Material Flow Accounts

Chapter 2

Material Flow Accounts

Infinite growth of material consumption in a finite world is an impossibility.
-E.F. Schumacher

Background

2.1 Human society cannot function without drawing in natural resources from the environment and using the environment to absorb the unwanted by-products of the economic production and of consumption. Natural resources and other inputs from the environment, as well as the capacity of the environment to act as a sink to absorb the residuals and unwanted by-products from economic productions, are necessary considerations for sustainable development. Driven by rapid economic and population growth, the demand for natural resources, especially materials have grown manifolds over the last few decades. In the endeavour for economic growth, natural resources have been largely unequally distributed, adversely impacting the environment and the biodiversity. Further, resource use, climate change, land degradation, biodiversity loss, air and water pollution are closely related. The growing concerns regarding the depletion of the vital resources resulting in adverse impacts on natural environment have lately gained greater prominence. This has helped shift the focus on judicious utilization of the resources globally through a combination of conservation and efficiency measures and aim for transitioning towards the circular economy.

2.2 India, one of the fastest growing economies with GDP of around ₹235 lakh crore for the year 2021-22 at current prices, has increased its material consumption at an enormous pace. However, this economic growth has been coupled with an inherent cost to the natural environment. Material consumption is expected to grow more in order to provide for increasing population, rapid urbanization and growing aspirations. The projected pace of economic development is going to put pressure on an already stressed and limited set of resources and may lead to resource depletion and environmental degradation affecting the economy, livelihoods and the quality of life. Further, material use is also closely associated with the problem of increasing wastes, which when suitably processed could deliver valuable secondary resources.

Therefore, it is the time to rethink how we exploit resources, how we build our cities and infrastructure, how we grow our food, and how we manage our waste.

2.3 In order to sustainably manage these resources, there is a need to identify ways to minimize the use of natural resources while at the same time maximizing the economic growth and social benefits of natural resource used. Developing policies which promotes circular economy and decoupling economic growth can only be done by tracking how materials are being used and identifying opportunities for improving efficiency, reducing material use and waste, promoting recycling and changing processes.

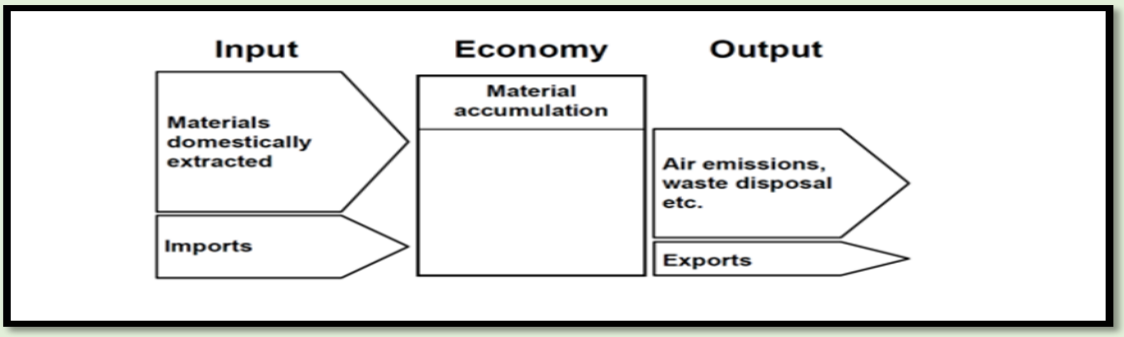
The Economy-Wide Material Flow Accounts (EW-MFA)

2.4 The Economy-Wide Material flow accounts (EW-MFA[1]) provide a physical measurement of the relationship between the economy and the environment through an aggregate overview, in tonnes, of the material inputs and outputs of an economy, including inputs from the environment, flows of materials back to the environment, and the physical amounts of imports and exports. Through the measurement of these flows, the EW-MFA and associated balances constitute the basis for a summary overview based on the derivation of a variety of material flow-based indicators.

2.5 The general purpose of the economy-wide material flow accounts is to describe in terms of the material flows, the interaction between the national economy, the natural environment and the rest of the world economy. Only those flows crossing the system boundary of the national economy, either on the input side or on the output side, are counted. Material flows within the economy are not represented in the EW-MFA. **Figure 2.1** provides an illustration of the flows recorded in the accounts.

[1] https://seea.un.org/sites/seea.un.org/files/mfa_final_draft.pdf

Figure 2.1: Scope of Economy-Wide Material Flow Accounts (EW-MFA)



Source: SEEA Technical Notes

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

2.7 EW-MFA follow the SEEA Central Framework's standard approach to physical flow accounting, which lays out a set of accounting principles and boundaries within which all types of physical flows relating to economic activities can be consistently recorded. The SEEA CF defines three generic types of physical flows as depicted in **Figure 2.2**, namely natural inputs, products and residuals. While the definition of products aligns with the national accounts' definition[2], natural inputs and residuals are concepts which do not exist in national accounts. They are included in the SEEA CF in order to account for the physical inter-relations between the national economy and the natural environment.

Figure 2.2: Natural inputs, products, and residuals: types of physical flow in relation to the production boundary of the economy

Source: SEEA-CF

[2] Being those goods and services created through a production process and have economic value (SEEA CF §1.40; see also SNA 2008 §§ 6.26-48 for the definition of the production boundary).

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

- Natural resource inputs are material resource extractions from the natural environment. They include materials actually used in production as well as natural resource residuals. These are natural resource inputs that do not subsequently become products but instead immediately return to the environment.
- Natural inputs from renewable energy sources include, for example, solar energy captured by economic units (often non-material, rather energy flows).
- Other natural inputs include, for example, inputs from soil (e.g. soil nutrients) and inputs from air (e.g. oxygen taken up in combustion processes or CO2 absorbed by cultivated plants).

2.9 **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. Products are relevant for EW-MFA in as much as they constitute physical trade flows (imports and exports). Product flows within the economy are not recorded in EW-MFA.

2.10 **Residuals** refer to flows of solid, liquid and gaseous materials and energy that are discarded, discharged or emitted to the environment (e.g., emissions to air and water) through economic processes of production, consumption or accumulation.

Linkages of System of Environmental Economic Accounting (SEEA)

2.11 Environment Accounts following the SEEA Framework describe the total scale of socio-economic activities in physical quantities but are fully compatible with economic national accounts. EW-MFA[3] are conceptually embedded into the framework of the SEEA, which extends the monetary national accounts by a physical and environmental dimension.

[3] https://wedocs.unep.org/xmlui/bitstream/handle/20.500.11822/36253/UNRE.pdf?sequence=3&isAllowed=y

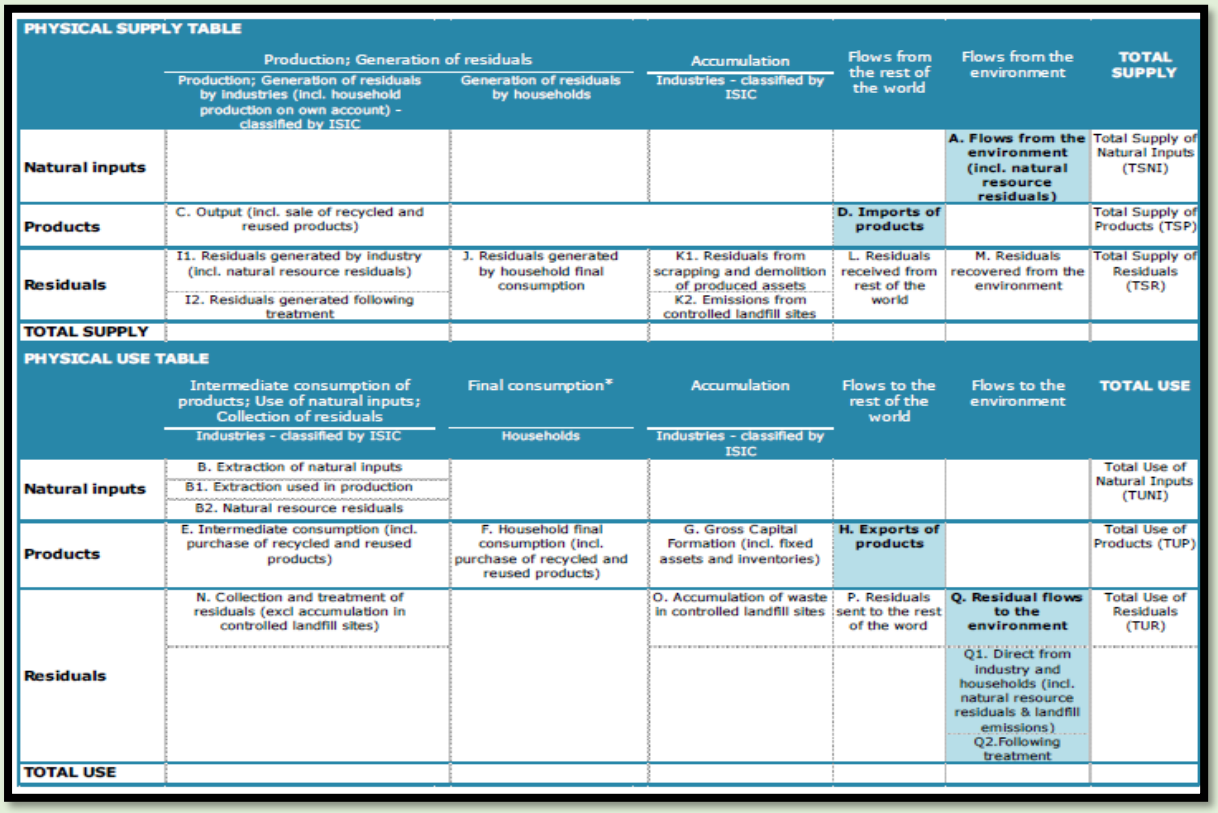
2.12 The integration of material flow accounts into the SEEA central framework achieves complementarity with national accounting principles to the extent possible. EW-MFA is a part of the physical flow accounts of the SEEA Central Framework. The SEEA-CF establishes PSUT (in parallel to monetary supply and use tables) as the accounting framework for physical flows. It introduces a set of accounting principles and boundaries that enable internally consistent recording of all types of physical flows that go hand in hand with economic activity. The physical flow accounts have two important features that are relevant for material flow accounting. The accounting framework of physical supply and use tables, and the delineation of three types of physical flows which are natural inputs, products and residuals relate quite directly and/or overlap with the EW-MFA accounting principles.

2.13 The division into natural inputs (domestic extraction of materials), products (traded materials or internal flows) and the division of residuals into waste and emission according to environmental gateway (water, air and soil) all resonate with EW-MFA terminology and accounting principles.

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

2.15 The PSUT framework is illustrated in **Figure 2.3**. It consists of a pair of tables with the same structure. Row-wise, the two tables show the various types of physical flows (namely natural inputs, products, and residuals). Column-wise they show the various origins and destinations supplying and using these flows, namely industries (i.e. production activities), households (i.e. consumption activities), accumulation (i.e. changes in stocks of produced assets and product inventories), rest of the world and environment. The physical supply table shows physical flows by origin. The physical use table shows physical flows by destination. MFA accounts are not fully articulated PSUT as introduced in the System for Environmental and Economic Accounting Central Framework (SEEA-CF). Establishing a full PSUT system would be an extremely time-consuming activity and will require various levels of reporting on physical flows by specific industries which are either not currently in existence, or not made available, and so are not made part of the EW-MFA accounts. **Figure 2.3** highlights those cells which are recorded in EW-MFA (shaded cells).

Figure 2.3: Physical Supply and Use Tables (PSUT) and the Economy-Wide Material Flow Accounts (EW-MFA)



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

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

Source: SEEA Technical Notes

2.16 The cells captured in the EW-MFA are described as follows:

(i) ***Sub-matrix A*** presents the supply of natural inputs from the natural environment to the economy. This is termed as domestic extraction in EW-MFA and is broken down by type of material and excludes natural resource residuals.

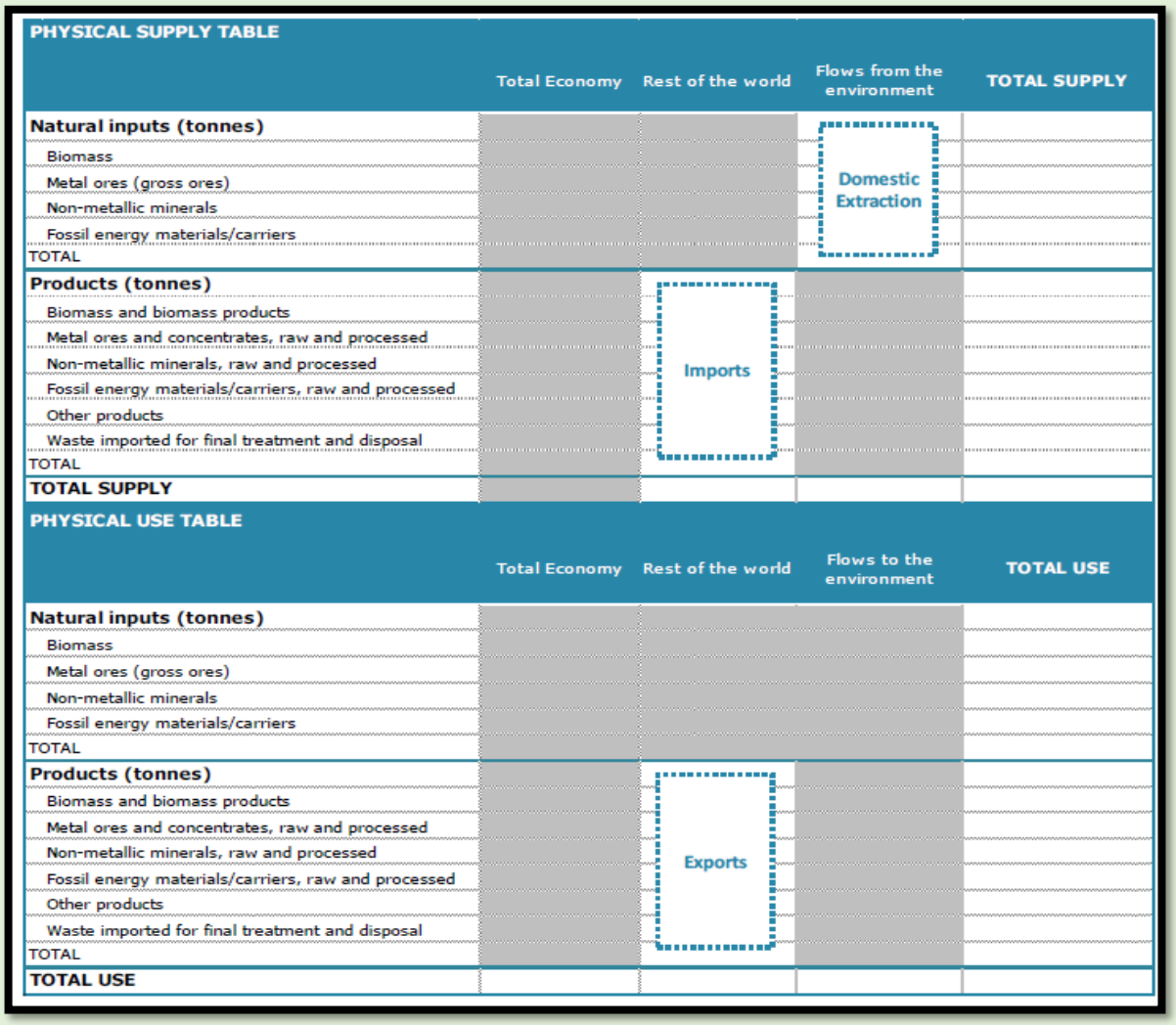
(ii) ***Sub-matrix D*** presents the supply of products by the rest of the world which is termed as imports in EW-MFA. This is measured in physical terms.

(iii) ***Sub-matrix H*** presents the supply of products to the rest of the world which is termed as exports in EW-MFA. This is measured in physical terms.

(iv) ***Sub-matrix Q*** presents the flows of residuals from the economy to the environment. This is termed as domestic processed output in EW-MFA, and is broken down by type of residual.

2.17 The Core Account of the MFA is presented in following **Figure 2.4**. This consists of information on the Domestic extraction, Imports and Exports (sub-matrices A, D, H of the above **Figure 2.3**). In the present chapter, the coverage has been restricted to the compilation of the Core Accounts only.

Figure 2.4: Core Accounts for the Economy-Wide Material Flow Accounts (EW-MFA)



Source: SEEA Technical Notes

2.18 The various components of the core accounts are explained in the subsequent paragraphs:

I. **Domestic Extraction (DE)** (sub-matrix A) is the amount of used material inputs from the environment to the economy. Domestic extraction as defined in EW-MFA includes only the used extraction of material; that is material extracted from the environment by humans and further processed in the economy. DE excludes unused extraction (termed natural resource residuals in SEEA CF). DE can be broken down into the following four categories:

(i) **Biomass** in general comprises of organic non-fossil material of biological origin. Not all generated biomass is considered DE, but the following two major types of biomass can be identified;

a. biomass generated within the environment by a natural process which is outside human control, such as non-cultivated forests or the growth of wild animals, and
b. biomass generated by a cultivation process which takes place more or less under human control, like the production of agricultural crops and plants.

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

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

(iv) **Fossil fuels** include flows of natural inputs of fossil energy, such as coal, peat, petroleum, and natural gas. Whereas energy statistics/balances show a comprehensive picture of the supply and use of all energy carriers, the domestic extraction of energy materials/carriers in EW-MFA is limited to the extraction of fossil energy carriers only. While in the SEEA Energy accounts measurement is in joules, in the EW-MFA measurement is in mass.

II. Imports and Exports (in physical terms) are product flows between the economy of concern and the rest of the world. They are recorded in terms of product weight and based on categories that, to the greatest extent possible, mirror the main categories used for domestic extraction. EW-MFA estimates of physical flows of imports and exports are typically based on international trade data.

2.19 Some conventions need to be respected when compiling imports and exports. (Physical) imports and exports exclude goods in transit through a country, which is consistent with the SNA and the SEEA.

2.20 There are some important differences between the SEEA-CF and the system boundaries of EW-MFA which are especially important in the domain of agriculture, where the SEEA conceptualises agricultural area and plants as part of the economy (cultivated biological resources) and EW-MFA as part of the environment. Consequently, the SEEA treats water, carbon dioxide, and nutrients as a natural input whereas EW-MFA interprets the harvest of crops as natural input.

2.21 Similar to the system of national accounts, material flow accounts serve two major purposes. The detailed accounts provide a rich empirical database for many

analytical studies. They are also used to compile different extensive and intensive material flow indicators for national economies at various levels of aggregation. EW-MFA is also closely related to other physical flow modules of the SEEA system, such as the Air Emissions Accounts, Physical Energy Flow Accounts, Water Accounts, etc. EW-MFA concepts, accounting rules and classifications are harmonized as far as possible with SEEA and the above-mentioned sub-modules. A more explicit integration of EW-MFA into the SEEA framework in the future would be worthwhile to yield the full explanatory strength of both approaches.

Linkages with the Sustainable Development Goals

2.22 Being a signatory to UN Sustainable Development Goals [4] India is committed to provide for sustained economic growth along with sustainable use of natural resources and safeguarding the environment. Resource efficiency has a vital role to play towards mitigation of climate change, land degradation and biodiversity loss. It is thus, imperative for India to charter and take the path of economic development supported with efficient use of resources and minimum negative impacts on environment, ultimately leading to sustainable development.

2.23 The United Nations 2030 Agenda for Sustainable Development and its 17 Sustainable Development Goals (SDGs) state that sustainable natural resource use and management is a necessary condition to achieve a better future for current and future generations. In two SDGs – Goal 8 "Decent work and Economic Growth", and Goal 12, "Sustainable consumption and production" – sub-targets have been defined (Target 8.4 and Target 12.2), which specifically require material flow-based indicators for monitoring. Data on economy-wide material flow accounts (EW-MFA) are necessary to inform policies not only for the management of natural resources and waste, but also policies related to circular economy, resource use and ecosystems.

Indicators derived from the MFA

2.24 A large number of indicators can be established from economy-wide material flow accounts. These indicators generally correspond to the main variables of the EW-MFA accounts and describe material use at different stages of economic

[4] https://moef.gov.in/wp-content/uploads/2019/07/Draft-National-Resourc.pdf

activities, from material extraction via international trade and material consumption to the generation of waste and emissions. In line with the materials balance scheme, the main types of indicators can be defined as input indicators, consumption indicators, trade and balancing indicators and output indicators. These different types of indicators deliver complementary information about various aspects related to national material use. They can also be combined to provide a more comprehensive depiction of the related issues. Furthermore, these indicators can be combined with economic indicators, such as Gross Domestic Product (GDP), to construct indicators of material productivity. Depending on the scope of material flows considered, the indicators can be grouped into several categories:

A. Indicators based on accounts of direct material flows, i.e. domestic material extraction and physical imports and exports.
B. Indicators which also include indirect material flows associated with direct imports and exports – these flows are also called raw material equivalents (RME).
C. Indicators which in addition consider unused material extraction, both of domestic and foreign origin.

2.25 Since the accounts is restricted to compiling the core account of EW-MFA, three particularly important indicators can be derived based on the information provided in the core account Three particularly important indicators can be derived based on the information provided in the core account.

- ***Direct Material Input (DMI)*** measures the direct input of materials for use in an economy (excluding bulk flows of water and air). Note that parts of the production system's output are exported

  DMI = DE + Imports

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

  DMC = DMI – Exports

- ***Physical Trade Balance (PTB)*** measures the physical trade surplus (positive value) or physical trade deficit (negative value) of a given national economy;

  PTB = Imports – Exports

Accounting identities inherent to EW-MFA

2.26 The above components and derived variables are linked by accounting identities. One important identity is the 'direct material input and use account'. Domestic extraction (DE) plus imports forms the direct material input (DMI). The use of DMI is composed of domestic material consumption (DMC) and exports:

DE + imports = DMI = DMC + Exports

2.27 The SDG Indicator 8.4.1 which is resource productivity [Domestic Material Consumption (DMC)/Gross Domestic Product in Market Prices (GDP)] can be compiled with the help of the MFA.

Material Flow Accounts in India

2.28 In this chapter the Core Accounts of the Material Flow Accounts which includes Domestic Extraction, Exports and Imports has been dealt with. The residual part (only the solid waste accounts) for some of the States has been covered separately in the Chapter 3 of the publication. The primary data sources for the Core MFA accounts is the M/o Agriculture, Tea Board of India, Coffee Board of India, Rubber Board of India, Narcotics Commissioner of India, Indian Bureau of Mines, Director General of Commercial Intelligence and Statistics (DGCIS) and National Accounts Division, MoSPI.

2.29 The core accounts, based on the available data for the MFA has been compiled for the years 2011-12, 2015-16 and 2020-21. **Table 2.1** presents the core accounts of the Material Flow Accounts for the year 2011-12, 2015-16 and 2020-21.

2.30 The prices for the biomass which includes agricultural crops, horticultural crops, fisheries etc. were not available in the required format of MFA, therefore the Gross Value of Output (GVO) of the respective item at an All-India level has been used as a proxy. Similarly, for those minerals where prices could not be obtained neither from the IBM or from the concerned Ministry, GVO has been used as a proxy. For cases where the production value was not available, only the price data has been compiled in the MFA. Also, as per the Gazette Notification [5]dated 10th February, 2015 by Ministry of Mines some of the major minerals have been

[5] https://egazette.gov.in/WriteReadData/2015/162767.pdf

categorized as Minor minerals. The data for major and minor minerals has been accordingly compiled.

Table 2.1: Core Account of Material Flow Accounts

Items	Quantity ('Lakhs Tonnes)	Value (Crore)	Quantity (Lakhs Tonnes	Value (Crore)	Quantity (Lakhs Tonnes	Value (Crore)
	2011-12		2015-16		2020-21	
Domestic Extractions						
Biomass	9,987	14,20,336	9,291	20,13,348	11,066	31,14,219
Minerals	11,271	2,97,981	12,400	3,15,830	13,897	4,38,238
Total DE	**21,258**	**17,18,317**	**21,691**	**23,29,178**	**24,963**	**35,52,457**
Export						
Export-Standard Units*	2,028	9,82,170	1,849	11,39,197	2,859	14,58,346
Export-Others**		4,05,286		5,43,744		6,46,169
Total Export	**2,028**	**13,87,456**	**1,849**	**16,82,941**	**2,859**	**21,04,515**
Import						
Import-Standard Units*	4,201	18,30,650	6,171	18,06,872	6,430	20,14,238
Import-Others**		4,55,173		5,61,838		7,93,935
Total Import	**4,201**	**22,85,823**	**6,171**	**23,68,710**	**6,430**	**28,08,174**

*Units: Kilograms, Tonnes; **Unit: Other than Kilograms, Tonnes

Totals may not match due to rounding off.

2.31 For the exports and the imports, all the relevant commodities have been segregated into two categories- those commodities whose units could be converted into standard units and those which could not. For the latter, only the prices have been considered for the MFA. The details of the commodities for DE, Export and Import for years 2011-12, 2015-16 and 2020-21 are provided in **Annexures 2.1 to 2.12**.

2.32 It can be seen from **Table 2.1** that in the period of 3 years there has been an increase in the material consumption. Using the core account of MFA, the following indicators including Global SDG Indicator (Indicator 12.2.2: Domestic material consumption, domestic material consumption per capita, and domestic material

consumption per GDP) similar to Global SDG Indicator 8.4.2 has been derived for the years 2011-12, 2015-16 and 2020-21 and presented in **Table 2.2**.

Table 2.2: Derived Indicators from Core Account of MFA

Indicators	2011-12		2015-16		2020-21	
	Quantity ('Lakhs Tonnes)	Price (Crore)	Quantity ('Lakhs Tonnes)	Price (Crore)	Quantity ('Lakhs Tonnes)	Price (Crore)
Direct Material Inputs (DMI)	25,459	40,04,140	27,862	46,97,888	31,393	63,60,631
Physical Trade Balance (PTB)	2,173		4,322		3,571	
Global SDG Indicator 12.2.2 (similar to Global SDG Indicator 8.4.2)						
Domestic Material Consumption (DMC)	23,430	26,16,684	26,013	30,14,947	28,534	42,56,116
DMC per unit of GDP		0.30		0.22		0.21
Indicator	**Quantity (Tonnes/capita)**	**Price (Rs./capita)**	**Quantity (Tonnes/capita)**	**Price (Rs./capita)**	**Quantity (Tonnes/capita)**	**Price (Rs./capita)**
DMC per capita	1.92	21,445.23	2.03	23,474.50	2.10	31,364.62

Totals may not match due to rounding off.

2.33 From the Table 2.2 above, it has been observed that Domestic Material Consumption (DMC) in terms of quantity has increased by 22% from 2011-12 to 2020-21. However, in terms of Rupees, it has increased by around 63% for the same period. In terms of DMC per unit of GDP, it has decreased from Rs. 30 lakhs in 2011-12 to Rs. 22 lakhs in 2015-16 and further decreased to Rs. 21 lakhs in 2020-21. Similarly, DMC per capita in terms of quantity, has increased from 1.92 tonnes in 2011-12 to 2.10 tonnes in 2020-21. However, in terms of rupees, DMC per capita has increased from Rs. 21,445 in 2011-12 to Rs. 31,365 in 2020-21.

Conclusion

2.34 Environmental Impacts including climate change and pollution cannot be effectively mitigated by focusing on emission abatement alone. The level of resource use determines the magnitude of final waste and emissions released to the environment, making resource management and efficiency the key strategies for environmental protection.

2.35 Decoupling economic activity and human well-being from resource use- i.e. enhanced resource efficiency is necessary to achieve sustainability. To achieve effective decoupling, today's linear material flows must become circular through a combination of intelligent infrastructure and product design, standardization, reuse, recycling and remanufacturing. An approach towards shifting to Circular economy would help to keep resources in use for as long as possible extracting the maximum value, recovering and regenerating products and materials at the end of each service life; so as to limit the extraction of natural resources to the maximum extent possible.

2.36 The MFA accounts helps to address the issue of resource efficiency, which means creating more output as products/services using lesser inputs. Resource Efficiency reduces waste, drives greater resource productivity, delivers a more competitive economy, addresses emerging resource security/scarcity issues, and helps reduce the associated environmental impacts.

2.37 The complete set of the Material Flow Accounts includes the Residuals part as well apart from the Domestic Extractions and Exports/Imports. Again, residuals comprise of Solid Wastes, Effluents and Air Emissions. As an initial step, NSO, India had attempted the compilation of the Physical Supply and Use Tables for the Solid Waste Accounts for the state of Delhi. In the current publication, (Chapter 3) Solid Waste Accounts have been taken up for some other States.

2.38 As regards the Effluent and the Air Emission Accounts, the work is yet to be initiated and can be taken up in due course of time depending on the data availability.

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