users of the accounts (i.e. researchers, policymakers, etc.) the combined presentation gives an overview of the key data that can be derived from the accounts. The data in the combined presentation come from the EW-MFA account and data from national accounts.

Table 2: Combined presentation for Economy-wide Material Flow Accounts (EW-MFA)

	Years					
	2009	2010	2011	2012	2013	2014
1. Domestic Extraction (DE) *(tonnes)*	6 307 084	6 074 298	6 312 556	5 856 878	5 795 457	5 852 293
2. Total Imports *(tonnes)*	3 049 508	3 275 748	3 378 306	3 308 093	3 281 513	3 305 589
3. Total Exports *(tonnes)*	1 964 921	2 157 441	2 233 869	2 257 587	2 299 992	2 315 136
4. Direct Material Input *(=1+2)*	9 356 592	9 350 046	9 690 862	9 164 971	9 076 970	9 157 882
5. Domestic Material Consumption *(= 1+2-3)*	7 391 671	7 192 605	7 456 993	6 907 384	6 776 978	6 842 746
6. Physical Trade Balance *(= 2-3)*	1 084 587	1 118 307	1 144 437	1 050 506	981 521	990 453
7. Gross Domestic Product *(market prices)*	6 149 174	6 396 748	6 614 533	6 730 010	6 790 865	6 997 258

43. The information in the combined presentation for EW-MFA is also useful for deriving other indicators such as those proposed in association with the Sustainable Development Goals. For example, SDG indicator 8.4.1 is resource productivity, which provides a broad measure of the efficiency with which material resources are used within an economy. It is defined as:

- **SDG Indicator 8.4.1 - Resource productivity** = Gross domestic product in market prices (GDP) / Domestic Material Consumption (DMC) ($ per kilogram)

- **SDG Indicator 12.2.1 – Material footprint and material footprint per capita:** This indicator may be defined as the raw material extraction equivalents (RME) necessary to produce goods and services for domestic final use. At the economy-wide level the indicator can be termed raw material consumption (RMC). See section V for more detail on how this indicator can be calculated using the EW-MFA as a starting point.

4. Compilation of EW-MFA accounts

44. The Generic Statistics Business Process Model (GSBPM) can be used to support the compilation of SEEA accounts as outlined in the first note in this series "Statistical Production

Processes for Implementation of the SEEA Central Framework". Figure 4 briefly outlines the steps in this process below.

Figure 4: Steps in the Generic Statistics Business Process Model (GSBMP)

OVERARCHING MANAGEMENT FUNCTIONS	**1. Specify Needs:** Engage users to identify their detailed statistical needs, propose high level solution options and prepare the business case
	2. Design: Design and develop activities and any associated practical research work needed to define the statistical outputs, concepts, methodologies, collection instruments and operational processes. Specify all relevant metadata as well as quality assurance procedures
	3. Build: Build and test the production solution
	4. Collect: Collect and gather all necessary information (data and metadata), using different collection modes and load them for further processing
	5. Process: Clean data and prepare them for analysis
	6. Analyze: Produce statistical outputs, examine them in detail and prepare them for dissemination. Prepare statistical content and ensure outputs are 'fit for purpose' prior to dissemination. Ensure statistical analysts understand the statistics produced
	7. Disseminate: Release the statistical product and support users to access and use the output
	8. Evaluate: Conduct an evaluation of the process and agree an action plan

45. When building accounts (SEEA or SNA for example) it is often the case that that existing data sources need to be used as much as possible. The Specify Needs, Design and Build phases will often need to be undertaken simultaneously and iteratively, as one evaluates the capacity of existing data sets to meet needs relative to the potential costs of initiating new data development.

46. This section outlines some basic steps that are relevant in the compilation of MFA accounts. The initial compilation of MFA accounts will require several steps that may not need to be undertaken for each data cycle but should be revisited periodically in conjunction with regular budget and planning cycles.

47. Detailed methodological guidelines for the compilation of MFA accounts have been developed by Eurostat and should be consulted for further detail[17].

4.1 Specify Needs

48. When starting compilation of MFA accounts first make the business case, defining the analytical and policy uses of the information being compiled. Obtain high level institutional and political buy-in through stakeholder discussions to ensure a solid basis for institutionalisation of the accounts' compilation in the longer term, also ensuring that appropriate institutional frameworks and adequate resources are in place.

[17] Visit the Eurostat website for the most up to date information: http://ec.europa.eu/eurostat/web/environment/methodology

49. It is common practice to begin compilation of accounts on a pilot basis, which can help to obtain the political buy-in for a more regular compilation, by providing an initial illustration of the information compiled and its associated uses. In the short term, compile pilot accounts using existing data. Learn from each phase of the pilot compilation and assess technical issues associated with implementation.. Undertake an evaluation, both of priority data gaps which require new data development and of needs to harmonize existing data collection processes.

50. In the longer term, harmonize to the extent possible data collection processes within different institutions responsible for the collection of material flow statistics[18]. Data collection should be harmonized to ensure that consistent SEEA-based definitions and classifications are used. This will make the compilation process of the accounts much easier and smoother in the long run.

4.2 Design and Build

Establish institutional arrangements

51. Build strong arrangements for collaboration from the outset to establish a common goal and combined strategy for compilation of MFA accounts, and to facilitate the exchange of knowledge, expertise and data. As a first step, understand the roles and responsibilities of relevant agencies and groups within agencies, as well as the data sources they hold (including availability and quality).

52. Where necessary, develop a mechanism to work together in a collaborative fashion, both across agencies and between different teams within the same agency. A high level steering group can often support more cooperative working arrangements and data sharing at the technical level. Establishing and maintaining good working relations between different groups can pay dividends later on in the production process when estimation challenges benefit from expertise in all those concerned.

Define statistical requirements - design outputs

53. Since the core account for EW-MFA cover the entire economy but are at a very high level of aggregation, there are few choices at the needs stage. The challenge lies in designing and building a program that provides estimates of all relevant flows in volume terms.

54. Consider possible extensions to the core account as laid out in section II.2, and discuss these during stakeholder discussions in the Specify Needs phase. The corresponding outcome of the Design phase will provide a basis to examine the adequacy of the existing data and assess data sources for new data items.

55. Find an appropriate balance between the information sought by policy makers and analysts, and the capacity of the statistical infrastructure to deliver sufficiently robust estimates, especially in the early stages of development. Recognise the demands for detailed estimates so that the development of data sources and systems can anticipate eventual improvements in these

[18] It is often the case that this is not as strongly needed for MFA as for other SEEA accounts, as much of the data already exists and is held within National Statistics Offices.

dimensions. It is important to manage expectations by clearly stating that the objectives of the accounts are to develop a *macro* picture of material flows.

Identify important data sources

56. A natural way to subdivide the Design and Build activities is by major component of the core account for EW-MFA[19], namely 1) Domestic Extraction, and 2) Imports and Exports in physical terms. Based on decisions made in the 'design output' phase, further components may include 3) Domestic Processed Outputs, and 4) Balancing Items.

57. While it may be beneficial to organize the work on this account by these four components, it must be recognized that they are not independent. The data sets utilized may well have information necessary for multiple components and these dependencies should be built into the Design and Build activities.

58. In particular, many balancing items arise either because water and oxygen flows (to be excluded form EW-MFA) are indivisible from the flows that are actually recorded, often related to agricultural products. Also, it may be necessary to consider offsets for measurement errors that could not be fully overcome in converting data to a common set of volume measures. Thus it will be important to ensure these are captured at each stage in developing the other components.

Domestic Extraction

59. Four groupings for domestic extraction should be considered, namely Biomass, Metal Ores, Non-metallic Minerals, and Fossil Energy Materials/Carriers. It is important to note that these natural inputs are estimated/approximated using statistics on products (e.g. agriculture statistics, energy statistics). Each of these groupings is considered in turn below.

60. ***Biomass:*** Data sources are generally found in the programs for agriculture, forestry and fishing statistics for the national economy. These data sets often already have volume measures but some may not be in terms of weight as specified for the EW-MFA. For example, crop data may be recorded at varying degrees of water content and need to be moved to a standard measure required for EW-MFA.

61. Where the original data does not provide the weight measures needed for EW-MFA, conversion factors will be required. National expertise should be sought for such conversions. If national factors are not available, international organization or other economies may have factors that can be used as substitutes.

62. ***Metal Ores:*** The second group of flows to be considered under Domestic Extraction are metal ores measured in terms of gross ore (which may also be called run of mine or crude ore). If data are only available for concentrated ore or pure metal content, then conversion factors will be required to estimate gross ore weight.

[19] The following section is based largely on Eurostat, Economy-wide material flow accounts (EW-MFA), Manual 2016, forthcoming. This Manual is also a source for examples of specific calculations and conversion factors that are too numerous and detailed to be included in this note.

63. The following grouping of metal ores is a good starting point for this set of natural inputs, but for specific economies there may be elements in the 'Other n.e.c.' group that may be significant and warrant inclusion as a distinct product;

- Iron - gross ore
- Non-ferrous metal
- Copper - gross ore
- Nickel - gross ore
- Lead - gross ore
- Zinc - gross ore
- Tin - gross ore
- Gold, silver, platinum and other precious metal – gross ore
- Bauxite and other aluminium - gross ore
- Uranium and thorium - gross ore
- Other n.e.c.- gross ore

64. There are often varying data sources for these flows and the factors to convert them to a common weight measure may well differ from mine to mine. National expertise should be sought on these conversion factors. General conversion factors may be available for international sources, such as the Eurostat manual 2016 (forthcoming), but these should be used as second best options.

65. In some cases mines may produce more than one type of ore. This is called coupled production and requires knowledge of the relative proportions to properly estimate the content of the two ores.

66. ***Non-metallic minerals:*** A basic grouping of the third group of flows to be considered under domestic extraction is provided in the list below:

- Marble, granite, sandstone, porphyry, basalt, other ornamental or building stone (excluding slate)
- Chalk and dolomite
- Slate
- Chemical and fertilizer minerals
- Salt
- Limestone and gypsum
- Clays and kaolin
- Sand and gravel
- Other n.e.c.
- Excavated earthen materials (including soil), only if used (optional reporting)

67. The volume data for some of these products will be in non-weight measures such as cubic metres. All such measures need to be converted into measures of gross weight for the EW-MFA. Again national expertise should be sought before international data sources are used for conversion.

68. Data coverage can be an issue for some of these flows as there may be a large number of small local producers not fully covered in standard data sources. Thus data gaps may have to be estimated based on economic data such as industry surveys and/or the national accounts' supply and use tables.

69. In many cases the volumes for these flows from the environment are recorded in cubic metres which will have to be converted to weight. Also, there will likely be coupled production of some of these materials. National expertise should be sought for the development of conversion factors for both of these issues.

70. ***Fossil Energy Carriers/Materials:*** The final group of flows to be considered under Domestic Extraction are those for natural inputs of fossil energy carriers/materials. The list below provides a basic set of categories for these natural inputs:

- Coal and Lignite; peat
- Hard coal
- Lignite (brown coal)
- Peat
- Crude petroleum and gas products
- Crude oil, condensate and natural gas liquids (NGL)
- Natural gas
- Bituminous or oil shale and tar sands

71. Again conversion for a variety of volume measures may be necessary. Care needs to be taken to confirm the original measure as some natural inputs such as natural gas may be reported in both liquid and gaseous volume measures.

72. Energy statistics are the main source for these flows. If SEEA Energy accounts have been prepared, they will provide a foundation for this section. The SEEA Physical Supply-Use Tables for Energy will contain information on the extraction and use of fossil energy carriers. While these will be reported in joules, the underlying volume measures will have likely been developed in the compilation of the accounts. The conversion factors used in compiling the SEEA energy accounts should be referred to.

73. Some adjustments will need to be made when using the information from the SEEA energy accounts for EW-MFA. In particular, SEEA energy accounts will include the domestic extraction of biomass used for energy purposes. This should be recorded under *Biomass* for the purposes of EW-MFA accounts. Similarly the domestic extraction of uranium for nuclear energy (reported in the energy accounts) should be reported under *Metal ores* for the EW-MFA. Finally, all kinds of peat should be reported in the EW-MFA under *Fossil energy carriers/materials*, including that which is used for non-energy purposes such as gardening. This extraction of peat for non-

energetic use will not have been included in the SEEA energy accounts, so an adjustment will need to be made.

Imports and Exports

74. The second major component to be considered in EW-MFA is imports and exports. There are often volume measures associated with international trade data; however, given the very large number of products and different stages of fabrication at which these products may be traded, the volume measures may vary greatly.

75. It is recommended that traded products are grouped, to the extent possible, parallel to the main categories used for domestic extraction. The traded goods are thereby assigned to one (and only one) category. The list in Table 3 provides a basic structure for physical trade data as recorded in EW-MFA.

76. International trade data provide the bulk of the information needed for this component of the EW-MFA. Balance of payments adjustments may be useful in making the appropriate adjustments for residency. It should be noted that the SEEA CF and the EW-MFA record goods sent abroad for processing on a gross basis.

77. It should be noted that international trade data is often recorded on a net basis - that is net of packaging. A study by Germany has found that packaging comprised only 0.5% of imports. Given this relatively small proportion, efforts to collect these small flows should be modest.

78. Readers should now skip to section IV.2 unless they intend to extend the core account presented in this note to also include Domestic Processed Output and Balancing Items.

Table 3: Physical trade data as recorded in EW-MFA

1 Biomass and biomass products
1.1 Crops, raw and processed
1.2 Crop residues and fodder crops
1.3 Wood and wood products
1.4 Fish capture and other aquatic animals and plants, raw and processed
1.5 Live animals other than in 1.4, and animal products
1.6 Products mainly from biomass
2 Metal ores and concentrates, raw and processed
2.1 Iron ores and concentrates, iron and steel, raw and processed
2.2 Non-ferrous metal ores and concentrates, raw and processed
2.3 Products mainly from metals
3 Non-metallic minerals, raw and processed
3.1 Marble, granite, sandstone, porphyry, basalt and other ornamental or building stone (excluding slate)
3.2 Chalk and dolomite
3.3 Slate
3.4 Chemical and fertilizer minerals
3.5 Salt

3.6	Limestone and gypsum
3.7	Clays and kaolin
3.8	Sand and gravel
3.9	Other n.e.c.
3.10	Excavated earthen materials (including soil), only if used (optional reporting)
3.11	Products mainly from non-metallic minerals
4	**Fossil energy materials/carriers, raw and processed**
4.1	Coal and other solid energy products, raw and processed
4.2	Liquid and gaseous energy products, raw and processed
4.3	Products mainly from fossil energy products
5	**Other products**
6	**Waste imported for final treatment and disposal**

Domestic processed output (DPO)

79. Domestic processed output (DPO) indicates the total weight of materials which are released back to the environment after having been used in the domestic economy. These flows occur at the processing, manufacturing, use, and final disposal stages of the economic production and consumption chain.

80. The DPO account comprises 5 major categories which are listed below:

- Emissions to air
- Emissions to water
- Waste landfilled (uncontrolled)
- Dissipative use of products
- Dissipative losses

81. The first two categories comprise flows that are recorded in two other SEEA accounts – the Air Emissions Account and the Water Accounts[20]. If these accounts already exist for the economy in question, then they should provide a basic source for the EW-MFA. If they are not yet available or incomplete, then development of data sources for these flows should be developed considering the needs of these associated accounts.

82. The third category in DPO is waste flowing to the environment. Waste refers to materials which are of no further use to the generator for purposes of production, transformation or consumption. Waste may be generated during the extraction of raw materials, during the processing of raw materials to intermediate and final products, or during the consumption of final products. These flows do not include waste that is deposited in controlled landfills as these are considered within the economy.

[20] Separate SEEA Technical Notes exist for both of these accounts and should be consulted for development in these areas.

83. ***Dissipative use of products:*** Some production processes require that materials be dissipated into the environment. The most common examples relate to agriculture where seeds, fertilizers and manure are dissipated regularly. Other examples are salt and other materials spread on roads for safety reasons, as well as solvents and mercury used in dental filings. The following list highlights the major categories for dissipative use of products:

- Organic fertiliser (manure)
- Mineral fertiliser
- Sewage sludge
- Compost
- Pesticides
- Seeds
- Salt and other thawing materials spread on roads (including grit)
- Solvents, laughing gas and other

84. ***Dissipative losses*** are flows of materials to the environment resulting from abrasion, corrosion, and erosion such as abrasive losses from tires and brakes. In addition, they include losses from leakages (e.g. during natural gas pipeline transport) or from accidents such as during the transportation of goods. There are few data sources for these losses, and initial efforts should focus on existing sources.

Balancing Items

85. As noted earlier Balancing Items are associated with the flows of materials described thus far. They arise either because water and oxygen flows (to be excluded from EW-MFA) are indivisible from the flows that are actually recorded, often related to agricultural products, or due to measurement challenges in transformations or incomplete data coverage. Readers should refer to the Eurostat methodological guide for further guidance.

86. Given the goal of creating 'economy-wide' indicators, the overall coverage must be evaluated to ensure that the resulting measures will, in fact represent the entire economy.

Build the mapping and correspondence

87. After identifying potential data sources, assess their suitability for estimating the desired variables identified in the accounts. It is important to thoroughly asses the metadata for the available datasets. First, assess whether or not the definitions conform to/and or support those set out in the design phase. Determine the severity of any shortcomings and whether they can be overcome with estimates based on alternate sources.

88. It is also key at this stage to clearly ascertain the classification, conceptual and coverage differences across the various data sets to be used as basic inputs. Assess whether there are readily available concordances between the classification systems and sources that can be used to estimate adjustments for conceptual and coverage differences. For EW-MFA, adjustments of this type are most likely related to trade statistics as these do not follow the residence principle.

Address data gaps

89. In some cases where partial data exist, but there are some important data gaps, it may be a good idea to construct a preliminary account filling in the missing data with estimates based on related coefficients or modelling. While such an exercise may not produce a viable account, it may well reveal more about the extent and importance of data gaps, thus providing a better foundation for the development of these missing basic data.

90. When addressing data gaps, compilers can use estimates based on related flows or modelling, or consider looking for ball park estimates using other countries' data. For large data gaps which are a priority for development, new questionnaires and samples may be necessary.

91. In the case where basic data must be developed, initiate a separate project to develop the necessary data. This project should follow the GSBPM steps and generic principles as set out in the first note in this Technical Note series. Depending on the organization of responsibilities within the National Statistical System this step may involve additional agencies or sectors of the NSO.

Build databases

92. Databases for the basic data and the accounts must be established. Given the SEEA links to the SNA, existing database structures and associated processing systems may be a good source for this development. Since PSUTs provide the foundation for a number of SEEA accounts, a common database structure for these cases is recommended.

93. Use of the same systems and processes will facilitate alignment of data sets and should help reduce the development costs for the new accounts, facilitating the integration of data for the production of indicators.

4.3 Collect and Process

94. At this phase, data is imported and processed and concordances are applied that are developed in the 'Design and Build' phase. The concordances may be required between the classifications used in the imported data and the classifications to be used in the estimates.

95. It is particularly important to assure that the units for the physical measures are well documented and stored with the data being collected. There may be a wide variety of units even when coming from a single source as these units are crucial for the transformation and aggregation processes to be undertaken.

96. Given that data may be acquired from a number of institutions or agencies, standard data transfer protocols may be established as a priority. Invariably agencies require changes/upgrades to systems and these may impact data integration if protocols are not in place. It is also important to collect metadata with each period or at least verify that it has not changed so as to be aware of any changes to classification, definitions, etc.

97. With the data imported and processed, estimates may be compiled, including the estimation of data for any data gaps. While the outputs for this account are at a very aggregate level, the large and varied number of flows, and the need to covert many flows to a standard weight measure will require that processing be done at a micro level.

98. The processing systems should provide the tools to asses and verify results at these micro data levels. This will be important to facilitate consultation with experts associated with the different data sources so as to respect confidentiality provisions across agencies.

99. As data is taken from different sources, validation or range checks should be introduced to ensure the numbers make sense when put together in the accounts. Where large disparities exist, expert judgement will be needed to understand the cause of these differences, potentially revisiting metadata and making adjustments to the data where needed.

4.4 Analyse

100. At this phase, the estimates are subject to analysis using tables and graphic representations, including undertaking an analysis of time series where possible. During the analysis, it is likely that multiple iterations between the analysis and the estimates determined in the previous step must be taken. Data quality should be assessed and documented at this stage.

101. The previous three steps are the core activities in building the accounts and will be repeated in cycle during each production period. This allows the strength of the accounting approach to be used to confront the various data sources and check for consistency and reasonableness in comparison to other datasets such as the related national accounts values.

102. The first time accounts are estimated for a new program, particular attention needs to be made with regard to adjustments required to the source data to ensure the methods used are appropriate and sound. Since these accounts deal with physical flows and stocks, care must be taken to fully understand the challenges in converting estimation methods from other domains where the focus has been economic values.

103. It is recommended that in cases where significant basic data come from other agencies, staff of those agencies be asked to participate in the analysis of the estimates. These experts often have in-depth knowledge that can allow the identification and resolution of inconsistencies.

4.5 Disseminate

104. The dissemination of data should always be accompanied by sufficient documentation and metadata to allow users to fully understand the information being disseminated (e.g. including indicators, methodological notes and statements of data quality). This is particularly important for the initial dissemination of a new program of data, where one might want to identify the initial data as ‘experimental’ or ‘preliminary’, and make it clear that user input is being sought in order to improve future releases.

105. An important part of the release of the data and accounts is publication of the metadata. Moreover, it is important to consider how the statistical tables can be accompanied by story lines and visualizations to draw out the main findings.

4.6 Evaluate

106. Archive data and related methodological and other documentation. Review estimates, data sources, methods and systems, including actively seeking user feedback.

107. These last two steps are very important for all statistical programs but when initiating a new program of data, seeking user feedback is crucial. This in turn depends on the existence of good documentation on the methods and systems so as to properly inform users and assess their feedback.

5. Extensions

108. An important extension that might be considered is transforming the import and export measures to Raw Material Equivalents (RME). In terms of mass weight, a product tends to have a lower weight the further it is manufactured, especially compared to the domestic extraction required for its production. This means that the weight of these traded goods may be much less than the weight of the raw materials needed to produce them. While Domestic Extraction basically measures raw material inputs, imports and exports are product flows, and are therefore largely goods that have undergone at least some processing and often extensive processing.

109. In addition, not all extracted materials required to produce a product necessarily become part of the product. For example, some products may require energy-intensive processing for which fossil energy carriers need to be extracted, but these are not represented in the mass weight of the product itself. Hence, the domestic extraction needed to produce a product, i.e. the product in terms of RME, will always be higher than its simple mass weight.

110. In order to overcome the measurement asymmetry inherent to DMI and DMC it seems advisable to convert traded products (imports and exports) into equivalents of domestic extraction - that is raw material equivalents (RME).

111. However, estimating the raw material equivalents is challenging. The most conceptually sound basis would be an input-output approach extended to include raw material flows. While examples of such tables have been constructed, they do require considerable effort and data resources. The benefit is a more consistent set of data on material flows.

112. A simpler extension to the development of full physical input-output tables is to open up the 'black box' of the economy and identify the weight of materials used by the main economic activities as well as the generation of waste (which can also be drawn from SEEA waste accounts).

113. If Raw Material Equivalents were calculated, the following indicators could then be derived:

- Imports in RME
- Raw material input (RMI): which equals DE plus imports in RME
- Exports in RME
- Raw material consumption (RMC), which equals RMI minus exports in RME
- Physical trade balance in RME, which equals imports in RME minus exports in RME

114. This would allow for alternate indicators to be developed and presented such as **Raw Material Consumption (RMC),** which is defined as the amount of raw material equivalents (RMEs) required directly and indirectly to produce the products consumed in a given national economy. RMC is defined as domestic extraction (DE) plus imports in raw material equivalents

minus exports in raw material equivalents. The latter two items can be derived from global multi-regional input-output modelling extended by vectors of domestic extraction.

6. References and links

Main SEEA Web site: http://unstats.un.org/unsd/envaccounting/default.asp

- SEEA-Central Framework (UNECE 2013 edition): http://unstats.un.org/unsd/envaccounting/White_cover.pdf
- SEEA-Energy: http://unstats.un.org/unsd/envaccounting/seeaE/GC_Draft.pdf
- International Recommendations for Energy Statistics (IRES): http://unstats.un.org/unsd/statcom/doc11/BG-IRES.pdf
- SEEA-Fisheries: http://unstats.un.org/unsd/envaccounting/Fish_final_whitecover.pdf
- SEEA-Water: http://unstats.un.org/unsd/envaccounting/seeaw/seeawaterwebversion.pdf
- International Recommendations for Water Statistics (IRWS): http://unstats.un.org/unsd/envaccounting/irws/irwswebversion.pdf
- SEEA Experimental Ecosystem Accounts (SEEA-EEA): http://unstats.un.org/unsd/envaccounting/seearev/Chapters/SEEA_EEA_v1.pdf
- SEEA Applications and Extensions: http://unstats.un.org/unsd/envaccounting/seearev/Chapters/SEEA_AE_v1.pdf
- SEEA Global Assessment 2006: https://unstats.un.org/unsd/envaccounting/assessment.asp.

Main Eurostat website: http://ec.europa.eu/eurostat/web/environment/methodology

- Economy-wide Material Flow Accounts and Derived Indicators: A Methodological Guide (European Commission and Eurostat, 2001).
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"Measuring material flows and resource productivity: OECD guidance manual" Vol. I (OECD, 2008)

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