Economy-wide material flow accounts

HANDBOOK

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Preface

Economy-wide material flow accounts (EW-MFA) are a statistical accounting framework describing the physical interaction of the economy with the natural environment and the rest of the world economy in terms of flows of materials.

EW-MFA is one of the modules included in Regulation (EU) No. 691/2011 on European environmental economic accounts. It contributes directly to the Union's policy priorities on circular economy, green growth, and resource productivity by providing important information and statistical indicators on material use.

This handbook presents the theoretical and conceptual foundations of EW-MFA and provides compilation guidelines as well as possible applications. It primarily addresses compilers of EW-MFA but also the users who are interested in understanding more of the underpinning statistical methodology.

The EW-MFA handbook 2018 edition is the successor of two previous documents:

- Economy-wide material flow accounts and derived indicators - A methodological guide, (Eurostat, 2001);
- Economy-wide Material Flow Accounts, Compilation Guide (Eurostat, 2013a).

Compared to them, this EW-MFA handbook has revised significantly the conceptual part with references to the most recent versions of the systems of national accounts (SNA 2008, ESA 2010) and environmental-economic accounting (SEEA-CF 2012).

The data structure definition has been revised for EW-MFA. Next to the usual dimensions (GEO, TIME, UNIT) each material flow record is now characterised and specified by a combination of material-type (MATERIAL) and type of flow and derived indicators (INDIC_NV).

The classification of materials – in particular its coding – has been revised (see paras. 81ff). The previously separated material classifications for various questionnaire tables have been integrated into one list.

This handbook was written by Eurostat staff with contributions from Renato Marra Campanale, Arturo de la Fuente, Maaike Bouwmeester, and Stephan Moll. Draft versions were subject to two written consultations involving experts from national statistical institutes, international organisations, and research institutions. Particular thanks deserve Aldo Femia, Nina Eisenmenger, Stephan Lutter, Lucia Maier, Sylvia Gierlinger, Florian Kohler, James West, Reamonn McKeever, Lajos Franczen, Mário Baptista, Mårten Berglund, Edith Brodda Jansen, Raúl Figueroa Díaz, Eva Smelkova, Myriam Linster, Florian Flachenecker, and José Antonio Sena.

I warmly thank all the colleagues that contributed to make this publication possible.

Anton Steurer

Head of Unit E2

Environmental statistics and accounts; sustainable development

List of abbreviations and acronyms

ACS	Annual crop statistics
AEA	Air emissions accounts
BGS	British Geological Survey
BPM6	Balance of Payments and International Investment Position Manual - Sixth Edition
CN	Combined Nomenclature
COMEXT	Eurostat online database for external trade
CPA	Statistical Classification of Products by Activity
CRF	Common reporting format
DE	Domestic extraction
DMC	Domestic material consumption
DMI	Direct material input
DPO	Domestic processed output
EAA	Economic Accounts for Agriculture
EFTA	European Free Trade Association (Iceland, Liechtenstein, Norway, Switzerland)
ESA	European System of Accounts
ESS	European Statistical System
EU	European Union
EW-MFA	Economy-wide material flow accounts
FAO	Food and Agriculture Organization
FSS	Farm structure survey
GNB	Gross nutrient balance
IEA	International Energy Agency
IEEAF	European framework for integrated environmental and economic accounting for forests
IMTS	International Merchandise Trade Statistics
ITGS	International trade in goods statistics
MFA-RME	Material flow accounts in raw material equivalents
NACE	Statistical classification of economic activities in the European Community
NAS	Net additions to stock
NSI	National statistical institute
PGM	Platinum group metals
PPS	(current prices in) Purchasing Power Standards
PRODCOM	PRODuction COMmunautaire (Community survey of industrial production)
PSUT	Physical Supply and Use Tables

PTB	Physical trade balance
RAMON	Reference and management of nomenclatures
RME	Raw material equivalents
RMC	Raw material consumption
RMI	Raw material input
RP	Resource productivity
SEEA-CF	System of Environmental Economic Accounting – Central Framework
SNA	System of National Accounts
UNFCCC	United Nations Framework Convention on Climate Change
CLRTAP	Convention on Long Range Transboundary Air Pollutants
USGS	United States Geological Survey

Table of contents

1 Introduction

1.1 Scope of economy-wide material flow accounts and its legal base

1. *Economy-wide material flow accounts* (EW-MFA) are a statistical accounting framework recording, in thousand tonnes per year, material flows into and out of an economy. They cover solid, gaseous, and liquid materials, except for bulk flows of water and air. The general purpose of EW-MFA is to describe the physical interaction of the national economy with the natural environment and the rest of the world economy in terms of flows of materials.

2. This handbook presents the theoretical and conceptual foundations of EW-MFA and provides compilation guidelines as well as possible applications. It primarily addresses compilers of EW-MFA but also the users of EW-MFA who are interested in understanding more of the underpinning statistical methodology.

3. The EW-MFA methodology described in this handbook is established by the European Statistical System through regular data collections since 2007 (see section 3.1 on the EW-MFA questionnaire). The data collections have legal coverage under Regulation (EU) No. 691/2011 on European environmental economic accounts, albeit some elements go beyond the Regulation and are voluntary.

4. These accounts are conceptually embedded in the *System of Environmental Economic Accounting 2012 – Central Framework*, the SEEA-CF 2012 (United Nations et al. 2014) which brings together economic and environmental information in a common framework to measure the contribution of the environment to the economy and the pressures of the economy on the environment. The SEEA-CF 2012 distinguishes physical flow accounts from physical asset accounts. EW-MFA are categorised as physical flow accounts.

5. EW-MFA, like other environmental accounts, are compatible with concepts, principles, and classifications of national accounts - thus enabling a wide range of integrated analyses of environmental and economic issues e.g. through environmental-economic modelling.

6. EW-MFA record the throughput of materials (excluding bulk flows of water and air) at the input and output sides of the national economy. The EW-MFA framework is shown in Figure 1.

7. *Material inputs* into national economies include:

- *Domestic extraction* of material originating from the domestic environment (*);
- *Physical imports* (all goods) originating from other economies (*);
- *Balancing items input side*.

8. *Material outputs* from national economies include:

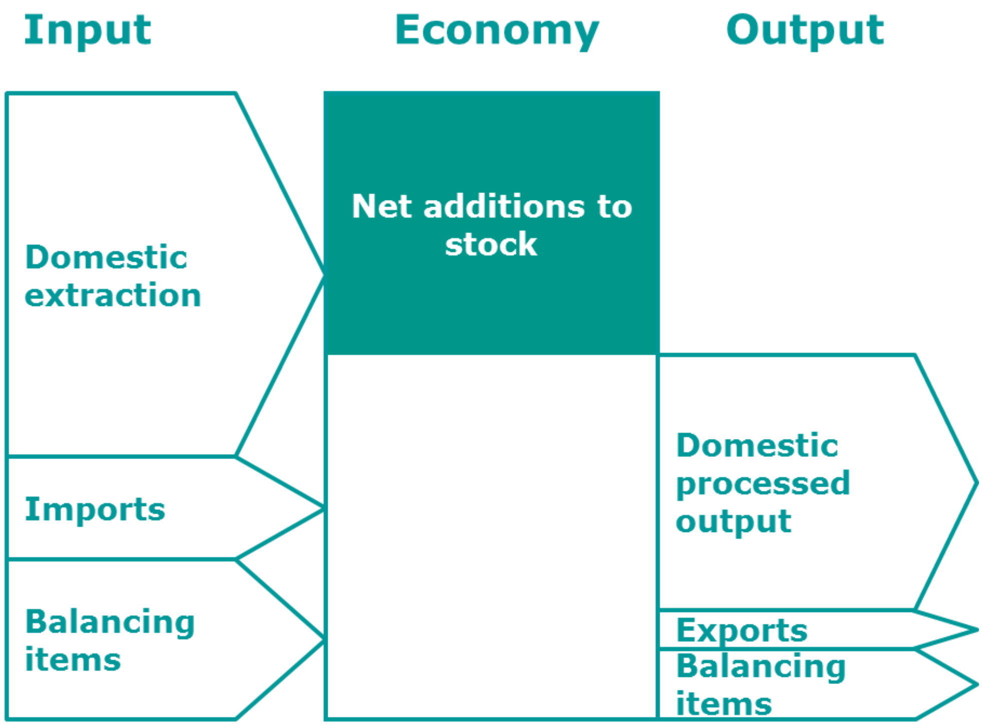
- *Domestic processed output* to the domestic environment;
- *Physical exports* (all goods) to other economies (*);
- *Balancing items output side*.

(*) items covered under Regulation (EU) No. 691/2011

9. In most national economies the amount of material inputs exceeds the material outputs (see e.g. Krausmann et al. 2017). The difference between inputs and outputs corresponds to the net accumulation of material in the economy in the form of e.g. buildings and infrastructures, machinery and durable goods. In EW-MFA this material accumulation is called *net additions to stock*.

10. EW-MFA record only material flows that cross the boundary of the national economy. The system boundary of the national economy is further explained in Chapter 2. All material flows inside the economy are not recorded in EW-MFA. This means that inter-industry product flows are not recorded whilst consumption of products or investments recorded only to the extent that they contribute to net additions to stock (NAS).

Figure 1: Simplified scope of economy-wide material flow accounts



1.2 Short historical overview of EW-MFA in Europe

11. In the 1990s the European Statistical System (ESS) started its work on The Integration of Environmental and Economic Information Systems (European Commission, 1994). Material flows were one of the first subjects addressed in this context. By that time only a few national statistical institutes (NSIs) in Europe were producing material flow accounts and most often these were not comparable due to conceptual and methodological differences.

12. In 2000 a Eurostat task force on material flows developed a methodological framework to record material flows in a harmonised way at the level of national economies. The work lead to the publication of a methodological guide (Eurostat, 2001). The Eurostat guide established the term 'economy-wide material flow accounts', specified the basic concepts and defined a wide range of material flow indicators derivable from EW-MFA.

13. In the following years Eurostat commissioned studies to estimate EW-MFA for the aggregated EU-15 economy (Eurostat 2002a; Weisz et al. 2004) in order to obtain comparable data and consistent time series. These estimates were broadly based on internationally available data sources such as IEA energy balances, FAO agriculture statistics, Eurostat foreign trade statistics and the US geological survey. These estimates covered domestic extraction, physical imports and exports, and the derivable indicators.

14. Between 2004 and 2006 the Eurostat task force continued its efforts on methodological standardisation by developing a classification of materials, standard tables (which later became the EW-MFA questionnaire) and harmonised compilation procedures.

15. In 2007, Eurostat launched the first EW-MFA data collection in the European Statistical System (ESS). Further voluntary ESS data collections took place in 2009, 2011 and 2012.

16. Regulation (EU) No. 691/2011 was adopted in 2011. This regulation created a legal obligation for EU Member States to report the EW-MFA data to Eurostat. Only domestic extraction of materials and physical trade are covered in the regulation and for mandatory reporting in the EW-MFA questionnaire[1]. The first mandatory annual data collection took place in 2013 and the deadline for transmissions to Eurostat was 31 December 2013.

17. In 2012, the *System of Environmental-Economic Accounting - Central Framework* (SEEA–CF) was adopted as an international statistical standard for official statistics by the Statistical Commission of the UN at its 43rd session. The SEEA-CF includes a section on EW-MFA (3.6.6), acknowledging the appropriateness of the long-established conventions of EW-MFA (see SEEA-CF para. 3.283), as e.g. for the recording of material flows related to cultivated agricultural plants and forests (see chapter 2).

[1] The EW-MFA questionnaire includes further voluntary components, namely domestic processed output (DPO), balancing items (BI), and material flow accounts in raw material equivalents (RME) (see section 3.1)

2 Conceptual foundations of EW-MFA

The physical economy as a metabolism

18. The national economy of a country is in a continuous physical exchange relation. Like the metabolism of an organism, the functioning ('living') of the economy is based and dependant on external exchanges (inputs and outputs) of materials and energy. The size and composition of this physical throughput characterises the 'metabolic profile' of the economy and thereby indicates its physical effects on the natural environment. EW-MFA describe the material throughput of an economy[2] and as such contribute to the metabolic profiling of the economy. Material inputs indicate the material throughput measured at the input side of the national economy.

Conceptual roots

19. Concepts and definitions of EW-MFA were developed since the late 1990ies and have been documented in a number of Eurostat publications. The Eurostat publication 'Economy-wide Material Flow Accounts and Derived Indicators – A Methodological Guide' (Eurostat 2001) laid the common ground. Several editions of EW-MFA compilation guidelines followed, the most recent of which is the 2013 edition (Eurostat, 2013a).

20. EW-MFA are consistent with and conceptually embedded into the wider framework of the System of Environmental-Economic Accounting 2012 – Central Framework (SEEA-CF 2012, see United Nations et. al. 2014). The SEEA-CF 2012 lays down the internationally agreed standard concepts, definitions, classifications, accounting rules and tables for producing internationally comparable statistics on the environment and its relationship with the economy.

21. The SEEA-CF 2012 is aligned and builds on the concepts, definitions and classifications of national accounts – the international System of National Accounts (SNA 2008, see: United Nations et al. 2009) and its European version European system of accounts (ESA 2010; see: Eurostat 2013b), and the Balance of Payments and International Investment Position Manual (BPM6; see: IMF 2009).

EW-MFA = physical flow accounts

22. The SEEA-CF 2012 distinguishes physical flow accounts from physical asset accounts (for the distinctions see SEEA-CF 2012, paras. 2.87ff, para. 3.3). EW-MFA are categorised as physical flow accounts. As such EW-MFA record the movement (flow) of material measured in tonnes over a given accounting period (usually one year) as they are crossing defined 'crossing points' or 'points of measurement'. Materials are physical bodies that have mass and volume.

[2] Physical energy flow accounts (PEFA) describe the energy throughput related to an economy

2.1. Definition of the national economy – an important 'boundary' in EW-MFA

23. EW-MFA focus on the material throughput of the economy measured at clearly defined 'crossing-points' at the outer boundary of the national economy (see also Figure 1). A clear common understanding of what constitutes the national economy and how its outer boundary is exactly defined is helpful for compilers of EW-MFA. This clear understanding ensures that the material flows are accounted for in a standardised way at conceptually coherent 'crossing points' or 'points of measurement'.

24. In order to specify coherent 'points of measurement' to be applied in EW-MFA, earlier guidelines made general reference to the concepts and principles of national accounts The latter provide a well-established definition of the economy (Eurostat 2001, paras. 2.12, 3.23) facilitating the specification of its boundary for the purpose of EW-MFA.

25. National accounts describe how labour, capital and natural resources are used to produce products (goods and services) which are used for the three main economic activities recognised in national accounts, namely: production, consumption and accumulation (SNA 2008, para. 3.19). Thereby, the national economy of a country is defined as the set of economic activities carried out by resident institutional units of that country.

26. The set of economic activities constituting the national economy includes a huge variety of transactions of various kinds for purposes of production, consumption, accumulation, redistribution, finance etc. (ESA 2010, para. 2.01). Activities related to accumulation include additions to and removals from produced assets (stocks). The set of economic activities recorded in monetary accounts of a national economy is not exactly the same set as recorded in physical accounts. Some activities involving monetary transactions do not have any physical correspondence, i.e. are of immaterial nature, while certain economic activities may involve physical transactions that may not have any monetary relevance or correspondence.

27. The units undertaking the aforementioned set of economic activities constituting the national economy must be resident units. In national accounts a resident unit is clearly defined as an institutional unit that has its centre of economic interest on the economic territory of the reporting country (see further ESA 2010, paras. 1.61, 2.04). A mine located in Chile is a resident institutional unit of Chile even if the owner is located in the UK. Resident units may undertake their activities outside the economic territory of its central economic interest (e.g. airlines or fishing fleets operating abroad).

28. In addition an economy includes the stock of non-financial produced assets[3] that are used in economic activity and whose economic owners are resident in the economy. It is relevant to note that according to national accounts and SEEA-CF controlled landfills and the stocks of cultivated agricultural plants and forests belong to the stock of produced assets of the economy; i.e. are considered within the boundary of the economy (see SEEA-CF paras. 3.47, 3.54ff., 3.63, 3.99, 5.24ff., 5.35).

29. In summary the national economy of a country is described as the transactions related to a very large number of activities (production, consumption, accumulation) carried out by resident units and the related stock of produced assets whose economic owner is a resident.

30. Two boundary aspects are particularly relevant for EW-MFA. Section 2.2 deals with the 'boundary' of the national economy towards the natural environment which needs to be specified for the recording of material flows actually crossing this 'environment-economy-boundary'. This concerns

[3] Non-financial assets include: (1) produced assets such as buildings and machines, and (2) non-produced assets such as natural resources (SNA 2008, paras. 3.37ff and 10.9ff; also SEEA-CF 2012 paras. 5.34ff and in particular Figure 5.1). EW-MFA consider material flows related to non-produced assets to be flows outside the economy since the assets themselves are not the output from production processes (SEEA-CF 2012, par. 2.11). Material flows from non-produced assets used by economic activities (e.g. wild fish catch) are considered a material flow from the environment to the economy.

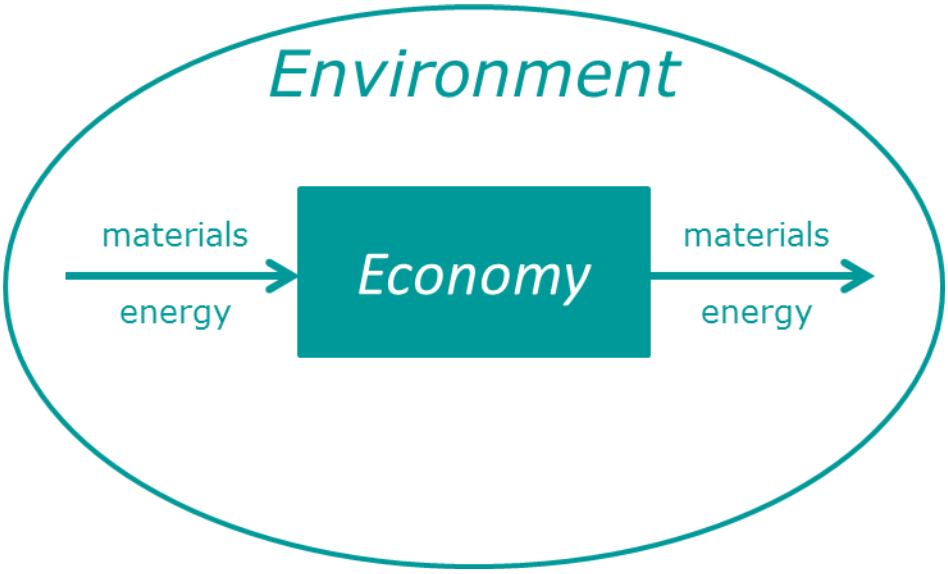
the domestic extraction of materials (material input) and the domestic processed outputs (material output). Section 2.3 deals with the 'boundary' of the national economy vis-à-vis the rest of the world economy highlighting the so-called 'residence principle'. This concerns physical imports and exports as recorded in EW-MFA.

2.2. Basic EW-MFA concepts as regards material flows between environment and economy

Simple environment-economy model

31. EW-MFA record material flows between the environment and the economy according to a simple environment-economy model (see Figure 2). The economy is in a physical exchange relation with the natural environment via material and energy flows (Eurostat 2001, para. 2.01). EW-MFA account for material flows at two points: flows from the environment to the economy and the flows from the economy to the environment.

Figure 2: Simple environment-economy model



Material flows from the environment to the economy = domestic extraction

32. Material inputs derived from the environment and used within the economy refer to the extraction or movement of natural materials on purpose and by humans or human-controlled means of technology (i.e. involving labour) (Eurostat 2001, para. 3.10). These flows accounted for in EW-MFA have been termed *domestic extraction* (see paras. 64ff. for the distinction 'used' versus 'unused' extraction). The extraction of materials causes various pressures on the natural environment, such as e.g. disruption of natural material and energy cycles and other ecosystem services.

Material flows from the economy to the environment = domestic processed output

33. Once entered into the economy materials are transformed and used in manifold ways. Some materials stay longer in the economy, others shorter. Materials are released back to the natural

environment in the form of residual material (e.g. emissions to air and water). These outputs accounted for in EW-MFA have been termed *domestic processed output*. They refer to material flows entering the environment as a result of production or consumption processes (Eurostat 2011, paras. 3.38, 3.78, also p. 36). Material outputs released to the environment means that society loses control over the location and composition of materials (Eurostat 2001, para. 3.10).

As regards to the 'boundary' between environment and economy, specific EW-MFA recording conventions have been established

34. The original conceptual idea of EW-MFA has been to record both, *domestic extraction* and *domestic processed output*, at the point where the respective materials cross the 'boundary' between the natural environment and the national economy (Eurostat 2001, paras. 3.09, 3.11, and 3.32); see also section 2.1 paras. 24-30. It was concluded that in certain cases deviating from national accounts' definition of the boundary of the economy could be more meaningful and more practical in the context of EW-MFA as long as the differences are made explicit through respective memorandum items (Eurostat 2001, 3.21, also OECD 2008; Schoer 2008; Femia and Paolantoni 2017).

35. Two particular cases were identified for which conventions had to be settled potentially (Eurostat 2001, para. 3.12): (1) treatment of domestic extractions in relation to production of cultivated biological resources (agricultural plants and forests), and (2) treatment of domestic processed output in relation to controlled landfills.

36. Regarding the first case: National accounts and SEEA -CF consider cultivated biological resources as produced assets within the boundary of the economy (see also para. 28). The growing of cultivated biological resources during a given accounting period constitutes a production process with inputs and output. The economically valuable part of the grown biomass is the production output. Applying this in EW-MFA would mean that material flows from the environment to the economy would be those materials that are taken up by the cultivated plants in order to grow, i.e. nutrients, carbon dioxide and water. Here, the specific EW-MFA recording convention was introduced (Eurostat 2001, para. 3.19) to account for the harvested amounts of biomass instead of accounting for the flows of nutrients, carbon dioxide etc. This convention has been termed 'harvest-approach'. Section 2.5 (paras. 74ff.) provide further explanations and justifications of the 'harvest approach'.

37. As regards the second case: controlled landfills constitute produced assets within the national economy according to national accounts (see also para. 2.12). In the case of waste material flowing to landfill EW-MFA reporting stays fully aligned with national accounts principles. This means they are considered material flows within the economy and are excluded from domestic processed output. For further explanations see section 2.5, paras. 77ff.

2.3. Basic EW-MFA concepts as regards material flows between economies – the residence principle and the change-in-ownership principle

38. Beside the material flows between environment and economy, EW-MFA record the material flows between the reporting economy and the rest of the world economy. These physical trade flows are conceptually aligned with principles of national accounts and SEEA-CF. There are two important principles employed by national accounts as regards the exact definition of trade: the 'change-in-ownership principle' and the 'residence principle' (see also para. 2.11 above).

Trade = change in ownership between resident unit and non-resident unit

39. Resident units may engage in transactions with non-resident units, i.e. units which are resident in other economies. These transactions are referred to as transactions between national economy and the economy of the rest of the world. Trade-in-goods is the most relevant type of transaction with regards to physical flows between the reporting national economy and the rest of the world economy. The main criteria to define a trade-in-goods transaction it the change of ownership.

40. EW-MFA record a physical trade flow when the ownership of a good changes from a resident unit to a non-resident unit (physical export) and vice versa (physical imports). There is one important exception: goods sent for processing (see further below paras. 80ff. and a Eurostat Technical Note[4] on this issue). Manifesting a change in ownership between a resident unit and a non-resident unit requires a clear concept of what is a resident.

The national economy vis-a-vis the rest of the world economy (residence principle)

41. SEEA-CF and EW-MFA use the same principle as national accounts, i.e. any economic activity is attributed based on the residence of economic units rather than on the location of the economic units at the time of their production, consumption or accumulation. In national accounts a resident unit is defined as an institutional unit that has its centre of economic interest on the economic territory of that country (see also para. 27 above, see further ESA 2010, paras. 1.61, 2.04). The residence principle is one important feature in both SEEA-CF and EW-MFA.

42. Notably the definition of the national economy (see section 2.1) is not identical to the economic activities taking place in the national territory. Some activities by resident units (e.g. international air and sea transport) may actually happen beyond the economic territory of the national economy concerned. Vice versa, non-resident units may undertake economic activities on the economic territory of the reporting country; e.g. non-residents purchasing fuels on the economic territory of the reporting country.

2.4. Conceptual relation between EW-MFA and SEEA-CF

43. As mentioned before, EW-MFA are consistent with and conceptually embedded into the wider framework of the System of Environmental-Economic Accounting 2012 – Central Framework (SEEA-CF 2012) (see above paras. 20ff.). This section elaborates briefly on the conceptual relations between EW-MFA and SEEA-CF.

The framework of physical supply and use tables (PSUT-framework)

44. The SEEA-CF extends the system of (monetary) national accounts by a physical dimension. Thereby, physical interactions between environment and economy enter into the focus. EW-MFA belong to physical flow accounts, one particular type of accounts in SEEA-CF.

45. SEEA-CF 2012 presents a specific accounting framework for physical flows (SEEA-CF 2012, para. 3.18): the framework of physical supply and use tables (PSUT-framework). It comprehensively records the physical inputs and outputs associated with the economic activities (production, consumption, accumulation) constituting the national economy (SEEA-CF, para. 3.19).

46. The PSUT-framework is A pair of tables: The physical supply table records the supply of physical flows by economic activity. The latter are distinguished into five main groupings, namely production, consumption, accumulation, rest of the world economy, and environment. The physical use table records the use of physical flows by the same five main groupings of economic activities.

[4] Technical note EEEA/2017/02: Further clarifying the conceptual treatment of physical imports and exports in economy-wide material flow accounts (EW-MFA)

The PSUT-framework may include physical flows which are not subject to monetary recordings in national accounts such as e.g. emissions to air and water (see also para.26).

Types of physical flows: natural inputs, products, and residuals

47. The SEEA-CF distinguishes three types of physical flows the supply and use of which is recorded in the PSUT-framework: *natural inputs*, *products*, and *residuals* (see SEEA-CF2012, paras. 2.89ff. and 3.18ff).

48. The PSUT-framework records physical flows from the environment into the national economy. These are termed *natural inputs*. Some *natural inputs*, after entering the economy, are immediately returning to the environment, as they are no longer required by the economy. These *natural inputs* that are not used in production are termed *natural resource residuals* (SEEA-CF2012, para. 3.20) and form a sub-category of natural inputs.

49. Physical flows within the economy are termed *products* when they fall within the definition of *products* in national accounts (the so-called SNA production boundary). *Products* are goods and services that result from a process of production in the economy. Generally *products* are evidenced by a transaction of positive monetary value between two economic units (SEEA-CF para. 2.91). Flows of *products* related to economic activities are common subject to the monetary recordings in national accounts. *Product* flows within the economy are not recorded in EW-MFA.

50. As a result of the various economic activities (production, consumption, accumulation) a range of physical flows occur that can result in the return of materials and energy to the environment. These flows from economy to environment are exclusively termed *residuals*. According to SEEA-CF the physical flow type of *residuals* refers 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) in association with economic processes of production, consumption or accumulation (SEEA-CF para. 3.73 and table 3.4). Notably, some *residuals* may also flow within the economy, as is the case when, for example, solid waste (i.e. a *residual*) is collected (SEEA-CF para.2.92) and recycled into new *products*. These are physical flows of 'non-products' (i.e. physical flows not included in the SNA definition of *products*) within the economy.

EW-MFA articulate only parts of SEEA's PSUT-framework

51. EW-MFA do not articulate a full PSUT for materials but only certain elements thereof. EW-MFA may be a good starting point for the development of a fully articulated PSUT for materials (SEEA-CF2012, para. 3.279).

52. EW-MFA establish the conventions for measuring the material inputs into and material outputs of the economy. Focus is laid on the mass of material extracted from the environment and used in the economy – immediately deriving from natural resources and other natural inputs – and the mass of residuals directed towards the environment after having undergone some transformation processes within the economy. EW-MFA do not record the physical flows within the economy. Given their economy-wide focus, EW-MFA also focus on physical flows of products to and from the rest of the world (SEEA-CF2012, para. 3.280).

Specific EW-MFA recording conventions have been agreed

53. As pointed out above (see paras. 34ff.), measuring natural inputs and residuals at the exact point where crossing the system boundary between environment and economy is challenging from a statistical perspective (SEEA-CF2012, para. 3.280) and not always the most meaningful thing to do. Certain recording conventions have been agreed so that actually flows of products are accounted for in practice[5] (see section 2.5 providing an overview of EW-MFA recording conventions). This has also influenced the classification of material flows, in particularly the labels (see section 2.6).

[5] Therefore, certain material flows within the economy – although in principle not recorded in EW-MFA (Eurostat 2001, para. 3.32) – are considered to be instrumental for estimating primary input flows, e.g. when data on primary extraction are lacking (Eurostat 2001, para. 3.11).

2.5. Specific EW-MFA recording conventions

54. This section provides an overview of most important EW-MFA recording conventions, some of which have already been introduced above (according cross-references are provided). The specific EW-MFA conventions concern the coverage of materials included (and excluded) in EW-MFA and the specification of 'measurement points'.

55. EW-MFA account for the throughput of a well specified set of material flows through the national economy of a country or a grouping of countries. Bulk material flows of water and air are excluded (see paras. 59ff.).

56. The material throughput is accounted for at two points[6]: material inputs at the point when materials enter the national economy and material outputs at the point when leaving the national economy. The boundary of the national economy is aligned with concepts and principles of national accounts and SEEA-CF. In general, material flows within the economy are not recorded in EW-MFA.

57. For EW-MFA the exact 'measurement points' or 'crossing points' have been specified by convention. Due to practical reasons[7] and content issues[8], EW-MFA measures some material flows not exactly at the conceptual boundary of the economy as set out in national accounts and SEEA-CF. However, the concerned material flows are always captured very near to this boundary, both on the input and at the output sides.

58. In the few cases where EW-MFA 'measurement points' deviate from the conceptual boundary of the economy as set out in national accounts and SEEA-CF, these are made explicit through so-called 'memorandum items' . The latter make it possible to 'bridge' between the two concepts.

Bulk material flows of water are excluded from EW-MFA

59. EW-MFA focus on flows of materials other than bulk water. The latter are recommended to be presented in separate water flow accounts (Eurostat 2001, para. 3.08). Notably EW-MFA take into account the water content of other materials (moisture), such as e.g. biomass material. Also goods imported and exported as recorded in EW-MFA may have some water content.

60. Bulk water flows entering the economy are any water abstractions from natural water bodies (groundwater, surface water, sea) but also the purposeful collection of precipitation in relation to economic activities of production, consumption, and accumulation. Examples of water flows out of the economy (i.e. related to economic activities) are waste water discharges to rivers and evaporation to the atmosphere.

61. It has been agreed by convention to exclude bulk material flows of water from EW-MFA because of their size. Water flows represent enormous mass flows one order of magnitude bigger than flows of all other materials. Including water in EW-MFA would dominate the accounts and 'dilute' the flow patterns of other materials.

Bulk flows of air are excluded from EW-MFA's core accounts; some selected gaseous material flows are recorded under balancing items

62. Air is a composite mix of gaseous material ubiquitously available in the atmosphere. It is composed (by mass fraction) of nitrogen (ca. 75%), oxygen (ca. 23%), argon (ca. 1%), water vapour (ca. 1%), and other gaseous material including carbon dioxide (less than 0.1%). Bulk flows of air from the atmosphere into the economy and vice versa are those related to combustion processes, in particular burning of fossil fuels, in association with economic activities (of production, consumption, accumulation).

[6] In both cases flows are specified in a way that avoids any double counting.
[7] Compilation of EW-MFA approach strongly builds on primary data available from statistical sources. Those do not always provide data measured exactly at the conceptual boundary of the economy as set in national accounts and SEEA-CF. Approximations based on certain assumptions are unavoidable.
[8] In the case of 'cultivated biological resources' the convention was agreed to employ the so-called 'harvest approach' as it is considered to be more meaningful (see below).

63. The recording of *domestic extraction* in EW-MFA excludes bulk flows of air into the national economy whilst the *domestic processed outputs* obviously record emissions to air, however excluding water vapour resulting from combustion processes. In order to close the material-wise balance between inputs and outputs, some specific bulk flows of gaseous material are recorded memorandum in the balancing items (see for further details section 4.8).

EW-MFA record domestic extraction of material for use in the economy - used versus unused domestic extraction

64. Material flows from the natural environment to the economy are called *domestic extraction* in EW-MFA. This refers to the purposeful extraction or movement of natural materials by humans or human-controlled means of technology (i.e., those involving labour) insofar as they are considered resident units. Not all materials that are deliberately extracted or moved in the extraction process ultimately enter the economy; and not all materials are moved with the intention of using them in the economy.

65. Therefore a distinction has been made between 'used' and 'unused' extraction (Eurostat 2001, paras. 3.29ff). 'Used' refers to an input for use in any economy, i.e. whether a material acquires the status of a product. […] 'Unused' flows are materials that are extracted from the environment without the intention of using them, i.e. materials moved at the system boundary of economy-wide MFA on purpose and by means of technology but not for use" (Eurostat 2001, paras. 3.29ff.). In some early publications 'unused extraction' was also called 'hidden flows'[9]. 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 at the extraction site.

66. EW-MFA record only extractions of materials that are used. The term *'domestic extraction'* - abbreviated DE - always refers to 'used' extraction if not otherwise specified (Eurostat 2009, p. 12).

Domestic extraction of metal ores and other minerals (non-metallic, fossils) – the 'run-of-mine' concept (ROM)

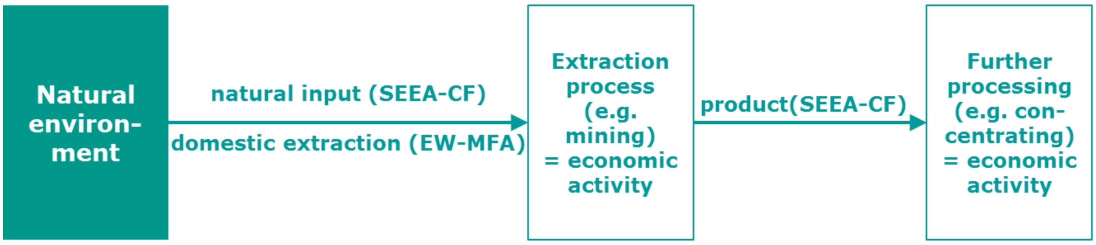
67. In the case of minerals (metal ores, non-metallic minerals, and fossil energy carriers) the amounts of *domestic extraction* are most often approximated from available statistics on the output of the respective mining activity. In order to infer from product output to domestic extraction in a standardised way, the so-called 'run-of-mine' concept (ROM) is applied in particular in the case of domestic extraction of metal ores.

68. The 'run-of-mine' is the amount of extracted material containing the wanted metal or mineral that is submitted to the first processing step. It is measured before any separation or concentration[10]. It excludes any overburden or other layer material removed which does not contain the wanted metal or mineral.

69. Figure 3 provides a scheme for the extraction process in the case of minerals (metal ores, non-metallic minerals, fossil energy carriers). The extraction process has physical inputs and physical outputs. The physical inputs into the extraction process are the domestic extraction, i.e. material flows from the environment to the economy. While the outputs are 'products' in the sense of SEEA-CF (see paras. 47ff.), i.e. flows already within the national economy as delivered to other economic activities for further processing.

[9] This term is not used anymore recently.
[10] Concentrating denotes an interim step between extraction of the gross ore 'run of mine' and the production of the metal. Usually the gross ores run of mine are already converted into concentrates within the mining industry before they are sold to other industries.

Figure 3: Terminology for physical inputs and outputs of the material extraction process



70. There is hardly any statistical data available on the amount of domestic extraction, as represented by the arrow between the left (natural environment) and middle box (extraction activity) in Figure 3. For this reason compilers of EW-MFA usually have to use statistics on the outputs from extraction processes to approximate the flows of domestic extraction. E.g. production statistics may report the amount of products produced by mining industries and energy statistics provide the output of primary energy products.

71. In many cases the domestic extraction, i.e. the material input, into the extraction process is transformed in the one or the other way before it leaves the extraction process in form of product for which statistics are available. For non-metallic minerals and fossil energy carriers such transformations between the amount of domestic extraction and the amount of product output may be minor and hence using statistics on amounts of production output may be an acceptable approximation of the amounts of domestic extraction. In the case of metal mining the transformations between domestic extraction material and product output are usually unneglectable and require adjustments using inter alia the 'run-of-mine' concept (ROM).

72. In the case of using statistics on the output from metal mining attention is required. Statistics reporting output from metal mining often use different measurement concepts and terms (see Table 1). Often statistics on output from metal mining are reporting amounts of pure metal or metal ore concentrate. By convention EW-MFA record the domestic extraction of metal ores in equivalents of amounts of metal containing material as originally extracted before any further separation or concentration. These amounts of gross ore are commonly referred to as 'run-of-mine' amounts. For further details see below in section 4.3. Reference is also made to the forthcoming UNEP Manual on Global Material Flow Accounting (publication planned for 2019) which includes detailed explanations of the 'run of mine' concept (ROM).

Table 1: Different measurement concepts and terms related to statistics on metal mining output

Description of the material	Common terminology	SEEA-CF terminology
Materials removed to get access to the metal containing material	Overburden; interburden	Natural resource residuals
Metal containing material as extracted, before any separation or concentration	'run of mine' (ROM) gross ore	Natural inputs excluding natural resource residuals
Concentrated ore produced from metal containing material (gross ore)	Ore concentrate	Product
Pure metal	Net ore or metal content*	-

** 'Metal content' is a concept often used by geological surveys and by metal mining companies and their associations*

73. It may also be the case that two or even more metals are obtained from the same gross ore, this is called coupled production. If this is the case, the ROM amount of gross ore has to be allocated to the different metals. The respective calculation procedure is explained in section 4.3.

Domestic extraction of biomass – the 'harvest' approach

74. National accounts and SEEA-CF consider cultivated biological resources as produced assets within the boundary of the economy (see paras. 28 and 36). The grown biomass is considered to be the production output. Material inputs, i.e. natural inputs, into this process would be soil nutrients, water and carbon dioxide according to SEEA-CF. EW-MFA accounting rules deviate in this particular case from the SEEA-CF and introduced a simplified recording: the 'harvest approach' (see also above para. 36). Applying the harvest-approach implies that cultivated forests and agricultural plants are treated as if they were part of the environment (Eurostat 2001, para 3.19). EW-MFA recognise the flow from environment to economy, i.e. domestic extraction, at the point of harvest rather than as growth occur (SEEA-CF, para. 3.283).

75. In the case of cultivated agricultural plants the 'harvest approach' does not make much difference compared to the SEEA-CF approach. The harvested amounts should equal in mass terms the natural inputs required to grow cultivated agricultural plants that are further used in economic activities. In the case of cultivated forests there might be differences between the amount harvested and the amount of timber grown in one accounting period. To 'bridge' between both concepts, a 'memorandum item' reporting the net increment of timber stock has been established in the EW-MFA questionnaire.

76. The decision in favour of the 'harvest approach' was made because of practical reasons (data availability) and for substantial reasons. In the case of forests the 'harvest approach' represents in the best way the environmental pressure associated. Whereas net increment of standing timber should be regarded a rather positive effect on the environment.

Domestic processed outputs – the treatment of controlled landfills

77. 2.68 In EW-MFA domestic processed outputs denote material flows from the economy to the environment (see para. 33). Controlled landfills are produced assets and hence part of the economy (see paras. 28 and 37). Material flows to controlled landfills are material flows within the economy and hence excluded from domestic processed outputs. Materials going to controlled landfills are recorded as 'memorandum item' in the EW-MFA questionnaire.

Physical imports and exports follow the 'residence principle'

78. EW-MFA follow the 'residence principle' as established in national accounts and SEEA-CF (see above paras. 27 and 41ff.). This implies that goods purchased by resident units abroad are to be considered imports, and, goods sold to non-residents on the territory are to be considered exports (see also SEEA-CF section 3.3.3, paras. 3.121ff.).

79. One particularity of EW-MFA's physical imports and exports concerns cross-border flows of waste destined for further treatment. Those are included and recorded in EW-MFA's physical imports and exports, although they may not necessarily constitute *products* in a national accounts sense.

'Goods sent abroad for processing' are included in EW-MFA's physical imports and exports

80. As mentioned before the main criteria to identify a trade flow between the national economy and the rest of world economy is the change of ownership between a resident unit and a non-resident unit (see paras. 39ff.). 'Goods sent abroad for processing' do not imply any change of ownership why they are excluded from trade transactions in national accounts. In contrary, the SEEA-CF recommends to include them in physical flow accounts as they represent the actual physical flows (SEEA-CF paras. 1.46 and 6.18)). EW-MFA follows the SEEA-CF recommendation and treats 'goods sent abroad for processing' as if they would represent a trade in goods transaction. Further details on this issue are provided in Eurostat Technical Note EEEA/2017/02 (Eurostat 2017a).

2.6. EW-MFA classification of materials

81. EW-MFA record physical flows of materials broken down by type of flow[11] and by type of material. The breakdown by type of material employs a classification[12] of materials which is addressed in this section.

82. Table 2 presents the classification of materials as employed in EW-MFA. It is a hierarchical classification with main material flow categories (1-digit level); i.e. MF.1 to MF.8. Each main category is further broken down, maximal down to 4-digit-level:

- 1-digit: material category
- 2-digit: material class
- 3-digit: material group
- 4-digit: material sub-group

83. The type of material corresponds in a certain way to the type of flow (see section 2.7). Most material categories have a one-to-one correspondence to a certain type of flow. The first four material categories MF.1 to MF.4 were initially designed for characterising *domestic extraction* of materials but are also applied to *physical imports* and *physical exports*.

84. Table 2 presents these correspondences by cross-tabling the type of material (rows) with the type of flow (columns A, B, D, F and G, which also correspond to the EW-MFA questionnaire tables). The main material categories MF.1 to MF.4 correspond to the following types of material flows: *domestic extraction*, *physical imports*, and *physical exports*. The material categories MF.5 and MF.6 (see also paras. 370 and 388) solely apply to *physical imports* and *physical exports*Material category MF.7 applies exclusively to *domestic processed output*; while MF.8 solely applies to *balancing items*.

85. The classes, groups, and sub-groups of MF.1 'biomass', MF.2 'metal ores', MF.3 'non-metallic mineral', and MF.4 'fossil energy materials/carriers' is based pragmatically on the statistical data sources employed to compile *domestic extraction* for these type of materials, e.g. agriculture, forestry, fishery, and energy statistics.

86. A notable particularity of EW-MFA is the attribution of type of material to *physical imports* and *physical exports* (see also paras. 366ff). Physical imports and exports are flows of products for which one commonly employs product classifications such as e.g. the Classification of Products by Activity (CPA) or Combined Nomenclature (CN). In EW-MFA traded products are not classified by product classifications but are assigned to material classes, groups and sub-groups according to the main material the product is composed of. For this, a correspondence between the CN product classification and MF classes has been established (see Annex to EW-MFA questionnaire).

87. The assignment from CN code to MF code as presented in the Annex to the EW-MFA questionnaire remains very crude. Each CN code is assigned to one and only one material class, group or sub-group (MF code). The majority of traded products, i.e. CN codes, is assigned to the four main material categories MF.1 to MF.4 as employed also for domestic extraction. Material category MF.5 'Other products' has been established for CN product codes which cannot be assigned clearly to MF.1 to MF.4. Further, a category MF.6 'Waste for final treatment and disposal' has been established accommodating a hand full of CN codes representing waste streams not assignable to one of the main material categories. MF.6 also hosts cross-border movement of waste material that is not included in international trade in goods statistics (ITGS).

[11] e.g. domestic extraction, domestic processed output, imports and exports; see next section 2.7.

[12] A statistical classification or nomenclature is an exhaustive and structured set of mutually exclusive and well-described categories, often presented in a hierarchy that is reflected by numeric or alphabetical codes, used to standardise concepts and compile statistical data. Some classifications, such as the NACE (Statistical Classification of Economic Activities), are multidisciplinary, i.e. applicable in different statistical domains, while others are very closely related to their domain, such as the classification of materials introduced in this section. The classifications used by Eurostat and the EU Member States are specified in regulations or agreements. This procedure ensures that the data published at European level are comparable between Member States. Note that, at national level, Member States may use more detailed, nationally adapted versions of a classification

88. In addition and parallel, physical imports and exports are classified into three broad groupings according to the stage of manufacturing (see paras. 389ff. and Annex B).

89. Material category MF.7 is dedicated to *domestic processed outputs*. Five classes are distinguished at 2-digit level (see also Table 2):

- MF.7.1 Emissions to air;
- MF.7.2 Waste disposal;
- MF.7.3 Emissions to water;
- MF.7.4 Dissipative use of products;
- MF.7.5 Dissipative losses.

90. The material category MF.8 is dedicated to so-called balancing items on the input and output side. Balancing items are a particularity of EW-MFA. They are only introduced for balancing purposes, i.e. needed to establish an economy-wide material balance. Balancing items include two categories: First, items to be added to material inputs such as oxygen for combustion processes and respiration, and nitrogen; secondly, items to be added to material outputs such as water vapour from combustion and gases from respiration. On the input side balancing items constitute natural inputs; on the output side balancing items constitute residuals.

Memo items

91. Various memo-items are included in the EW-MFA questionnaire and are also shown in the classification of materials (Table 2 and Annex A). The reporting of these memo-items is voluntary, i.e. for information only. In general, a 'memo-item' (alternatively: 'memorandum-item') is a useful piece of information that goes beyond the actual accounting framework of EW-MFA. The meaning and usefulness of these memo-items has been agreed among experts who developed the EW-MFA methodology and questionnaire. All memo-items in the EW-MFA questionnaire are excluded from the calculation of any aggregates and derived indicators. The meanings of the various memo-items are explained in the respective sections of chapter 4.

Table 2: Classification of materials in EW-MFA (cross tabled with type of flows)

Code	Label	EW-MFA Questionnaire Table				
		A	B	D	F	G
	EW-MFA type of flow:	**domestic extraction**	**physical imports**	**physical exports**	**domestic processes output**	**balancing items**
	SEEA-CF type of flow:	*natural inputs*	*products*	*products*	*residuals*	*natural inputs or residuals*
MF.1	Biomass	x	x	x		
MF.1.1	Crops (excluding fodder crops)	x	x	x		
MF.1.1.1	Cereals	x	x	x		
MF.1.1.2	Roots, tubers	x	x	x		
MF.1.1.3	Sugar crops	x	x	x		
MF.1.1.4	Pulses	x	x	x		
MF.1.1.5	Nuts	x	x	x		
MF.1.1.6	Oil-bearing crops	x	x	x		
MF.1.1.7	Vegetables	x	x	x		
MF.1.1.8	Fruits	x	x	x		
MF.1.1.9	Fibres	x	x	x		
MF.1.1.A	Other crops (excluding fodder crops) n.e.c.	x	x	x		
MF.1.2	Crop residues (used), fodder crops and grazed biomass	x	x	x		

Code	Label	EW-MFA Questionnaire Table				
		A	B	D	F	G
	EW-MFA type of flow:	domestic extraction	physical imports	physical exports	domestic processes output	balancing items
	SEEA-CF type of flow:	*natural inputs*	*products*	*products*	*residuals*	*natural inputs or residuals*
MF.1.2.1	Crop residues (used)	x	x	x		
MF.1.2.1.1	Straw	x	x	x		
MF.1.2.1.2	Other crop residues (sugar and fodder beet leaves, etc.)	x	x	x		
MF.1.2.2	Fodder crops and grazed biomass	x	x	x		
MF.1.2.2.1	Fodder crops (including biomass harvest from grassland)	x	x	x		
MF.1.2.2.2	Grazed biomass	x				
MF.1.3	Wood	x	x	x		
MF.1.3.1	Timber (industrial roundwood)	x	x	x		
MF.1.3.2	Wood fuel and other extraction	x	x	x		
MF.1.3 MEMO	*Net increment of timber stock (memo item)*	*x*[13]				
MF.1.4	Wild fish catch, aquatic plants and animals, hunting and gathering	x	x	x		
MF.1.4.1	Wild fish catch	x	x	x		
MF.1.4.2	All other aquatic animals and plants	x	x	x		
MF.1.4.3	Hunting and gathering	x				
MF.1.5	Live animals and animal products (excluding wild fish, aquatic plants and animals, hunted and gathered animals)		x	x		
MF.1.5.1	Live animals (excluding wild fish, aquatic plants and animals, hunted and gathered animals)		x	x		
MF.1.5.2	Meat and meat preparations		x	x		
MF.1.5.3	Dairy products, birds, eggs and honey		x	x		
MF.1.5.4	Other products from animals (animal fibres, skins, furs, leather, etc.)		x	x		
MF.1.6	Products mainly from biomass		x	x		
MF.2	Metal ores (gross ores)	x	x	x		
MF.2.1	Iron	x	x	x		
MF.2.2	Non-ferrous metal	x	x	x		
MF.2.2.1	Copper	x	x	x		
MF.2.2.1 MEMO	*Copper - metal content*	*x*[13]				
MF.2.2.2	Nickel	x	x	x		
MF.2.2.2 MEMO	*Nickel - metal content*	*x*[13]				
MF.2.2.3	Lead	x	x	x		
MF.2.2.3 MEMO	*Lead - metal content*	*x*[13]				
MF.2.2.4	Zinc	x	x	x		
MF.2.2.4 MEMO	*Zinc - metal content*	*x*[13]				
MF.2.2.5	Tin	x	x	x		
MF.2.2.5 MEMO	*Tin - metal content*	*x*[13]				
MF.2.2.6	Gold, silver, platinum and other precious metals	x	x	x		
MF.2.2.7	Bauxite and other aluminium	x	x	x		
MF.2.2.8	Uranium and thorium	x	x	x		
MF.2.2.9	Other non-ferrous metals	x	x	x		

[13] Not taken into account when aggregating domestic extraction (DE)

Code	Label	EW-MFA Questionnaire Table				
		A	B	D	F	G
	EW-MFA type of flow:	**domestic extraction**	**physical imports**	**physical exports**	**domestic processes output**	**balancing items**
	SEEA-CF type of flow:	*natural inputs*	*products*	*products*	*residuals*	*natural inputs or residuals*
MF.2.3	Products mainly from metals		x	x		
MF.3	Non-metallic minerals	x	x	x		
MF.3.1	Marble, granite, sandstone, porphyry, basalt, other ornamental or building stone (excluding slate)	x	x	x		
MF.3.2	Chalk and dolomite	x	x	x		
MF.3.3	Slate	x	x	x		
MF.3.4	Chemical and fertiliser minerals	x	x	x		
MF.3.5	Salt	x	x	x		
MF.3.6	Limestone and gypsum	x	x	x		
MF.3.7	Clays and kaolin	x	x	x		
MF.3.8	Sand and gravel	x	x	x		
MF.3.9	Other non-metallic minerals n.e.c.	x	x	x		
MF.3.A	*Excavated earthen materials (including soil), only if used (optional reporting)*	*x*[13]				
MF.3.B	Products mainly from non-metallic minerals		x	x		
MF.4	Fossil energy materials/carriers	x	x	x		
MF.4.1	Coal and other solid energy materials/carriers	x	x	x		
MF.4.1.1	Lignite (brown coal)	x	x	x		
MF.4.1.2	Hard coal	x	x	x		
MF.4.1.3	Oil shale and tar sands	x	x	x		
MF.4.1.4	Peat	x	x	x		
MF.4.2	Liquid and gaseous energy materials/carriers	x	x	x		
MF.4.2.1	Crude oil, condensate and natural gas liquids (NGL)	x	x	x		
MF.4.2.2	Natural gas	x	x	x		
MF.4.2.3	Fuels bunkered (Imports: by resident units abroad; Exports: by non-resident units domestically)		x	x		
MF.4.2.3.1	Fuel for land transport		x	x		
MF.4.2.3.2	Fuel for water transport		x	x		
MF.4.2.3.3	Fuel for air transport		x	x		
MF.4.3	Products mainly from fossil energy products		x	x		
MF.5	Other products		x	x		
MF.6	Waste for final treatment and disposal		x	x		
MF.7	Domestic processed output				x	
MF.7.1	Emissions to air				x	
MF.7.1.1	Carbon dioxide (CO_2)				x	
MF.7.1.1.1	Carbon dioxide (CO_2) from biomass combustion				x	
MF.7.1.1.2	Carbon dioxide (CO_2) excluding biomass combustion				x	
MF.7.1.2	Methane (CH_4)				x	
MF.7.1.3	Dinitrogen oxide (N_2O)				x	
MF.7.1.4	Nitrous oxides (NO_x)				x	
MF.7.1.5	Hydroflourcarbons (HFCs)				x	

Code	Label	EW-MFA Questionnaire Table				
		A	B	D	F	G
	EW-MFA type of flow:	**domestic extraction**	**physical imports**	**physical exports**	**domestic processes output**	**balancing items**
	SEEA-CF type of flow:	*natural inputs*	*products*	*products*	*residuals*	*natural inputs or residuals*
MF.7.1.6	Perflourocarbons (PFCs)				x	
MF.7.1.7	Sulfur hexaflouride				x	
MF.7.1.8	Carbon monoxide (CO)				x	
MF.7.1.9	Non-methane volatile organic compounds (NMVOC)				x	
MF.7.1.A	Sulfur dioxide (SO_2)				x	
MF.7.1.B	Ammonia (NH_3)				x	
MF.7.1.C	Heavy metals				x	
MF.7.1.D	Persistent organic pollutants (POPs)				x	
MF.7.1.E	Particles (e.g. PM_{10}, Dust)				x	
MF.7.1.F	Other emissions to air				x	
MF.7.2	Waste disposal to the environment				x	
MF.7.2MEMO	*Waste disposal to controlled landfills (memo item)*				*x*[14]	
MF.7.3	Emissions to water				x	
MF.7.3.1	Nitrogen (N)				x	
MF.7.3.2	Phosphorus (P)				x	
MF.7.3.3	Heavy metals				x	
MF.7.3.4	Other substances and (organic) materials				x	
MF.7.3.5	Dumping of materials at sea				x	
MF.7.4	Dissipative use of products				x	
MF.7.4.1	Organic fertiliser (manure)				x	
MF.7.4.2	Mineral fertiliser				x	
MF.7.4.3	Sewage sludge				x	
MF.7.4.4	Compost				x	
MF.7.4.5	Pesticides				x	
MF.7.4.6	Seeds				x	
MF.7.4.7	Salt and other thawing materials spread on roads (including grit)				x	
MF.7.4.8	Solvents, laughing gas and other				x	
MF.7.5	Dissipative losses				x	
MF.8	Balancing items: net output (= Balancing item: output side - Balancing item: input side)					x
MF.8.1	Balancing items: input side					x
MF.8.1.1	Oxygen for combustion processes					x
MF.8.1.2	Oxygen for respiration of humans and livestock; bacterial respiration from solid waste and wastewater					x
MF.8.1.3	Nitrogen for Haber-Bosch process					x
MF.8.1.4	Water requirements for the domestic production of exported beverages					x
MF.8.2	Balancing items: output side					x
MF.8.2.1	Water vapour from combustion					x

[14] Not taken into account when aggregating domestic processed output (DPO)

Code	Label	EW-MFA Questionnaire Table				
		A	B	D	F	G
	EW-MFA type of flow:	domestic extraction	physical imports	physical exports	domestic processes output	balancing items
	SEEA-CF type of flow:	*natural inputs*	*products*	*products*	*residuals*	*natural inputs or residuals*
MF.8.2.1.1	Water vapour from moisture content of fuels					X
MF.8.2.1.2	Water vapour from the oxidised hydrogen components of fuels					X
MF.8.2.2	Gases from respiration of humans and livestock (CO_2 and H_2O), and from bacterial respiration from solid waste and wastewater (H_2O)					X
MF.8.2.2.1	Carbon dioxide (CO_2)					X
MF.8.2.2.2	Water vapour (H_2O)					X
MF.8.2.3	Excorporated water from biomass products					X

2.7. EW-MFA classification of types of flows and derived indicators

92. In this section the classification of types of material flows and derived indicators are presented (Table 3). Basic types of material flows comprise domestic extraction (DE), physical imports and exports, domestic processed output (DPO), and balancing items (BI). These basic flow types (DE, physical trade and DPO) are the minimum set needed in order to derive EW-MFA indicators which describe the physical basis of an economic system.

Table 3: Classification of types of material flows and derived indicators

Code	Label	*SEEA-CF type of flow*	Formula for derived indicators
DE	Domestic extraction	*natural input*	-
IMP	Physical imports	*product*	-
EXP	Physical exports	*product*	-
DPO	Domestic processed output	*residual*	-
BI_in	Balancing items (input side)	*natural input*	-
BI_out	Balancing items (output side)	*residual*	-
DMC	Domestic material consumption	*n.a.*	DMC = DE + IMP - EXP
DMI	Direct material inputs	*n.a.*	DMI = DE + IMP
PTB	Physical trade balance	*n.a.*	PTB = IMP - EXP
BI	Balancing items (input - output)	*n.a.*	BI = BI_in – BI_out
NAS	Net additions to stock	*n.a.*	NAS = DMC + BI_in - DPO – BI_out

93. Based on known volumes of *domestic extraction* (DE), *physical imports*, and *exports*, important indicators such as *direct material input* (DMI), *domestic material consumption* (DMC) and the *physical trade balance* (PTB) can be calculated.

94. DMI measures the direct and actual input of materials originating from the natural environment or from the rest of the world, i.e. all materials which are of economic value and available for the national economy's production system. Note that parts of the production system's output are exported. DMI of a given national economy is calculated as the sum of *domestic extraction* plus physical *imports*. For individual countries, all imports are considered for the calculation of DMI; whereas for the DMI calculation of the aggregated EU all intra-EU-trade flows are excluded (see Box 1).

95. DMC measures the total amount of materials that are directly used in a national economy, i.e. by resident units. DMC is conceptually defined in the same way as other key physical indictors such as e.g. gross inland energy consumption. DMC is the amount of materials that become part of the material stock within the economy or are released back to the environment (DPO). The DMC of a given country's national economy can be calculated as *direct material input (DMI)* minus physical *exports*.

96. PTB, calculated as physical imports minus physical exports, measures the physical trade surplus or physical trade deficit of a given national economy.

97. Net additions to stock (NAS) is a measure of the physical growth of the economy. Materials in form of buildings, infrastructures, durable goods such as e.g. 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 disposed of (removals). In theory, NAS is derived as difference between *gross additions* and *removals*. However NAS is very difficult to measure statistically following this approach. Hardly any data are available on gross additions to and removals from physical stock. Alternatively, NAS can be approximated using the formula provided in Table 3.

98. Further policy relevant indicators such as *resource productivity* are derivable beyond the narrow EW-MFA framework.

Box 1: Methodology for calculating DMI and DMC for the aggregated EU economy

Since the 2016 EW-MFA data collection, Eurostat estimates the EU aggregates for physical imports and exports based on Eurostat's database COMEXT (international trade in goods statistics, ITGS). For the aggregated EU economy only extra-EU-trade is considered. See also the Eurostat Technical Note EEEA/2017/02 (Eurostat 2017a). The COMEXT extra-EU imports are adjusted for the residence principle, i.e. fuel purchases by resident units outside the EU are added.

This implies that the DMI for the aggregated EU economy is smaller than the sum of the Member States' DMI. The latter include physical imports from extra-EU and intra-EU countries. The DMC of the aggregated EU economy is theoretically[15] equal to the sum of Member States' DMC.

2.8. Material flow accounts in raw material equivalents (MFA-RME)

99. The currently established EW-MFA framework can be extended to enrich the picture of the demand for material resources by national economies. This chapter presents the concept[16] of one possible extension: material flow accounts in raw material equivalents (MFA-RME).

100. MFA-RME account for products in terms of the amount of material extraction necessary to produce them, irrespective of where the material was extracted (sometimes referred to as 'material

[15] There might be minor differences due to the estimation method applied for estimating fuel purchases by resident unit outside EU territory

[16] Compilation guidelines are provided in section 4.9

footprints'). Extending the current framework by compiling MFA-RME enhances the analytical potential of the EW-MFA framework. It has to be noted that the estimation of MFA-RME requires modelling leading to higher levels of uncertainty (see also section 4.9).

2.8.1. Why raw material equivalents

101. A feature of the indicators DMI and DMC (see section 2.7) is that their components domestic extraction (DE) on the one hand and physical trade (IMP and EXP) on the other hand are measuring two different things, although in the same unit, i.e. tonnes. The former measures the weight of amounts of virgin materials as extracted from the environment while the latter measure the weight of products as crossing borders. This asymmetry is sometimes perceived as a shortcoming.

102. The weight of a traded product does not represent the extraction of materials that was necessary to produce the traded product. The material extractions needed to produce a product will always be higher than its simple mass weight (as far as no secondary materials were used in production).

103. Almost all products go through different stages of manufacturing, starting from raw products followed by further processing and assembling into semi-manufactured products and finally into finished products. At each stage the resulting products becomes relatively lighter in terms of actual weight compared to the material extractions needed to produce that product. Not all material inputs into the manufacturing process necessarily become part of the product. For example, products may require energy-intensive processing for which fossil energy carriers need to be extracted, but these are not part of the actual weight of the product itself.

104. A country may reduce domestic extraction, e.g. the mining of metal ores, by increasing the imports of products, e.g. metal concentrates or even further manufactured (semi-)finished metal products in order to meet the same demand as before. Due to the measurement asymmetry between domestic extraction and physical trade this country would significantly reduce its DMI and/or DMC, even though the worldwide demand for material resources associated with its production and consumption activities does not change.

105. The conceptually different measurement of domestic extraction and physical trade also hampers comparability of DMI and DMC across countries. Some countries are endowed with material resources which tend to result in comparably higher domestic material extractions whilst other countries do not have exploitable material deposits and need to import raw products or (semi-) manufactured and finished products, which are relatively lighter. Resource-rich countries tend to have a higher DMI and/or DMC compared to resource-poor countries, which have to rely on imports to meet the demand for material resources.

106. In order to overcome the different measurement of components of DMI and DMC, traded products (imports and exports) can be converted into equivalents of domestic extraction – called *raw material equivalents*.

107. Expressing material flows in *raw material equivalents* (RME) captures consistently the amount of extracted material needed to produce a certain (set of) product(s); all traded products are converted into the (virtual) amount of material extractions needed to produce it. Extraction of raw materials throughout the product's entire production chain is taken into account, irrespective of whether the material extraction took place domestically or in the rest of the world.

108. Compiling MFA-RME effectively implies allocating material extraction (domestic extraction as recorded in EW-MFA) to products at the stage of their final use[17]. As such MFA-RME provide a consumption-based view of material requirements.

[17] The concept of 'final use' (of products) is derived from national accounts and comprises products going to final consumption, cross capital formation, and exports (see e.g. ESA 2010)

2.8.2. Components of MFA-RME and the derived indicators

109. Material flow accounts in raw material equivalents (MFA-RME) consist of the following components (flow types):

- Domestic extraction (source: EW-MFA),
- Imports in RME,
- Exports in RME.

They can be used to derive various indicators RME based indicators (see below, paras. 111ff.):

- Raw material input (RMI),
- Raw material consumption (RMC),
- Physical trade balance in RME (RTB).

110. The different components are broken down by material, following the EW-MFA material classification applicable to domestic extraction (see section 2.6 Table 2). Depending on the estimation method used (see section 4.9), the components of MFA-RME can also be broken down by product group and, in addition, RMC can be broken down in types of final uses (final consumption, gross capital formation, exports).

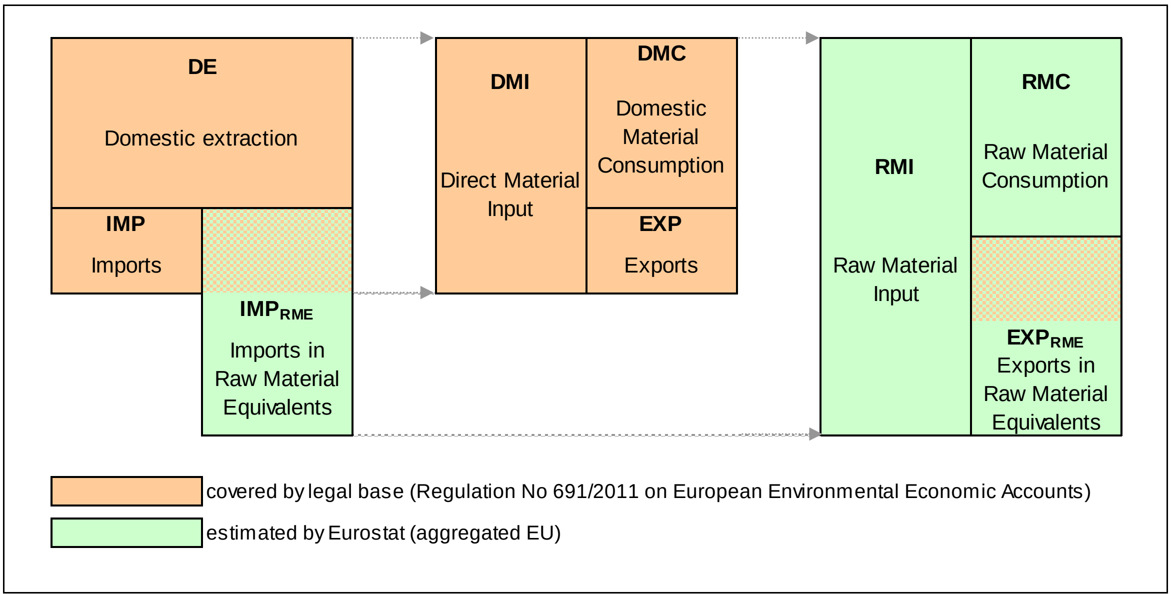
111. *Raw material input* (RMI) represents total final use of products (= final consumption expenditure + gross capital formation + exports) expressed in RME. It captures the amount of materials required as input to the production system in order to meet a country's consumption, investment, and export demand. It also represents the imports in RME, i.e. imports in equivalents of original materials extractions, in addition to domestic extraction of materials.

112. *Raw material consumption* (RMC) represents the domestic final use of products in terms of RME. In other words, RMC captures the amount of domestic and foreign extraction of materials needed to produce the final products used by households, governments or non-profit institutions serving households, or used for gross capital formation. The indicator RMC – also known as 'material footprint' – takes a domestic consumption perspective by excluding exports in RME from the RMI. Broken down by product group, RMC can be used to analyse which final products have the largest impact on material extraction, and hence the largest 'material footprint'.

113. RTB is the physical trade balance expressed in raw material equivalents. It is equal to imports in RME minus exports in RME. A positive value for RTB indicates that the worldwide material extractions necessary to produce the imported goods are bigger than those associated with the exported goods.

114. The MFA-RME are not covered in Regulation (EU) 691/2011 but are collected on a voluntary basis. Figure 4 shows how the set of indicators in RME fits with the other EW-MFA indicators currently covered in the Regulation (EU) 691/2011.

Figure 4: EW-MFA indicators and RME extensions



115. Political demand for a 'material footprint' indicator has been articulated in the context of the European Union's resource efficiency initiative. A 'material footprint' indicator has also been defined to track progress towards Sustainable Development Goal 8 – Decent work and economic growth and Sustainable Development Goal 12 – Responsible consumption and production (indicator 8.4.1 / 12.2.1).

116. Eurostat disseminates EW-MFA results measured in RME for the aggregated EU economy in its online database.

3 Reporting EW-MFA to Eurostat

117. This chapter addresses various aspects of the reporting of EW-MFA. National statistical institutes (NSI) transmit EW-MFA to Eurostat using an electronic questionnaire[18] (currently Excel) which is briefly introduced in section 3.1. Section 3.2 provides guidelines on the reporting and correct flagging of confidential data. Next to the data, NSI submit quality reports containing important meta data related to their national compilation methods (section 3.3).

118. One important notification is made: The classification of materials – in particular its coding – has been revised (see paras. 129ff). The previously separated material classifications for various questionnaire tables have been integrated into one list.

Memo items

119. Various memo-items are included in the EW-MFA questionnaire. The reporting is voluntary, i.e. for information only (see para. 91).

3.1. The EW-MFA questionnaire

120. The EW-MFA questionnaire evolved over the last 10 years. The first Eurostat EW-MFA questionnaire dates from 2007. After voluntary data collections between 2007 and 2012, Tables A to E of this EW-MFA questionnaire became legally mandatory in 2013.[19]

121. Eurostat uses the EW-MFA questionnaire to collect data from NSIs. Table 4 outlines the 9 questionnaire tables A to I of which two (C and E) are not used.[20] Each table is dedicated to certain types of flows (see section 2.5) and has years (starting with 2000) in columns and types of materials in rows.

122. The EW-MFA Tables A and B include material inputs, namely domestic extraction, i.e. natural inputs (Table A), and physical imports of products originating from other economies (Table B). Material outputs include physical exports of products to other economies (Table D) as well as the flows stemming from economic activities that are released to the environment, i.e. residuals (Table F). According to Regulation (EU) No 691/2011 only Tables A, B and D are mandatory for reporting.

123. Table G, includes balancing items that are needed when the full material balance related to a national economy is calculated.

124. Table H presents the main indicators derivable from Tables A to G.

125. With the 2017 data collection Table I was added to the EW-MFA questionnaire. It collects on a voluntary basis material flow accounts in raw material equivalents (MFA-RME) at the level of the four main material categories. Sections 2.8.1, 2.8.2, and 4.9 provide further details on material flow

[18] Means of data transmission will change in the mid term from Excel questionnaires to SDMX transmission standards.
[19] Annex III of Regulation (EU) No 691/2011 of the European Parliament and of the Council of 6 July 2011 on European environmental economic accounts
[20] The Eurostat Working Group on environmental accounts held on 3-4 May 2017 decided not to report any more tables C and E of the questionnaire as they are no longer used by Eurostat for calculating EW-MFA indicators for the aggregated EU economy

accounts in raw material equivalents.

Table 4: Outline of the Eurostat EW-MFA questionnaire

Questionnaire's tables	2000	2001	…	2016	2017
Table A* MF.1 Biomass MF.2 Metal ores MF.3 Non-metallic minerals MF.4 Fossil energy materials/carriers	**Domestic extraction**				
Tables B* and D* MF.1 Biomass (with additional material classes for animal and biomass products) MF.2 Metal ores (with additional material class for metal products) MF.3 Non-metallic minerals (with additional material class for products mainly from non-metallic minerals) MF.4 Fossil energy materials/carriers (with additional material class for products mainly from fossil energy material) MF.5 Other products MF.6 Waste traded for final treatment and disposal	**Physical imports and exports**				
Table F MF.7.1 Emissions to air MF.7.2 Waste disposal MF.7.3 Emissions to water MF.7.4 Dissipative use of products MF.7.5 Dissipative losses	**Domestic processed output**				
Table G MF.8.1 Balancing items: input side MF.8.2 Balancing items: output side	**Balancing items**				
Table H DE - Domestic extraction IMP - Imports EXP - Exports DMI - Direct material input DMC - Domestic material consumption PTB - Physical trade balance DPO - Domestic processed output NAS - Net additions to stock	**EW-MFA derived indicators**				
Table I DE - Domestic extraction IMP_RME - Imports in RME RMI - Raw material input EXP_RME - Exports in RME RMC - Raw material consumption	**MFA in raw material equivalents**				

** These tables record mandatory data according to Regulation (EU) No 691/2011*

126. The questionnaire (*sheet 'instructions'*) provides important technical instructions related to the handling of the electronic EXCEL questionnaire on how to report figures and symbols, footnotes,

confidential data. Finally, it includes built-in checking tool (VBA macros).

127. Beside the data reporting tables A to I the questionnaire includes tools and annexes:

- 'compilation tool' sheets for grazed biomass, crop residues, sand and gravel, clay, limestone, balancing items. These tools are described in Chapter 4;
- seven annexes which aim to support data compilation, such as correspondence keys between EW-MFA and different classifications, e.g. CN and PRODCOM. Annexes are provided in an additional EXCEL workbook (see Annex C).[21]

128. A checking tool is built into the questionnaire. It checks empty cells, illegal symbols, errors in footnotes, inconsistencies, plausibility issues and identifies incorrect use of confidentiality flags. It visualises errors and warnings in the data sheets through cells highlighted in different colours. In addition, by moving the mouse over the highlighted cell a comment appears with detailed explanation of the detected problem.

129. The checking tool produces an error report which is available in the *sheet 'Check Report'*. It provides a list of all cells with links where errors or other issues were detected. The list below details the checks performed:

- Symbol check: it verifies if the symbols used in the questionnaire are legal;
- Footnote check: it verifies if footnotes are used correctly;
- Consistency check: the sum of components have to equal the corresponding total or subtotal;
- Confidentiality check: it verifies that confidentiality rules are applied;
- Plausibility check: it concerns unlikely changes between consecutive years.

3.2. Confidential data – how to report and flag

130. In certain circumstances NSIs may report confidential data to Eurostat through flagging them accordingly. Eurostat guarantees that reported data flagged as confidential are protected, i.e. not published.

131. Producing and disseminating data at most detailed level for individual countries is essential for users and is an important objective strengthening the application of environmental accounts. Data flagged as confidential hinder this objective.

132. In addition, one of Eurostat's main duties is to disseminate data for EU aggregates. The Commission needs these statistics in order to develop and monitor EU policies. They also meet an increasing demand from users outside the Commission, such as national administrations and private businesses. In order to make data useful for users, EU aggregates should be available to the maximum extent possible while guaranteeing that no confidential national data is disclosed. If one cell is flagged as confidential at the most detailed level of EW-MFA classification, there are two consequences:

- For a given country it forces to flag the cell at the next superior hierarchical classification level also as confidential. This is usually done by the reporting country.
- For the EU aggregate the cell at the most detailed level as well as the cell at the next superior hierarchical level is to be flagged as confidential.

133. As a matter of principle, Eurostat wants to avoid any discrepancy between Eurostat

[21] Both, the latest questionnaire and annex files are available on *Eurostat's website* > *Environment* > *Methodology* > heading: 'Material flows and resource productivity'

publications and national publications by NSIs. Eurostat cannot remove any (primary and/or secondary) confidentiality-flag reported by the NSI. Eurostat may encourage the NSI to make sure that confidentiality is really justified and Eurostat may ask the NSI to provide evidence for the need for a given confidentiality flag.

134. To ensure proper use of environmental accounts, it is necessary to reduce the number of cells that cannot be published to a minimum. For this purpose, NSIs should undertake the following steps before sending EW-MFA questionnaires with confidential cells:

- ***Step 1: Unreliable data are not to be flagged confidential***

135. Lack of faith/confidence in the accuracy of data does not justify setting a confidentiality flag. In those cases the NSI is asked to remove the confidentiality flag and to add the standard footnote 'u = low reliability'.

- ***Step 2: Check whether data is published elsewhere***

136. If data is publicly available (i.e. published elsewhere) there is no confidentiality to be flagged:

> *Data obtained from sources lawfully available to the public and which remain available to the public according to national legislation shall not be considered confidential for the purpose of dissemination of statistics obtained from those data.*[22]

137. If a cell is confidential, EW-MFA compilers are advised to check whether concerned data are published elsewhere. Potential sources are national ministries and agencies on environment; BGS and USGS.

- ***Step 3: Consider changing methodology to allow disclosure***

138. If the confidentiality flag is justified by national rules, the NSI could consider changing the compilation method for the concerned cell, e.g. instead of using micro data NSI may make an estimate and add the 'estimated data' flag.

- ***Last option: Setting secondary confidentiality flags***

139. NSIs can set secondary confidentiality flags in a way that enables disclosure of hierarchically superior cells according to the national confidentiality rule. This facilitates Eurostat to publish at least EU totals for more aggregated levels of EW-MFA classification.

140. If a frequency rule with a threshold of 3 exists: Flag two additional cells on the same hierarchical level (usually the most detailed level of EW-MFA classification) in order to enable disclosure of the hierarchically superior cell. This last option bears the risk of inconsistent publication: data published nationally by NSIs may be hidden (flagged confidential) in Eurostat's publication. The country should make sure that the two publications are aligned.

3.3. The quality report

141. As part of the transmission obligations of the Regulation (EU) No 691/2011, Article 7, paragraph 2, each submission of data has to be accompanied by a quality report. These reports shall inform on the quality of sources used for data transmitted, the adjustments made to basic statistics to make the result align to the concepts and definitions of the accounts or for other methodological reasons, the estimation and compilation of data which cannot be derived directly from statistical sources, the breaks in time series resulting from changes in methodology or data sources and the steps taken to ensure time series are as comparable as possible.

142. The most recent quality report template for EW-MFA is available on Eurostat's website ('Material flows and resource productivity' heading). The quality report follows the guidelines of the

[22] Regulation (EC) No 223/2009 of the European Parliament and of the Council, Article 25

European Code of Practice (European Statistical System Committee, 2011) and covers the following quality aspects:

- Relevance;
- Accuracy;
- Timeliness;
- Punctuality;
- Accessibility and clarity;
- Comparability;
- Coherence.

143. In addition, EW-MFA compilers are requested to provide, if available: the national description of EW-MFA methodology as well as national quality reports; detailed information on voluntary reporting of MFA in RME.

144. Quality reports transmitted along with questionnaires are published in the Communication and Information Resource Centre for Administrations, Businesses and Citizens (CIRCABC)[23] – an internet based information platform of the European Commission.

[23] Browse categories (Main menu): *Eurostat > Environment Statistics, Indicators and Accounting > Quality Reports environmental accounts*

4 Compilation guidelines

145. This chapter presents compilation guidelines with the aim to facilitate and support the compilation of economy-wide material flow accounts (EW-MFA). After some introductory remarks, sections 4.2 to 4.5 provide guidelines for compiling Table A of the EW-MFA questionnaire, namely domestic extraction of biomass, metal ores, non-metallic minerals and fossil energy materials. Section 4.6 is on physical trade (Tables B to E) and section 4.7 continues with compilation guidelines for domestic processed output (Table F). Section 4.8 provides guidelines for balancing items (Table G). Finally, section 4.9 presents guidelines for material flow aggregates in raw material equivalents (Table I).

146. One important notification is made: The classification of materials – in particular its coding – has been revised (see paras. 129ff). The previously separated material classifications for various questionnaire tables have been integrated into one list.

4.1. General remarks on data sources and compilation

147. Like in the case of national accounts, the compilation of EW-MFA is based on a wide range of existing statistical data sources and does not require statistics that are specifically collected for the purpose of compiling EW-MFA. Sometimes the existing statistical sources do not provide the exact information needed for EW-MFA. In such cases compilers of EW-MFA undertake respective modifications and adjustments.

148. In the context of EW-MFA compilation three principal categories of existing statistical data sources can be distinguished: (i) specific national sources of statistical data, (ii) EU-wide harmonised sources of statistical data, and (iii) some important international sources of statistical data, such as those from the Food and Agriculture Organization (FAO) of the United Nations, the British Geological Survey (BGS), and the United States Geological Survey (USGS).

149. As a general principle, compilers of EW-MFA should give priority to specific national data sources (i). This handbook cannot make any references to specific national data sources (i) because these vary from country to country. Instead this handbook makes references to EU-wide harmonised sources of statistical data (ii) and some international data sources (iii) and provides guidelines how those may be used for compiling EW-MFA.

150. National sources of statistical data include, besides specific national statistics also EU-wide harmonised statistics, such as production statistics, international trade in goods statistics, energy and agricultural statistics. Often, the national versions of such EU-wide harmonised statistics may provide more details than those submitted to and disseminated by Eurostat.

151. International sources of statistical data should preferably be consulted for cross-checking national data sources and for filling gaps which are not covered by national data sources or in cases where the quality of the national sources is considered insufficient. Often, international organisations

providing international data sources manipulate the original data received from countries. Compilers of EW-MFA are advised to contact and cooperate with those national bodies that report respective data to international organisations in order to avoid inconsistencies.

152. Before compiling EW-MFA, the original data sources may have to be adjusted and aligned to the required statistical principles, definitions, accounting rules, and classifications relevant for EW-MFA (see section 2.1). E.g. not all data sources report in metric tonnes and data reported in other units need to be converted. Or, amounts of gross ore need to be derived from statistics reporting metal content only. Another adjustment need may arise from the fact that the original data are not yet adjusted to the residence principle (see paras. 26ff.).

153. Certain EW-MFA items for which data are not directly available (e.g. grazed biomass, crop residues, oxygen for combustion processes) need to be estimated – often based on statistical data sources that are multiplied with specific coefficients, e.g. those available in the compilation tools of the EW-MFA questionnaire. Compilers of EW-MFA should always search for and apply country-specific coefficients and factors. Using default average coefficients presented in this chapter further below constitute only the second best choice.

4.2. Domestic extraction of biomass (Table A)

154. Domestic extraction of biomass (MF.1) records material flows from the environment to the economy related to the human appropriation of cultivated and non-cultivated biomass. While the latter (e.g. wild fish catch, hunting and gathering, logging from natural forests) can be measured straightforwardly at the boundary between environment and economy, the former cannot and by convention the so-called 'harvest-approach' has been introduced (see chapter 2, paras. 34ff. and 74ff.). Amounts harvested from cultivated biological resources are available from agriculture and forestry harvest statistics.

155. In the European Union, the domestic extraction of biomass has been rather constant over the last two decades, ranging between 3.1 and 3.5 tonnes per capita. This is a bit less than 30% of total domestic extraction of materials within the European Union.

4.2.1. Classification overview

156. The classification of material flows for *domestic extraction* of biomass has four sections at the two digit level: the items MF.1.1 and MF.1.2 cover the harvest of common agricultural crops and plants; item MF.1.3 represents harvest from cultivated timber resources; item MF.1.4 comprises all biomass extraction from non-cultivated (wild) natural biological resources (see Annex A).

157. It is important to note that cultivated livestock (e.g. cows, pigs) is not a *natural input* and hence excluded from EW-MFA's domestic extraction (Table A of EW-MFA questionnaire).

4.2.2. Data sources

158. Statistical reporting of harvest from cultivated biomass stocks in agriculture and forestry has a long tradition. Most fractions of biomass harvest are reported by national statistical offices (or national ministries and/or agencies concerned with agriculture and forestry) in their series of agricultural, forestry, and fishery statistics. Additional information useful for biomass accounts may be provided by national food, feed, and wood balances. The accounting frameworks are well established and have a high degree of international standardisation and accuracy. The collection of many biomass harvest data is harmonised at European level.

159. The most important harmonised data sources for the calculation of *domestic extraction* of biomass at the national and the European level are:

- Annual crop statistics (see Eurostat online database: apro_acs_a);
- Forestry statistics: Roundwood removals (see Eurostat online database: for_remov);
- Fishery statistics: Catches (see Eurostat online database: fish_ca_main);

160. Eurostat's annual crop statistics (ACS) provide data on area under cultivation, harvested production and yield for more than 100 crops. Agricultural production of crops includes marketed quantities, as well as quantities consumed directly on the farm, losses and waste on the farm and losses during transport, storage and packaging. The harvested production (thousand tonnes) is accompanied by respective humidity degree, i.e. the moisture content of the harvested amount. The metadata provide more details, in particular reference shall be made to the Eurostat Handbook for Annual Crop Statistics (Eurostat 2017b) which is annexed to the metadata.

161. European forestry statistics based on the Joint Forest Sector Questionnaire (JFSQ) provide data on 'roundwood removals' (for_remov). Removals of roundwood comprise all quantities of wood felled and removed from the forest and other wooded land or other felling sites. They are measured in cubic metres and need to be converted into tonnes by EW-MFA compilers. Statistics on the volume of standing timber stock and its annual net increment is provided in the data set 'wood volumes' (for_vol). Although this data is disseminated by Eurostat it is produced by FAO and Forest Europe.

162. Catches of fish, crustaceans, molluscs and other aquatic organisms caught in commercial, industrial and recreational fishing operations are reported in tonnes live weight.

163. Supplementary sources for closing gaps and for cross-checking are the Eurostat complete agricultural statistical database, within which the Farm structure and Economic Accounts for Agriculture (EAA)[24] datasets can be found.

164. The statistics on structure of agriculture holdings provide data on area used for crop cultivation (notably, annual crop statistics also provide data on areas and yields). The EAA primarily report in monetary units, but internally the monetary estimates are usually based on physical statistical data or estimates.

165. Another rather comprehensive international source of data on biomass extraction is the statistical database by the United Nations Food and Agricultural Organization (FAO). The FAO database covers a huge range of data concerning agriculture, forestry, and fishery, and the food system on the level of nation states in time series since 1961.

4.2.3. Data compilation

General approach

166. The so-called 'harvest-approach' (see chapter 2, paras. 34ff. and 74ff.) is applied by using mainly statistics on harvested amounts of biomass. The above mentioned primary data sources may have data gaps. Possible gaps must be closed by additional statistical information or by estimation models. Some entries of EW-MFA are outside the scope of the above primary data sources, i.e. they are not covered by the classification of that statistical source. In other cases data for existing classification items may not be reported at the national level (missing data), data may be inaccurate or reporting could be systematically biased (e.g. under-reporting). The risk for estimation errors is particular high for 'fodder crops and grazed biomass' (MF.1.2.2.1 and 1.2.2.2). These items need to be partly estimated/modelled whilst their size is significant (about 30% of domestic extraction of biomass).

[24] The *Economic Accounts for Agriculture* (EAA) are a satellite account of the European system of national and regional accounts, adapted to the specific nature of the agricultural sector, providing complementary information and concepts. Although the structure of EAA matches very closely to that of national accounts, their compilation requires the formulation of appropriate rules and methods

167. As far as agricultural crop production is concerned, it is recommended to employ the Economic Accounts for Agriculture (EAA) as a secondary data source for closing data gaps. The EAA are published in monetary terms. However, usually the compilation of the monetary data is internally based on physical data and estimates. Note that the EW-MFA is designed as a physical accounting system. Therefore it should be ensured that the results of both systems are harmonised both at the conceptual and at the data level.

Moisture content (humidity degree)

168. A characteristic feature of all types of biomass is its considerable moisture content (mc) also referred to as humidity degree. The moisture content, respectively humidity degree, is very variable across plant parts, species, and vegetation periods.

169. As a general rule, EW-MFA record the domestic extraction of biomass (MF.1) in wet weight, i.e. the weight of the crop at harvest. Exceptions are the sub-items MF.1.2.2 'Fodder crops and grazed biomass' and MF.1.3 'Wood' which are recorded on the basis of a standard humidity degree of 15% (also referred to as dry-weight) if estimated.

170. Eurostat's annual crop statistics (ACS) report the harvested amounts at its weight at the time of harvest (wet weight). Eurostat collects and publishes both, the harvested production amount (in tonnes) and the respective (national, i.e. country specific) humidity degree. Eurostat has developed a methodology to re-calculate the harvested amounts assuming a standard European humidity (see Table 3 in ACS Handbook p.11): This re-calculation is, however, only applied for estimating EU aggregates. As a consequence the EU aggregates are not necessarily equal to the sum of the nationally reported harvest amounts. Countries may as well apply standard European humidity degrees and report harvest amounts based on those to Eurostat.

171. In cases where ACS is used (most of MF.1.1 and MF.1.2) compilers of EW-MFA should use the harvested production amounts reported by national statistical sources (most likely employing country specific national humanity degrees).

172. Exceptions are 'fodder crops and grazed biomass' (MF.1.2.2)[25]. By convention these are to be recorded in air dry weight, which is standardised by a humidity degree of 15%. See also paras. 189ff.

Biomass production by households for own consumption

173. Following the rules of national accounts (ESA and SNA respectively) which are also applicable to EW-MFA, production of agricultural goods for own final consumption has to be regarded as *domestic extraction*. However, there are only few reliable data sources or estimation procedures available for quantifying those items in physical terms. In Eurostat's online database the production of fruits and vegetables in kitchen garden of agricultural households is included in the list of crop production items (kitchen gardens), which however would only be a fraction of total agricultural own account production in home gardens. But only some few countries report estimates for even those items. However, as far as data are reported that information should be included into *domestic extraction* estimate.

Biomass waste from management of parks, infrastructure areas, gardens etc.

174. A significant amount of biomass is generated as a by-product of management of home gardens, infrastructure areas, public parks, and sports facilities etc. A certain fraction of this biomass flow (e.g. mown grass, woody biomass, residues from pruning and foliage etc.) may be subject to further economic use, e.g. for energy generation or the production of compost or it may appear in waste statistics. In EW-MFA these fractions are regarded as *domestic extraction* of biomass (*domestic processed output*, respectively). However, due to lack of reliable data sources and estimation procedures, they are currently not accounted for. Recently, this biomass flow has received increasing attention in the context of strategies for sustainable resource use and might be included at a later stage of EW-MFA method development.

[25] as well as 'Wood' (MF.1.3) which is also recorded with a standard moisture content (humanity degree) of 15%

Crops (excluding fodder crops) – MF.1.1

175. This class includes primary harvest of all crops from utilised agricultural area excluding crop residuals, fodder crops, and grazed biomass. MF.1.1 includes major groupings of crops such as cereals, dry pulses and protein crops, root crops, industrial crops, fresh vegetables, permanent crops etc.

176. The *domestic extraction* of MF.1.1 'crops (excluding fodder crops)' is widely covered by agricultural crop statistics. Agricultural crop statistics usually report data in mass units of harvested amounts (wet weight, i.e. weight as at harvest) which may be used directly to compile Table A of EW-MFA questionnaire.

177. Annex 1 of the EW-MFA questionnaire provides the correspondences to European annual crop statistics (ACS). For most material groups and sub-groups under MF.1.1 corresponding codes of annual crop statistics can be easily identified with the exception of MF.1.1.A '*other crops (excluding fodder crops) n.e.c.'* for which major gaps occur in the annual crop statistics. Additional estimations are required, see following paragraphs.

Other crops (excluding fodder crops) n.e.c. (MF.1.1.A)

178. The domestic extraction of some specific crops like *flowers and ornamental plants* (crop code N0000) and *seeds and seedings* (crop code E0000) which are to be reported under the item MF.1.1.A are covered by ACS but provided in thousand hectares. The area information has to be converted into tonnes by employing yield factors. Preferably specific national information on average yields should be used. If no national yield factors are available Table 5 presents approximate yield factors compiled by IFEU-Institute Heidelberg which may be applied.

179. MF.1.1.A also comprises the ACS items (reported in tonnes) *tobacco* (crop code I3000), *hops* (crop code I4000), aromatic, medicinal and culinary plants (crop code I5000), energy crops n.e.c. (crop code I6000), *other industrial crops* (crop code I9000) and *other permanent crops* (crop code PECR9[26]).

Table 5: Average yield factors for selected agricultural crops and plants

Crop/plant		Yield (t/hectare)
Nurseries	Average: expert estimate	51.3
Outdoor-flowers and ornamental plants	Aster	22
Under glass-flowers and ornamental plants	Rose	123.19
Seeds and seedlings	Beet seeds	2.43 - 4.86
	Sugar beet seeds	0.9 - 1.8

Source: IFEU-Institut Heidelberg based on sources for Germany

Crop residues (used), fodder crops and grazed biomass – MF.1.2

180. This class is further broken down into:

- Crop residues (used) – MF.1.2.1 and
- Fodder crops and grazed biomass – MF.1.2.2

which are further explained below.

[26] The item PECR9 includes Christmas trees. See section 2.5.9 p.19 in Eurostat Handbook for Annual Crop Statistics

Crop residues (used) – MF.1.2.1

181. The amounts of harvested production of crops as reported in annual crop statistics include marketed quantities, as well as quantities consumed directly on the farm, losses and waste on the farm and losses during transport, storage and packaging. In many cases, these harvested amounts form only a fraction of total growing of biomass of the respective crop. The residual biomass, such as straw, leaves etc., is not included in the annual crop statistics. Nevertheless, those crop residues are often subject to further economic use and hence to be included in EW-MFA. A large fraction of crop residues is used as bedding material in livestock husbandry but crop residues may also be used as feed, for energy production, or as industrial raw material.

182. In EW-MFA used crop residues are regarded as *domestic extraction*, disregarding whether they are sold or used for intra-unit consumption. Residues which are left in the field and ploughed into the soil or burned in the field are not accounted for as *used extraction*. This is important to bear in mind as it concerns the category of 'green manure' (code Q0000) in annual crop statistics.

183. EW-MFA distinguishes between two types of crop-residues:

- MF.1.2.1.1 Straw of cereals (all harvested straw of cereals including maize) and
- MF.1.2.1.2 all other crop-residues

184. In most European countries *all other crop residues* will refer to tops and leaves of sugar beets and only occasionally to residues from other crops e.g. sugar cane, etc.

185. The items for *crop residues* are not covered by any other European statistics; currently some data are available for some countries in the so-called *Gross Nutrient Balances*. If *used crops residues* are also not reported by other national sources[27] an estimation procedure has to be applied for the purpose of EW-MFA. The following estimation approach is suggested which is also implemented as compilation tool in the EW-MFA questionnaire (*'Crop residues v1'* sheet):

- ***Step 1: Identification of crops which provide residues for further socio-economic use***

186. In most cases this will include all types of cereals, sugar crops, and oil bearing crops. Only in exceptional cases other crops need to be considered.

- ***Step 2: Estimation of available crop residues via harvest factors***

The procedure to estimate the amount of crop residues makes use of assumptions about the relation relation between primary harvest and residues of specific crops. In agronomics, different measures are used for this relation: the most prominent ones are the ***harvest index***, which denotes the share of primary crop harvest in the total aboveground plant biomass, and the ***grain to straw ratio***. These relational measures are specific for each crop. Based on these relational measures, a ***harvest factor*** can be calculated, which allows for the extrapolation of total residue biomass from primary crop harvest as reported in crop statistics. Typical harvest factors, which can be used in absence of national information, are provided in

187. Table 6.

Available crop residues [t] = primary crop harvest [t] * harvest factor

[27] These amounts, at least in terms of monetary values (also for the intra-unit-use) should be included in the background data of the economic accounts for agriculture (EAA) as part of the intermediate consumption: - position 19063 *Animal feeding stuffs – feeding stuffs produced and consumed by the same holding* and 19900 *other goods and services* (for example for bedding materials). Both positions also include other flows so their total cannot be directly used; but usually these crops residues are a part of it and should appear in the calculations of the EAA

Table 6: Standard values for harvest factors and recovery rates for the most common crop residues used in Europe

	Harvest factor	Recovery rate
Wheat	1	0.7
Barley	1.2	0.7
Oats	1.2	0.7
Rye	1.2	0.7
Maize	1.2	0.9
Rice	1.2	0.7
All other cereals	1.2	0.7
Rape seed	1.9	0.7
Soy bean	1.2	0.7
Sugar beet	0.7	0.9
Sugar cane	0.5	0.9

Source: Wirsenius, 2000

- ***Step 3: Estimation of fraction of used residues***

In most cases, only a certain fraction of the total available crop-residue will be further used. The The actual fraction of crop residues used is termed ***recovery rate***. It can be estimated based on expert knowledge or specific studies. It should be noted that it may vary considerably across regions, countries, and over time. In cases in which no country-specific information is available, *recovery rates* provided in

188. Table 6 can be applied for European countries.

Used crop-residues [t] = available crop-residues [t] * recovery rate

Fodder crops and grazed biomass – MF.1.2.2

189. MF.1.2.2 *fodder crops and grazed biomass* subsumes different types of roughage. Not included are commercial feed crops such as barley, soy bean etc. the harvest of which has been counted elsewhere (MF.1.1).

190. It is important to note that amounts of MF.1.2.2 *'fodder crops and grazed biomass'* are to be recorded in air dry weight, which corresponds to a humidity degree of 15%.

191. Some components of MF.1.2.2 can be voluntarily reported in European annual crop statistics ACS (since 2015 based on an ESS agreement).

192. MF.1.2.2.1 *'Fodder crops'* correspond to the ACS items:

- Other root crops n.e.c. (crop code R9000), and
- Plants harvested green from arable land (crop code G0000), with its sub-classes:

- Temporary grasses and grazings (G1000),
- Leguminous plants harvested green (G2000)
  - Lucerne (2100)
  - Other leguminous plants harvested green n.e.c. (G2900)
- Green maize (G3000)
- Other plants harvested green from arable land (G9000)
  - Other cereals harvested green (excluding green maize) (G9100)
  - Other plants harvested green from arable land n.e.c. (G9900)

193. Notably, ACS report those in wet weight (weight as at harvest). If ACS is used, compilers of EW-MFA have to convert the respective amounts to a standard humidity degree of 15% (air dry weight).

194. MF.1.2.2.2 'Grazed biomass' is not reported by European ACS. It has to be estimated (see further below). European ACS only report the area for *permanent grassland* (crop code J0000) which can be used for plausibility checking. Two main estimation methods have been developed to estimate MF.1.2.2.2 *'grazed biomass'*: the *supply-side approach* and the *demand-side approach*. Both are explained in the following. Both approaches are implemented in a compilation tool within the EW-MFA questionnaire (sheet: *'Grazed biomass v1'*). Ideally both approaches should be undertaken to crosscheck the results.

Supply-side approach

195. The supply-side approach attempts to close gaps in data for individual categories of fodder crops and grazed biomass.

196. *MF.1.2.2.1 'Fodder crops (including biomass harvest from grassland)':* Data may be available in ACS, see above para. 192. If not one should try to refer to internal estimates of economic accounts for agriculture EAA where *fodder crops (including biomass harvest from grassland)* have to be completely covered in monetary terms. The underlying physical data or models from the EAA could also be used to close those gaps.

197. *MF.1.2.2.2 'Grazed biomass':* A significant amount of fodder is directly taken up by animals from grazing pastures. This *grazed biomass* is to be regarded as *domestic extraction* according to the EW-MFA conventions. Physical amounts on the uptake of biomass from pastures[28] are not directly available in European annual crop statistics. The utilised agricultural area in form of permanent grasslands (code J0000 in annual crop statistics) is included though.

198. Information on amounts of grazed biomass might be available from national gross nutrient balances, form national feed balances or from agricultural experts. These data can be used for EW-MFA. If necessary, quantities given in other units have to be converted into air dry weight (15 % moisture content) with the support of expert knowledge.

199. Another possible source – if it exists at national level – may be animal feed balances.

200. For countries with no or with incomplete direct data grazed biomass supply-side estimates via grazed area and information on area yield can possibly be applied. Often, statistical offices and Eurostat[29] provide data on the extent of grazing land (often differentiated by quality or intensity) in their agricultural or land use statistics. Based on information on the extent of pastures and typical area yields, the biomass taken up by grazing can be calculated.

201. Country or region specific area yields of pastures and rangelands can be estimated based on

[28] Like for crop residues, the grazed biomass (except the one grazed in 'wild' pastures, like e.g. Alpine pastures) is included in the intermediate consumption of the EAA in the position 19063 *Animal feedingstuffs – feedingstuffs produced and consumed by the same holding*

[29] Eurostat's annual crop statistics include the utilised agricultural area for the category of 'permanent grassland' (code J0000) which does most likely not include wild pastures. Notably, the yields from 'permanent grassland' may include energy crops and not only grazed biomass

different sources. As mentioned above, Eurostat online database reports for some countries the actual uptake of grass per hectare. For countries with no direct data it could be considered to estimate the uptake of *grazed biomass* by utilising information on area yields (kg per hectare) from other countries or a mix of other countries with similar natural conditions.

Grazing potential [t at 15% mc] = pasture area [ha] * pasture yield [t at 15% mc / ha]

202. Those calculations should be cross-checked as far as possible with expert knowledge and literature data. Further, Table 7 provides information on typical grazing yields potential for different quality types of pastures in Central Europe (based on data for Austria).

Table 7: Typical area yield of permanent pastures

	Yield range [t at 15 % mc / ha]	Average yield [t at 15 % mc / ha]
Rough grazing, alpine pasture	<1	0.5
Extensive pasture	1-5	2.5
Improved pasture	5-10	7

Source: The values are derived from data for Austrian grassland systems given in Buchgraber et al. (1994) and can be assumed typical for Central Europe

Demand-side approach

203. The demand-side approach takes the annual fodder requirement of the existing livestock as the starting point for estimating the domestic extraction of fodder crops and grazed biomass (MF.1.2.2).

204. The demand for *grazed biomass* can be estimated starting from estimates of typical roughage requirements of ruminants and other grazing animals and information on livestock numbers. Daily roughage intake depends on the live weight of the animal, animal productivity (e.g., weight gain, milk yield), and the feeding system (e.g. share of concentrate), and may vary considerably within one species. This method is based on European average values and allows a rough estimate.

Roughage requirement = livestock [number] * annual feed intake [t per head and year]

205. European average factors for roughage uptake by livestock species are provided in Table 8. The values are given in air dry weight (i.e. at a moisture content of 15 %) and take into consideration that the share of market feed (industrial fodder products) in total feed ranges between 5-20 % (dry matter basis, average across all species).

Table 8: Typical roughage intake by grazing animals in Europe

	Daily intake (range) [kg/head and day]	Annual intake (range)[t/head and year]	Annual intake (average)[t/head and year]
Cattle (and buffalo)	10-15	3.6-5.5	4.5

	Daily intake (range) [kg/head and day]	Annual intake (range)[t/head and year]	Annual intake (average)[t/head and year]
Sheep and goats	1-2	0.35-0.7	0.5
Horses	8-12	2.9-4.4	3.7
Mules and asses	5-7	1.8-2.6	2.2

Source: The values are typical for industrialised livestock production systems and derived from national feed balances and literature (Wirsenius, 2000; Hohenecker, 1981; Wheeler et al., 1981; BMVEL, 2001)

206. Roughage uptake may be covered from grass type fodder crops, hay or silage, or from grazing and industrial fodder products, as suggested by the following formula. To estimate grazed biomass, total roughage requirement has to be reduced by the amount of fodder crops including biomass harvest from grassland (item MF.1.2.2.1) and industrial fodder products[30].

207. In addition, if 'green maize' used for biogas production is identified in MF.1.2.2.1, it must be excluded, i.e. added to roughage requirement, when estimating the demand for grazed biomass, as shown below.

Demand for grazed biomass = roughage requirement [t at 15% mc]
– fodder crops incl. biomass harvest from grassland, MF.1.2.2.1 [t at 15% mc]
+ green maize used for biogas production

208. If estimates for grazed biomass are available from the supply-side approach, they should be used for crosschecking with estimates from the demand-side approach. If the two estimates do not match, the underlying assumptions should be reviewed, which may after expert consultation lead to an adaptation of the estimates. Reasons for differences may be overgrazing of pasture resources or significant grazing on areas other than those reported as pasture or 'permanent grasslands' in statistics used for the estimates (e.g. animals could graze also on non-agricultural utilised area such as woodlands, waste lands etc.).

Wood – MF.1.3

209. This item records the biomass harvested from cultivated and non-cultivated forests, whereby the latter is quantitatively less important in Europe. In the case of cultivated forests, EW-MFA records by convention the harvested amounts of wood, following the so-called 'harvest-approach (see chapter (see chapter 2, paras. 34ff. and 74ff.).

210. The following sub-items are recorded under the *domestic extraction* of wood: *timber (industrial round-wood)* (MF.1.3.1) and *fuel wood and other extractions* (MF.1.3.2).

Timber (industrial roundwood) (MF.1.3.1) and wood fuel and other extraction (MF.1.3.2)

211. Statistical data on items MF.1.3.1 *timber (industrial round-wood)* and part of MF.1.3.2 *wood fuel and other extraction* can be found in Eurostat forestry statistics, namely data set 'Roundwood removals by type of wood and assortment' [for_remov].

212. Roundwood removals (codes RW_IN for *industrial roundwood* and RW_FW for *fuelwood, including wood for charcoal*) are reported in thousand cubic metres in for_remov. For EW-MFA's

[30] And also by part of the crops under MF.1.1 (barley, grain, maize etc.) to avoid an over-estimation. This should not be neglected. E.g. Swiss animal feed balance reveal that these represent 4% of the intake of cattle. This can be probably higher in countries with for example beef meat production where animals don't go so much in the pastures

domestic extraction, cubic metres have to be converted into tonnes. The conversion factors differ by tree species. If no national conversion factors are available the international default factors as given in Table 9 can be applied.

Table 9: Conversion factors from cubic metres to metric tonnes for coniferous and non-coniferous round wood (applicable for both, 'over bark' or 'under bark')[31]

	Density [t at 15 % moisture content / m^3]
Coniferous	0.52
Non-coniferous	0.64

213. *Source: Good Practice Guidance for Land Use, Land-Use Change and Forestry, IPCC National Greenhouse Gas Inventories Programme (Penman et al., 2003;* Table 3A.9-1*, please note that moisture content in Penman et al. is zero)*

214. Roundwood removals in Eurostat forestry statistics distinguish between *'under bark'* (without bark) and '*over bark'* (including the bark). Bark accounts for approximately 10 % of stem wood weight. Significant parts of the bark are subject to further economic uses (e.g., energy production). The part of the bark which is used has to be regarded as domestic extraction in EW-MFA. All biomass which remains in the forest and is not used (branches, root-stock etc.), is not accounted as domestic extraction in EW-MFA. It should be assumed that all harvested wood over bark which is statistically reported is used economically. I.e. compilers of EW-MFA should use reported amounts for 'over bark' if available and elsewise those available and reported for 'under bark'.

215. *Other extractions from forest:* This subset of MF.1.3.2 includes natural gum, cork and other forest products (see Eurostat 2002; Table 3a). Other wild products which are related to wooded land such as wild mushrooms, truffles, berries, nuts, wild animals and products from wild animals etc. are reported under the item MF.1.4.3 hunting and gathering. Short rotation wood, such as Christmas trees and poplars, are reported under classification item MF.1.1.A.

Net increment of timber stock (memo item) (MF.1.3 MEMO)

216. The classification entry MF.1.3. MEMO '*Net increment of timber stock'* is a memo-item (see para. 91) and hence not taken into account when aggregating domestic extraction over all material classes. It reports the growth (annual increment) of cultivated timber which – according to national accounts' concepts – is considered to be the output of the production activities in forestry. This memo item has been included in order to enable comparisons between EW-MFA's 'harvest approach' and national accounts' concepts.).

217. This memo item can be derived from existing European statistics. Eurostat's data set 'Wood volume' [for_vol] reports the item 'Net annual increment in forests available for wood supply (NAI)' (code NAI_FAWS). NAI denotes the average annual growth net of the average annual natural mortality. It can be used to approximate the memo item MF.1.3.M.

218. Data stem from FAO and are re-published by Eurostat. Data are available for selected years (currently 1990, 2000, 2005, 2010 and 2015). Those data should also be available from national forest inventories. Further information on this item can be obtained from the database of the European Forest Institute. Data reported in volume [m³] should be converted into mass [t at 15 % moisture content] by using the factors provided in Table 9.

219. So far, the memo item MF.1.3.M has not been considered when EW-MFA aggregates are derived. Currently EW-MFA aggregates, such as DMI and DMC, take into account the amounts of harvested timber (removals) i.e. MF.1.3 is the sum of MF.1.3.1 and MF.1.3.2.

[31] Those density factors refer to oven dry mass of wood, as for the purpose of IPCC a conversion from m3 to tonnes is required as an interim step for estimating carbon content of wooded biomass. But according to the conventions of EW-MFA biomass has to be reported in air dry weight (moisture content of 15 %). Therefore the original density factors of the IPCC publication were transformed into factors which convert solid cubic metres into metric tonnes at 15 % moisture content

Wild fish catch, aquatic plants/animals, hunting and gathering (non-cultivated biomass) – MF.1.4

220. Item MF.1.4 relates to the domestic extraction of biomass material from non-cultivated stocks of wild animals and plants (natural biological resources). It includes wild fish catch (MF.1.4.1), all other aquatic animals and plants (MF.1.4.2), and biomass from hunting and gathering (MF.1.4.3).

Fish catch, aquatic animals/plants – MF.1.4.1 and MF.1.4.2

221. Data for domestic extraction of MF.1.4.1 and MF.1.4.2 may be available from national and/or European fishery statistics. It has to be noted that data are reported separately for cultivated and non-cultivated (i.e. natural) aquatic biomass. According to the EW-MFA principles the domestic extraction of biomass only includes catches from non-cultivated aquatic biomass stocks (natural aquatic resources), i.e. wild fish and other aquatic animals and plants (see also section 2.2, paras. 35-36).

222. Amounts of wild fish catch and extraction of other aquatic animals and plants are reported in national fishery statistics and in Eurostat's fishery statistics. For all items the Eurostat fishery statistics provides a differentiation between (1) catch of natural (wild) resources and (2) production from aquaculture (cultivated resources). The data for the former in mass units can be directly used for EW-MFA. The latter is not accounted for in EW-MFA because it is a production process within the economy. In accordance with the national account's residence principle (see paras. 26ff), all landings by national vessels should be included, regardless of the geographic location of landings.

Hunting and gathering – MF.1.4.3

223. Data on *hunting and gathering* (MF.1.4.3) is hardly available from official statistics; at least it is not included in any European statistic.

224. Item MF.1.4.3 hunting and gathering refers to extraction of wild non-aquatic animals, wild animal products and of wild crops and plants. Hunting comprises the hunting and trapping of animals for food, for their pelt or hide, for research purposes, zoos, or for use as pets. Breeding of game on holdings should not be included under this position (as it is part of animal cultivation). Gathering includes the collection of non-cultivated mushrooms, truffles, berries, nuts, egg etc.

225. Hunting and gathering is quantitatively of minor significance and is only accounted for if data are available in national statistics.[32]

226. A conversion of hunting data from pieces into tonnes might be necessary by referring to information on average weight per piece (see Annex D). But it should be considered that determining the average life weight might be burdened with considerable inaccuracy, as that weight is usually only reported as a range.

227. Conceptually the weight of the bowels has to be deducted from the life weight, as hunted animals are usually disembowelled directly after hunting and the bowels are left behind in the forest.[33] Therefore those parts of the animals have to be regarded as unused extraction. The used extraction comprises the disembowelled bodies including skins, head, and antlers. Usually estimated average life weight per piece is reported as the primary information. The share of the bowels differs considerably from species to species and usually no comprehensive information is available on that item.

228. If that specific information on unused extraction is not available it is recommend to use a simplified approach.[34]

[32] See: Deutscher Jagdschutz-Verband e.V. (Hrsg.): Jahresjagdstrecken Bundesrepublik Deutschland and Schweinert (2004), p 61. For Switzerland see http://www.jagdstatistik.ch/
[33] And also part of the blood
[34] E.g. 20 % for big animals; one may assume that small animals (rabbits, birds etc.) are not disembowelled in the forest

4.3. Domestic extraction of metal ores (Table A)

229. Domestic extraction of metal ores (MF.2) records material flows from the environment to the economy related to mining of metallic minerals (ores) performed through underground or open-cast extraction, seabed mining etc. The intention of EW-MFA is to measure domestic extraction of metal ores at the point where the respective metal-containing material crosses the 'boundary' between the natural environment and the national economy (see paras. 34ff).

230. The metal containing material extracted in metal mining is a composite material including metals[35] and other non-metal material. In EW-MFA the 'gross ore' following the 'run-of-mine' concept is the amount accounted for (see paras. 67ff.). This is the amount of raw mined metal containing material as it is delivered by the mine cars, skips, or conveyors and prior to treatment of any sort. The amount of gross ore run-of-mine may be crushed into smaller pieces; but it must not be further separated or elsewise concentrated. Although the gross ore run-of-mine is a material conglomerate it excludes any non-metal-containing-material that has been (re-)moved to access the metal containing material layers – so-called 'overburden', which is material of any nature that overlies a deposit of useful materials (see paras. 67ff., in particular Table 1; see also paras. 64ff.).

231. If available, data on the 'run-of-mine' amounts should be used. Official statistics, however, may be available only for the production output of mining activities. In the case of metal mining further separation and concentration often happens on site so that there may be significant quantitative differences between the amounts extracted and those leaving the gate of the mine in form of ready-to-sale products. Statistics on the production output from metal mining can be used to estimate the run-of-mine amounts. In most cases, the run-of-mine amounts of metal containing material include more than one metal – so-called 'coupled production'. In those cases the run-of-mine amounts need to be distributed and assigned to the various metals. A specific assignment method has been developed for this (see paras. 267ff).

232. Although EW-MFA primarily seek for amounts of metal ores measured in 'gross ore run-of-mine' (see above) it has been considered useful and meaningful to additionally collect certain metal ores in terms of actual 'metal content' as 'memo-item'. The 'metal content' is important for further analyses. In addition, it can be used for cross-checking the amounts reported in 'gross ore run-of-mine'. The EW-MFA questionnaire includes memo-items (see para. 91) in metal content for five non-ferrous metals, namely copper, nickel, lead, zinc, and tin (see also Table 2 and Annex A). Notably, these memo items are not taken into account for deriving EW-MFA indicators and aggregates. Their reporting is voluntary.

233. In the European Union, the domestic extraction of metal ores is comparably low. With 0.3 to 0.4 tonnes per capita it is only about 3 % of total domestic extraction within the European Union. Significant metal ore mining happens only in a few Member States. According to Eurostat's structural business statistics about 300 enterprises are engaged in metal ore mining EU-wide. Iron ore is mainly mined in Sweden (about 30 Mt which is about 90 % of EU-wide iron ore mining). Non-ferrous metal ore mining amounts to about 150 Mt. Mentionable amounts are mined in Sweden (ca. 40 Mt), Poland and Bulgaria (each ca. 30 Mt), Finland (ca. 20 Mt), Portugal (ca. 10 Mt) and Spain (ca. 10 Mt).

4.3.1. Classification overview

234. Metals as chemical elements are systematised and listed in the *Periodic Table of the Elements*. The classification of material flows for domestic extraction of metal ores (see Annex A) has been based on the chemical characteristic on the one hand, and on different classifications as practically applied by a range of potential data sources (see next section 4.3.2). On the 2-digit level

[35] In most cases a number of various metals.

metal ores are distinguished into two classes: iron (MF.2.1) and non-ferrous metals (MF.2.2). The non-ferrous metal ores are further broken down into 9 material groups (3-digits). Due to the high importance of certain non-ferrous metals (critical raw materials) it may be considered to further increase detail down to a 4-digit level in future.

235. Platinum group metals (PGM) is a term sometimes used to collectively refer to six metallic elements clustered together in the periodic table. The six platinum group metals are ruthenium, rhodium, palladium, osmium, iridium, and platinum. They have similar physical and chemical properties, and tend to occur together in the same mineral deposits.

4.3.2. Data sources

236. Data on the physical output of the metal mining industry can be obtained from various sources at national and international level. It is recommended to always contact the experts in charge of the respective national data sources in order to avoid misinterpretations of data which is a particular risk in the case of data on metal mining.

European production statistics (PRODCOM)

237. The European statistics on the production of manufactured goods (PRODCOM) provide comparable data on the production of metal ores. However, the PRODCOM is less suited for the compilation of EW-MFA domestic extraction of metal ores for various reasons.

238. The PRODCOM classification for metal mining output is rather aggregated. See Table 10 and Annex 2 of the EW-MFA questionnaire that reports the correspondence between PRODCOM-codes and MF-codes).

Table 10: PRODCOM codes and labels related to metal ores

Code	Label
07.10.10.00	Iron ores and concentrates (excluding roasted iron pyrites)
07.29.11.00	Copper ores and concentrates
07.29.12.00	Nickel ores and concentrates
07.29.13.00	Aluminium ores and concentrates
07.29.14.00	Precious metal ores and concentrates
07.29.15.00	Lead, zinc and tin ores and concentrates
07.29.19.00	Other non-ferrous metal ores and concentrates

239. The production output reported by PRODCOM might be concentrate and/or ore whereby it is not clear whether the latter follows the 'run-of-mine' definition (see paras. 114ff., in particular Table 1). This makes it almost impossible for EW-MFA compilers to derive the amounts of gross ore 'run-of-mine' immediately from PRODCOM without further information.

240. The completeness (coverage) of the PRODCOM data varies considerably across countries and years; often due to confidentiality reasons or because small enterprises may not be included in the underpinning survey.

241. PRODCOM reports physical data for two production volumes: sold and total volume. Data on total volume are more comprehensive as they comprise also extracted materials which are not sold but used for intermediate consumption within the extracting establishment. Therefore, as far as PRODCOM data are used, the data on total volume and not on sold volume should be used for the

purpose of compiling figures on domestic extraction.

National data sources (geological surveys, ministries, and industrial associations):

242. Further information may be available from specific national data sources on metal mining, such as statistics from geological surveys, ministries and industrial associations.

Individual mining companies:

243. Annual business reports of individual mining companies or other direct information from mining companies may be a very important source, especially for estimating ore grades or for identifying coupled production, i.e. where the extracted ore contains more than one metal (see paras 267-277).

International data sources:

244. Apart from national mining statistics, especially the following international sources can be useful also for compilations at the national level:

- British Geological Survey (BGS): European Mineral Statistics;
- United States Geological Survey (USGS): Minerals Yearbook;
- Federal Ministry of Science, Research and Economy Austria: World Mining Data.
- European Minerals Knowledge Data Platform (EU-MKDP)

245. Note that the metal mining output is predominantly reported as metal content by these data sources.

246. Those sources use as far as possible official statistical data of the countries concerned. ‘Where official data are not available or where there is reasonable cause to doubt the accuracy or completeness of such data information is sought from other sources such as geological survey organisations, chambers of mines, universities, trade associations and primary producers themselves’ (British Geological Survey, 2011).

247. In addition, the USGS provides detailed information on the mineral industry within the studied country, in particular about the structure of the mineral industry in terms of commodity, major operating companies, and major equity owners, location of main facilities, and annual capacity.

248. The estimates published by BGS and USGS are the results of comprehensive cross checking of various sources.

4.3.3. Data compilation

General approach

249. The preferred approach is to use information on the actual 'run-of-mine' amounts of metal containing material as extracted, preferably from the operator (see paras. 114ff. and 229-231). In case of 'coupled production' these amounts need to be distributed and attributed to the various individual metals contained in the material extracted (see paras. 313ff).

250. If no direct information is available on 'run-of-mine' amounts the latter need to be estimated from other data sources that report in the one or the other way production output from metal mining. Attention has to be paid to the reference unit in which the amounts of mining output is reported: e.g. tonnes of (pure) metal content, tonnes of metal ore concentrate, or tonnes of gross ore (see paras. 114ff.; in particular Table 1). In most cases, original data on metal mining output need to be converted to tonnes gross ore 'run-of-mine'. When re-calculating, special attention has to paid to the 'couple production' issue.

251. It is highly advisably to consult and evaluate not only one but all available data sources. These are cross-checked and compared in order to achieve balanced and realistic estimates. Preference should always be given to national data sources.

252. National and Eurostat production statistics basically report the products which are sold in the market. As metal ores are usually sold as concentrates, PRODCOM data on production of metal ores in weight units are provided as weight of *metal ores and concentrates*. An exception is iron which is partly reported also as gross ore. As far as only data on ore concentrates are available, conversion factors have to be established for estimating gross ore as well as metal content (see below).

253. Moreover, special attention has to be put on the issue of coupled production of ores. In case of coupled production the ore concentrate reported in PRODCOM under a specific metal may also contain other metals which are going to be separated only at the smelter stage. A further problem is that the PRODCOM classification is not detailed enough for tracking each individual metal.

254. Individual mining companies: It is highly recommended to refer to the annual business reports of individual mining companies. The number of those companies is rather limited per country. Usually they publish annual financial reports which should provide information on value and quantities of the metal ores that are mined, and especially on the ores grades and the occurrence of coupled production of ores.

255. International sources: It is also recommended to pay special attention to BGS and USGS at least for cross-checking and, if necessary for gap filling.

256. It is generally recommended to use national data sources (preferably mine specific or e.g. geological survey, national production statistics) as a priority for both, metal content and gross ore. Depending on data availability and quality it is useful to combine different data sources.

257. In some cases national information for individual metals may not be satisfactory for different reasons:

- No information is available for a metal;
- Information is not available with the required level of detail e.g. if production statistics (PRODCOM) is used;
- The available information is considered to have questionable accuracy after crosschecking with alternative sources or due to other plausibility checks (e.g. consistency of time series, plausibility with respect to monetary information from supply and use tables from national accounts and structural business statistics).

258. In cases of lack or non-satisfactory quality of national data sources it is proposed to refer to the above-mentioned international data sources, preferably to USGS.

259. In some cases it may also be useful to combine USGS (or BGS) data on metal content, which cover the complete national production, with information on ore grades from annual business reports of mining companies.

The concept of gross ore 'run-of-mine'

260. As mentioned before (paras. 67ff.) for the purpose of EW-MFA, extraction of metal ores is measured as gross ore 'run-of-mine' which refers to the metal containing material as extracted, before any separation or concentration.

Conversion factors

261. Data on the production output volumes of metal mining that are used by EW-MFA compilers may refer to different measurement concepts: gross ore 'run of mine', ore concentrate, or pure metal content. It might be necessary to convert data into amounts of gross ore 'run-of-mine'.

262. As already mentioned, PRODCOM usually reports tonnes of 'ore concentrates'. Other sources such as BGS and USGS usually report tonnes of 'metal content'. Therefore most of the original data cannot be used directly, but have to be converted into the required EW-MFA reference unit 'gross ore run-of-mine' using appropriate conversion factors.

263. In general one has to distinguish two types of conversion factors:

- from metal content towards gross ore run of mine;

- from ore concentrate towards gross ore run of mine.

264. Conversion factors may differ substantially from mine to mine and from year to year. Therefore those factors should be derived from national sources, preferably on the basis of information from individual mines. Partly, conversion factors can also be obtained from USGS country tables or from literature. See for example: Bureau of Mines (1987).

265. When specific national conversion factors are not available, general conversion factors may be applied as a default setting. The general conversion factors provided in Table 11 are predominantly based on annual business reports for about 160 metal mines. They should be used only as a last option because they do not take into account variations across mines and time.

Table 11: General conversion factors from metal content towards gross ore, and ore concentrate towards gross ore 'run-of-mine'

Metal	**% of pure metal content in gross ore** *(to convert from 'metal content' towards 'gross ore run of mine')*	**% of concentrate content in gross ore** *(to convert from 'ore concentrate' towards gross ore 'run-of-mine')*
Iron	43.32	81.93
Copper	1.04	3.33
Nickel	1.83	23.45
Lead	11.86	16.52
Zinc	8.34	14.5
Tin	0.24	0.33
Gold	0.00021	0.0663
Aluminium	18.98	67.55
Silver	0.034	2.552
Uranium	0.0015	0.3744
Antimony	NA	NA
Bismuth	NA	NA
Cadmium	NA	NA
Chromium	25.7	67.79
Cobalt	0.77	9.9
Germanium	NA	NA
Manganese	35.88	58.52
Mercury	NA	NA
Strontium	NA	NA
Titanium (Ilmenite)	9.09	15.97
Titanium (Rutile)	1.96	2.06
Tungsten	0.39	1.23

Molybdenum	0.13	0.24

Source: Schoer et al., 2012

266. Example: A country has a domestic extraction of 14 535 kg iron concentrate. To convert it into the required EW-MFA reference unit (gross ore run of mine), the second column of Table 11 should be used. The correct calculation is the following:

100 / 81.93 * 14 535 kg 'ore concentrate' = 17 741 kg 'gross ore run of mine'

Coupled production

267. Coupled production refers to the case where a gross ore contains two or more metals. Care must be taken to ensure that the same 'gross ore run-of-mine' amount is not accounted for several times. For example, lead is often associated with zinc, or tin is often associated with copper in the same deposit.

268. The occurrence of coupled production should be identified on a mine by mine basis by referring to annual business reports. That information is also partly reported in the USGS country reports.

269. In the case that coupled production has been identified for two or more metals, a specific calculation model has to be applied to count the respective gross ore only once and to assign it to the two or more metals. The calculation approach suggested in this guide is predominantly based on the value relationships of the metals which are mined in coupled production.

Calculation approach:

- ***Step 1: Calculation of the amount of 'gross ore run-of-mine' for a coupled production setting ('total gross ore')***

270. Whenever the amount of 'gross ore run-of-mine' of a coupled production setting (in the following: total gross ore) cannot be obtained from the primary data source, it could be calculated by dividing the production output volume of one of the co-mined metals by the specific conversion factor[36] (see paras. 261ff.).

total gross ore [t gross ore run-of-mine] =
production output volume of metal [t metal content] / conversion factor [t metal content / t gross ore]

or

total gross ore [t gross ore run-of-mine] =
production output volume of metal [t ore concentrate] / conversion factor [t ore concentrate / t gross ore]

271. However, calculating the gross ore like this for each of the co-mined metals will most likely lead to different results due to possible incoherencies of the conversion factors (as it is illustrated in example 1 of Table 13.

272. Table 13In order to obtain an unambiguous result a rule has to be established for estimating the total gross ore. For that purpose it is suggested to identify the ‘main metal’ by using the value criterion.

[36] 'From metal content towards gross ore' or 'from ore concentrate towards gross ore'; depending on the reference unit reported/available in the primary data source

273. The 'main metal' of a coupled production is that metal with the highest production output value. If the primary data source does not provide the value for the extracted amounts (i.e. production output value) by each metal, one can estimate it using specific prices. The production output volume of the extracted metal (in a given reference unit, e.g. metal content in tonnes) is multiplied with a specific price. As the focus is not on correct absolute values but on the values in relation to the other co-mined metals, it is suggested to apply long term average prices from USGS sources (see Table 12). Long-term averages have the advantage of widely neutralising short-term fluctuations.

Table 12: Metal prices in the United States, average 1990-2009 (USD per tonne metal content)

Metal	USD per tonne metal content
Iron	44
Copper	3 382
Nickel	12 362
Lead	1 270
Zinc	1 542
Tin	9 721
Gold	14 008 593
Silver	230 197
Aluminium	1 827
Strontium	849
Antimony	3 261
Bismuth	11 801
Cadmium	2 674
Chromium	1 338
Cobalt	37 888
Germanium	1 110 515
Manganese	876
Mercury	7 932
Titanium	11 020
Tungsten	16 762
Molybdenum	21 426

Source: USGS, 2014

- ***Step 2: Allocation of total gross ore to the various single metals of a coupled production setting***

274. The total gross ore amount – identified in step 1 – needs to be attributed to the different metals mined in a coupled production setting. This can be done by using the production output value relationships between the metals co-mined. For example, for metal m_1, the attributed fraction of total gross ore (gm1) should be calculated as follows:

$$gm_i = \text{total gross ore in } [t] \frac{vm_i}{(vm_1 + vm_2 + \ldots + vm_n)}$$

where gm_i is the fraction of the total gross ore attributable to the extraction of metal m_i.

vm_i is the value of the metal *i*

275. Table 13 presents two numerical examples for the suggested calculation approach.

276. In example 1, copper is identified as the 'main metal' as its production output has the highest value (column 4 = 1 945 million USD). The total gross ore is therefore set to 30 423 million tonnes (column 7). That amount is allocated to the individual metals (column 8) using the value relations (column 6) as a key.

277. In example 2, zinc is identified as the 'main metal' as its production output value (column 4) is highest among the co-mined metals. Therefore it is assumed that the total gross ore of this coupled production setting is 3 714 million tonnes (column 7). That amount is distributed over the individual co-mined metals (column 8) using the output value relations (column 6).

Table 13: Coupled production: allocation of total gross ore to various co-mined metals

	Conversion factor from metal content towards gross ore	Production output volume	Specific price (average 1999-2009)	Production output value (metal content x specific price)	Production output value - % in total	Total gross ore (calculated for each co-mined metal))	Total gross ore, based on 'main metal' (metal with the highest contribution to the total output value)	Total gross ore, allocated by value relations
	1	2	3	4 = 2 x 3 / 1000	5	6 = 2 / 1 x 100	7 = 6 according to ranking in 4	8 = 5 x 7
	% of pure metal content in gross ore	1000 tonnes metal content	USD / tonne metal content	Million USD	%	1 000 tonnes	1 000 tonnes	1 000 tonnes
	Example 1							
Copper	1.89	575	3 382	***1 945***	95	30 423	***30 423***	28 927
Lead	0.10252	31	1 270	39	2	30 238		586
Gold	0.000001675	0.00005	14 008 593	1	0	2 985		10
Silver	0.000864165	0.263	230 197	61	3	30 434		901
Total		606.3		2 045	100			30 423
	Example 2							
Lead	1.7	69	1 270	88	16	4 059		583
Zinc	4.2	156	1 542	***241***	43	3 714	***3 714***	1 600
Silver	0.02689	1	230 197	230	41	3 719		1 531
Total		226		558	100			3 714

Source: numerical examples based on USGS data for Poland

4.4. Domestic extraction of non-metallic minerals (Table A)

278. Domestic extraction of non-metallic minerals (MF.3) records material flows from the environment to the economy related to mining and quarrying of mineral material other than metals and fossil energy carriers such as stone, sand, clay, salt etc. It refers to the extraction from a mine or quarry, but also dredging of alluvial deposits, rock crushing and the use of salt marshes. Non-metallic minerals are used most notably in construction (e.g. sands, gravel, stones etc.), manufacture of mineral products (e.g. glass, cement etc.), or manufacture of chemicals (e.g. mineral fertilisers).

279. The intention of EW-MFA is to measure domestic extraction of non-metallic minerals at the point where the respective mineral-containing material crosses the boundary between the natural environment and the national economy (see paras. 81ff). In EW-MFA the so-called 'run-of-mine' amount is accounted for (see paras. 114ff.) which is the mineral-containing material before any further separation or concentration. In the case of non-metallic minerals

280. If available, data on the 'run-of-mine' amounts should be used. Official statistics, however, may be only available for the production output of quarrying activities. In the case of non-metallic minerals statistics on the production output from non-metallic mineral quarrying can be used to approximate the 'run-of-mine' amounts. The underlying assumption is made that there is not much quantitative difference between the amounts extracted and those leaving the gate of the quarry in form of ready-to-sale products.

281. Domestic extraction of non-metallic minerals represents by far the biggest material category with almost 60 % of total domestic extraction in the European Union. It amounts to about 6 tonnes per capita in 2016. Over the last 17 years it has been up and down, much depending on the business cycles of construction activities. At the start of the economic crisis in 2008 it was at its maximum with almost 9 tonnes per capita.

282. Natural deposits of non-metallic minerals are available all over Europe and their mining and quarrying takes place in all European countries. In 2013, more than 16 000 enterprises are counted for the EU-28 in the NACE Rev.2 industry *B08 – Other mining and quarrying*, of which about 75 % are small sized, i.e. less than 10 employees (see the Eurostat dataset Annual enterprise statistics by size class for special aggregates of activities).

4.4.1. Classification overview

283. The material flow classification of non-metallic minerals (MF3; see Annex A[37]) has been developed as a kind of compromise based on classifications that can be found in relevant data sources (see next section). Unlike in the cases of metals and fossil fuels the various classifications are not very coherent. And there is a risk that the unambiguous placement of certain non-metallic minerals data can be difficult.

284. The material classification of non-metallic minerals used in EW-MFA is maybe closest to the Statistical Classification of Products by Activity in the European Economic Community (CPA) and the related PRODCOM classification. Products are identified in PRODCOM by an 8-digit code: the first four digits are the classification of the producing enterprise given by the NACE classification and the first six correspond to the CPA classification; the remaining digits specify the product in more detail. Correspondences of MF.3 codes towards PRODCOM and other classifications are provided in Annexes 2 and 3 to the EW-MFA questionnaire.

285. The item 'Excavated earthen materials (including soil), only if used (optional reporting)' (MF.3.A) – included in Annex III of Regulation (EU) No 691/2011 as optional reporting – is not

[37] It is important to keep in mind that the category “domestic extraction of non-metallic minerals” does not include the extraction of gases from the atmosphere for industrial purposes, such as the extraction of nitrogen in the Haber-Bosch process. These flows, if quantitatively important, are accounted for as 'balancing items' (see section 4.8)

covered by the CPA and the further detailed PRODCOM classifications. Data compilation for this item is particularly challenging (see paras. 338ff.) and only a few countries estimate this item and report it to Eurostat. Because data for this item are incomplete and hence not comparable it is currently excluded from aggregates of domestic extraction over all materials and hence not included in derived EW-MFA indicators such as DMC and DMI.

4.4.2. Data sources

286. There are various sources potentially providing data on the physical output of mining and quarrying of non-metallic minerals which is used to approximate respective natural inputs. Unfortunately, various data sources are not always reporting coherent data; similar to those used for compiling domestic extraction of metal ores.

Production statistics

287. National and Eurostat production statistics (PRODCOM) provide comparable data at the national and the European level on the production output from mining and quarrying of non-metallic minerals. However, the completeness of production statistics varies considerably across countries and years.

288. PRODCOM reports both, physical data for volume sold and total volume. Data on total volume are more comprehensive as they comprise also extracted mineral materials which are not sold but used for intermediate consumption within the extracting establishment. Therefore, as far as PRODCOM data are used, the data on 'total volume' and not on 'sold volume' should be used for the purpose of compiling figures on domestic extraction.

289. PRODCOM, and also other sources, may typically under-report the extraction of so-called bulk mineral materials, i.e. materials which are mainly used for construction purposes, like sand and gravel or crushed stones and clay for manufacturing of brick. There are two main reasons for those statistical gaps: Significant amounts are not covered because the extracted materials do not enter the market but are used within the extracting establishment for further processing (intermediate consumption e.g. in construction or brick manufacturing). Secondly, bulk minerals are extracted by small establishments which are not surveyed. These data gaps (under-reporting) have to be closed by further information or by estimation models (see below).

290. Compared to bulk minerals mainly used for construction, other minerals which are predominantly used for industrial purposes are usually covered rather well in the production statistics and other sources.

291. Further the PRODCOM has some major practical and conceptual gaps:

- Values may be removed for confidentiality reasons;
- PRODCOM is designed for achieving a coverage of at least 90 % of the national production (value); small scale companies which employ less than 20 people are excluded;
- PRODCOM does not cover all industries, i.e. extraction of minerals by some industries that are out of scope of PRODCOM - such as agriculture, trade and transport – is not recorded in PRODCOM.

Other data sources

292. Other information useful to obtain comprehensive data on domestic extraction of minerals may be available from industrial associations e.g. for gravel and sand industry, natural stones industry, or cement industry. These data sources may include estimates in order to reach full coverage, for example including small scale enterprises not considered by other statistics. In case statistics from industrial associations or related data sources are used, it should be ensured that they report the same items consistently over time. In some cases, however, data about minerals for construction will have to be estimated as described below.

293. Further information may be available from specific national data sources on mining, such as statistics from ministries, geological surveys and from industrial associations. Annual business reports of individual mining companies may also provide data.

294. In addition to national mining statistics, important international sources are the data collections of BGS and USGS (see also section about metals, paras. 244ff.). BGS and USGS data represent estimates which are the results of comprehensive cross checking of various data sources.

Inconsistent classification systems between various data sources

295. A correspondence table between the EW-MFA classification for non-metallic minerals (MF.3) and the PRODCOM classification, and the lists of materials in BGS and USGS can be found in Annex 3 of the EW-MFA questionnaire. It has to be noted that the relationship between PRODCOM on the one hand and BGS and USGS on the other hand is not straightforward in all cases, as BGS and USGS do not clearly follow any established statistical product classification. An unambiguous comparison turns out to be especially difficult for bulk minerals used for construction purposes and for limestone.

4.4.3. Data compilation

General approach

296. The country level information on the mining output of individual non-metallic minerals may differ substantially from source to source. Therefore it is highly advisable to consult and evaluate not only one but all available sources for arriving at balanced and realistic estimates. National sources should be used with priority but it is recommended to use BGS and USGS to crosscheck and fill gaps

297. The risk that various data sources provide significant differences is particular high for 'sand and gravel' (MF.3.8) which is by far the quantitative most important item (about 2/3 of domestic extraction of non-metallic minerals). Production statistics which often cover only enterprises with more than 10 employees may report too low amounts of sand and gravel production. It is recommended to cross check with reports or other information sources by industry associations representing the sand and gravel industry.

Run-of-mine concept

298. The run-of-mine concept concerns particularly metals (see paras. 67ff.), but it holds true for all non-metallic minerals as well. For minerals other than metallic ores, it may generally be assumed that the difference between run-of-mine production and reported production is not relevant.

299. Non-metallic minerals have low moisture content that is usually not subject to high variability. Therefore data for the extraction of minerals are simply taken as they are reported. Salt (MF.3.5) is a special case, see below.

Conversion from cubic metres to tonnes

300. In most data sources data on mining output of non-metallic minerals are reported in mass unit. However, some statistics may provide data in cubic metres (m^3). Those data have to be converted to tonnes. Table 14 provides conversion factors for selected materials.

Table 14: Specific densities of selected non-metallic minerals (tonnes per cubic metre)

Material	Tonnes per cubic metre
Ornamental and building stone	
Marble, solid	2.563
Granite, solid	2.691

Material	Tonnes per cubic metre
Sandstone, solid	2.323
Porphyry, solid	2.547
Basalt, solid	3.011
Stone (default value if no other specifications are available)	2.5
Chalk and dolomite	
Chalk, lumpy	1.442
Dolomite, lumpy	1.522
Chalk and dolomite (default value if no other specifications are available)	1.5
Slate	
Slate, solid	2.691
Slate, broken	1.29 - 1.45
Slate, pulverised	1.362
Slate (default value if no other specifications are available)	1.4
Limestone and gypsum	
Gypsum, crushed	1.602
Limestone, broken	1.554
Limestone (default value if no other specifications are available)	1.5
Clay	
Clay, dry excavated	1.089
Clay, wet excavated	1.826
Clay, dry lump	1.073
Clay, fire	1.362
Clay, wet lump	1.602
Clay, compacted	1.746
Clay (default value if no other specifications are available)	1.5
Sand and gravel	
Gravel, loose, dry	1.522
Gravel, with sand, natural	1.922
Gravel, dry 1,3 to 5,1 cm	1.682
Gravel, wet 1,3 to 5,1 cm	2.002
Sand, wet	1.922
Sand, wet, packed	2.082

Material	Tonnes per cubic metre
Sand, dry	1.602
Sand, loose	1.442
Sand, rammed	1.682
Sand, water filled	1.922
Sand with Gravel, dry	1.65
Sand with Gravel, wet	2.02
Sand and gravel (default value if no other specifications are available)	1.9

Source: SIMETRIC Standard to Metric Conversion Factor Tables: Mass and Density of Materials

Description of material classes and specific compilation issues

Marble, granite, sandstone, porphyry, basalt, other ornamental or building stone (excluding slate) – MF.3.1

301. This category comprises almost any competent rock type that may be used in the form of shaped and/or sized blocks for either structural or decorative purposes. It includes marble and other calcareous ornamental or building stone (e.g. travertine, ecausine, limestone and alabaster), and granite, sandstone, and other ornamental or building stone (e.g. porphyry, basalt), as well as roofing stone and may even include slate, which should, however, be counted under MF.3.3.

Chalk and dolomite – MF.3.2

302. Chalk is a soft, white, porous form of limestone composed of the mineral calcite. It is also a sedimentary rock. Uses are widespread and comprise blackboard chalk, to mark boundaries, in sports, applied to the hands or to instruments to prevent slippage, and as tailor's chalk.

303. Dolomite (also dolostone) is a carbonate rock composed by the mineral dolomite (calcium magnesium carbonate = $CaMg(CO_3)_2$). It is mainly used as ornamental or building stone.

304. Limestone (see below para. 314ff.) is another carbonate rock which is often combined with dolomite in statistical reporting.

Slate – MF.3.3

305. Slate is a fine-grained, homogeneous, metamorphic rock derived from an original shale-type sedimentary rock composed of clay or volcanic ash through low grade regional metamorphism. Slate can be made into roofing slates, also called roofing shingles. Fine slate can also be used as a whetstone to hone knives. Because of its thermal stability and chemical inertness, slate has been used for laboratory bench tops and for billiard table tops. Slate tiles are often used for interior and exterior flooring, roofing or wall cladding.

Chemical and fertiliser minerals – MF.3.4

306. This group of minerals mainly comprises:

307. Natural calcium or aluminium calcium phosphates, often combined under the heading 'phosphate rock'. Most of it (over 90 %) is used to produce fertilisers; the remainder is used in the production of detergents, animal feedstock, and many other minor applications.

308. Carnallite, sylvite, and other crude natural potassium salts are often combined under the

heading 'potash'. Potassium is essential in fertilisers and is widely used in the chemicals industry and in explosives. Data for potash are often reported in K_2O contents. In this case, as for metals, the run-of-mine production has to be calculated to obtain the used domestic extraction. Germany is by far the biggest producer of potash in the EU and the third biggest in the world. The K_2O content in run of mine production of potash in Germany is about 55 %.

309. Unroasted iron pyrite which is an iron disulfide. Pyrite is used for the production of sulphur dioxide, e.g. for the paper industry, and in the production of sulphuric acid, though such applications are declining in importance.

310. Crude or unrefined sulphur is a fundamental feedstock to the chemical industry. Please note that not all domestic sulphur production is accounted for in class MF.3.4. For the purpose of EW-MFA three principle types of sulphur can be distinguished: (i) Sulphur from mining: This sulphur should be accounted for in category MF.3.4. (ii) Sulphur produced in the refinery through desulphurisation of petroleum resources. This sulphur is included in the amounts of extracted fossil energy materials/carriers and should not be reported under MF.3.4. (iii) In some cases sulphur can occur as an unused by-product of the extraction of petroleum resources. This sulphur is considered unused extraction (SEEA-CF: natural resource residuals, see para.48) and is not accounted for in EW-MFA.

311. Other chemical minerals are mainly:

- Baryte, which is used in a variety of industries for its properties of high specific gravity;
- Witherite, a barium carbonate mineral which is the chief source of barium salts and is mined in considerable amounts in Northumberland. It is used for the preparation of rat poison, in the manufacture of glass and porcelain, and formerly for refining sugar;
- Borates, which are chemical products from borate minerals, which are e.g. used as wood preservatives. Borate minerals contain the borate anion, BO33-, the most common borate mineral is boron;
- Fluorspar (fluorite) is a colorful mineral which is industrially used as a flux for smelting, and in the production of certain glasses and enamels.

Salt – MF.3.5

312. This material class concerns sodium chloride (NaCl). Salt may be produced from rock salt, brine or seawater. It is used for human consumption, in the chemical industry, or to ‘grit’ roads to prevent the formation of ice.

313. Using brine for salt production is quite a common technology to extract salt from salt caverns in the earth crust. With this technology fresh or recycled water is pumped into salt caverns, the salt dissolves in the water up to its saturation and is pumped up to the surface. About 80 % of salt for the chlorine production in Europe is from brine. It is recommended to calculate salt in brine as dry weight and always with a concentration of 26 % salt in brine.

Limestone and gypsum – MF.3.6

314. Limestone is a carbonate rock composed mainly of the minerals calcite and aragonite, which are different crystal forms of calcium carbonate ($CaCO_3$).Limestone which is used for industrial purposes (e.g. production of lime or cement) is reported in this material class MF.3.6 whereas crushed limestone aggregate is allocated to class MF.3.8 and limestone as ornamental or dimension stone is assigned to class MF.3.1.

315. Limestone requires special attention in the account for non-metallic minerals. Statistics often underreport amounts of limestone extracted for construction purposes, in particular for cement production. Often cement manufacturers extract limestone from own quarries. These amounts are potentially not reported in production statistics (the latter may only report the output of cement). This position, however, commonly represents a large mass flow representing a considerable share of total domestic extraction of non-metallic minerals.

316. To check and if necessary correct for missing limestone extraction for cement production, the following estimation based on (finished) cement production can be applied. The factor 1.19 comes from the German Federal Institute for Geosciences and Natural Resources (BGR).

Limestone for cement production [t] = cement production [t] * 1.19

317. Data for cement production can be obtained from production statistics (see Table 15 for respective PRODCOM codes).

Table 15: Cement production in PRODCOM

PRODCOM code	Description
23.51.12.10	Grey Portland cement (including blended cement)
23.51.12.90	Other hydraulic cements

318. It is recommended to compare the estimated figure for limestone extraction for cement with the figure for limestone reported in production statistics. The higher number should be selected as data for the domestic extraction of limestone (with a tolerance of about 10 % in favour of using the original statistics). If limestone for other use than for cement is clearly indicated in statistics (e.g. bedding aggregate for road construction), this figure has to be added to the estimate for limestone for cement.

319. In the case of cement production, limestone may be partially replaced by dolomite which is referred to as dolomitic limestone. Please note that in case data for limestone are derived from an estimate described above data reported for dolomite under MF.3.2might have to be corrected for double counts (if the data source used for MF.3.2 'dolomite' should include parts which are used for cement production, they need to be deducted from MF.3.2). It is recommended to consult a national expert for clarification of this issue.

320. A compilation tool is provided in the sheet *limestone v1* of the EW-MFA questionnaire.

Clays and kaolin – MF.3.7

321. Kaolinite is a clay mineral. Rocks that are rich in kaolinite are known as china clay or kaolin. Other kaolinic clays are kaolin minerals such as kaolinite, dickite and nacrite, anauxite, and halloysite-endellite.

322. The largest use of kaolin is in the production of paper, as it is a key ingredient in creating “glossy” paper (but calcium carbonate, an alternative material, is competing in this function). Other uses of clays and kaolin are in ceramics, medicine, bricks, as a food additive, in toothpaste, in other cosmetics, and since recently also as a specially formulated spray applied to fruits, vegetables, and other vegetation to repel or deter insect damage.

323. In statistics, kaolin may be grouped together with other clays under the heading 'industrial or special clays'. Other industrial or special clays can be: ball clay, bentonite, attapulgite, ceramic clay, fire (refractory) clay, flint clay, fuller’s earth, hectorite, illite clay, palygorskite, pottery clay, saponite, shale, and slate clay.

324. Kaolin and other special clays used for industrial purposes are commonly well documented in statistics. Clay and loams for construction are often not or under-represented in production statistics because manufactures of bricks and tiles may operate their own quarries and report only the

production output of bricks and tiles.

325. To check for this, data on the volume of production of products manufactured from clay can be used to estimate the use of crude clay. Preferably specific national sources should be used for converting the data on production of products manufactured from clay into amounts of crude clay. If those national sources are not available conversion factors as shown in Table 16 could be used.

Table 16: PRODCOM codes and conversion factors for manufacture of bricks, tiles, and construction products, in baked clay

PRODCOM		Unit	Conversion factors original units to tonnes of product	Conversion factors tonnes of raw clay to tonnes of product	Conversion factor product in original units to tonnes of raw clay
Code	Description				
23.32.11.10	Non-refractory clay building bricks (excluding siliceous fossil meals or earths)	m³	0.74 m3 = 1 t of product	1.349	0.998 1 m3 = 1.349/0.74 t raw clay
23.32.11.30	Non-refractory clay flooring blocks, support or filler tiles and the like (excluding siliceous fossil meals or earths)	kg	1 000 kg = 1 t of product	1.349	1 349
23.32.12.50	Non-refractory clay roofing tiles	pieces	421.9 pieces = 1 t of product	1.349	569 1 piece = 1.349/421.9 t raw clay
23.32.12.70	Non-refractory clay constructional products (including chimneypots, cowls, chimney liners and flue-blocks, architectural ornaments, ventilator grills, clay-lath; excluding pipes, guttering and the like)	kg	1 000 kg = 1 t of product	1.349	1 349
23.32.13.00	Ceramic pipes, conduits, guttering and pipe fittings: drain pipes and guttering with fittings	kg	1 000 kg = 1 t of product	1.349	1 349

326. The individual clay product groups in PRODCOM are shown in different units like m^3, kg or piece. The table shows the estimated average conversion factors to tonnes of crude clay for clay products as reported in PRODCOM. The general conversion factor from kg of clay product to tonnes of crude clay was obtained by a study on 12 brick factories in Germany, Austria and Switzerland (Bruck 1996). See also Swiss Federal Statistical Office (Bundesamt für Statistik 2005). According to this study 1.349 tonnes of clay are required for producing 1 tonne of clay product. PRODCOM reports bricks and roofing tiles rather in cubic metres and/or pieces than in kg. Hence, bricks have to be converted from cubic metres to tonnes and roofing tiles from pieces to tonnes. The conversion factor for brick has rather a wide range depending on the type of brick, ranging from clinkers over solid bricks to cellular or hollow bricks. For the purpose of the above conversion table a factor of 740 kg/m^3 is suggested. That factor is an average value in an environmental declaration for brick by the

Institut Bauen und Umwelt e.V. according to ISO 14025. The conversion factor for roofing tiles was derived from Eurostat's international trade in goods statistics (ITGS). ITGS reports roofing tiles in pieces as well as in kg. The suggested factor was estimated as an average of all imports and exports of roofing tiles during the period 2000 to 2009 for EU 27 (2.37 kg per piece).

327. The estimation result should be compared with the figures for common clays and loams extraction reported in statistics (excluding industrial or special clays). The higher number should be selected as data for the domestic extraction used of common clay and loam (with an eventual tolerance of about 10 % for using the original statistics figure). A compilation tool is provided in the sheet '*Clay v1'* of EW-MFA questionnaire.

Sand and gravel – MF.3.8

328. There are two major groups of sand and gravel (sometimes also subsumed under the notion natural aggregates) which are distinguished by their principal uses:

- Industrial sand and gravel: Industrial sands and gravels show specific material properties that are required for use in iron production and manufacturing including fire resistant industrial use in glass and ceramics production, in chemical production, for use as filters, and for other specific uses. Statistical data sources (e.g. the USGS) often report the amount of sand and gravel in industrial production processes explicitly.
- Sand and gravel for construction: Sand and gravel for construction is used in structural engineering (e.g. buildings) and civil engineering (e.g. roads and other infrastructures). Use of sand and gravel in structural engineering is mainly for the production of concrete. In civil engineering gravel is mainly used for different kinds of layers in road construction, in concrete elements and for asphalt production.

329. Statistics for sand and gravel may not report the total amount extracted for both industrial and construction use adequately. Often, only special sand and gravel for industrial use is included (see above). Statistics also may report numbers for sand and gravel for construction but not report total numbers due to e.g., exclusion of small scale enterprises from the survey. Construction enterprises may operate their own quarries the production output of which may not be reported. To find out if sand and gravel is not adequately reported or underestimated in statistical data sources, the following checks can be performed:

330. The amount of sand and gravel per capita of the population in the respective year can be taken as an indicator. As a rule of thumb, if this amount is significantly below 1 tonne per capita, it can be assumed that sand and gravel for construction purposes is not adequately reported and has to be estimated. Additionally stakeholders and experts concerned with this economic activity should be consulted to clarify the significance of the reported numbers. If no adequate statistical data are available, the total amount of sand and gravel extracted for construction can be estimated.

331. The following simple procedure to estimate the amount of sand and gravel for construction – a compilation tool is provided in the EW-MFA questionnaire (*'Sand and gravel v1'* sheet) – takes into account the two most important uses of sand and gravel. It combines an estimate of sand and gravel required for the production of concrete (step 1) with an estimate of sand and gravel used in layers in road construction (step 2). In step 3 the total amount of sand and gravel is calculated as the sum of the results obtained from step 1 and step 2.

- ***Step 1: Estimation of sand and gravel required for the production of concrete***

Concrete is a mixture of Portland cement, gravel or crushed stone (coarse aggregate), sand, and water[38].Sand and gravel make up about 67 % of the produced concrete. Based on these relations two ways for calculating sand and gravel required for concrete production are possible:

[38] Portland Cement Association: Cement & Concrete Basics

- ***Method 1a) Estimate of sand and gravel based on concrete production data:***

Sand and gravel input [t] = concrete production [t] * 0.67

where data on concrete production can be obtained from production statistics (PRODCOM code 23.63.10.00 – Ready-mixed concrete); in general, method 1a) tends to underestimate the amount of sand and gravel, because concrete reported in statistics commonly refers to transport concrete (ready-mixed) and does not include concrete produced directly at the construction site.

- ***Method 1b) Estimation of sand and gravel based on the consumption of cement:***

The required input of sand and gravel to produce one tonne of concrete is 6.09 times the input of cement.[39] Accordingly, sand and gravel input into concrete production can be calculated as follows:

Sand and gravel input [t] = cement (apparent consumption) [t] * 6.09

where apparent consumption of cement can be derived from data on production of and trade with cement:

cement (apparent consumption) = cement production + cement imports – cement exports

Data on cement flows can be obtained from statistical sources. For covering production the PRODCOM items for cement in Table 15 have to be considered. Trade flows include the CN-items 25.23.21 (White Portland cement, whether or not artificially coloured); 25.23.29 (Portland cement, excl. white, whether or not artificially coloured); 25.23.30 (Aluminous Cement); 25.23.90 (Cement, whether or not coloured; excl. Portland cement and Aluminous cement).

- ***Step 2: Estimation of sand and gravel for road layers (freezing protection and carrying layers)***

332. It is possible to estimate the amount of sand and gravel used in road construction based on information on the length of newly built roads (by type of road and year). Sand and gravel required for annual maintenance of the total existing kilometres of roads should also be included. Data on the length and enlargement of the road network are commonly provided by national transport or road statistics and Eurostat online database (Road transport infrastructure).

333. In addition to information on the length of the road network, data on the amount of sand and gravel required to build one kilometre of a certain road type have to be acquired. Table 17 provides data on sand and gravel requirement per km for construction and maintenance for German roads.

[39] See footnote 38

Table 17: Requirements of sand and gravel per km of road construction in Germany

	Tonnes sand and gravel per km		Reference data	
	for construction	for annual maintenance	average width in m	total length in km
Highways	28 383	518	24.4	12 531
National roads	9 692	151	8.8	40 711
Federal state roads	8 719	76	7.5	86 597
District roads	6 777	65	6.5	91 520
Local roads	5 729	67	5.5	460 000
All roads	6 886	81	6.4	691 359

Source: Ulbricht, 2006; Steger et al., 2009

334. Those German coefficients can be used to estimate the sand and gravel consumption for construction and maintenance of roads in other European countries. However, when doing so, it has to be considered that German road standards may be different from other European countries. Information on average width of roads compared to German roads (see Table 17) could be useful when applying German coefficients for other countries. Other factors, such as different requirements for frost protection, should be considered too.

- ***Step 3: comparison with official statistics***

335. Estimated figures for sand and gravel for concrete production (step 1) and sand and gravel for road construction (step 2) are finally added and compared with the figure for sand and gravel reported in statistics. The higher number should be selected as data for the domestic extraction of sand and gravel for construction (with an eventual tolerance of about 10 % in favour of using the original statistics figure). If sand and gravel for industrial uses is given as a specific position in statistics, this figure has to be added to the estimated figure.

336. The use of recycled sand and gravel should also be taken into account and subtracted.

Other non-metallic minerals n.e.c. – MF.3.9

337. This is a mixed material class of non-metallic minerals that essentially comprises all minerals not covered by the previous classes. Some of the minerals that are allocated to MF 3.9 are listed below.

- Graphite, a stable form of pure carbon, is mainly used in refractories;
- Quartz and quartzite are special qualities of silicon used e.g. in the optical industry or in metal manufacturing;
- Siliceous fossil meals such as Kieselgur, Tripolite, Diatomite and other siliceous earths, used e.g. as absorption agent or material for heat insulation;
- Steatite and talc are magnesium silicate minerals, used for several industrial purposes;
- Feldspar is an essential component of glass and ceramic manufacture.

Excavated earthen materials (including soil), only if used (optional reporting) – MF.3.A

338. The item ‘Excavated earthen materials’ denotes material such as e.g. soil which is excavated

and further used in economic activities, e.g. in construction. According to Regulation no. 691/2011 it is only for optional reporting and therefore it is not included in the aggregate of domestic extraction nor in the derived EW-MFA indicators DMI and DMC.

339. This item is not a typical product and hence not covered by CPA and PRODCOM. It is difficult to measure and identify what is further used in economic activities. In its economy-wide EW-MFA for 1980 to 1998, the Italian Statistical Office has reported soil from excavation activities that are reused in construction as material input. So far, standardised estimation procedures for this material flow class are not available (see Barbiero et al., 2003).

Specific issue: crushed rock

340. Several statistical sources use the category ‘crushed rock’ or ‘crushed stone’. Crushed rock is commonly produced as broken natural stones for road-, railway-, waterway-, and buildings construction. A range of natural stone types can be used to produce crushed rock.

341. There is a risk of double-counting when using statistics on 'crushed rock'. Crushing rock is a production process after the mining and quarrying. Crushed rock is the output from crushing to which the output of mining and quarrying forms the input. It is the output of mining and quarrying that EW-MFA compilers are aiming for to approximate the natural inputs recorded under MF.3.

4.5. Domestic extraction of fossil energy materials/carriers (Table A)

342. Domestic extraction of fossil energy materials/carriers (MF.4) records material flows from the environment to the economy related to extraction of solid, liquid and gaseous fossil mineral fuels through underground or open-cast mining, and the operation of crude oil and natural gas fields. Extraction of oil shale and sands is included. The intention of EW-MFA is to measure domestic extraction of fossil energy materials/carriers at the point where the respective material crosses the 'boundary' between the natural environment and the national economy (see paras. 81ff). Data on the extracted amounts of fossil energy materials/carriers are available in form of energy statistics which can be widely used one-to-one for EW-MFA purposes.

343. In the European Union, domestic extraction of fossil energy materials/carriers has been constantly falling from ca. 2.1 tonnes per capita in 2000 to 1.3 tonnes per capita in 2016. Nowadays (2016) fossil energy materials/carriers make up roughly 12 % of total domestic extraction. In the early 2000s this share was at 16 %. Between 600 and 700 enterprises are engaged of which about one fourth is medium to large sized, i.e. with more than 50 employees (see Eurostat dataset Annual enterprise statistics by size class for special aggregates of activities).

4.5.1. Classification overview

344. The classification of fossil energy materials/carriers (see Table 2 and/or Annex A of this handbook) is derived from the classification of energy products in European energy statistics. It is compatible with the relevant NACE and CPA divisions 05 and 06. Moreover, Annex 2 to the EW-MFA questionnaire provides correspondence to the respective codes of Eurostat energy statistics/balances.

345. This classification distinguishes at 2-digit level two main classes: solid energy carriers versus liquid and gaseous energy carriers.

346. Not included are primary renewable energy carriers, such as hydro, wind, solar and geothermal energy because they are immaterial. The domestic extraction of biomass which might be used for energy purposes is reported under the material category of biomass (MF.1). The domestic

extraction of uranium ore, which is used to manufacture nuclear fuels, is reported under the material category of metal ores (MF.2).

4.5.2. Data sources

Energy statistics

347. National and European-wide harmonised energy statistics are the most important data source. They provide production output from mining and extraction of all relevant solid, liquid and gaseous fossil energy materials/carriers. National energy statistics – which are recommended to be used primarily – may deviate slightly from the European energy statistics.

348. It is recommended to consult and carefully study methodological guidelines related to energy statistics when using as a data source for EW-MFA. Eurostat provides guidelines for European energy statistics at its website.

349. In the case of solid energy materials (e.g. coal and lignite) international energy statistics are in line with the concept of 'run-of-mine' (see paras. 114ff.); i.e. amounts of raw materials are accounted before further separation or concentration.

350. International energy statistics report the amounts of extracted crude oil, natural gas liquids (NGL), and natural gas excluding any accompanying water.

351. The extracted amounts of natural gas – reported by international energy statistics – include both 'non-associated' gas originating from fields producing hydrocarbons only in gaseous form, and 'associated' gas produced in association with crude oil as well as methane recovered from coal mines (colliery gas) or from coal seams (coal seam gas). In energy statistics the production outputs of natural gas extraction are usually reported as amounts after purification and extraction of NGLs and sulphur. Extraction losses and quantities reinjected, vented or flared at the extraction site are reported separately in energy statistics. They should be included in the domestic extraction of natural gas (MF.4.2.2).

352. In the case of crude oil, condensate and natural gas liquids (NGL) (MF.4.2.1) and oil shale and tar sands (MF.4.1.3) compilers of EW-MFA may use the respective production amounts reported in energy statistics without any adjustments.

Other data sources (production statistics, geological surveys)

353. Although energy statistics form the major data source for compiling domestic extraction of fossil energy materials/carriers (MF.4), some other potential data sources should be mentioned here. These could be used to cross-check data obtained from energy statistics.

354. National and European-wide harmonised production statistics provide data on the production output from mining and extraction of petroleum resources and other fossil energy carriers.. National or international geological surveys (such as e.g. USGS, BGS) may also provide data on the production output from mining and extraction of fossil energy materials/carriers.

4.5.3. Data compilation

General approach

355. National energy statistics are the preferred data source to compile domestic extraction of fossil energy materials/carriers (MF.4) for EW-MFA. Energy statistics are harmonised at international level (joint annual questionnaires operated by Eurostat and International Energy Agency). It has to be noted that in some cases the national energy statistics may follow their specific principles, concepts and definitions which may deviate from those agreed in internationally harmonised energy statistics.

356. Energy statistics report the production output of mining and extraction of so-called primary

energy commodities – coals, crude oil etc., and natural gas being the main ones. Table 18 introduces the primary energy commodities relevant for MF.4.

Table 18: Primary energy commodities relevant for MF.4

EW-MFA	Product according to European energy statistics		Data set in Eurostat online data base		Product according to Standard International Energy Product Classification - SIEC	
code	name	code	name	code	name	code
MF.4.1.2	Anthracite	2115	solid fuels - annual data	nrg_101a	Anthracite	0110
MF.4.1.2	Coking Coal	2116	solid fuels - annual data	nrg_101a	Coking coal	0121
MF.4.1.2	Other bituminous coal	2117	solid fuels - annual data	nrg_101a	Other bituminous coal	0129
MF.4.1.1	Sub-bituminous Coal	2118	solid fuels - annual data	nrg_101a	Sub-bituminous coal	0210
MF.4.1.1	Lignite/Brown Coal	2210	solid fuels - annual data	nrg_101a	Lignite	0220
MF.4.1.4	Peat	2310	solid fuels - annual data	nrg_101a	Peat	11
MF.4.1.3	Oil shale and oil sands	2410	solid fuels - annual data	nrg_101a	Oil shale / oil sands	2000
MF.4.2.1	Crude oil (without NGL)	3105	oil - annual data	nrg_102a	Conventional crude oil	4100
MF.4.2.1	Natural gas liquids (NGL)	3106	oil - annual data	nrg_102a	Natural gas liquids (NGL)	4200
MF.4.2.1	Other hydrocarbons	3193	oil - annual data	nrg_102a	Other hydrocarbons	4500
MF.4.2.2	Natural gas	4100	gas - annual data	nrg_103a	Natural gas	3000

357. The relevant item recording production output from mining and extraction is termed 'indigenous production' in the IEA/Eurostat energy questionnaires and 'primary production' in the Eurostat online data base. The production output is reported in natural units in the original questionnaires; which are metric tonnes for solid and liquid commodities and cubic metres for natural gas. Eurostat online database reports natural gas in energetic units only (terajoule and tonnes oil equivalents). Conversion factors are presented further below.

Peat

358. All kind of peat is to be reported under MF.4.1.4. It has to be noted that the energy balance excludes peat for non-energetic use. However extraction of peat for non–energetic use (gardening) accounts for a substantial proportion of total peat extraction. Therefore the energy statistics figures have to be supplemented for extraction of peat for non-energetic use. As far as no national sources are available for that purpose, USGS can be used as a data source.

359. If peat data are reported in cubic metres the following conversion factor can be used (UN, 1987):

$$1\ m^3 = 0.753\ t$$

Natural gas

360. International energy statistics separately report (as memo item) natural gas that is lost at extraction and quantities reinjected, vented or flared at the extraction site (see also para. 349). Notably, they should be included in the domestic extraction of natural gas (MF.4.2.2).

361. Production output from natural gas extraction is most likely reported in cubic metres and/or energetic units (terajoule or tonnes of oil equivalents). Hence, data on natural gas have to be converted into tonnes. Preferably country specific conversion factors should be applied, as the technical characteristics of natural gas vary from region to region (see below). If that specific information is not available, general factors could be used (see Table 19).

Table 19: Calorific value and density of natural gas of fossil energy carriers

	kg / m³ (standard cubic metre at 15°C)	GCV [MJ/kg]	GCV [MJ/m³]
Natural gas (range)	0.76-0.83	36-55	30-45
Natural gas (default value)	0.8	50	40

Source: derived from OECD/IEA/Eurostat, 2005

4.6. Physical imports and exports (Tables B to E[40])

362. EW-MFA record the material flows into and out of an economy. Trade flows are part of it. Physical imports belong to the material inputs and physical exports belong to the material outputs.

363. Physical trade flows are flows of *products* that have mass and volume and can be measured in tonnes[41]. *Products* are clearly defined in national accounts and they constitute one particular physical flow type in the System of Environmental-Economic Accounting Central Framework (SEEA-CF), see e.g. para. 49ff.

364. Physical trade in goods occurs when the transaction involves a change in ownership between a resident unit (see paras. 19ff.) of the reporting country and a non-resident unit. There are two exceptions from this general 'change in ownership' principle where EW-MFA actually record the physical cross-border flow of goods (see paras. 38ff.):

- goods sent abroad for processing, and
- goods under merchanting.

365. Adjustments for the residence principle are required when physical imports and exports are compiled from international trade in goods statistics (see paras. 382ff.).

[40] Currently, two tables recording extra-EU imports (Table C) and extra-EU exports (Table E) are not used (see para. 121)
[41] Products comprise goods and services. Goods are material products; services are immaterial products. Trade flows of services cannot be measured and presented in mass weights (i.e. tonnes) and hence are not included in physical imports and exports as recorded in EW-MFA

366. Notably, in EW-MFA physical imports and exports are recorded in a breakdown by material classes (see paras. 367ff.); i.e. the usual product classifications are not employed.

4.6.1. Classification overview

367. In EW-MFA the physical imports and exports are classified in two ways:

- by type of material: The material categories MF.1 to MF.4 (are the same as those used for domestic extraction (see paras. 81ff. and Table 2). The coherent classification by materials of domestic extraction and physical imports and exports ensures that certain EW-MFA indicators (e.g. DMI and DMC) can be presented in a breakdown by type of material. In addition material categories MF.5 and MF.6 – which solely apply to physical imports and physical exports – accommodate traded products which cannot be assigned to material categories MF.1 to MF.4.
- by stage of manufacturing: traded products are grouped into three broad groupings reflecting their 'stage of manufacturing' (see paras. 389ff).

368. Employing a classification by type of material for physical imports and exports has some important implications. The main data source for compiling physical imports and exports in the context of EW-MFA are international trade in goods statistics (ITGS; see: Eurostat 2016a) which report in monetary as well as physical units. Most importantly, ITGS employ product classifications – in Europe it is the *Combined Nomenclature* (CN). Compilers of EW-MFA need to transpose the ITGS data classified by CN codes towards MF classes.

369. Actually each single CN product group is composed of many types of material. For instance, a motor vehicle includes many materials such as steel, copper, aluminium, plastic, rubber, textiles, glass etc. For the purpose of compiling physical imports and exports a simplified approach is taken: each CN code is assigned to one and only one MF code according to the dominant material[42]. One of the Annexes of the EW-MFA questionnaire provides this one-to-one correspondence between the EW-MFA classification of materials (MF) and the *Combined Nomenclature* (CN).

MF.5 'Other products' and MF.6 'Waste for final treatment and disposal'

370. The majority of the more than 20 000 CN product groups is assigned to the four main material categories MF.1 to MF.4. However, a considerable number of CN products cannot for which specific categories MF.5 and MF.6 have been introduced; see details below (paras. 387 and 388).

MF.4.2.3 'Adjustments for residence principle: Fuel bunkered by resident units abroad (imports) or Fuel bunkered by non-resident units domestically'

371. Some specific and optional items have been added to Table B and D for the adjustment of imports and exports for the residence principle (see paras 383ff. below).

4.6.2. Data sources

372. ITGS[43] are the main data source for compiling physical trade flows in EW-MFA. ITGS cover all flows of material goods as well as waste flows as long as they have a monetary value. Eurostat provides European-wide harmonised statistics on international trade in goods (COMEXT database) which distinguishes about 9 500 subheadings (CN at 8-digit level). National external trade in goods statistics or data bases may offer even more details.

373. The CN classification is up-dated/revised each year. Eurostat ensures that the correspondence between CN and MF codes is also up-dated and made available to EW-MFA

[42] The 'dominant material' is that material which has the highest share (in terms of mass weight) in the material composition of the respective CN product group

[43] At international level the term International Merchandise Trade Statistics (IMTS; see UN 2011) has been established. In the European Statistical System the term International Trade in Goods Statistics (ITGS) has been established recently

compilers (the respective Annex to the EW-MFA questionnaire is up-dated each year before the EW-MFA questionnaire is sent out).

374. Compilers may use national data sources (international trade in goods statistics) which are not classified by CN. The Eurostat Metadata server RAMON (Reference and Management of Nomenclatures) provides a number of correspondences between CN and other classifications which might be helpful in this case.

375. European-wide harmonised statistics on international trade in goods (COMEXT database) report the imports and exports of goods in monetary, physical units, and in supplementary units (only for some goods). The standard physical unit in COMEXT is 100 kilograms.

376. ITGS follow certain concepts that are not fully aligned to the concept, principles and definitions of EW-MFA. Eurostat provides a technical note (*Further clarifying the conceptual treatment of physical imports and exports in economy-wide material flow accounts*, Eurostat 2017a) that gives a detailed overview of the conceptual differences between EW-MFA and ITGS. In particular, compilers of EW-MFA need to adjust external trade data to the residence principle. This concerns mainly the import and export of transport fuels (see paras. 382ff.). For these adjustments compilers of EW-MFA may consult other data sources, such as e.g. balance of payments (BoP) and/or energy statistics.

377. European ITGS (COMEXT database) have one specific feature. They include 'quasi transit' of goods. EW-MFA should exclude 'quasi transit' flows of goods[44] (because no change in ownership to a resident unit of the reporting country). Compilers of EW-MFA should preferably use national data sources for ITGS as those usually record 'quasi transit' separately. Further details on this issue are provided in the already mentioned technical note (*Further clarifying the conceptual treatment of physical imports and exports in economy-wide material flow accounts*, Eurostat 2017a).

4.6.3. Data compilation

378. ITGS can be obtained from national sources as well as from Eurostat's international trade in goods statistics (COMEXT data base) which employ the product classification *Combined Nomenclature* (CN).

Unit of measurement

379. EW-MFA are reported in thousand tonnes. COMEXT data report the imports and exports of goods in monetary and physical units. The standard physical unit is 100 kilograms measured at the point in time when a good crosses an administrative border. For some commodities, data are reported in other physical units such as length (metres), area (square metres), volume (cubic metres, litres), numeric units (pieces, pairs, dozens, packs), or, for electricity, in kilowatt-hours.

380. ITGS data might be available only in other units than kilogram. In this case they need to be converted into kilograms. For some items national conversion factors may be available, for example information from national aircraft and ships registers. If no appropriate national information is available EU level conversion factors for exports and imports which are provided by Eurostat could be applied. See Annex 6 to the EW-MFA questionnaire.

Crosschecking

381. It is recommended to check the plausibility of ITGS data expressed in kilograms. One easy plausibility check is to calculate specific prices (EUR per kilogram) for each ITGS item. This might help to identify errors or data gaps.

[44] Quasi transit in a broader definition denotes goods transported into the reporting country, custom cleared by a non-resident, and subsequently sold and sent to a third country. The good physically enters the country. The ownership does not change to a resident unit but to a non-resident unit who functions as a kind of trader/administrator. The case of quasi transit occurs in particular when a good physically arrives for the first time in the EU custom union. Then it needs to be custom cleared for free circulation in the EU. Often, the agencies carrying out the custom clearance are non-resident units in the reporting country where the good arrives for the first time.

Resident adjustment

382. In case Eurostat international trade in good statistics (ITGS) are used to compile physical imports and exports for EW-MFA, one particular adjustment related to fuels needs to be performed by compilers:

- All kind of transport fuel bunkered by resident units abroad need to be added to the physical imports of fuel reported in ITGS;
- Road transport fuel[45] bunkered by non-resident units on the territory need to be added to physical exports reported in ITGS.

383. The EW-MFA questionnaire provides the additional items MF.4.2.3.1 to MF.4.2.3.3 to accommodate the adjustments for the residence principle if appropriate. Please be aware that these items are only needed if the remaining items of category MF.4 are un-adjusted i.e. are directly filled from Eurostat's ITGS. Please report real zero for material group MF.4.2.3 (and sub-groups) in case material groups MF.4.2.1 and MF.4.2.2 are already adjusted for the residence principle.

384. The relative size of the flows of transport fuel accounted for under item MF.4.2.3 can vary substantially from country to country. Some of these flows can be negligible; others can be of considerable size. In particular in countries with large airports and/or harbours, or important transit routes, the amount of fuel bunkered by non-resident units domestically can be considerable. The data required for these adjustments are, however, not readily available, as there are no corresponding items for those entries in the CN. In general three approaches to obtain the required information (or a combination of these paths) are possible:

- Energy and transport statistics: In some countries national energy or transport statistics collect data on fuel use in international transport. Experts in energy and transport statistics should be consulted to provide a first assessment of the significance of the concerned flows and to identify potential statistical sources;
- Other physical flow accounts such as e.g. air emissions accounts (AEA) and physical energy flow accounts (PEFA): Like EW-MFA other physical flow accounts (e.g. AEA, PEFA) follow the residence principle and require respective adjustments. In the course of the compilation of respective adjustment items for AEA or PEFA certain pieces of information might become available that can be used to approximate the transport fuel uses needed for EW-MFA adjustments, namely transport fuel purchases by resident units abroad and road transport fuel purchases by non-residents on the territory. Please note that the adjustments should be coherent among AEA, EW-MFA and PEFA;
- National accounts: National accounts have a long experience in dealing with practical difficulties to implement the residence principle. In general, national accounts experts have a good overview of the required adjustments and monetary data on fuel use in international transport may be available from national accounts. Usually the monetary data should be based on estimates in physical terms. On the basis of national accounting data on fuel used by non-resident units domestically and fuel used by resident units abroad, the required mass flows can be estimated.

Bulk pipeline flows of water

385. EW-MFA exclude bulk flows of water (and air) that cross the system boundary of the national economy. Therefore, water that enters countries by pipelines shall be excluded from EW-MFA accounts whenever it is clearly identified. Compilers of EW-MFA are recommended to contact the national specialist on international trade statistics in order to check whether the CN code '*2201 90 00 Other*' also comprises water that enters countries by pipelines.

Packaging materials

386. From a conceptual point of view, packaging materials should be accounted for in EW-MFA.

[45] Note that the deliveries of fuels to vessels and aircraft of non-resident operators at domestic harbours or airports are already included in the exports reported in Eurostat's ITGS.

However, external trade statistics only report net weight, which usually excludes the weight of packaging material. In practice, packaging materials are often of negligible importance. A German study on traded packaging materials revealed that the amount of packaging materials in imported goods was only 0.5 % of the imported tonnes (GVM, 2005). Considering the minor importance and the huge efforts an estimation of packaging materials in traded goods would take, the Eurostat Task Force on MFA recommended that no additional estimation of packaging materials needs to be performed.

MF 5 'Other products'

387. Some 5 400 CN product groups cannot be assigned to the main four material categories because their material-wise composition is too heterogeneous. A specific material category MF.5 'Other products' has been established to accommodate these heterogeneous CN product groups.

MF 6 'Waste for final treatment and disposal'

388. Another specific material category is dedicated to cross-border flows of waste material: MF6 'Waste for final treatment and disposal'. It accommodates a handful of CN codes of waste flows which cannot be assigned to the four main material categories. In addition MF.6 is supposed to accommodate cross-border movement of waste material that is not included in international trade in goods statistics (ITGS). Actually, this should be a very seldom case.

4.6.4. Physical trade by stage of manufacturing

389. In EW-MFA, physical imports and exports are firstly reported in a breakdown by type of material (see previous sections). In addition it was agreed to report – on a voluntary basis – the physical trade in a breakdown by three broad product groupings reflecting the 'stage of manufacturing' (Table 20).

Table 20: EW-MFA classification by stage of manufacturing

Code	Label	EW-MFA Questionnaire Table				
		A	B	D	F	G
	EW-MFA type of flow:	**domestic extraction**	**physical imports**	**physical exports**	**domestic processes output**	**balancing items**
	SEEA-CF type of flow:	*natural inputs*	*products*	*products*	*residuals*	*natural inputs or residuals*
SM_FIN	Stage of Manufacturing - finished products		x	x		
SM_SFIN	Stage of Manufacturing - semi-finished products		x	x		
SM_RAW	Stage of Manufacturing - raw products		x	x		

390. Traded goods can be grouped according to the following three levels ("stages") of manufacturing:

- raw products: products produced by primary industries such as agriculture, forestry, fishing, and mining;
- semi-finished products: products which are further processed raw products but do not yet constitute finished products; they obviously need to be further processed;
- finished products: products which are finalised in the sense that they are not further processed or transformed.

391. The physical trade tables in the EW-MFA questionnaire have been extended with three

additional rows to report figures for these three broad product groupings. Annex 5 to the EW-MFA questionnaire provides the correspondence between the CN classification and the three stages of manufacturing.

392. This correspondence was a joint effort of Eurostat, the German Federal Statistical Office, and the Swiss Federal Statistical Office. An exact statistical definition for the three product groups does not exist and could not be employed to develop formal criteria. In practice the assignment was mainly based on the CN labels. It is considered more important that the correspondence is harmonised and that all European NSIs use the same.

393. EW-MFA physical imports and exports by stage of manufacturing can be useful to assess the resource requirements (in terms of domestic material extraction needed) behind the traded product flows. The lower the stage of manufacturing the closer is the product's weight to the domestic material extractions required for its manufacture. That is, whereas the weight of raw products is usually rather close to the weight of the domestic extraction. Vice versa, the higher the stage of manufacturing the bigger is the difference between the actual product weight and the weight of the materials extracted to provide this good. A finished product may contain only the metal content, which is a small fraction of the weight of the metal ore and the energy carriers which were used for its production. Insofar the results of the 'level ('stage') of manufacturing approach' can serve as a first approximation for raw material equivalents (RME), see also section 2.8.1.

4.7. Domestic processed output (Table F)

394. EW-MFA record material inputs into and material outputs out of national economies. The material outputs include – beside physical exports – *domestic processed output* (DPO) which denotes all material flows (excluding bulk flows of water) from the national economy to the environment. DPO belongs to the SEEA type of physical flows entitled 'residuals' (see also paras. 54ff.). By convention, DPO does not include water vapour from combustion or any gases from respiration of humans and cultivated livestock (see balancing items – output side, paras. 501ff.).

395. DPO is composed of 5 material classes (at 2-digit level) which are partly further detailed by material groups (3-digit) and sub-groups (4-digit) (see for details Table 2 and Annex A to this handbook):

- MF.7.1 Emissions to air
- MF.7.2 Waste disposal to the environment
- MF.7.3 Emissions to water
- MF.7.4 Dissipative use of products
- MF.7.5 Dissipative losses

396. The first three classes (MF.7.1 to MF.7.3) refer to the three environmental spheres to which residual materials are released, i.e. air, land, and water. The remaining two classes (MF.7.4 and MF.7.5) are reflecting types of release processes. There are a few cases where the assignment of residual flows is not clear because they could be assigned to several classes. Those cases concern certain emissions to air and are addressed further below (see Table 22).

397. DPO presents only material flows from the economy to the environment. DPO excludes material flows within the economy. Notably waste disposed to controlled landfills is excluded from DPO because according to SEEA-CF controlled landfills belong to produced fixed assets (SEEA-CF paras. 3.31 and 3.85) and are hence part of the economy.

398. In quantitative terms, DPO is dominated by 'emissions to air' (MF.7.1) with more than 90%. CO_2 constitutes the quantitatively most important gas emitted to air. Table 21 shows DPO by main classes for Austria and Switzerland.

Table 21: Domestic Processed Output (DPO) for EU-28, 2014 (tonnes per capita)

	EU-28
MF.7 Domestic Processed Output	**8.7**
MF.7.1 Emissions to air	8.2
of which: MF.7.1.1 Carbon dioxide (CO_2)	8.0
MF.7.2 Waste disposal to the environment	0.0
MF.7.2 MEMO Disposal of waste to controlled landfills (memorandum item)	*1.6*
MF.7.3 Emissions to water	0.02
MF.7.4 Dissipative use of products	0.5
MF.7.5 Dissipative losses	0.001

Source: Eurostat, EW-MFA 2017 data collection

399. The following sections provide general compilation guidelines, potential data sources, and specific accounting rules/conventions for each of the 5 material classes included in DPO.

4.7.1. Emissions to air (MF.7.1)

400. Emissions to air are gaseous or particulate materials released to the atmosphere from production or consumption processes in the economy. Bulk flows of water to the atmosphere (evaporation, water vapour) are excluded. By convention, all the gases listed under MF.8.2 (balancing items output side) are not included in DPO item MF.7.1 (see Table 2).

401. The air emissions recorded under DPO in EW-MFA must be those generated by production and consumption activities undertaken by resident units (see paras. 26ff. for the residence principle).

402. The class MF.7.1 'emissions to air' is further broken down into the following groups and sub-groups:

- MF.7.1.1 Carbon dioxide (CO_2)
  - MF.7.1.1.1 Carbon dioxide (CO_2) from biomass combustion
  - MF.7.1.1.2 Carbon dioxide (CO_2) excluding biomass combustion
- MF.7.1.2 Methane (CH_4)
- MF.7.1.3 Dinitrogen oxide (N_2O)
- MF.7.1.4 Nitrous oxides (NO_x)
- MF.7.1.5 Hydroflourcarbons (HFCs)
- MF.7.1.6 Perflourocarbons (PFCs)
- MF.7.1.7 Sulfur hexaflouride
- MF.7.1.8 Carbon monoxide (CO)
- MF.7.1.9 Non-methane volatile organic compounds (NMVOC)
- MF.7.1.A Sulfur dioxide (SO_2)
- MF.7.1.B Ammonia (NH_3)
- MF.7.1.C Heavy metals

- MF.7.1.D Persistent organic pollutants (POPs)
- MF.7.1.E Particles (e.g. PM_{10}, Dust)
- MF.7.1.F Other emissions to air

Data sources

403. Two main data sources related to emissions to air[46] are recommended to compilers of EW-MFA:

- Air emission accounts (AEA): AEA record flows of gaseous and particulate materials (six greenhouse gases including CO2 and seven air pollutants) to the atmosphere. AEA offer a detailed breakdown by 64 emitting industries plus households as defined and classified in national accounts. AEA follow the national accounts' residence principle, which implies that emissions by resident economic units are included even if these occur outside the territory (for example, resident airlines and shipping companies operating in the rest of the world). AEA are produced by the European Statistical System under Regulation (EU) No 691/2011 on European environmental economic accounts.
- National emission inventories for greenhouse gases and air pollutants reported under two important international conventions:
  - Greenhouse gas emissions are officially reported under the United Nations Framework Convention on Climate Change (UNFCCC). UNFCCC-greenhouse gas emission inventories are classified by emissions sources using the CRF classification (common reporting format).
  - Emissions of air pollutants are officially reported under the Convention on Long-Range Transboundary Air Pollution (CLRTAP) to the EMEP Programme (Co-operative Programme for Monitoring and Evaluation of the Long-Range Transmission of Air pollutants in Europe). CLRTAP-inventories of air pollutants are classified by emission sources using the NFR classification (nomenclature for reporting).

Both emission inventories record those emissions emitted on the territory or related to fuels sold on the territory (territory principle). The two classifications of emission sources, CRF and NFR, are aligned to each other and widely compatible.

Compilation

404. It is recommended that compilers of DPO employ both data sources. Air emissions accounts (AEA) are the recommended starting point because the total emissions emitted by economic production and consumption activities reported in AEA are already adjusted for the residence principle.

405. In a second step the AEA data need to be adjusted. Some emissions need to be deducted from AEA totals due to specifics of the classification of DPO. The reason is to avoid double counting of certain materials released to the environment.

[46] Note that both data sources report emissions of F-gases in tonnes of CO2-equivalnets which need to be converted into ordinary metric tonnes.

Table 22: Air emissions to be excluded from DPO item MF.7.1 'Emissions to air'

Description (why to be excluded from MF.7.1)	**UNFCCC greenhouse gas inventories**		**CLRTAP emission inventories of air pollutants**	
	CRF code and label	**relevant greenhouse gases**	**NFR code and label**	**relevant air pollutants**
Emissions to air that arise directly from the application of fertilising material on land. These are excluded from MF.7.1 'emissions to air' because their mass weight is already incorporated in the fertilising material which is a material flow to the environment recorded under DPO class MF.7.4 'dissipative use of products'	*3D 'Agricultural soils'*	N_2O		NH_3, NO
	3Da 'Direct N_2O emissions from managed soils'			
	3Da1 'Inorganic N fertiliser'		3Da1 'Inorganic N-fertilisers (includes also urea application)'	
	3Da2 'Organic N fertiliser'			
	3Da2a 'Animal manure applied to soils'		3Da2a 'Animal manure applied to soils'	
	3Da2b 'Sewage sludge applied to soils'		3Da2b 'Sewage sludge applied to soils'	
	3Da2c 'Other organic fertiliser applied to soils'		3Da2c 'Other organic fertilisers applied to soils (including compost)'	
	3Da3 'Urine and dung deposited by grazing animals		3Da3 'Urine and dung deposited by grazing animals (Excreta deposited by grazing livestock)'	
			3Da4 'Crop residues applied to soils'	
Emissions to air arising from the (dissipative) use of certain products, in particular solvents and fuels. These are excluded from MF.7.1 'emissions to air' because they are recorded under DPO class MF.7.4 'dissipative use of products'	*2D 'Non-energy use of fuels and solvents'*	CO_2		
	2D1 'Lubricant use'			
	2D2 'Paraffin wax use'			
	2D3 'Use of other non-energy products'			
			2D3a 'Domestic solvent use including fungicides'	NMVOC
			2D3b 'Road paving with asphalt'	NMVOC, PM
			2D3c 'Asphalt roofing'	NMVOC, PM
			2D3d 'Coating applications'	NMVOC
			2D3e 'Degreasing'	NMVOC
			2D3f 'Dry cleaning'	NMVOC
			2D3g 'Chemical products'	NMVOC, PM
			2D3h 'Printing'	NMVOC
			2D3i 'Other solvent use'	NMVOC, PAH
	2F 'Use of products substituting for ozone depleting substances (ODS)'			
	2F5 'Solvents'	HFCs		
	2G 'Manufacture and use of other products'		2G 'Other product use'	NMVOC
	2G3 'N_2O from product uses'	N_2O		
	2G4 'Other'	CO_2		
Emissions to air stemming from automobile tyre and brake wear and road abrasion. These are excluded from MF.7.1 'emissions to air' because they are recorded under DPO class MF.7.5 'dissipative losses'			1A3bvi 'Road transport: Automobile tyre and brake wear'	PM, Heavy metals
			1A3bvii 'Road transport: Automobile road abrasion'	

406. In order to avoid double-counting the following emissions need to be deducted from AEA totals (residence principle) in order to obtain DPO item MF.7.1 'emissions to air' (see Table 22):

- Emissions to air (relevant are: NH3, NO, and N2O) that arise directly from the application of fertilising material on land. These are excluded from MF.7.1 'emissions to air' because their mass weight is already incorporated in the fertilising material which is a material flow to the environment recorded under DPO class MF.7.4 'dissipative use of products'.
- Emissions to air arising from the (dissipative) use of certain products, in particular solvents and fuels. These are excluded from MF.7.1 'emissions to air' because they are recorded under DPO class MF.7.4 'dissipative use of products'.
- Emissions to air stemming from automobile tyre and brake wear and road abrasion. These are excluded from MF.7.1 'emissions to air' because they are recorded under DPO class MF.7.5 'dissipative losses'.

4.7.2. Waste disposal to the environment (MF.7.2)

407. Waste is a legally defined phenomenon and refers to materials (substances or objects) which the holder discards or intends or is required to discard.[47]

408. Beside its legal meaning, waste also constitutes a physical flow. According to the SEEA typology of physical flows, waste belongs to the category of residuals (see above paras. 47ff., see also SEEA-CF section 3.2.4).

409. DPO item MF.7.2 includes only those amounts of solid waste which are disposed to the natural environment; i.e. to uncontrolled landfills. In Europe, one may assume that this is zero because uncontrolled landfills are illegal.

410. Notably, in EW-MFA any solid waste disposed to controlled landfills is considered a flow within the economy (and not to the environment). According to principles, concepts, and definitions in national accounts and SEEA controlled and managed landfill sites are considered to be part of the produced assets of the national economy. This implies that waste disposed to controlled landfills is part of the net additions to stock (NAS), see para. 97.

411. EW-MF experts have agreed to record solid waste flow to controlled and managed landfills[48] as memo item (see para. 91) in Table F of the EW-MFA questionnaire. It is a useful piece of information when analysing the net additions to stock (NAS). Waste disposed to controlled landfills may form a quantitative relevant part of NAS.

Data sources and compilation

412. Data sources reporting the illegal disposal of solid waste to the environment may be available at national level. At European level such a data source does not exist. As mentioned, one may assume that illegal disposal of solid waste is close to zero in the EU.

413. For the memo item MF.7.2 MEMO 'Waste disposed to controlled landfills', compilers are recommended to use waste statistics which are harmonised at European level.

414. European data on waste to controlled landfills can be found in Eurostat online database: dataset 'Treatment of waste by waste category, hazardousness and waste operations' (env_wastrt), which reports data from 2004 onwards for each second year. Compilers have to select the waste operation: 'DSP_D - Deposit onto or into land'. Not all waste streams treated in this particular waste operation category shall be accounted. Compilers have to de-select (exclude) the following two waste streams *W126 Soils* and *W127 Dredging spoils*. In fact, *W126* and *W127* consist of excavated soil which is not accounted as domestic extraction on the EW-MFA material input side and thus should not be accounted for at the material output side either.

[47] Waste Framework Directive, or *Directive 2008/98/EC* of the European Parliament and of the Council
[48] Emissions from controlled and managed landfills (e.g. methane) are recorded as DPO, class MF.7.1

4.7.3. Emissions to water (MF.7.3)

415. The DPO class 'emissions to water' accounts for materials (excluding water) released to natural waterbodies by human activities after or without passing waste water treatment. 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

416. Emissions to water, along with dissipative losses (MF.7.5), represent the smallest material class of DPO. In the context of a full material balance of a national economy it is therefore sufficient to roughly estimate emissions to water.

417. The EW-MFA classification for emissions to water represents an aggregation of the main categories reported in the emissions statistics.

Data sources

418. Statistics on water are available in the European Environment Agency data set WISE SoE – Emissions (WISE-1) on the emissions to water from point sources (municipal waste water treatment plants and industrial direct discharge) and diffuse sources. The data set includes national emission data, also reported in the EU Water Framework Directive, Waterbase - UWWTD: Urban Waste Water Treatment Directive and European Pollutant Release and Transfer Register (E-PRTR) databases. Emissions from diffuse sources have to be included in the DPO category MF.7.4 'dissipative use of products'. Consequently, for MF.7.3 we are just considering emissions from point sources.

419. An alternative approach to estimate emissions to water uses the maximum legal limit value for each pollutant and multiplies it by the quantity of water treated by wastewater treatment plants. This approach assumes that plants respect legal regulations and the concentration of pollutant in water emitted is close to the legal maximum. One would expect these estimates to be higher than the actual emissions.

420. 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.

Compilation

MF.7.3.1 Nitrogen (N)

421. Total nitrogen (N) stands for the sum of all nitrogen compounds. N-emissions to water include emissions by waste water from households and industry. Nitrogen from agriculture is not included in the category emissions to water because it is already included in the DPO material class 'dissipative use of products' as nitrogenous fertilisers (MF.7.4.1 and MF.7.4.2).

MF.7.3.2 Phosphorus (P)

422. 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 included in category 'dissipative use of products' as phosphorus fertilisers (MF.7.4.1 and MF.7.4.2).

MF.7.3.3 Heavy metals

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

MF.7.3.4 Other substances and (organic) materials

424. 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 that all these indicators measure organic substances in water 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:

- Decide which 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.

425. Alternatively, as a rule of thumb, 5 % of the item MF.7.4.1 *Organic fertilisers* could be accounted for in MF.7.3.4, i.e. a 5 % loss of manure in water is assumed to occur (see also para.431).

MF.7.3.5 Dumping of materials at sea

426. Dumping of materials at sea is not a common reporting format and data may not be available. Please note that 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.

4.7.4. Dissipative use of products (MF.7.4)

427. 'Dissipative use of products' denotes material flows from the economy to the environment arising from the application of products. Examples of dissipative use flows are fertilisers such as manure, compost, or sewage sludge applied to land.

428. 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[49], pesticides[50] and seeds. Data for organic fertiliser usually have to be estimated. Data for sewage sludge, compost, and salt applied as thawing material on roads may be reported in statistics or reports on the environment or in specific studies[51]; in addition, waste statistics may report the output of compost from waste management.

429. 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.

Conventions

430. **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.

Data compilation

MF.7.4.1 Organic fertiliser (manure)

431. Manure is organic matter excreted by animals which is used as a soil amendment and fertiliser. Manure spread on agricultural land is usually not (or not sufficiently) reported in agricultural statistics, it has to be estimated. An estimate could be based on the number of livestock by type multiplied by the manure production per animal per year and a coefficient to correct for dry matter. Examples for required coefficients are given in Table 23.

[49] Note that manufacturing statistics on domestic sales from producing or importing units to consumers or sales organisations can also be used

[50] 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

[51] Further options are (estimates based on) statistics of mining and quarrying industry, and fishery

Table 23: 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
Horses	7	0.07
Poultry	0.2	0.15

Source: Meissner, 1994

432. Eurostat data for number of livestock by type can be derived from the following data sets:

- Bovine population - annual data [apro_mt_lscatl]
- Goat population - annual data [apro_mt_lsgoat]
- Sheep population - annual data [apro_mt_lssheep]
- Pig population - annual data [apro_mt_lspig]
- Livestock: number of farms and heads of animals of different types by agricultural size of farm (UAA) and NUTS 2 regions [ef_olsaareg].

Number of horses can be derived from the farm survey data set, which includes data for the years 2005, 2007, 2010 and 2013. In addition, poultry is only reported in the farm survey data set.

433. 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.

434. 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. Emissions from manure storage are recorded in emission inventories under the NFR-code 3.B. Notably, these emissions are already included in DPO item MF.7.1'emissions to air'.

MF.7.4.2 Mineral fertiliser

435. 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.

436. Accordingly, agricultural statistics commonly report domestic consumption in agriculture of

specified nitrogenous, phosphate, potash and multi-nutrient fertilisers (NP/NPK/NK/PK). Eurostat database provides the Consumption estimate of manufactured fertilisers (online data code: 'aei_fm_manfert'; source: Fertilisers Europe), the Use of inorganic fertilisers and the Gross Nutrient Balance[52]; data are in tonnes of nutrient.

437. FAOSTAT reports fertilisers for the EU countries. Data refer to consumption and consumption 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).

438. In principle, the total masses of fertilisers should be accounted for. 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[53]. The International Fertilisers Association (IFA) provides a database for the production and international trade of mineral fertilisers, which is available in tonnes of nutrients as well as in tonnes of product. From these two values, coefficients for the conversion of nutrient mass into total mass can be derived (see Table 24), and afterwards the different IFA fertiliser products can be allocated to the Eurostat categories. Table 24 also shows a mean coefficient for an average nitrogen and phosphorus fertiliser.

439. It would certainly be useful to calculate a weighted mean depending on the amounts of each fertiliser used in a country. For instance, the major source of nitrogen fertiliser in Austria is calcium ammonium nitrate (CAN), which should be weighted higher in the calculation of an Austria specific coefficient. National differences might play an important role, so a calculation of national coefficients for nutrient classifications would definitely improve the quality of the results.

Table 24: Conversion factors for mineral fertiliser

Fertiliser classification EUROSTAT	Fertiliser classification IFA	Conversion from nutrient content to total mass (1=nutrient mass)	Mean
Nitrogen	Ammonia	1,21655	2,97
	Urea	2,174	
	AN	2,96	
	CAN	3,734	
	AS	4,762	
Phosphate	Phosphate Rock	2,74	2,74
Phosphorus	MAP	1,92	2,03
	DAP	2,174	
	TSP	2,175	
	Phosphoric Acid	1,852	
Potash	Potash	1,667	1,667

Source: IFA

MF.7.4.3 Sewage sludge

440. 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

[52] 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

[53] Total weight is estimated by Switzerland using two sources: i) the fertiliser statistics in nutrient content and ii) the trade statistics which is in total mass. Given that the trend of the trade flow follows the fertiliser statistics, the latter is calibrated on the weight of trade statistics

environment and human and animal health. The application of sludge on agricultural land is therefore subject to strict regulations in many countries.

441. For calculating total dissipative use of sewage sludge, the Eurostat data set on sewage sludge production and disposal (env_ww_spd) can be used. This data set captures the amounts of sludge treated in municipal waste water treatment plants.

442. The database differentiates several sewage sludge disposal operations: agricultural use, compost and other applications, landfill, dumping at sea, incineration and other. Per convention, MF.7.4.3 should only include sewage sludge disposals for agricultural use and other uses because sewage disposals for compost, landfill and incineration are covered by other DPO categories or are not a material output according to EW-MFA:

- 'Sewage sludge disposal – compost and other applications' should be already included in MF.7.4.4 (Compost) if applied to land.
- 'Sewage sludge disposal - landfill' should be already included in MF.7.2.
- 'Sewage sludge disposal - incineration' is implicitly included in MF.7.1.

443. Sewage sludge has to be reported in dry matter, which is already the case for the Eurostat database. If data is reported in wet weight one may assume water content of 85 % for conversion to dry weight.

444. Sewage sludge spread on agricultural land is also reported in environment statistics as well as in UNFCCC inventories within sectoral background data for agriculture (see the CRF table 3.D).

MF.7.4.4 Compost

445. 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 fertilising and conditioning land.

446. Per convention, material flow group MF.7.4.4 should only include compost released to nature (land); i.e. a material flow from economy to environment.

447. Data for the dissipative use of compost can be approximated using waste statistics. The Eurostat data set on Municipal waste by waste operations (env_wasmun) includes the treatment operation 'Composting and digestion' (RCY_CO) showing the aerobic and anaerobic treatment of biodegradable waste used as a recycled product, material or substance for land treatment. The total 'composting of sewage sludge' should be included under this item of DPO, whereas 'composting in households and specific industries' is excluded. An attempt should be made to estimate those flows.

448. Compost applied as fertiliser to land should be reported in dry weight. The data set 'env_wasmun' provides the amount of compost in wet matter, therefore it can be assumed a water content of 50 % for the conversion to dry weight.

449. Compost is also reported in agricultural statistics and in UNFCCC inventories within sectoral background data for waste (see the CRF table 5.B).

450. 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 after consultation with waste statistics experts regarding imputatios they may make for e.g. households not connected to municipal waste collection schemes.

MF.7.4.5 Pesticides

451. 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. 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).

452. 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.

453. 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 since the conversion factor to total mass is usually bigger than 2.

MF.7.4.6 Seeds

454. Seeds are the encapsulated embryos of flowering plants. Seeds for agricultural production are a common position in agricultural statistics (e.g. FAO crop database) and has to be estimated within the Gross Nitrogen Budget (see the Eurostat/OECD methodological guide).[54]

MF.7.4.7 Salt and other materials spread on roads (incl. grit)

455. This item should not be neglected, e.g. in some winters it can account for about 10 % of MF.7.4 in Switzerland. Götzfried (2008) estimated the salt and sand consumption for some Nordic countries (Finland, Sweden and Denmark) from 2000 until 2006.

456. Besides salt, other materials like grit or waste products from the iron and steel industry are spread on roads. However, there is no plausible estimation procedure available so far to calculate these flows. A possible estimation approach could be developed based on the length of roads in each European country differentiated by street types (altitude and slope could be important issues to consider), average amount of frost days per year, and average amount of deployed materials. Information on these topics can be found in Burtwell and Öberg (2002).

MF.7.4.8 Solvents, laughing gas and others

457. This category includes emissions from diverse dissipative use of products, e.g. use of solvents (NMVOC emissions), laughing gas, road paving, N_2O for anaesthesia.

458. Several compounds are involved. The data sources for these emissions are the national inventory submissions to the CLRTAP and to the UNFCCC[55]. 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 MF.7.4.8 *Solvents, laughing gas and others* are shown in Table 22.

459. 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.

460. The categories included in the NFR sectors 2D and 2G are the following (see also Table 22):

- 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

[54] 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

[55] Adjustments for the residence principle are very unlikely for the source codes concerned

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.

461. 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.

462. 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.

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

- 2.G.3 – N_2O from product uses (i.e. N_2O emissions from the use of N_2O for anaesthesia, aerosol cans, explosives and from fire extinguishers);
- 2.G.4 – Other.

4.7.5. Dissipative losses (MF.7.5)

464. 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.

465. This category includes various types of dissipative flows (abrasion from tyres, friction products, buildings and infrastructures and others). Many of them have never been quantified. It is recommended to fill in only those data that can be provided with a justifiable effort.

466. 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 MF.7.1 (see also Table 22):

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

467. 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 MF.7.5.

468. 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. The same may hold for data on (heavy) metal emissions to water from some sources (see para 420).

469. 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.

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

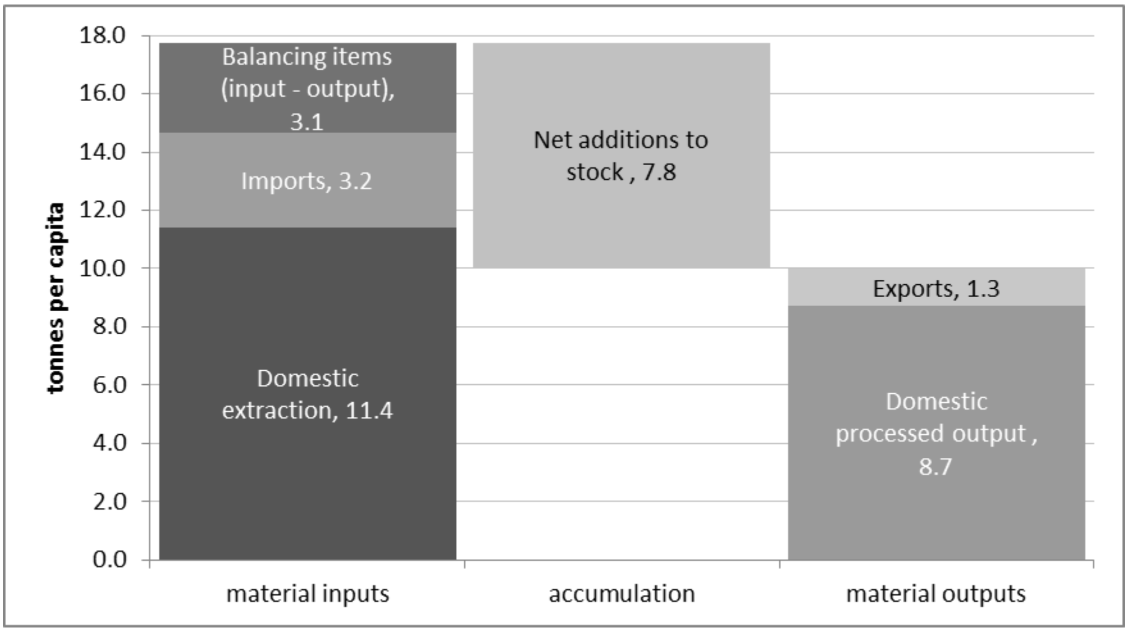
4.8. Balancing items (Table G)

471. 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.

472. These additional inputs and outputs that are needed to compile a full mass balance 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.

473. Balancing items are significant mass flows, as can be seen from Figure 6 which shows the material balance for the EU 2014.

Figure 5: EW-MFA material balance for EU-28, 2014 (tonnes per capita)



Source: Eurostat, EW-MFA 2017 data collection

474. Balancing items are quantitatively dominated on both sides by adjustments related to combustion processes. The combustion process is an oxidation; it requires considerable amounts of

oxygen which unusually comes from the ambient air. This exogenous oxygen is not accounted for in domestic extraction or imports. Hence, it needs to be added as balancing item on the input side. On the output side the combustion process releases water (vapour) which is not accounted for in DPO. This water vapour needs to be added as balancing item on the output side.

475. The following chemical equation illustrates the case for the combustion of the most simple fossil fuel, methane (CH_4):

CH_4	**+**	**$2\ O_2$**	**=**	**CO_2**	**+**	**$2\ H_2O$**
Methane	+	Oxygen	=	Carbon Dioxide	+	Water
(DE, IMP)		balancing item		(DPO)		balancing item

476. The EW-MFA questionnaire provides a compilation tool to estimate all the balancing items with a reasonable accuracy based on the available data, ideally based on the data already reported other tables of the EW-MFA questionnaire, otherwise provided within the tool. This requires a number of simplifying assumptions. More precise calculations, according to the procedure explained in this chapter, are possible and encouraged, e.g. compilers are recommended to investigate and use national factors.

477. The tool includes comments and descriptions explaining which particular calculation steps they refer to. A more detailed background explanation on the assumptions made is provided in this chapter hereafter.

4.8.1. Balancing items: input side (MF.8.1)

478. Balancing items on the input side account for those material flows of air and water that are included in DPO or exports, but not included in DE or imports. The main processes concerned are combustion of fuels, respiration of humans and livestock, the production of ammonia via the Haber-Bosch process, and water requirements for the domestic production of exported beverages. Oxygen for combustion processes is by far the quantitative most important balancing item on the input side (ca. 90%).

Data sources and compilation

479. The following sections provide possible data sources and further compilation guidelines for the various groups within MF.8.1 'balancing items: input side'.

MF.8.1.1 Oxygen for combustion processes

480. Oxygen for combustion is calculated in a stepwise approach. Step 1 determines the mass weight of the oxygen included in the emissions arising from combustion (CO_2, CO, SO_2, N_2O and NO_2). Step 2 determines the oxygen requirement for the oxidation of the hydrogen incorporated in the combusted material. Oxidation of the hydrogen (H) leads to water vapour (H_2O) (see equation presented in para. 475). Step 3 corrects the oxygen requirements determined in steps 1 and 2 by deducting the oxygen already incorporated in the combusted material itself (indigenous oxygen). As a result one obtains the exogenous oxygen demand for combustion processes, i.e. the balancing item MF.8.1.1.

Step 1

481. 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;

- $C + O \rightarrow CO$, 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.

482. The required data for emissions from combustion should be taken from the DPO class MF.7.1 'emissions to air' (see section 4.7.1). The emissions recorded under MF.7.1 are multiplied with the above factors for each emission compound.

Correcting for process-related CO_2 emissions

483. The CO2-emissions recorded in MF.7.1 include so-called process-related CO2-emissions. 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 can be derived from the UNFCCC greenhouse gas emission inventories: CRF codes 2A1 and 2A2 – Mineral industry, Cement and lime production).

484. Process-related CO2-emissions are included in DPO item MF.7.1. However, they do not constitute combustion emissions. Hence, they need to be deducted before compiling step 1 of MF.8.1.1.

Step 2

485. In addition, oxygen is required for oxidising the hydrogen (H) intrinsically incorporated in the combusted material, with the resulting emission being water vapour (H_2O) (see balancing item: output side MF.8..2.1):

- $2H + O \rightarrow H_2O$, 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 intrinsic H.

486. Step 2 requires knowing the overall amount of hydrogen intrinsically incorporated in the materials combusted. First, one needs to know how much of the different materials has been combusted. Secondly, one needs to know the hydrogen content of each of the different materials combusted.

487. Three possible data sources can be used to determine the materials combusted:

- The most appropriate source for determining the various materials combusted are physical energy flow accounts (PEFA): PEFA table C records the combustion-emission-relevant use of energy products. Notably, PEFA reports in energetic units (tera joule) which need to be converted into mass units (tonnes) employing respective net calorific values.
- Energy statistics and balances could also be used. Note that emission-relevant use is not explicitly separated in energy statistics. Further, energy statistics are not adjusted for the residence principle.
- Data reported in the EW-MFA questionnaire: The compilation tool included in the EW-MFA questionnaires uses data already reported in the EW-MFA questionnaire (tables A, B and D; i.e. domestic extraction plus imports minus exports of fossil energy materials/carriers) to approximate the material combusted.

488. Step 2 also requires information on the hydrogen incorporated in the various materials combusted. The hydrogen content of a combusted material determines the amount of resulting water vapour which again reveals the amount of oxygen required. Table 25 provides respective coefficients used in German emission inventories.

Table 25: Intrinsic hydrogen, oxygen demand for oxidising intrinsic hydrogen, and resulting water vapour by energy carriers

Energy carrier	Intrinsic hydrogen in t per t energy carrier	Oxygen demand in t per t energy carrier	Water vapour in t per t energy carrier
Sewage gas/ Biogas/ Landfill gas	0.20	1.57	1.77
Hard coal	0.05	0.37	0.42
Coke (hard coal)	0.01	0.06	0.07
Hard coal briquettes	0.04	0.33	0.37
Brown coal, crude	0.02	0.15	0.17
Dust- and dry coal	0.04	0.33	0.37
Hard brown coal	0.04	0.32	0.36
Brown coal briquettes and -coke	0.04	0.33	0.37
Mine gas	0.20	1.57	1.77
Coke oven gas	0.20	1.57	1.77
Natural gas, Crude oil gas	0.23	1.83	2.05
Gasoline	0.14	1.14	1.28
Diesel	0.13	1.06	1.19
Aviation gasoline	0.15	1.19	1.34
Fuel oil, light	0.13	1.07	1.21
Fuel oil, medium and heavy	0.12	0.93	1.05
Liquid gas	0.18	1.41	1.59
Refinery gas	0.21	1.71	1.92
Other solid fuels	0.05	0.40	0.45
Blast furnace gas	0.002	0.02	0.02

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

Step 3

489. Most materials combusted contain oxygen. This intrinsic oxygen content is used in the combustion process. It has to be subtracted from the oxygen demand calculated in the previous steps in order to derive the actual amount of exogenous oxygen requirement. Table 26 presents some coefficients on the oxygen content of various energy carriers.

Table 26: Oxygen content of energy carriers (% 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

490. Note that the three data sources for determining the amounts of materials combusted mentioned in Step 2 can be used in Step 3 as well.

MF.8.1.2 Oxygen for respiration of human and livestock; bacterial respiration from solid waste and wastewater

491. MF.8.1.2 records the oxygen inputs related to respiration of human and cultivated livestock (the corresponding outputs is recorded under MF.8.2.2). Oxygen for respiration can be calculated using standard coefficients based on population numbers and livestock numbers (see Table 27). Data on livestock are available in various Eurostat data sets (see para. 432).

Table 27: 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

Oxygen demand for respiration	t O_2 per capita resp. head and per year
Horses	1.84
Pigs	0.25
Poultry	0.01

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

492. MF.8.1.2 also includes oxygen for bacterial respiration from solid waste and wastewater. It can be calculated based on the amounts of the corresponding CO_2 emissions (0.727 tonnes of oxygen are required for one tonne of CO_2, see para. 481). the following CRF codes record the corresponding CO_2-emissions:

- 5A 'Solid waste disposal on land',
- 5B 'Biological treatment of solid waste' and
- 5D 'Wastewater handling'.

MF.8.1.3 Nitrogen for Haber-Bosch process

493. The Haber-Bosch process is a process that uses nitrogen (N_2) and hydrogen (H_2) for industrial production of ammonia.

494. $N_2 + 3H_2 \rightleftharpoons 2NH_3$

495. The nitrogen required for the Haber-Bosch process is taken from the ambient air and hence needs to be considered as a balancing item on the input side of the economy-wide material balance.

496. The nitrogen used in the Haber Bosch process can be estimated. About 0.83 tonnes of N_2 are required to produce 1 tonne of ammonia.

497. Data on the amount of ammonia produced by the Haber Bosch process might be found in national data sources. One important international data source is USGS.

MF.8.1.4 Water requirements for the domestic production of exported beverages

498. 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.

499. Data for this item can be extracted from ITGS: the exported quantities of fruit and vegetable juices (code CN 20.09) and beverages (CN 22) adjusted by a factor of water content (0.85 and 0.9, respectively).

Specific issues related to balancing items input side (and in total): Nitrogen for combustion as balancing item - input side

500. Emissions of nitrogen oxides (NO, NO_2) from fuel combustion in motors result at least partly from inputs of elementary nitrogen originating from ambient air. This nitrogen input can in principle be calculated using standard coefficients based on emissions of NO_2.. For the time being this is not undertaken in EW-MFA due to non-availability of appropriate coefficients. This item is also of minor quantitative importance.

4.8.2. Balancing items: output side (MF.8.2)

501. Balancing items on the output side of the economy-wide material balance correspond widely

to the balancing items on the inputs side. The main processes concerned are combustion of fuels and respiration of humans and livestock. Water vapour from combustion is by far the quantitatively most important balancing item on the output side (more than 60%).

Data sources and compilation

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

- water vapour related to combustion: data for the combustion of materials to account for resulting emissions of water vapour, taken e.g. from energy statistics (see also MF.8.1 balancing items – input side);
- 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, respectively.

MF.8.2.1 Water vapour from combustion

503. Water vapour from combustion (MF.8.2.1) is further broken down depending on the origin of the water vapour. Some originates from the moisture content of the material combusted (MF.8.2.1.1). Another part originates from the oxidation of the intrinsic hydrogen incorporated in the combusted material.

MF.8.2.1.1 Water vapour from moisture content of fuels

504. The combusted material usually has some moisture content (humidity degree). In the combustion process the moisture contained in the combusted material is emitted as water vapour (H_2O). Resulting emissions can be estimated based on average values for water vapour emitted per tonne material combusted. Table 28 presents coefficients for moisture content that converts into water vapour for some common materials combusted (energy carriers).

Table 28: Moisture content of selected energy carriers that convert into water vapour during combustion

Energy carrier	Moisture content converting to water vapour during combustion 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

505. The compilation tool included in the EW-MFA questionnaire uses some average moisture content coefficients for 7 material groups reported already in the EW-MFA questionnaire. It is implicitly assumed that the consumption (domestic extraction plus imports minus exports) of these 7 material groups is entirely for combustion.

MF.8.2.1.2 Water vapour from the oxidised hydrogen components of fuels

506. MF.8.2.1.2 quantifies the water vapour resulting from the oxidation of hydrogen intrinsically incorporated in the combusted material (see also paras. 474 and 475).

507. MF.8.2.1.2 relates very closely to step 2 when calculating the corresponding oxygen demand for combustion (MF.8.1.1), see paras. 488ff. Table 25 presents all the coefficients needed to estimate the water vapour for commonly combusted materials.

508. The compilation tool included in the EW-MFA questionnaire employs 7 material groups reported already in the EW-MFA questionnaire to estimate the amount of material combusted. It is implicitly assumed that the consumption (domestic extraction plus imports minus exports) of these 7 material groups is entirely for combustion.

MF.8.2.2 Gases from respiration of humans and livestock, and from bacterial respiration from solid waste and wastewater

509. CO_2 and water vapour (H_2O) from respiration can be calculated using standard coefficients based on population numbers and livestock numbers (see Table 29).

Table 29: 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

510. The biological treatment of solid waste and waste water involves bacterial respiration. The hydrocarbons contained in the respective waste and waste water are digested by bacteria. As a result one obtains CO_2 and water vapour. The CO_2 is accounted for in DPO (it is recorded in UNFCCC greenhouse gas emissions; CRF codes 5B 'Biological treatment of solid waste' and 5D 'Wastewater handling'). The water vapour can be estimated from the CO_2, assuming that one molecule CO_2 corresponds to one water molecule: the coefficient 0.41 (18/44, the ratio of the molar masses of H_2O and CO_2) can be used.

MF.8.2.3 Excorporated water from biomass products

511. MF.8.2.3 accounts for two sub-items: (1) the loss of water from biomass products, and (2) the water contained in imported beverages. .

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

- Water content of biomass

513. On the input side of the material balance biomass is accounted for under domestic extraction and imports mainly in wet weight. On the output side of the material balance biomass is widely accounted for in dry weight (sewage sludge or compost). 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 MF.8.2.1.1) 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

514. 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.

515. The compilation tool in the EW-MFA questionnaire provides a table of the moisture content of crops at a more detailed level than the EW-MFA categories in the tool (sheet name: 'Annex to Table G tool') of which NSIs with more detailed consumption data 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.

- Water contained in imported beverages

516. Bulk water from imports of beverages, which is exactly the mirror image of the item MF.8.1.4 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 (0.85 and 0.9, respectively).

4.9. Material flow accounts in raw material equivalents (Table I)

517. Table I of the EW-MFA questionnaire provides the possibility to voluntarily report material flow accounts in raw material equivalents (MFA-RME) in a breakdown by main material categories.

518. Not all components of MFA-RME (see section 2.8.2) are to be filled into Table I. Only estimates of imports in RME and exports in RME can be entered in Table I. The domestic extraction data is automatically taken from Table A. The indicators raw material input (RMI) and raw material consumption (RMC) are calculated automatically as following:

RMI = domestic extraction + imports in RME
RMC = RMI – exports in RME

519. MFA-RME cannot be observed directly. There are different estimation methods or approaches.

520. A global multi-regional input-output model extended by domestic material extraction data can be used to re-attribute the domestic material extraction to the final use categories. National data (symmetric input-output tables, domestic material extraction) are arranged in a consolidated input-output table representing each country individually in the entire and closed global economy. Well-established Leontief modelling is used to re-attribute the domestic material extraction to the final use categories (Miller and Blair, 2009).

521. Such an extended global multi-regional input-output model is conceptually conform to SNA and SEEA-CF and hence the preferred option if the degree of detail is sufficient to accurately estimate MFA-RME. International joint ventures of academic and research oriented groups have developed several global multi-regional input-output data sets (e.g. EXIOBASE, see Tukker et al.,

2013 and Wood et al., 2015; WIOD, see Timmer et al., 2015; Eora, see Lenzen et al., 2013) which have been extended by global material flow databases (e.g. materialflows.net, UNEP 2016). However, these databases have complex underlying methodologies and national statistical authorities cannot easily use or adapt them for their specific needs. Efforts by OECD and Eurostat have started to institutionalise a global multi-regional input-output data set. In future this institutionalised MRIO database could become the reference database for demand-based material flow accounts.

522. The ESS has been developing an interim solution. Eurostat developed its own EU RME model (Schoer et al., 2012; Eurostat 2017) and a country-tool that can be used by national authorities.

523. The EU RME model is a hybrid environmentally-extended input-output model for the aggregated EU economy. The EU RME model has been developed with the aim to estimate extended EW-MFA indicators – such as e.g. RMC – for the aggregated EU economy. The EU RME model has the following features:

- The model is developed for the aggregated EU economy;
- The underlying EU input-output tables are broken down by around 180x180 products and partly hybridised (i.e. physical structures replace monetary structures);
- The model assumes domestic production technologies for most of the imported products; for some 35 products which are not produced in Europe (fuels and metals) the RMEs of imports are determined externally using life-cycle-inventory data and other sources (mine reports);
- The model is used to estimate time series fully in line with the original EW-MFA data set that is fed into the model;
- The model has the same detailed material breakdown (ca. 50 material categories) as the EW-MFA questionnaire Table A, which is also the breakdown used for the Eurostat online database;
- As a complement to domestic extraction, DMI, and DMC (i.e. the EW-MFA indicators derivable from the annual questionnaire) the RME model estimates the imports and exports in RME;
- The latter allows deriving extended EW-MFA indicators such as RMC, calculated as domestic extraction + imports in RME – exports in RME.

524. NSIs may use an existing nationally developed model to estimate the requested values for imports in RME and exports in RME.

525. Alternatively, NSI reporters may develop a national model for estimating MFA-RME. The documentation of the EU RME model (Eurostat 2016b), available on Eurostat's Environment – Methodology page, can be used as reference when developing a national model.

526. If NSIs do not yet produce MFA-RME and do not wish to develop a national model, the country RME tool can be used that was developed by Eurostat to support MFA-RME compilers. The tool, a handbook explaining the calculation method applied in the tool, and a file with input data, are also available on Eurostat's Environment – Methodology page.

527. The country RME tool was developed with the following conditions:

- to have an acceptable degree of accuracy;
- to be in line with the concepts, methods and data of the EU RME model;
- to provide a harmonised approach;
- to need a relatively limited amount of time to run the model.

528. The tool implements a simplified methodology to produce a set of RME indicators. It has been developed with the experience gained in building Eurostat's EU RME model. The tool is based on the RME coefficients for trade flows derived from Eurostat's EU RME model. The RME coefficients for

trade flows are used to translate trade vectors in mixed units (monetary and physical terms, depending on the product group) into trade vectors expressed in RME.

529. The country RME tool is implemented in Excel, using formulas only. This makes the tool easily accessible and transparent. Some experience in working with Excel is recommended.

530. The country RME tool only requires national compilers to insert certain country-specific data sets into the relevant input data sheets. These data can be copied from the accompanying file with input data published alongside the country RME tool. Once this work is completed, the results can be found in the final worksheets of the Excel workbook.

531. NSIs using the country RME tool may want to consider adjusting the trade data they enter as input in case there are significant flows of re-exports.

532. It is recommended to validate the outcomes of the estimation procedure to the extent possible. Comparison with other data, for example EW-MFA data and trade data, focusing on the trends over time, is useful. In case of large deviations, explanations will need to be sought, and when found, it is recommended to communicate these findings when presenting the results.

533. Further support in the use of the model or the interpretation of the results can be requested by reaching out to the contact person at Eurostat listed on the cover page of the country RME tool.

5 Use and presentation of material flow data

534. This chapter provides an overview of the uses of EW-MFA data and derived indicators. This is illustrated with standard figures and general descriptions and analyses based on these. The applications include policy messages that can be addressed with the data and graphs and shall point out the specific use of EW-MFA data as a support of policy making.

535. The EW-MFA accounting framework builds on a consistent database that can be used for various policy-oriented analyses on the economy-environment interactions. EW-MFA-based indicators provide aggregate information on the trends and composition of the in-flows of physical resources into socioeconomic systems, i.e. countries. EW-MFA indicators neither convey direct information on the benefits generated from these resource flows and their distribution, nor provide information on specific environmental impacts caused by resource flows. Other indicators or accounting frameworks can address these issues better. However, EW-MFA provide a consistent and systemic view on the physical dimension of economic activities, in particular on socioeconomic resource requirements and the efficient use of resources.

536. Meanwhile, material flow indicators have made their way into public policies. As one of the earliest initiatives, the Fundamental Plan for a Sound Material-Cycle Society was adopted in Japan in 2003, where a set of three EW-MFA indicators was chosen and numerical targets were set (Moriguchi 2007). In Europe, the Thematic Strategy on the Sustainable Use of Natural Resources from 2005 (European Commission, 2005) laid ground for the Flagship initiative on 'a resource-efficient Europe' (European Commission, 2011a) and the Roadmap to a resource efficient Europe (European Commission, 2011b), both published in 2011. These policies aim at supporting the shift towards a resource-efficient, low-carbon economy to achieve sustainable growth. More recently EW-MFA data in conjunction with waste statistics have been used for the monitoring framework on circular economy.

5.1. Descriptive presentation of EW-MFA data

537. In general, analyses on EW-MFA can be presented in:

- Absolute size of material flows (tonnes per year), used to describe the overall physical scale of an economy and its material flows (metabolic scale). The indicators derived from EW-MFA show the total quantity of physical mass that is used by a national economy. They can be used to represent, for example, the environmental pressure driven by resource use. Time series allow performing historical analyses on the development of certain environmental pressures for particular countries or the world economy, e.g. physical trade flows show dependency on the rest of the world.
- Absolute size of physical trade flows in raw material equivalents (tonnes per year), used to express trade flows in equivalents of domestic extractions that have been induced worldwide

to produce the respective good.

- *Per capita* material flows (tonnes *per capita* per year), used to describe the material use in relation to the population of a country. These indicators allow for cross country comparison. Material flows per capita express the average amount of material associated with sustaining one individual during a year (metabolic rate).
- Material flows in relation to economic aggregates (e.g. GDP, in order to calculate resource productivity). EW-MFA and national accounts both apply the same system boundaries so that indicators from both accounting framework are highly compatible.

538. Eurostats comprehensive database Material flows and resource productivity allows to evaluate material flows at different levels of detail. EW-MFA data can be:

- differentiated by flow types, namely DE, exports and imports, and DPO;
- differentiated by material type, most commonly four material groups (biomass, metal ores, non-metallic minerals and fossil energy carriers), but also along renewables (biomass) and non-renewable materials (mineral and fossil materials);
- used to calculate aggregate headline indicators, such as DMC at EU and country level;
- analysed at a more detailed level, distinguishing about 50 different materials or material groups or even on the level of individual material such as paddy rice or lead ore;
- analysed by stage of manufacturing (only physical trade flows): raw products, semi-finished products and finished products.

539. This minimum set of indicators can be further combined and extended in order to undertake more sophisticated analysis and address specific policy issues. Indeed, ratios between EW-MFA derived indicators can be produced for specific purposes, such as identify economies' dependency from imported materials; moreover, other consistent data sets, such as national account aggregates, can be juxtaposed to EW-MFA aggregates in order to produce composite indicators, such as resource productivity, that can summarise complex or multi-dimensional issues in view of supporting decision-makers.

540. *Resource productivity*, defined as gross domestic product (GDP) at market prices over DMC, expresses how much GDP is generated from the materials that are directly used in a national economy.

541. The EU policy initiative A resource-efficient Europe – Flagship initiative under the Europe 2020 Strategy (European Commission 2011a) supports the shift towards a resource-efficient, low-carbon economy to achieve sustainable growth. It provides a long-term framework for actions in many policy areas. *Resource productivity* is the lead indicator of above initiative.

542. In macroeconomics it is common to use the term *productivity* for ratios where GDP (as a numerator) is related to any – often physical – production factor input (denominator): e.g. labour productivity in form of GDP over working hours, or energy productivity expressed as GDP over gross inland energy consumption.

543. Eurostat disseminates results on *resource productivity* (RP) in its online database. The dimensions for customising the table, as illustrated above, are: Geo, Time and Unit of measure. Different units of resource productivity, stemming from different units of measure of GDP at market prices, are available and suit different analytical perspectives:

- *Euro per kilogram*, where GDP is presented at current prices (nominal), used when looking at one country for one (most recent) year;
- *Euro per kilogram, chain linked volumes*, where GDP is expressed in volumes (i.e. prices of the previous year normalised to a specific base year). This unit is used when looking at one country and over a period of time; it eliminates the effect of inflation. In addition, *indexed resource productivity (RP) series* are available.

- *Purchasing Power Standard per kilogram*, where GDP (at current prices) is expressed in Purchasing Power Standards (PPS) to better compare countries at one point in time; PPS eliminates differences in price levels among countries.

544. Finally, the EW-MFA Metadata file documents statistical data and provides summary information useful for assessing data quality and the statistical production process of the domain.

545. Except in cases where a different source is mentioned, the analyses in the following sections are based on the Eurostat Material flows and resource productivity (env_mrp) data sets.

Domestic extraction

546. Domestic extraction (DE) allows analysing how much material is extracted annually, most commonly differentiated by renewable resources (biomass) and non-renewables (fossil energy carriers, metals ores, non-metallic minerals). Growing trends in domestic extraction reveal a growing pressure on the natural resource base, which is limited by either the regenerative capacity of local ecosystems or by the natural stock of non-renewable resources.

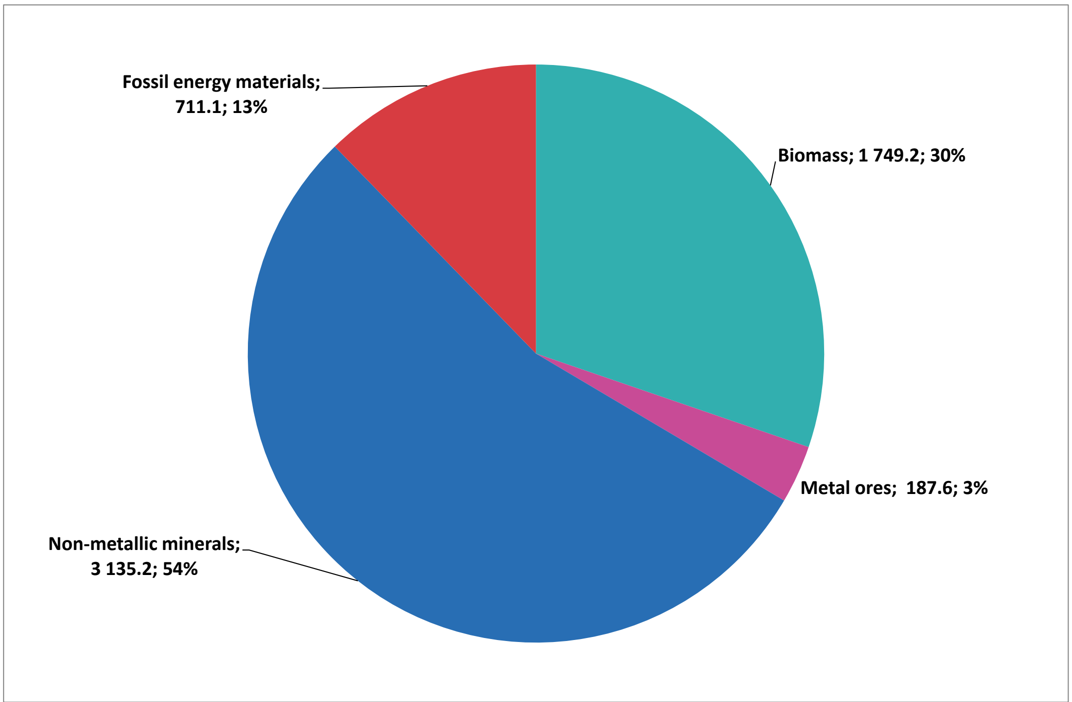
547. Figure 6 to Figure 9 illustrate the development of DE within the EU-28 in 2015 and between 2000 and 2015, in million tonnes, in percentage and indexed. All four figures illustrate total domestic extraction by the four main material categories.

548. In 2015 non-metallic minerals account for the largest share of DE in the EU-28, followed by biomass and fossil energy carriers. Metal ores account for 3.2 % of total material extraction in the EU-28 (Figure 6).

549. Total material extraction was 6.53 billion tonnes in 2000 and increased to 7.03 billion tonnes in 2007 (+7.6 %). In the years following the global financial crisis DE declined by 17.7 % to 5.78 billion tonnes between 2007 and 2015 (Figure 7).

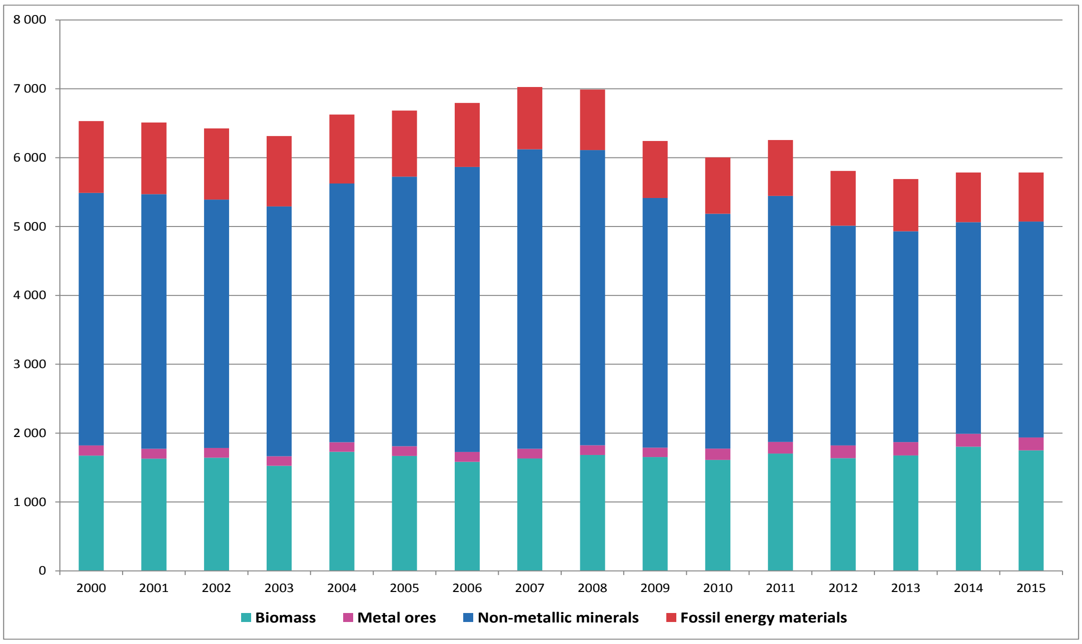
How much material is extracted in EU-28? What material is extracted in EU?

Figure 6: Domestic extraction by material category in 2015, EU-28 (million tonnes and percentages)



How much material has been extracted in EU-28 over time? What material has been extracted in EU-28 over time? How has material composition of extraction in EU-28 changed over time?

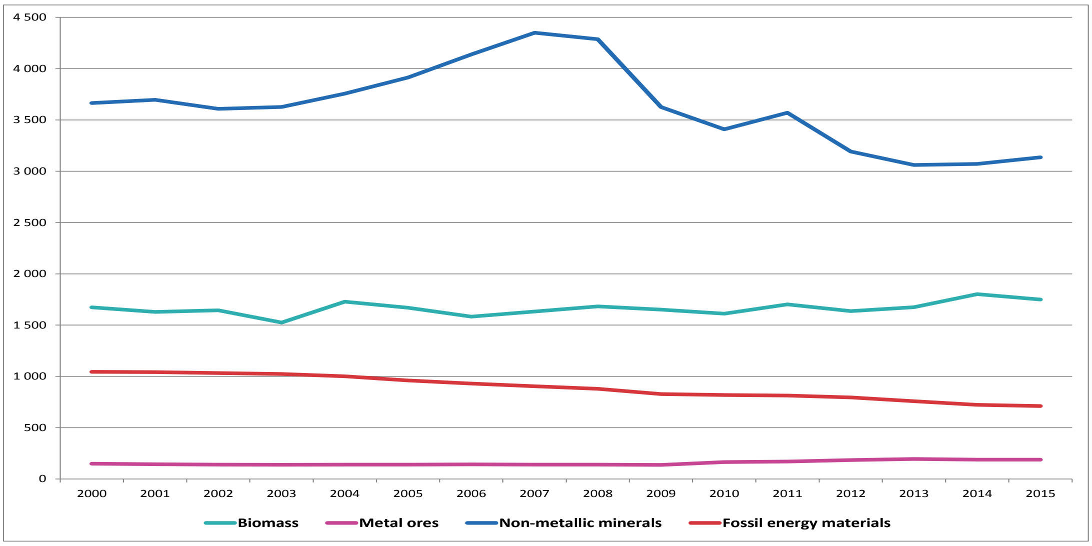
Figure 7: Domestic extraction by material category in 2000-2015, EU-28 (million tonnes)



550. A line chart such as Figure 8 shows the development of individual material categories more clearly. A line chart can either use totals or indexed values as in Figure 9. Figure 8 corrects the shortcoming of Figure 7, since it clearly shows developments of each material category. DE of non-metallic minerals and fossil energy carriers show a significant decline caused by the economic crisis starting from 2007, while the extraction of biomass remained fairly constant at around 1.66 billion tonnes per year. The economic crisis marked the opposite change in 2009 for metal ores, which account for 2.5 % of total extraction on average over the period 2000-2015.

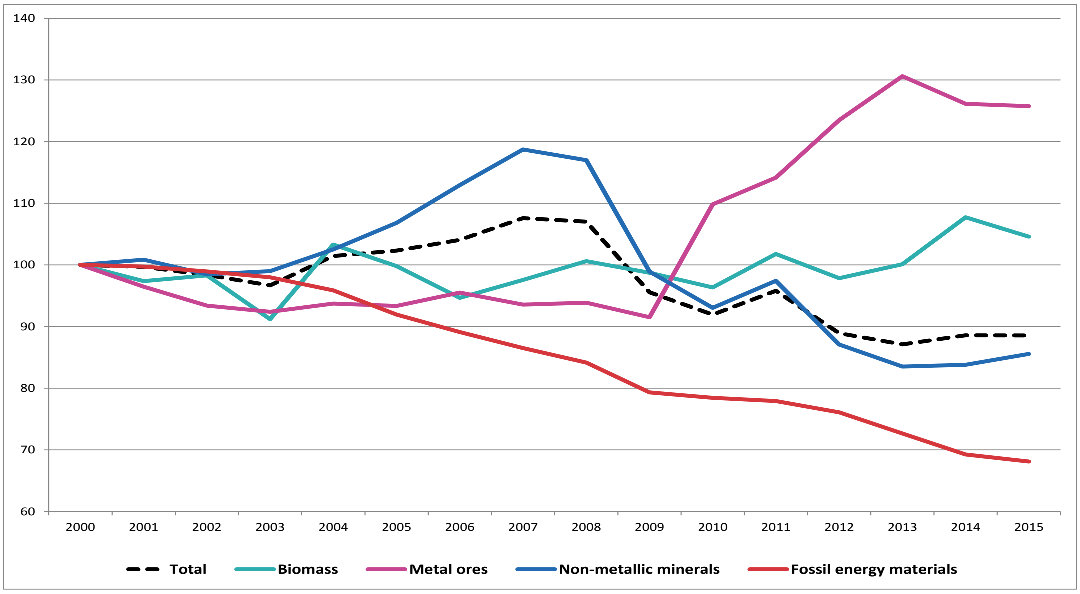
How did the EU-28 material extraction of the four main material categories evolve over time, in absolute volumes?

Figure 8: Domestic extraction by material category in 2000-2015, EU-28 (million tonnes)



How did the EU-28 material extraction of the four main material categories evolve over time, in relation to the first year?

Figure 9: Domestic extraction by material category in 2000-2015, EU-28 (2000=100)



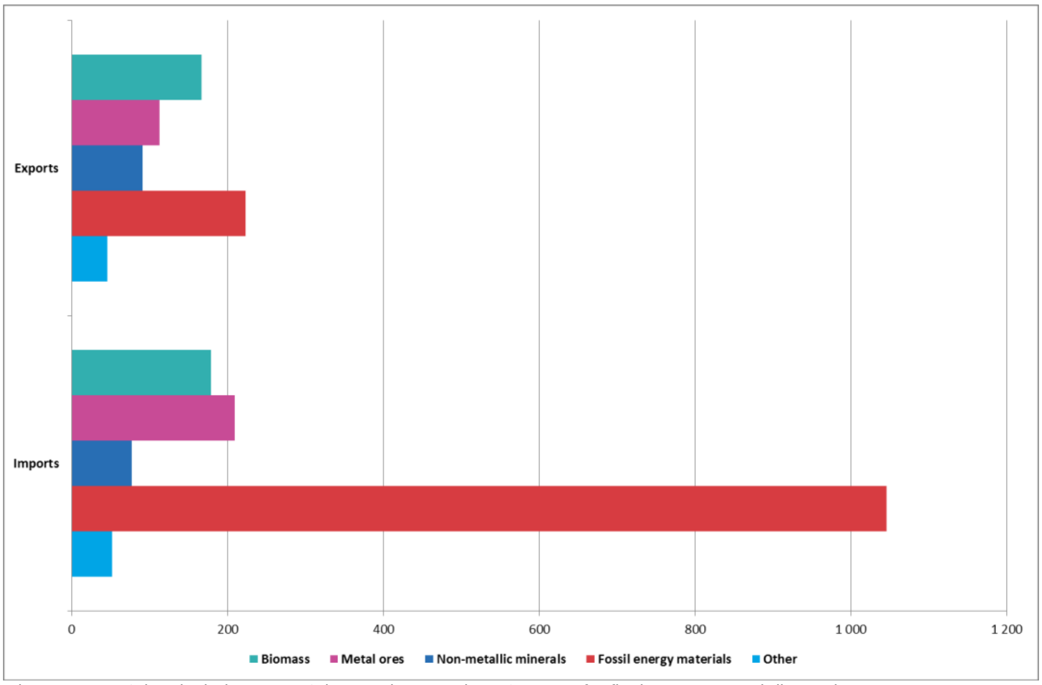
551. Figure 9 focuses on growth or contraction dynamics of individual material categories in contrast to Figure 7 and Figure 8, which obviously emphasise bigger categories such as non-metallic minerals, and the extraction of metal ores appears close to the zero line and rather stable. In Figure 7 and Figure 8 any clear development in the extraction of metal ores, such as the sudden increase between 2009 and 2013 is lost at the expense of bigger categories.

Physical trade flows

552. Next to DE, international physical trade flows, i.e. imports and exports, are compiled in EW-MFA. A number of EW-MFA indicators are calculated from DE and international trade flows. Any analysis has to consider that physical trade flows contain products at different stages of manufacturing and thus, differently from DE, comprise not only raw materials but also products that have undergone any processing step (see paras. 367ff.). Consequently, trade flows comprise two additional material categories which do not apply to DE: *Other products* that cannot be allocated to one material category due to a complex or unknown mixture of different materials, and *Waste for final treatment and disposal*. Growing trends in international trade show that countries are more intensively linked to the global economy, while a distinction between imports (depending on foreign resources) and exports (providing resources) reveals the specific role of a country in world markets.

How much is physically imported to and exported from EU-28? Which main material does the EU-28 import and export?

Figure 10: EU-28 physical trade by material category in 2015 (million tonnes)*

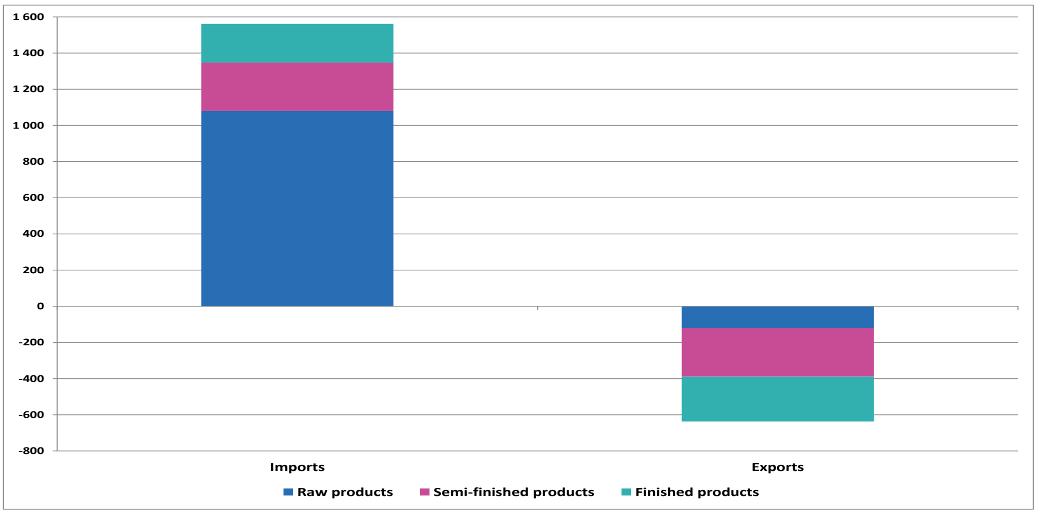


** The category 'Other' includes MF.5 'Other products' and MF.6 'Waste for final treatment and disposal'.*

553. The bar chart in Figure 10 compares imports and exports of main material groups in 2015 for the European economy and allows for a quick and easy comparison of the size of import and export flows by material category for one particular year. The EU-28 economy is both importing and exporting significant amounts of all material groups; in particular, about half of EU total imports is due to fossil energy materials. In 2015 trade flows are unbalanced for fossil fuels and metal ores. In 2015 imports exceed exports by a factor 2.5. This result is mainly due to the imports of fossil energy carriers, which are higher than all other imported material groups together.

What broad categories of products, according to their stage of manufacturing, do the EU-28 import and export?

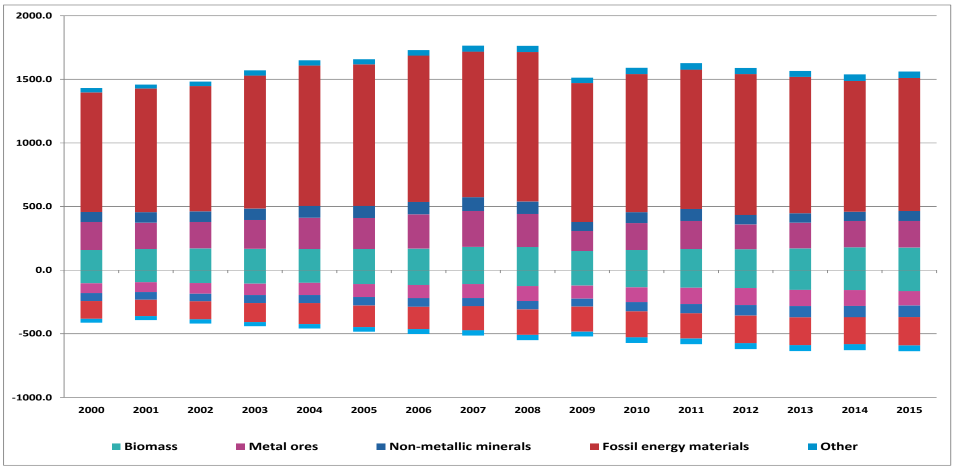
Figure 11: EU-28 imports and exports by stage of manufacturing, EU-28, 2015 (million tonnes)



554. The massive import of fuels and metals is not only for domestic final uses, but it also contributes to the manufacturing of European exports of manufactured products. This means that EU-28 imports raw products and transforms them into semi-finished and finished products to be exported (Figure 11).

How much has the EU-28 physically imported and exported over time? Which main materials has the EU-28 been importing and exporting over time?

Figure 12: EU-28 physical imports and exports of goods by main material category. 2000-2015 (million tonnes)*

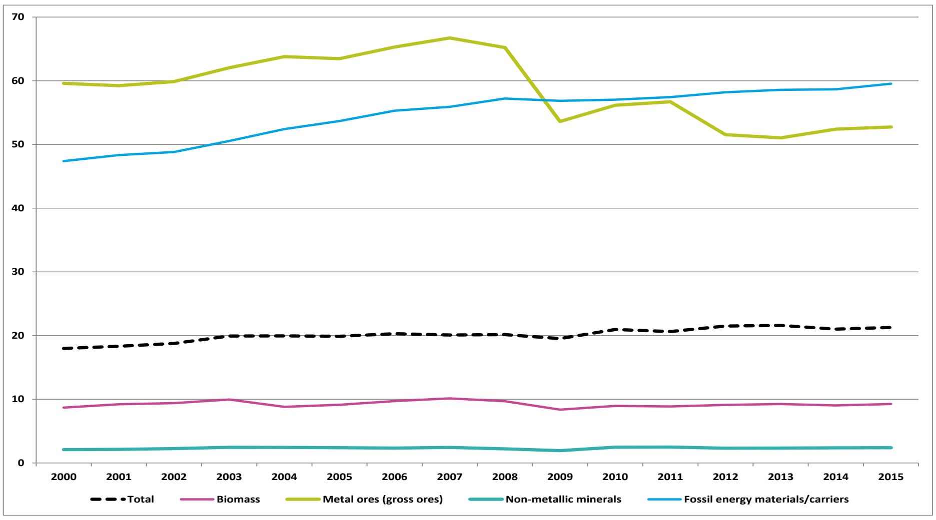


** The category 'Other' includes MF.5 'Other products' and MF.6 'Waste for final treatment and disposal'.*

555. A bar chart as presented in Figure 12 can be used to analyse trends in total trade and also to shows the development of imports and exports by main material group. Figure 12 highlights trends in imports and exports and emphasises any major changes therein such as the different effects of the economic crisis on imports and exports from 2008 onwards.

How has the share of physical imports in overall material input (DMI) developed over time - differentiated by main material categories?

Figure 13: Import dependency by main material category, as share of extra-EU imports in total materials made available to EU-28 economy. EU-28, 2000-2015



556. Growing globalisation together with increasing resource prices and the risk of supply are issues that can be monitored and discussed with trade dependency indicators. The EU-28 is a net-importing region, just as most of the Member States. Thus, the import dependency of the EU-28 region is as high as 20% of total material throughput, i.e. DMI (Figure 13). The highest trade dependency is shown by fossil energy carriers (steadily increasing from 2000 to 2015) and metal ores. The import dependency of the latter material category shifted to a lower level after the economic crisis, possibly as a result of lower level of production and increased EU-wide metal ore extraction since 2009 (see also Figure 9).

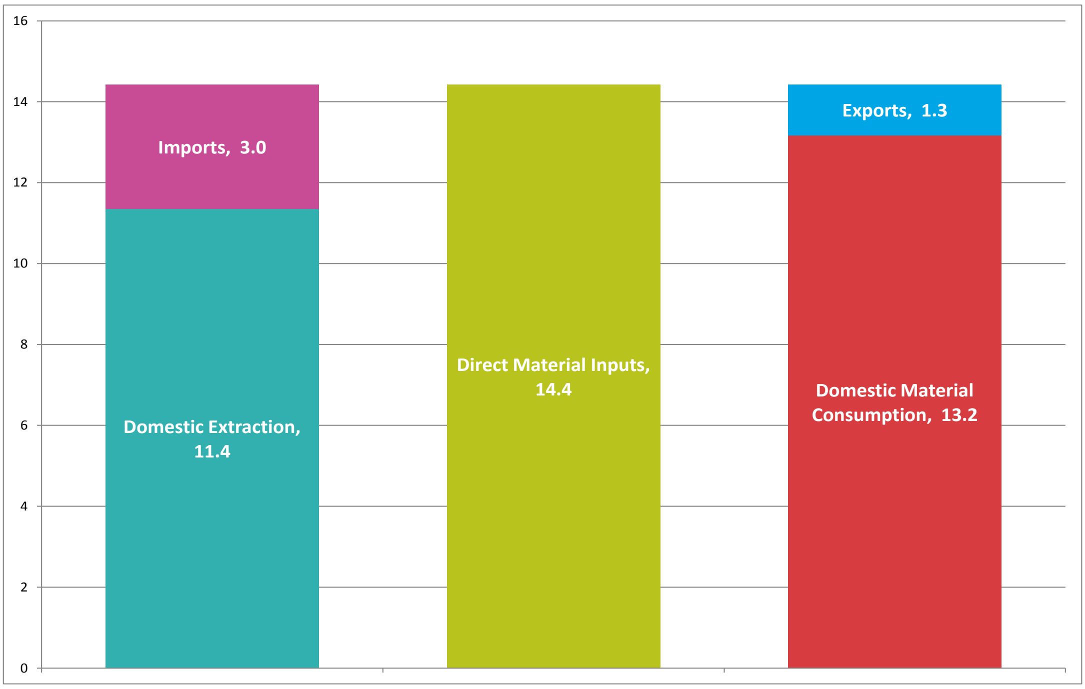
Domestic material consumption

557. DMC represents the total amount of material used within an economy that is either transformed into wastes and emissions or gets accumulated in societal stocks. DMC equals domestic extraction plus physical imports minus physical exports. The physical trade balance (imports minus exports) comprises mostly fossil energy carriers in the EU countries. DMC can be added across scales, i.e. the DMC of the EU-28 equals the sum of the DMC of the 28 Member States. However, see Box 1 in section 2.7 on how Eurostat calculates the EU aggregate.

558. In some cases, net exports might exceed DE and thus turn DMC negative. This in particular applies to material categories such as other products, where no extraction occurs but only traded goods are accounted for. But also in the category of fossil fuels, exports from short-term stocks can result in a negative DMC, or in some rare cases in the category of wood products due to a difference in moisture content of extracted and traded goods.

How much material is domestically consumed in the EU? I.e. how much material is transformed to emissions, waste and additions to stocks? How is domestic material consumption composed (domestic extraction vis-à-vis physical trade)?

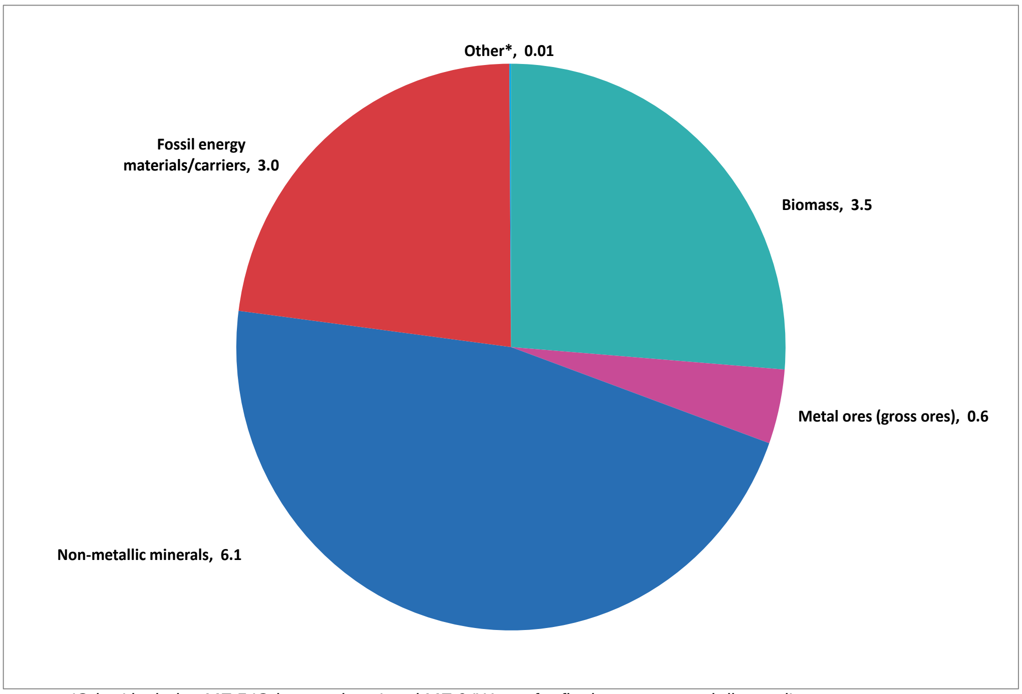
Figure 14: Relationship between EW-MFA indicators. EU 28, 2015 (tonnes per capita)



559. Figure 14 shows the relationship between various EW-MFA indicators. The first bar shows the domestic and foreign origin of material flows and represents the DMI, i.e. all the materials that enter the economy. All the materials supplied are then used (third bar in the figure) by the same economy (DMC) or are consumed abroad (Exports).

What materials are consumed in EU? How is the domestic material consumption of the EU composed by main material categories?

Figure 15: Domestic material consumption by main material category, EU-28, 2015 (tonnes per capita)*

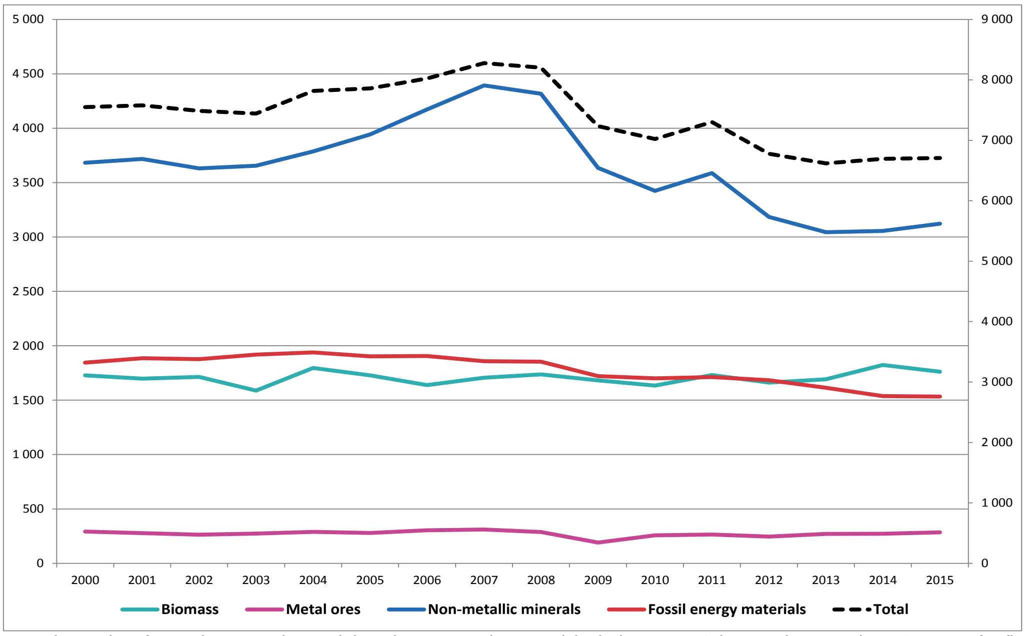


** The category 'Other' includes MF.5 'Other products' and MF.6 'Waste for final treatment and disposal'*

560. An analysis of DMC by material category conveys the relative significance of various materials and their potential for reuse, recovery or recycling. In Figure 15 materials are classified in five categories: biomass, metal ores, non-metallic minerals, fossil energy materials and *other* (the latter includes *Other products* and *Waste for final treatment and disposal*). Total DMC of the EU-28 economy is estimated at 13.2 tonnes per capita in 2015. The EU-28's DMC is dominated by non-metallic minerals, making up nearly half of the total. Biomass and fossil energy materials each made up approximately one quarter of DMC, about 26 % and 23 % respectively. Metal ores constitute the smallest among the main categories.

Which categories of material are consumed over time in the EU? How did the EU material consumption - broken down by 4 main material categories - evolve over time - in absolute volumes?

Figure 16: EU-28 domestic material consumption by main material category, 2000-2015 (million tonnes)*

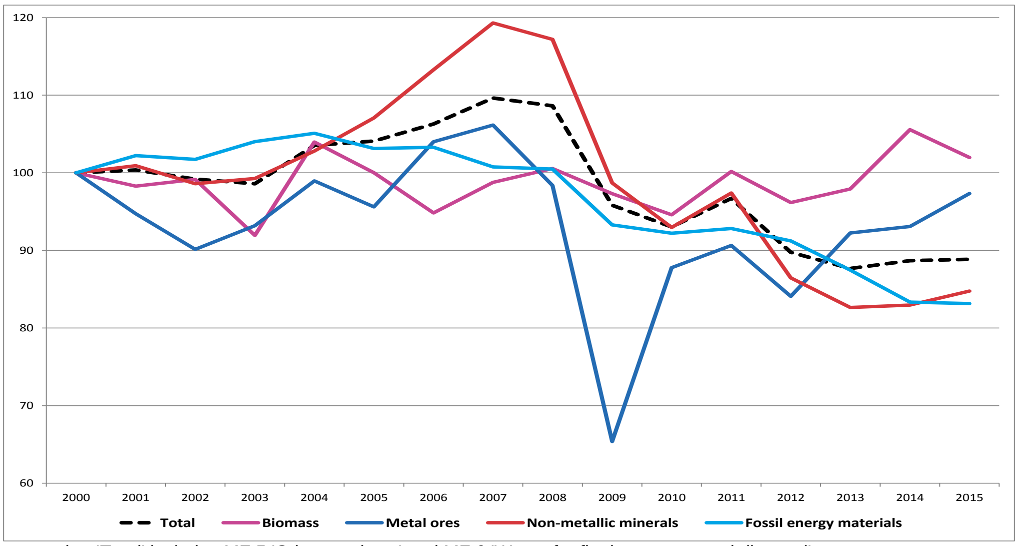


** The secondary axis refers only to 'Total materials'. Please note that 'Total' includes MF.5 'Other products' and MF.6 'Waste for final treatment and disposal'*

561. Material use in the EU-28 was rather stable or even declined from the economic crisis onwards. Non-metallic minerals make up for the biggest share in DMC, hence its development has a significant impact on the trend of aggregate material use. Trends of individual material categories are visible but might be blurred even by a non-stacked graph as Figure 16, which allows to focus on trends of individual material categories and in comparison to each other.

How did the EU material consumption of the four main material categories evolve over time - in relation to the first year?

Figure 17: Development of domestic material consumption by main material category, EU-28, 2000-2015 (index 2000=100)*



** Please note that 'Total' includes MF.5 'Other products' and MF.6 'Waste for final treatment and disposal'*

562. Figure 17 is an indexed representation of DMC which focuses on the changes in DMC by main material category in relation to the initial value. In order to better show the dynamics of biomass, metal ores, non-metallic minerals, and fossil fuels, the group *Others* is not included in Figure 17 since it is very small (about 0.1% of total DMC in the period 2000-2015) and it is characterized by high fluctuations relatively to its size (fluctuations in a small flow turn to high fluctuations in a indexed graph).

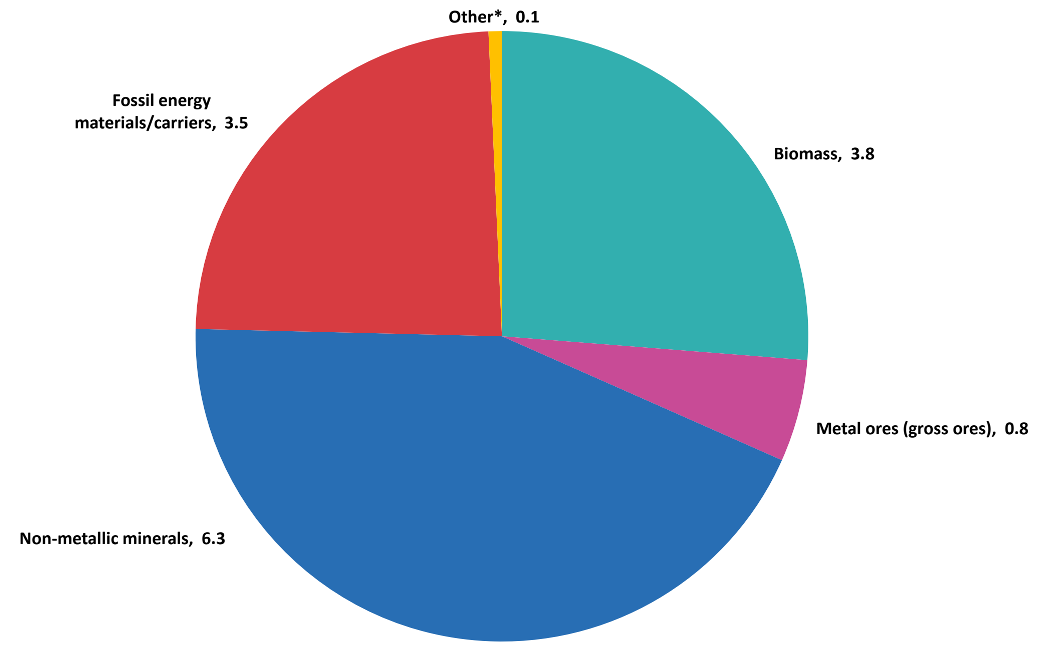
563. The consumption patterns of the four main categories are different over time. The level of consumption of biomass was relatively stable over the long term but can be impacted by strong cyclical fluctuations due to climatic conditions. The consumption of metal ores and non-metallic minerals show a strong dependency on economic development. Quite remarkable is the drop in consumption of metal ores by one third in 2009 after the onset of the financial and economic crisis. Metal ores and non-metallic minerals both show an upward trend from 2002 to 2007 followed by a notable decrease in the consumption of non-metallic minerals from 2007 to 2015 and of metal ores from 2007 to 2009. The trend of this latter material category changes again from 2009 to 2015, due to growth of both domestic extraction and imports of metal ores. The consumption of fossil energy materials is also affected by the overall economic development, although it is the least volatile among the material components; consumption of these materials decreases steadily from 2004 to 2015.

Direct material input

564. DMI is the total amount of material entering an economy, i.e. DE plus imports, and thus represents the total material throughput or material scale of an economy. DMI cannot be added across countries.

What materials are made available to EU economy? How is the direct material input of the EU composed by main material categories?

Figure 18: EU-28 direct material input by material category, 2015 (tonnes per capita)*



** The category 'Other' includes MF.5 'Other products' and MF.6 'Waste for final treatment and disposal'*

5.2. Relating EW-MFA to economic aggregates

565. Relating economic to physical measures reveals progress in decoupling resource use from economic activity, measured in terms of resource efficiency or productivity.[56] It has to be considered that flows and products can be of very different size if measured in monetary or physical units. E.g. primary goods such as crops or gravel make up for large masses but only very little economic value. In contrast, highly manufactured goods such as electronic devices or art works contain relatively little mass but are valued with a very high price.

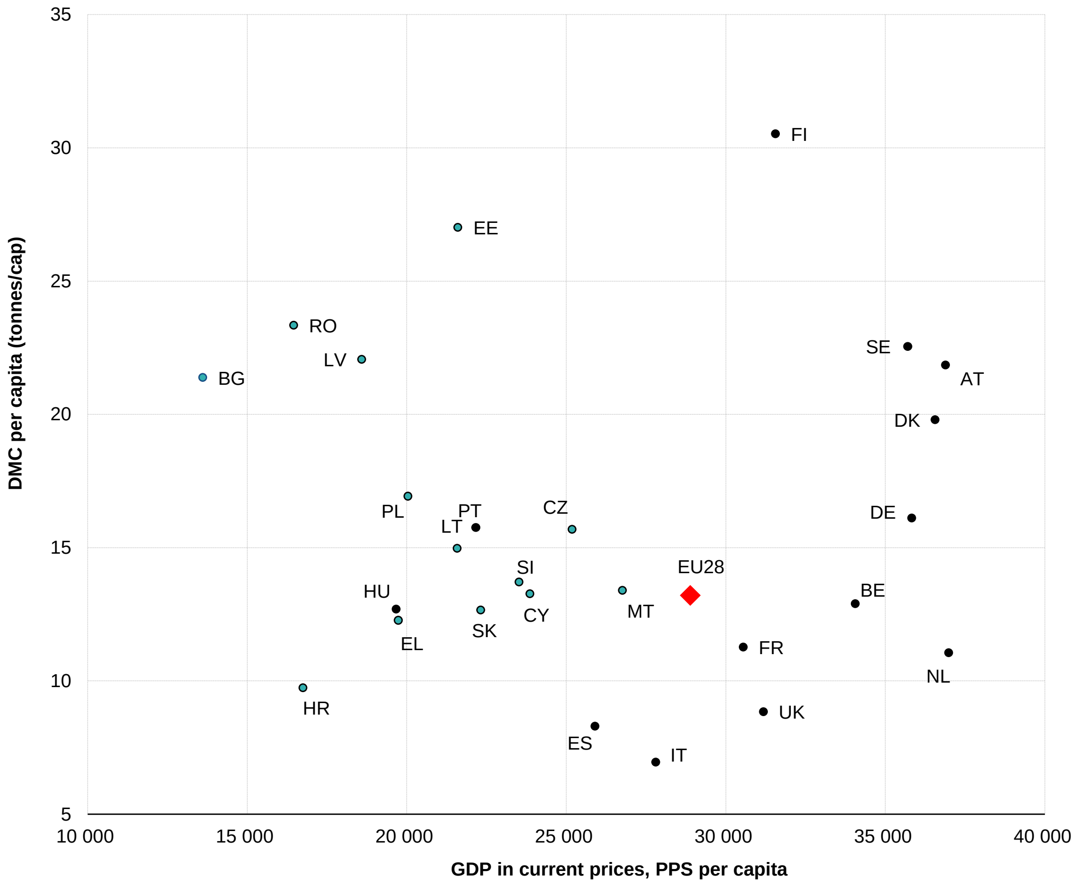
566. Resource use is often discussed in close relation to GDP in order to identify options for sustainable development by decoupling these two indicators. In the next paragraphs we discuss different ways of addressing the relation between resource use and economic development.

567. The variation of resource productivity across EU Member States is shown in Figure 19. Expressed in GDP in PPS over DMC, the resource productivity amounts to 2.19 PPS/kg for the aggregated EU-28 economy in 2015. The ratio varies considerably across EU Member States from 0.64 PPS/kg in Bulgaria to 4.00 PPS/kg in Italy.

[56] The term decoupling refers to breaking the link between an environmental and economic variable. As defined by the Organisation for Economic Co-operation and Development (OECD), decoupling occurs when the growth rate of an environmental pressure (for example, DMC) is less than that of its economic driving force (for example, GDP) over a given period. Decoupling can be either absolute or relative. Absolute decoupling is said to occur when the environmental variable is stable or decreases while the economic driving force grows. Decoupling is said to be relative when the rate of change of the environmental variable is less than the rate of change of the economic variable (OECD, 2002)

568. Figure 19 plots DMC against GDP. Besides the structure of the economy, the resource endowment and climatic conditions, population density may explain differences between EU Member States in relation to consumption patterns. More densely populated Member States such as the Netherlands, the United Kingdom and Italy tend to consume somewhat lower amounts per capita than the EU-28 average, whereas higher per capita consumption may be observed for low population density Member States like Finland, Estonia and Sweden

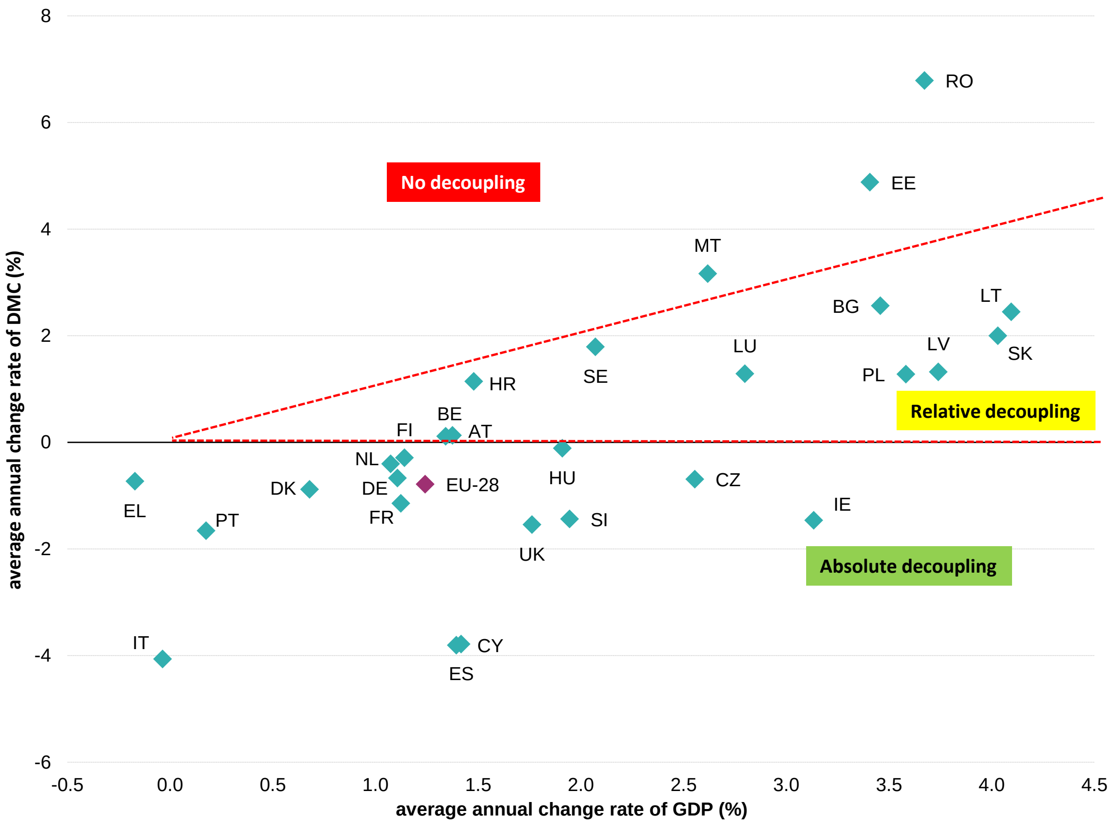
Figure 19: Resource productivity, cross-country comparison. 2015



(¹) Outlier excluded: LU

569. When the average annual change rates of DMC and GDP are considered, decoupling between the economic activity and the pressure on the environment can be investigated. Figure 20 illustrates how far decoupling has been achieved in the EU economy. The diagonal line represents same average change rates of both GDP and DMC between 2000 and 2015. Countries which find themselves above this diagonal line had higher DMC growth than GDP growth and did not de-couple. Below that diagonal line are all countries whose GDP increased faster than their DMC and which thus achieved at least relative decoupling. Absolute decoupling, i.e. below the x-axis where GDP grows and DMC falls, was achieved in the majority of European countries over the period, including the EU-28 economy as a whole.

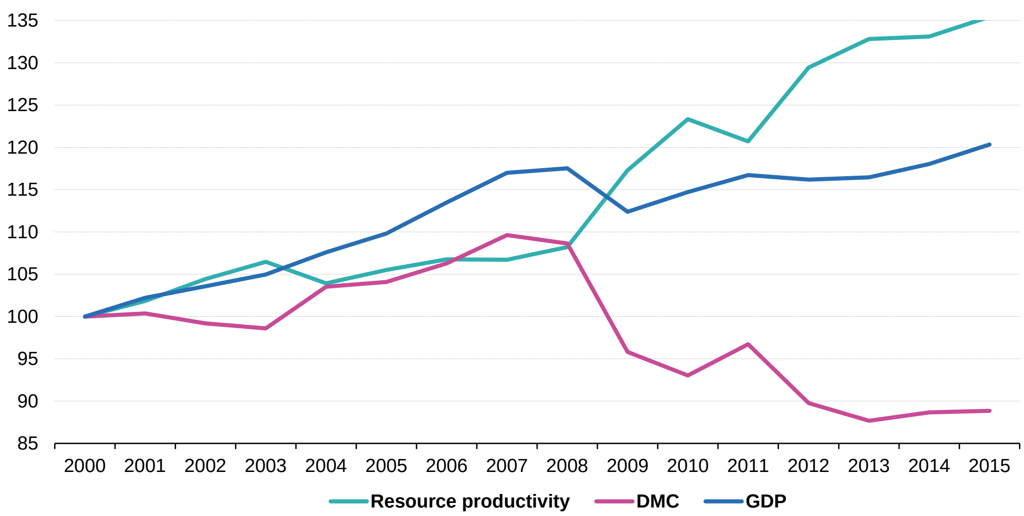
Figure 20: DMC and GDP(¹) - average annual change rates in EU-28 and countries between 2000 and 2015 (%)



(¹) GDP in chain-linked volumes, reference year 2010

Did the EU-28 succeed in decoupling resource use from economic growth?

Figure 21: Development of resource productivity in comparison with GDP and DMC, EU-28, 2000–2015 (index 2000=100)



570. Figure 21 shows that EU-28 resource productivity increased from 1.47 EUR/kg in 2000 to 2.01 EUR/kg in 2015, an increase of 36.5 %. This was not a steady increase: in particular the financial and economic crisis marked a change in 2008. Indeed, resource productivity reported a steady but modest increase from 2000 to 2008 (7.6 %). From 2008 to 2014 resource productivity surged from 1.59 to 2.01 EUR/kg, despite a dip in 2011. During this period annual growth was highest in 2009 (8.6 %) and 2012 (7.3 %).

571. An analysis of the resource productivity components helps to explain these developments. During the period from 2000 to 2007, GDP and DMC grew in parallel and there was no apparent decoupling between economic and environmental variables. Between 2007 and 2009 there was a relative decoupling of GDP from DMC, while an absolute decoupling of GDP from DMC was apparent in most years between the low point of the financial and economic crisis and the latest period for which data are available, in other words from 2009 to 2015.

572. Further conclusions about resource productivity can be attained through a more in-depth analysis of DMC into its component parts and a broadening of the analysis of material flows associated with international trade.

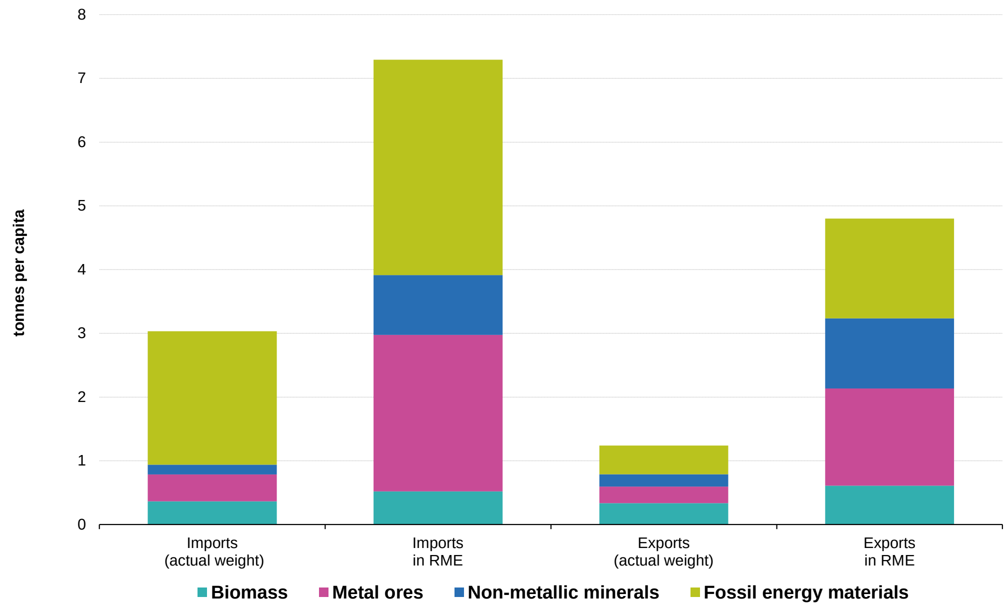
5.3. Presenting material flows in raw material equivalents

573. The data presented in this section are based on import and export flows expressed in their raw material equivalents (RME; see also section 2.8.1). These are estimated for the aggregated EU economy by Eurostat with models that are still under development and therefore do not produce official statistics yet. The results have a higher statistical uncertainty. According to the estimates, EU imports in 2014 were 2.4 times higher when expressed in RME than imports recorded in EW-MFA. Exports were 3.9 times higher. The derived global material footprint, also referred to as raw material consumption (RMC), was 13.9 tonnes per capita in the EU in 2014, or 5.3% higher than DMC.

574. Figure 22 shows that imports in RME and exports in RME are both substantially higher than the same flows measured in the actual weight of the traded goods as they cross the border. Imports in RME for the EU are estimated at 7.3 tonnes per capita, 2.4 times higher than the weight of imported goods. At 4.8 tonnes per capita, exports in RME are 3.9 times higher than the weight of exported goods.

575. It is important to realise that, in general, trade flows expressed in RME are larger than the actual weight of the products traded. Almost all products go through different stages of manufacturing, starting from the extraction of raw materials, then the transformation into raw products, followed by further processing and assembly into semi-manufactured products and finally into finished products. The mass weight of the extracted raw materials, e.g. gross ore, is generally much higher than the weight of the traded products that contain the processed material only.

Figure 22: Comparison of the actual weight of traded goods with trade in raw material equivalents (RME), EU-28, 2014 (tonnes per capita)



576. For example, while the concentration of metals in extracted metal ores is often less than 1 %, the metal content of concentrates and basic metals is much higher or even close to 100 %. This means that extracting concentrates and basic metals from virgin metal ores, often done in non-EU countries and reflected in EU imports, results in a much higher RME than the actual weight of the traded goods. Hence, it is not surprising that the largest difference between the actual weight of imports and imports in RME is found for metal ores: 2 tonnes per capita. The basic metals are usually further treated in the EU and integrated into final goods. These goods are then consumed in the EU or exported.

577. Non-metallic minerals also show a significant difference; 0.2 tonnes per capita in actual physical imports compared to 0.9 tonnes per capita in RME imports. The category is only a small part of both indicators however. This is because most non-metallic materials are usually extracted in the country in question, rather than traded.

578. For exports, the largest difference is found for the same material: metal ores. However, the different material categories contribute more evenly to the difference than for imports.

579. The physical trade balance (imports minus exports) in RME is 2.5 tonnes per capita whereas the actual physical trade balance itself is 1.8 tonnes per capita. As for imports and exports, the difference is mostly due to the material category of metal ores.

580. There are several other sources of differences, although these cannot be directly identified in Figure 22. An important source of difference is that not all extracted materials required for producing 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. This is also known as indirect material use. Generally, high-end consumer durables that require much processing and consist of many different parts will require more indirect use of materials than basic products. Another source of difference is due to the fact that in EW-MFA each traded product is assigned to one material category only, whereas traded products in RME are recorded with the whole range of materials that have contributed directly or indirectly to the production of the traded product.

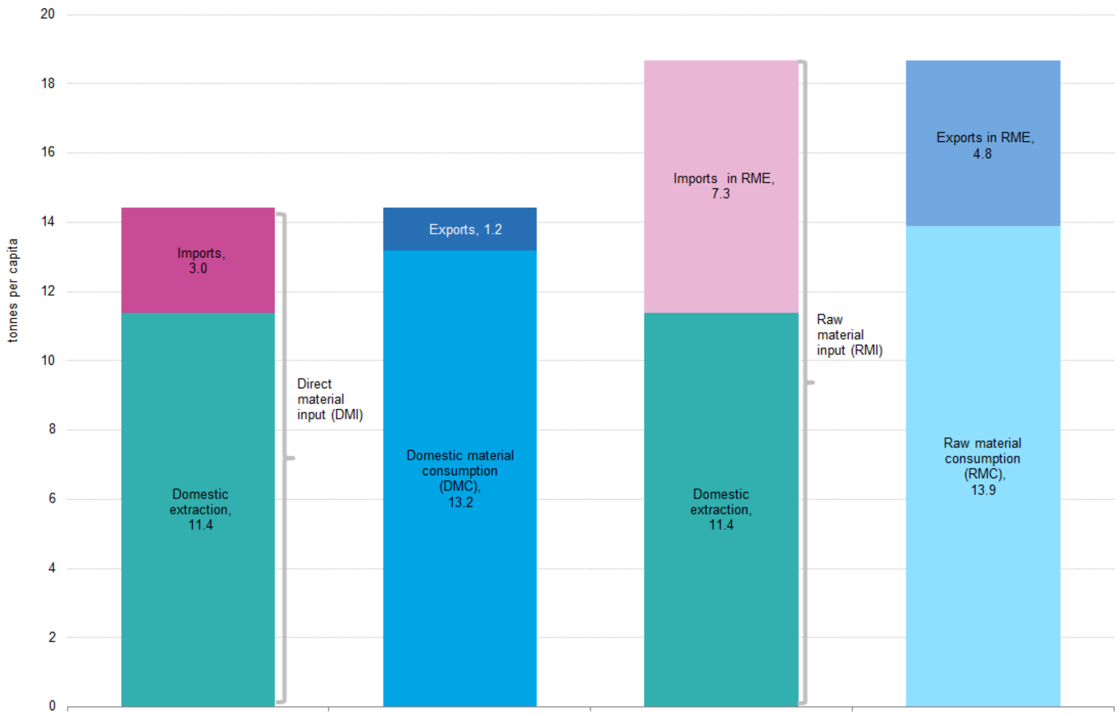
Material flow indicators in RME compared to EW-MFA indicators

581. The adjustment of the trade flows from actual weight when crossing the border to RME also

impacts the material flow indicators. The main RME-based indicator is raw material consumption (RMC), which mirrors DMC from the EW-MFA. It is also referred to as the EU's material footprint. RMC represents the total amount of extracted raw materials needed to produce the goods and services consumed and invested by residents of the EU.

582. Figure 23 explains how EW-MFA indicators and indicators expressed in RME are derived and compares these indicators for the aggregated EU-28 economy[57]. The first two bars on the left show the calculation of DMC. Imports of 3.0 tonnes per capita of actual weight are added to domestic extraction (11.4 tonnes per capita) after which exports of 1.2 tonnes per capita are subtracted. The third bar and fourth bar show the same expressed in RME, i.e. the amount of raw material extraction carried out in the whole world to produce the goods in question. RMC is calculated by adding 7.3 tonnes per capita of imports to domestic extraction (the same 11.4 tonnes per capita), and subtracting 4.8 tonnes per capita of exports. These calculations result in an estimate of RMC of 13.9 tonnes per capita in RME, 5.3% higher than DMC, which equals 13.2 tonnes per capita.

Figure 23: Material flow indicators derived from EW-MFA and MFA in RME, EU-28, 2014 (tonnes per capita)



583. Direct material input (DMI) and raw material input (RMI) are auxiliary indicators that represent the amount of materials that are available to an economy. DMI represents the weight of the material as it enters the economy, either from the environment or because it crosses the EU's borders. RMI represents all the material that is directly and indirectly extracted to supply all inputs required for EU production. In 2014, at 18.7 tonnes of RME per capita, RMI in the EU was 29.5 % higher than DMI.

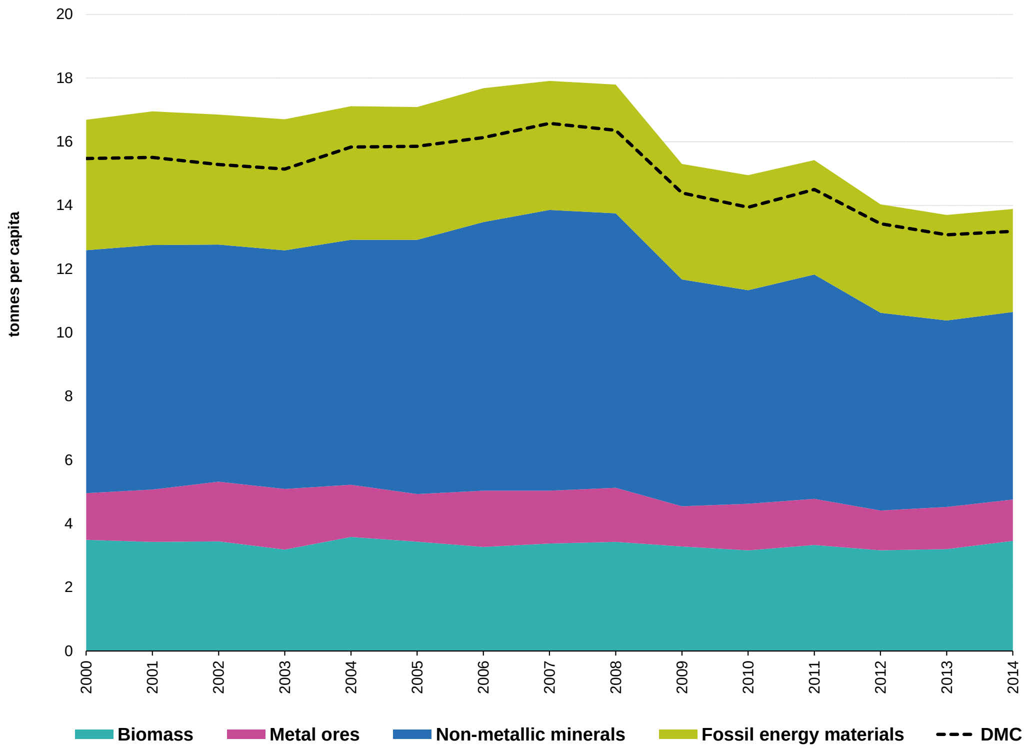
The EU's material footprint by material category over time

584. Figure 24 shows the development of the EU's material footprint or raw material consumption (RMC) over time. The change in total RMC is captured by combining the four areas reflecting the different material categories. For comparison, the development of DMC is included in the graph as a dotted line. Both indicators show almost the same development. For 2014, the absolute difference

[57] Note that the difference between DMC and RMC can be significantly higher at level of individual countries

between RMC and DMC is 0.70 tonnes per capita. The minimum difference over the time period shown is 0.61 tonnes per capita, in 2012, and the maximum difference is 1.62 tonnes per capita in 2002.

Figure 24: Raw material consumption (RMC) by main material categories, EU-28, 2000-2014 (tonnes per capita)



585. The RMC of non-metallic minerals is the major driver of the observed trend given that its development over time has the largest impact on the overall development. As the physical trade of non-metallic minerals is small and the trade balance in RME is close to zero, the total amount of RMC of this material category is close to the domestic extraction. This means that the change in total RMC is mainly determined by changes in domestic extraction of non-metallic minerals. Non-metallic minerals are mostly composed of construction minerals such as sand and gravel. Gross value added in construction increased by 14 % in the EU-28 between 2000 and 2007. Domestic extraction of non-metallic minerals increased by 18 % in the same period. Gross value added in construction decreased by 11 % during the economic crisis (2010 compared to 2008) and by 8 % in 2013 (compared to 2010). Domestic extraction of non-metallic minerals decreased by 20 % (2010 compared to 2007) and by 10 % in 2013 (compared to 2010). It therefore seems that domestic extraction of non-metallic minerals tends to increase or decrease more than gross value added in construction. It also suggests that gross value added in construction is not only the main factor affecting the development of domestic extraction of construction minerals, but that it also drives the development of RMC.

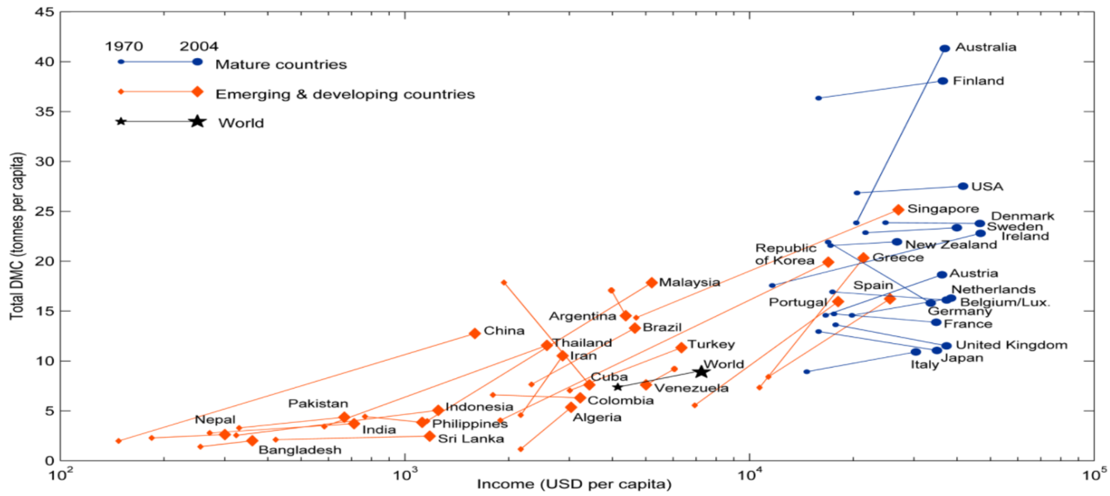
5.4. Analytical applications

586. This section presents some further going analytical applications which may be undertaken rather by research Most of these analytical applications cannot be performed solely on the EW-MFA data as derivable from the questionnaire; moreover they require substantial additional information and efforts.

587. Steinberger et al. (2013) investigated the dependency of resource use and economic growth for a set of countries and country groups with the use of a panel and cluster analysis. The authors showed that material use and economic development was more strongly coupled in emerging and developing countries than in mature industrialised economies. However, in the short run the picture reversed. In their findings, the authors also supported the argument that industrialisation of developing countries relies heavily on growing use of resources. On the other hand, they found that economic growth was limited in phases of declining resource use.

Is resource use dependent on economic growth?

Figure 25: Income and Domestic Material Consumption per capita for mature (blue circles), emerging/developing countries (orange diamonds), and the world (black star), in 1970 (small marker) and 2004 (large marker)



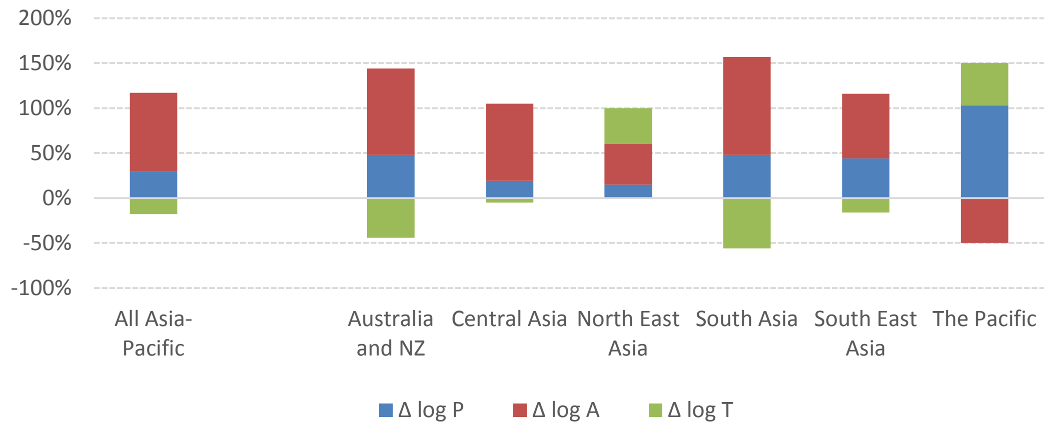
Source: Steinberger et al. (2013)

588. On the same issue, Agnolucci et al (2017) provide new evidence for a causal and positive impact of the GDP growth rate on the DMC growth rate for Western European economies, using the number of storm occurrences as an instrument for GDP. Results for Western Europe contradict previous studies and the current wisdom among policy circles, both suggesting that Western European countries have indeed 'decoupled' economic growth from material use. This article present new evidence that the link between the two variables is likely to exist and to be higher than previously thought.

589. Schandl and West (2010) compiled an EW-MFA database for the Asia–Pacific region and applied a decomposition analysis by using the IPAT equation in order to investigate how the three factors of population (P), affluence (A) and technology (T) contribute to resource use (I). The authors found that increases in per capita incomes had a stronger effect on material use than did population growth. Technology on the other hand could not compensate for the growth in material use induced by the other effects (further reading in: Steinberger and Krausmann, 2011).

Which are main drivers of resource use?

Figure 26: Analysis and attribution to major drivers of the change in domestic material consumption in the Asia–Pacific region for the period 1995–2005 using the IPAT framework. Own depiction based on Schandl and West (2010)



Legend: P = population, A = GDP/population, T = DMC/GDP. GDP is denominated in exchange rate based, constant year 2000 US$.*

Source: Schandl, H. and West, J., 2010

Material productivity vs. macroeconomic competitiveness

590. Flachenecker (2018) investigates the causal impact of material productivity on competitiveness in the European Union (EU). The results indicate that claiming increases in material productivity improves macroeconomic competitiveness might not be justified. While it is debateable whether higher wages improve or harm competitiveness, overall, there is no evidence that increasing material productivity is a setback to competitiveness, while acknowledging that there is no optimal set of indicators approximating competitiveness.

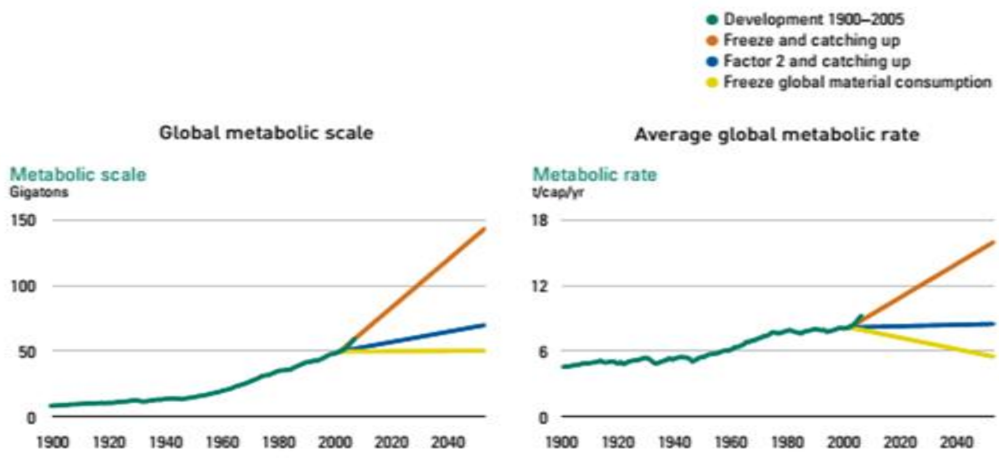
591. Channelling the gains from material productivity could be the focus of policy making since increased wages are likely to result in a more pronounced rebound effect and thus environmental pressures. Thus, through incentives, including tax breaks and financial support, policy makers could redirect gains into eco-innovations, which helps to further improve productivity and make the absolute reduction of material use and reduction of associated environmental pressures become more likely.

Which development of resource use shall we expect?

592. The UNEP assessment report Decoupling natural resource use and environmental impacts from economic growth (2011) compiled relevant literature on global resource use and investigated examples and trends of decoupling human well-being from resource use. The decoupling report also performed an illustrative outlook on possible future trajectories of resource use based on three scenarios: (1) freeze material use in industrialised countries and catching up of developing countries, (2) reduction of material use in industrialised countries by a factor of 2, catching up of developing countries to these reduced levels, (3) freezing of global material use at 2000 levels.

593. The authors found that scenario (1) would still lead to a major increase of material use, resulting in a tripling of global resource use between 2000 and 2050. The third scenario on the other hand requires a reduction of average global per capita material use had to be reduced to 5 tonnes per capita until the year 2050.

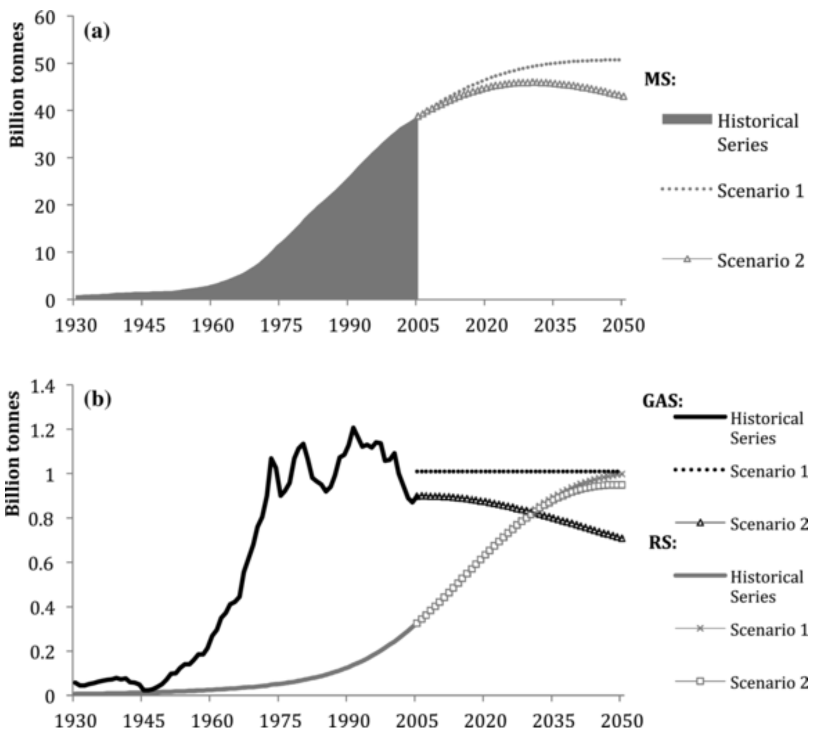
Figure 27: Resource use according to three different scenarios up to 2050



Source: UNEP (2011)

Modelling stocks and flows

Figure 28: Stocks and flows in Japan, 1930–2050: (a) material stock (MS), (b) gross additions to stock (GAS), and removals from stock (RS)



Source: Fishman et al. (2014)

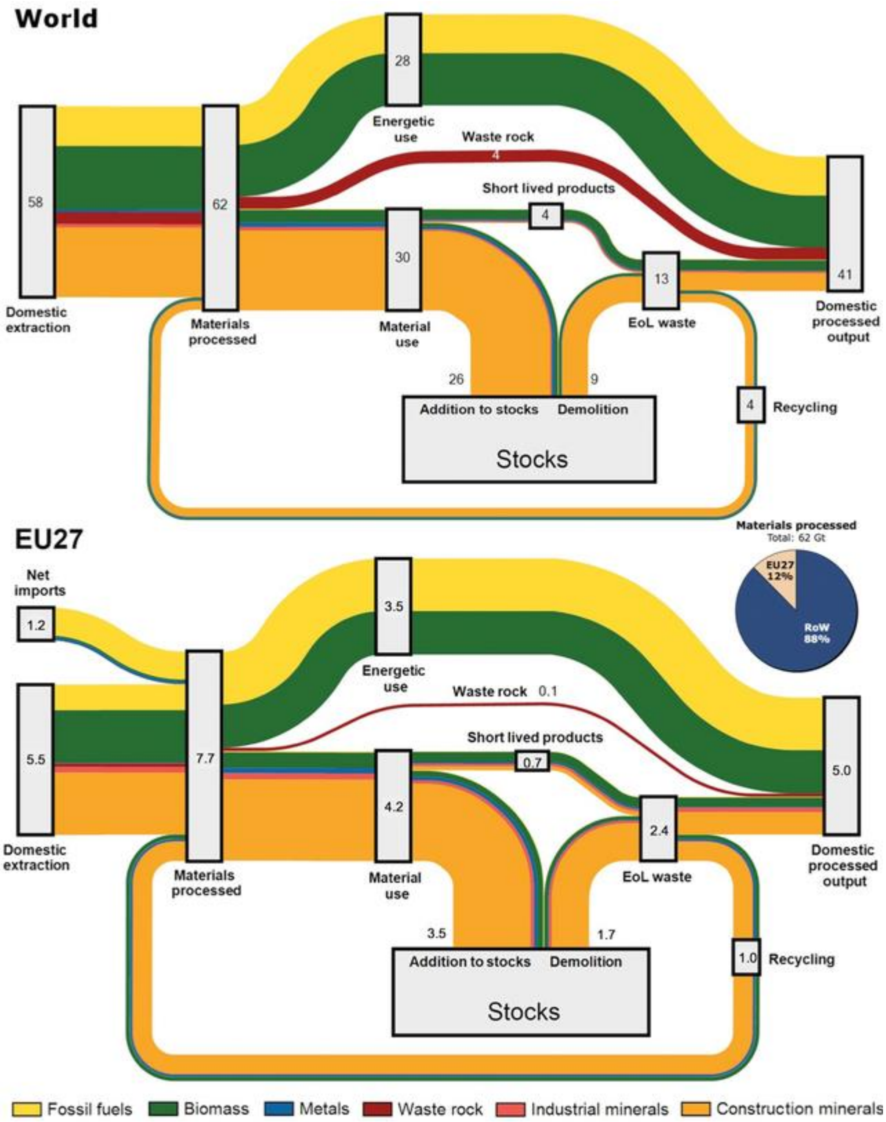
594. Data from EW-MFA include all material flows within one year that are required to build up and maintain socio-economic stocks. In recent years, several research activities emerged that account for societal stocks in order to capture the physical scale of societies. Fishman et al. (2014) presented a novel approach to modelling national material stocks based on historical material flow data and applied this approach to Japan and the USA. Investigating the years 1930–2005, the authors found that Japan experienced higher growth rates as compared to the US. In the year 2005, material

stocks arrived at comparable levels in both countries (310 to 375 tonnes per capita).

595. In another publication, Fishman et al. (2015) investigated drivers of Japanese material stocks based on the IPAT framework for five decades. They found that material stock accumulation mainly occurred due to growth in economic activity, specifically by tertiary sector demand, while a new stock saturation trend was observed in the last years (further reading: Wiedenhofer et al., 2015).

596. Following on the EU policy on the “circular economy”, Haas et al. (2015) assessed the circularity of global material flows. The authors estimated that of the 62 Gt/yr of processed materials, only 4 Gt/yr of waste materials are recycled and 41 Gt/yr end up as wastes and emissions. The authors identified two main reasons for this low degree of circularity: (1) materials used for the provision of energy (44 %) are used up and not available for recycling. (2) materials are accumulated in growing socioeconomic stocks (17 Gt/yr of net-additions to stocks).

Figure 29: material flows through the global economy and the EU-27 in 2005



Source: Figure 2. Sankey diagram of material flows through the global economy (world) and the EU-27 in 2005. Numbers show the size of flows in billion tonnes per year. For a definition of flows, see the article text. EU = European Union; EoL waste = end-of-life waste; RoW = rest of the world by Haas et al. (2015), DOI: 10.1111/jiec.12244, is licensed under CC BY

Annex A

Classification of materials in EW-MFA (cross tabled with type of flows)

Code	Label	A	B	D	F	G
	EW-MFA Questionnaire Table					
	EW-MFA type of flow:	**domestic extraction**	**physical imports**	**physical exports**	**domestic processes output**	**balancing items**
	SEEA-CF type of flow:	*natural inputs*	*products*	*products*	*residuals*	*natural inputs or residuals*
MF.1	Biomass	x	x	x		
MF.1.1	Crops (excluding fodder crops)	x	x	x		
MF.1.1.1	Cereals	x	x	x		
MF.1.1.2	Roots, tubers	x	x	x		
MF.1.1.3	Sugar crops	x	x	x		
MF.1.1.4	Pulses	x	x	x		
MF.1.1.5	Nuts	x	x	x		
MF.1.1.6	Oil-bearing crops	x	x	x		
MF.1.1.7	Vegetables	x	x	x		
MF.1.1.8	Fruits	x	x	x		
MF.1.1.9	Fibres	x	x	x		
MF.1.1.A	Other crops (excluding fodder crops) n.e.c.	x	x	x		
MF.1.2	Crop residues (used), fodder crops and grazed biomass	x	x	x		
MF.1.2.1	Crop residues (used)	x	x	x		
MF.1.2.1.1	Straw	x	x	x		
MF.1.2.1.2	Other crop residues (sugar and fodder beet leaves, etc.)	x	x	x		
MF.1.2.2	Fodder crops and grazed biomass	x	x	x		
MF.1.2.2.1	Fodder crops (including biomass harvest from grassland)	x	x	x		
MF.1.2.2.2	Grazed biomass	x				
MF.1.3	Wood	x	x	x		
MF.1.3.1	Timber (industrial roundwood)	x	x	x		
MF.1.3.2	Wood fuel and other extraction	x	x	x		
MF.1.3 MEMO	*Net increment of timber stock (memo item)*	*x**				
MF.1.4	Wild fish catch, aquatic plants and animals, hunting and gathering	x	x	x		
MF.1.4.1	Wild fish catch	x	x	x		
MF.1.4.2	All other aquatic animals and plants	x	x	x		
MF.1.4.3	Hunting and gathering	x				
MF.1.5	Live animals and animal products (excluding wild fish, aquatic plants and animals, hunted and gathered animals)		x	x		
MF.1.5.1	Live animals (excluding wild fish, aquatic plants and animals, hunted and gathered animals)		x	x		
MF.1.5.2	Meat and meat preparations		x	x		
MF.1.5.3	Dairy products, birds, eggs and honey		x	x		

Code	Label	EW-MFA Questionnaire Table				
		A	B	D	F	G
	EW-MFA type of flow:	domestic extraction	physical imports	physical exports	domestic processes output	balancing items
	SEEA-CF type of flow:	*natural inputs*	*products*	*products*	*residuals*	*natural inputs or residuals*
MF.1.5.4	Other products from animals (animal fibres, skins, furs, leather, etc.)		x	x		
MF.1.6	Products mainly from biomass		x	x		
MF.2	Metal ores (gross ores)	x	x	x		
MF.2.1	Iron	x	x	x		
MF.2.2	Non-ferrous metal	x	x	x		
MF.2.2.1	Copper	x	x	x		
MF.2.2.1 MEMO	*Copper - metal content*	*x**				
MF.2.2.2	Nickel	x	x	x		
MF.2.2.2 MEMO	*Nickel - metal content*	*x**				
MF.2.2.3	Lead	x	x	x		
MF.2.2.3 MEMO	*Lead - metal content*	*x**				
MF.2.2.4	Zinc	x	x	x		
MF.2.2.4 MEMO	*Zinc - metal content*	*x**				
MF.2.2.5	Tin	x	x	x		
MF.2.2.5 MEMO	*Tin - metal content*	*x**				
MF.2.2.6	Gold, silver, platinum and other precious metals	x	x	x		
MF.2.2.7	Bauxite and other aluminium	x	x	x		
MF.2.2.8	Uranium and thorium	x	x	x		
MF.2.2.9	Other non-ferrous metals	x	x	x		
MF.2.3	Products mainly from metals		x	x		
MF.3	Non-metallic minerals	x	x	x		
MF.3.1	Marble, granite, sandstone, porphyry, basalt, other ornamental or building stone (excluding slate)	x	x	x		
MF.3.2	Chalk and dolomite	x	x	x		
MF.3.3	Slate	x	x	x		
MF.3.4	Chemical and fertiliser minerals	x	x	x		
MF.3.5	Salt	x	x	x		
MF.3.6	Limestone and gypsum	x	x	x		
MF.3.7	Clays and kaolin	x	x	x		
MF.3.8	Sand and gravel	x	x	x		
MF.3.9	Other non-metallic minerals n.e.c.	x	x	x		
MF.3.A	*Excavated earthen materials (including soil), only if used (optional reporting)*	*x**				
MF.3.B	Products mainly from non-metallic minerals		x	x		
MF.4	Fossil energy materials/carriers	x	x	x		
MF.4.1	Coal and other solid energy materials/carriers	x	x	x		
MF.4.1.1	Lignite (brown coal)	x	x	x		
MF.4.1.2	Hard coal	x	x	x		
MF.4.1.3	Oil shale and tar sands	x	x	x		
MF.4.1.4	Peat	x	x	x		

Code	Label	EW-MFA Questionnaire Table				
		A	B	D	F	G
	EW-MFA type of flow:	**domestic extraction**	**physical imports**	**physical exports**	**domestic processes output**	**balancing items**
	SEEA-CF type of flow:	*natural inputs*	*products*	*products*	*residuals*	*natural inputs or residuals*
MF.4.2	Liquid and gaseous energy materials/carriers	x	x	x		
MF.4.2.1	Crude oil, condensate and natural gas liquids (NGL)	x	x	x		
MF.4.2.2	Natural gas	x	x	x		
MF.4.2.3	Fuels bunkered (Imports: by resident units abroad; Exports: by non-resident units domestically)		x	x		
MF.4.2.3.1	Fuel for land transport		x	x		
MF.4.2.3.2	Fuel for water transport		x	x		
MF.4.2.3.3	Fuel for air transport		x	x		
MF.4.3	Products mainly from fossil energy products		x	x		
MF.5	Other products		x	x		
MF.6	Waste for final treatment and disposal		x	x		
MF.7	Domestic processed output				x	
MF.7.1	Emissions to air				x	
MF.7.1.1	Carbon dioxide (CO_2)				x	
MF.7.1.1.1	Carbon dioxide (CO_2) from biomass combustion				x	
MF.7.1.1.2	Carbon dioxide (CO_2) excluding biomass combustion				x	
MF.7.1.2	Methane (CH_4)				x	
MF.7.1.3	Dinitrogen oxide (N_2O)				x	
MF.7.1.4	Nitrous oxides (NO_x)				x	
MF.7.1.5	Hydroflourcarbons (HFCs)				x	
MF.7.1.6	Perflourocarbons (PFCs)				x	
MF.7.1.7	Sulfur hexaflouride				x	
MF.7.1.8	Carbon monoxide (CO)				x	
MF.7.1.9	Non-methane volatile organic compounds (NMVOC)				x	
MF.7.1.A	Sulfur dioxide (SO_2)				x	
MF.7.1.B	Ammonia (NH_3)				x	
MF.7.1.C	Heavy metals				x	
MF.7.1.D	Persistent organic pollutants (POPs)				x	
MF.7.1.E	Particles (e.g. PM_{10}, Dust)				x	
MF.7.1.F	Other emissions to air				x	
MF.7.2	Waste disposal to the environment				x	
MF.7.2MEMO	*Waste disposal to controlled landfills (memo item)*				*x***	
MF.7.3	Emissions to water				x	
MF.7.3.1	Nitrogen (N)				x	
MF.7.3.2	Phosphorus (P)				x	
MF.7.3.3	Heavy metals				x	
MF.7.3.4	Other substances and (organic) materials				x	
MF.7.3.5	Dumping of materials at sea				x	
MF.7.4	Dissipative use of products				x	
MF.7.4.1	Organic fertiliser (manure)				x	

Code	Label	EW-MFA Questionnaire Table				
		A	B	D	F	G
	EW-MFA type of flow:	**domestic extraction**	**physical imports**	**physical exports**	**domestic processes output**	**balancing items**
	SEEA-CF type of flow:	*natural inputs*	*products*	*products*	*residuals*	*natural inputs or residuals*
MF.7.4.2	Mineral fertiliser				x	
MF.7.4.3	Sewage sludge				x	
MF.7.4.4	Compost				x	
MF.7.4.5	Pesticides				x	
MF.7.4.6	Seeds				x	
MF.7.4.7	Salt and other thawing materials spread on roads (including grit)				x	
MF.7.4.8	Solvents, laughing gas and other				x	
MF.7.5	Dissipative losses				x	
MF.8	Balancing items: net output (= Balancing item: output side - Balancing item: input side)					x
MF.8.1	Balancing items: input side					x
MF.8.1.1	Oxygen for combustion processes					x
MF.8.1.2	Oxygen for respiration of humans and livestock; bacterial respiration from solid waste and wastewater					x
MF.8.1.3	Nitrogen for Haber-Bosch process					x
MF.8.1.4	Water requirements for the domestic production of exported beverages					x
MF.8.2	Balancing items: output side					x
MF.8.2.1	Water vapour from combustion					x
MF.8.2.1.1	Water vapour from moisture content of fuels					x
MF.8.2.1.2	Water vapour from the oxidised hydrogen components of fuels					x
MF.8.2.2	Gases from respiration of humans and livestock (CO_2 and H_2O), and from bacterial respiration from solid waste and wastewater (H_2O)					x
MF.8.2.2.1	Carbon dioxide (CO_2)					x
MF.8.2.2.2	Water vapour (H_2O)					x
MF.8.2.3	Excorporated water from biomass products					x

* Not taken into account when aggregating domestic extraction (DE)
** Not taken into account when aggregating domestic processed output (DPO)

Annex B

EW-MFA classification of trade by stage of manufacturing

Code	Label	EW-MFA Questionnaire Table				
		A	B	D	F	G
	EW-MFA type of flow:	**domestic extraction**	**physical imports**	**physical exports**	**domestic processes output**	**balancing items**
	SEEA-CF type of flow:	*natural inputs*	*products*	*products*	*residuals*	*natural inputs or residuals*
SM_FIN	Stage of Manufacturing - finished products		x	x		
SM_SFIN	Stage of Manufacturing - semi-finished products		x	x		
SM_RAW	Stage of Manufacturing - raw products		x	x		

Annex C

Overview of Annexes to the EW-MFA questionnaire

The EW-MFA questionnaire includes 7 Annexes as a separate EXCEL file which Eurostat revises and publishes year by year on its Environment – Methodology page along with the launch of the annual data collection:

Annex1: Correspondence table between EW-MFA classification for biomass and Eurostat agricultural crop statistics, forestry statistics, fishery statistics

Annex 2: Correspondence table between EW-MFA classification for metal ores, non-metallic minerals and fossil energy materials, and Eurostat energy statistics and PRODCOM

Annex 3: Correspondence table between EW-MFA classification for non-metallic minerals and PRODCOM, BGS and USGS

Annex 4: Correspondence table between EW-MFA classification for imports and exports and Combined Nomenclature

Annex 5: Correspondence between EW-MFA classification for stages of manufacturing and Combined Nomenclature

Annex 6: Conversion factors for imports and exports in Combined Nomenclature

Annex 7: Complete version of Combined Nomenclature including 2, 4, 6, and 8 digits codes, valid from 1988

Annex D

Weight of European hunted animals (kg)

Animal species		Source		Life weight in kg								
English	Latin			Total			Male			Female		
		Burnand[1]	Wikipedia	min	max	average	min	max	average	min	max	average
Mammals												
Rabbit	Oryctolagus cuniculus	X		2.0	3.0							
Hare or brown hare	Lepus europaeus	X		4.0	5.0							
Variable hare	Lepus timidus varronis	X				3.0						
Red deer or Stag	Cervus elaphus	X		100	200.0							
Roedeer	Capreolus capreolus	X		14.0	20.0							
Fallow deer	Dama dama	X				65.0						
Sika (deer)	Cervus nippon		X		80.0							
Wildbear	Sus scrofa	X		50.0	120.0							
Wolf	Canis lupus	X		35.0	45.0							
Lynx	Lynx lynx	X				30.0						
Wild cat	Felis sylvestris	X		6.0	10.0							
Badger	Meles meles	X		20.0	25.0							
Fox	Vulpes vulpes	X		6.0	12.0							
Beech marten	Martes foina		X	1.1	2.3							
Pine marten	Martes martes		X	0.8	1.8							
Polecat	Mustela putorius		X				0.4	1.7		0.2	0.9	
Raccoon dog	Nyctereutes procyonoides		X	6.5	7.0							
Raccoon	Procyon lotor		X	3.5	9.0							
Nurek vison	Mustela lutreola		X	0.4	0.8							
Weasel	Mustela nivalis		X	0.0	0.3							
Stoat	Mustela erminea		X	0.0	0.4							
Genet	Genetta genetta		X	1.0	3.0							
Mangoose	Herpestes ichneumon		X	0.2	5.0							
Squirrel	Sciurus vulgaris		X	0.2	0.4							
Chamois	Rupicapra rupicapra	X		50.0	65.0							

Animal species		Source		Life weight in kg								
English	Latin			Total			Male			Female		
		Burnand[1]	Wikipedia	min	max	average	min	max	average	min	max	average
Bouquetin	Capra ibex	X		75.0	100.0							
Mufflon	Ovis orientalis musimon	X		20.0	40.0							
Brown bear	Ursus arctos	X		250.0	300.0							
Elk	Alces alces		X						320.0			225.0
Reindeer	Rangifer tarandus		X				159.0	182		80.0	120.0	
Marmot	Marmota marmota	X		5.0	8.0							
Otter	Lutra lutra	X		15.0	16.0							
Common seal	Phoca vitulina	X				75.0						
Birds												
Common partridge	Perdix perdix	X					0.40	0.45				0.38
Red legged partridge	Alectoris rufa	X					0.40	0.65		0.35	0.45	
Rock partridge	Alectoris graeca	X		0.60	0.80							
Pintailed sandgrouse	Pterocles alchata	X										
Blackbellied sandgrouse	Pterocles orientalis	X										
Pallas' sandgrouse	Syrrhaptus paradoxus	X										
Quail	Coturnix coturnix	X		0.08	0.13							
Song trush	Turbus philomelos	X		0.07	0.08							
Fieldfare	Turbus pilaris	X		0.09	0.11							
Mistletrush	Turbus viscivorus		X			0.14						
Redwing	Turbus iliacus	X				0.06						
Blackbird	Turbus mercula	X				0.10						
Ring ouzel	Turbus torquatus	X										
Great bustard	Otis tarda	X					4.00	11.00		4.00	5.00	
Little bustard	Tetrax tetrax	X		0.75	1.00							
Stone curlew	Burhinus oedicnemus	X		0.38	0.48							
Praticole	Glareola pratincola	X										
Sky lark	Alauba arvensis	X										

Animal species		Source		Life weight in kg								
English	Latin			Total			Male			Female		
		Burnand[1]	Wikipedia	min	max	average	min	max	average	min	max	average
Wood lark	Lullula arborea	X										
Crested lark	Galerida cristata	X										
Calandra lark	Melanocorypha calandra	X										
Short toed lark	Calandrella brachydactyla	X										
Pheasant	Phasianus colchicus	X					1.35	1.55		1.00	1.15	
Woodcock	Scolopax rusticola	X		0.30	0.40							
Woodpigeon or Ringdove	Columba palumbus	X				0.50						
Stock dove	Columba oenas	X				0.30						
Rock dove	Columba livia	X				0.30						
Turtle dove	Streptopelia turtur	X		0.12	0.16							
Hazel grouse	Tetrastes bonasia	X		0.40	0.48							
Black grouse	Lyrurus tetrix	X					1.00	1.70		0.70	1.00	
Capercaillie	Tetrao urogallus	X					3.00	4.50		1.80	2.30	
Ptarmigan	Lagopus mutus	X		0.40	0.50							
Red grouse	Lagopus scoticus	X				0.60						
Mallard	Anas platyrhynchos	X		0.90	1.40							
Gadwall	Anas strepera	X		0.70	0.85							
Shoveler	Spatula clypeata	X		0.55	0.75							
Pintail	Anas acuta	X					0.80	1.20		0.70	0.90	
Widgeon	Anas penelope	X		0.70	0.90							
Garganey	Anas querquedula	X		0.30	0.45							
Teal	Anas crecca	X		0.27	0.45							
Marbled duck	Marmaronetta angustiroistris	X										
Grey lag goose	Anser anser	X		3.00	4.00							
White fronted goose	Anser albifrons	X		2.00	3.00							
Pinkfooted goose	Anser brachyrhynchus	X		2.00	2.50							
Bean goose	Anser fabalis	X		2.50	4.00							
Brentgoose	Branta bernicla	X		1.20	1.70							

Animal species		Source		Life weight in kg								
English	Latin			Total			Male			Female		
		Burnand[1]	Wikipedia	min	max	average	min	max	average	min	max	average
Barnacle goose	Branta leucopsis	X				1.20						
Shelduck	Tadorna tadorna	X		0.90	1.20							
Redcrested pochard	Netta rufina	X		1.00	1.20							
Pochard	Aythya ferina	X		0.80	1.10							
Ferruginous duck	Aythya nyroca	X		0.50	0.70							
Scaup duck	Aythya marila	X		0.80	1.30							
Tufted duck	Aythya fuligula	X		0.70	1.00							
Goldeneye	Bucephala clangula	X		0.80	1.10							
Harlequin	Histrionicus histrionicus	X		0.25	0.45							
Velvet scoter	Melanitta fusca	X		1.20	2.00							
Common scoter	Melanitta nigra	X		0.80	1.20							
Common eider	Somateria molissima	X		1.50	2.50							
Common snipe	Gallinago gallinago	X		0.10	0.15							
Great snipe	Gallinago media	X		0.18	0.25							
Jack snipe	Lymnocryptes minimus	X		0.06	0.07							
Golden plover	Pluvialis apricaria	X		0.13	0.18							
Grey plover	Pluvialis squatarola	X		0.17	0.24							
Dotterel	Charadrius morinellus	X				0.12						
Ringed plover	Charadrius hiaticula	X				0.06						
Little ring plover	Charadrius dubius	X		0.04	0.05							
Kentish plover	Charadrius alexandrius	X				0.04						
Lapwing	Vanellus vanellus	X				0.20						
Moorhen	Gallinula chloropus	X		0.25	0.30							
Purple gallinule	Porphyrio porphyrio	X										
Coot	Fulica atra	X		0.60	0.80							
Corn crake or Land rail	Crex crex	X		0.12	0.18							

Animal species		Source		Life weight in kg								
English	Latin	Burnand[1]	Wikipedia	Total			Male			Female		
				min	max	average	min	max	average	min	max	average
Water rail	Rallus aquaticus	X		0.10	0.13							
Spotted crake	Porzana porzana	X		0.08	0.12							
Little crake	Porzana parva	X		0.05	0.05							
Baillon's crake	Porzana pusilla		X				0.02	0.05		0.02	0.06	
Common heron	Ardea cinerea	X		1.50	2.00							
Purple heron	Ardea purpurea	X		1.00	1.50							
Night heron	Nycticorax nycticorax	X				0.75						
Little bittern	Ixobrychus minutus	X		0.13	0.16							
Bittern	Botaurus stellaris	X		1.00	1.30							
Squacco heron	Ardeola ralloides	X		0.25	0.35							
Little egret	Egretta garzetta	X				0.50						
Spoonbill	Platalea leucorodia	X				1.70						
Glossy ibis	Plegadis falcinellus	X				0.75						
Common crane	Grus grus	X		4.00	6.00							
Common curlew	Numenius arquata	X		0.70	1.10							
Whimbrel	Numenius phaeopus	X		0.35	0.40							
Bar-tailed godwit	Limosa lapponica	X					0.16	0.25		0.25	0.29	
Black-tailed godwit	Limosa limosa	X		0.24	0.34							
Blackwinged stilt	Himantopus himantopus	X		0.14	0.18							
Avocet	Recurvirostra avosetta	X		0.30	0.40							
Ruff (male), Reeve (female)	Philomachus pugnax	X							0.20	0.12	0.15	
Common red shank	Tringa totanus	X				0.13						
Greenshank	Tringa nebularia	X		0.15	0.17							
Spotted redshank	Tringa erythropus	X				0.14						
Marsh sandpiper	Tringa stagnatilis	X				0.08						
Green sandpiper	Tringa ochropus	X		0.08	0.10							

Animal species		Source		Life weight in kg								
English	Latin	Burnand[1]	Wikipedia	Total			Male			Female		
				min	max	average	min	max	average	min	max	average
Common sandpiper	Actitis hypoleucos	X		0.05								
Wood sandpiper	Tringa glareola	X		0.05	0.08							
Rednecked phalarope	Phalaropus lobatus	X		0.04	0.05							
Grey phalarope	Phalaropus fulicarius	X		0.05	0.05							
Dunlin	Calidris alpina	X		0.05	0.05							
Curlew sandpiper	Calidris feruginea	X				0.05						
Little stint	Calidris minuta		X	0.02	0.03							
Temminck stint	Calidris temminckii		X	0.02	0.04							
Purple sandpiper	Calidris maritima		X				0.05	0.09		0.06	0.11	
Broadbilled sandpiper	Limicola falcinellus		X	0.03	0.05							
Knot	Calidris canutus		X	0.12	0.17							
sanderling	Calibris alba		X	0.05	0.07							
Turnstone	Arenaria interpres	X				0.11						
Oystercatcher	Haematopus ostralegus	X				0.50						
Rook	Corvus frugileus	X										
Carrion crow	Corvus corone	X										
Hooded crow	Corvus cornix	X										
Jay	Garrulus glandarius		X			0.17						
Magpie	Pica pica	X				0.20						

1 Source: Burnand (1964)

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Economy-wide material flow accounts

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