Material flow accounts and balances

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Summary

The elaboration of Material flow accounts by the National Statistical Institute (INE) completes the first phase of environmental accounts development, which are integrated by water and air emissions satellite accounts, environmental protection investment, forestry accounts and these presented in this work. Compiling these accounts will provide a solid information basis to develop a **system of sustainable development indicators**.

According to main principles of the United Nations' System of Integrated Environmental and Economic Accounting (SEEA), three ways of focussing relations between environment and economy can be distinguished. Integrated focus try to give an appropriate statistical basis to sustainable development accounting.

Economy-wide material flow accounts and balances approach provides indicators to evaluate certain sustainable development aspects, as resources use and efficiency, or environmental impacts of the economy. They are also adequate indicators to assess the effectiveness of different policies related to sustainable development.

1 Introduction

Natural resources use and efficiency is one of the key policy issues in the Sixth Environmental Action Programme 2001-2010. Furthermore, natural resources use and/or material consumption parameters should be included in a sustainable development indicators system. An integrated environmental and economic accounting system seems to be the finest tool to achieve this indicators framework.

The integrated environmental and economic accounting system objective is to provide a detailed description of environment and economy relationships. It is essential, to describe this relationships, the availability of environmental and economic data based in similar accounting standards and concepts.

The right interpretation and analysis of the results requires data expressed in physical units, as they are more suitable than monetary units. Therefore, to measure material flows from the environment to the economy and this to the environment, data should be expressed in tonnes, as material flows change their shape and composition across production and consumption processes.

This work represents a first approach of the National Statistical Institute (INE) to compile the **material flow accounts and balances** which will be incorporated to develop a **system of sustainable development indicators**.

2 Objectives

The main purposes of economy-wide material flow accounts implementation are to:

Provide information over the structure and changes over time of the physical metabolism of the economy.

Derive a set of aggregated indicators for natural resources use.

Derive indicators for resources productivity and eco-efficiency, by relating resource use indicators to GDP and other economic indicators.

Provide indicators for the material intensity of lifestyles, by relating these indicators to population size and other demographic indicators.

Integrate information into the national accounts.

Supply statistical data and information to settle any kind of users requests.

3 Definitions

Material flow accounts show material physical inputs that get into national economic system, and the outputs to other economies or to the environment. They are accounts expressed in physical units (tonnes) that describe extraction, transformation, consumption and final disposal of chemicals, raw materials or products.

The first law of thermodynamics, or the conservation of matter principle, is the conceptual basis of these accounts. It states that matter is neither created nor destroyed by any physical transformation, it just gets transformed. This principle can be applied to specific substances and materials with high environmental impact; including fuels, strategic materials, wood, pesticides, zinc, … . Next diagram shows input and output flows, and material accumulation in the economic system.

General scheme of material flows into the economy
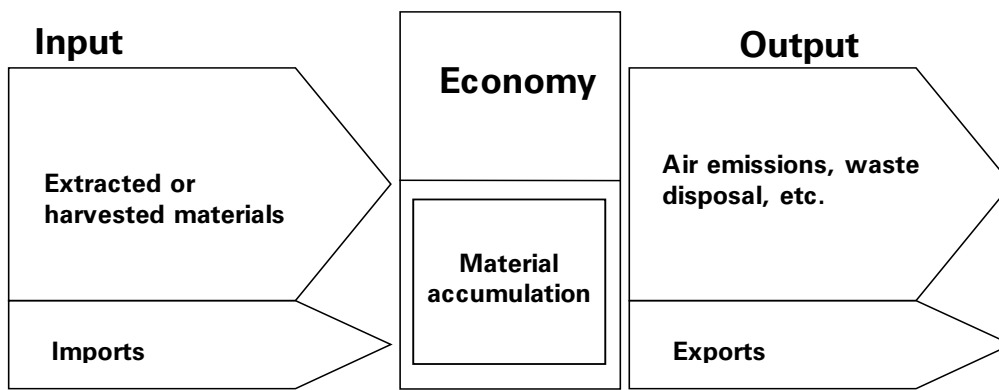
4 Accounts framework

4.1 ACCOUNTS SCOPE

Material flow accounts should be consistent with *national* economic *accounts*. National accounts define national economy as a whole of activities and transactions of resident economic agents, these which have a centre of interest in the national economic territory. Some of these transactions carry out outside the national economic territory, and others, inside this territory, are carried out by non resident units.

Therefor, material flow accounts, the same as national accounts, should apply the *residence principle*. According to this principle, material used by resident units away the national territory have to be considered as domestic economy inputs, and materials used by non resident units inside the national territory should be excluded from the accounting framework.

National economic territory, according to national accounts, is constituted by the geographical territory and free zones, national air space, territorial waters, continental shelf placed on international waters over which the country has exclusive rights, territorial enclaves and deposits situated on international waters that are exploited by resident units. National economic territory does not include other countries' or international organisations' extra-territorial enclaves placed into the geographical territory.

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Territories out of the boundaries of national economic territory are considered as the "rest of the world".

National environment is defined as the geographical space of national economic territory. Territories out of the boundaries of national environment are named "rest of the world environment".

4.2 SYSTEM BOUNDARIES OF FLOWS BETWEEN ECONOMIC AND NATURAL SCOPES

Material flow accounts show material physical inputs of the national economic system and outputs to other economies or to the environment. These accounts describe extraction, transformation, consumption and final disposal of materials.

It is difficult to succeed a whole material balance of the economy, since not every material input or output have a systematic follow-up. Material flows are classified into three main categories: raw materials, as material inputs extracted from the environment; products, which are the final result of production process; and wastes, not wanted by-products of production and consumption processes.

MFA can provide a detail level depending on material characteristics:

– Extraction/ harvesting (agriculture, forestry, mining and quarrying).

– Transformation/ conversion (refineries, metal industry).

– Intermediate uses (manufacture industry).

– Final uses (household consumption).

– Material stocks (gross capital formation, durable consumer goods).

– Imports/ Exports.

– Wastes (waste disposal, air emissions, waste water).

– Flows and accumulation in nature.

Next scheme shows account flows.

Physical flows and the scope of physical flow accounting
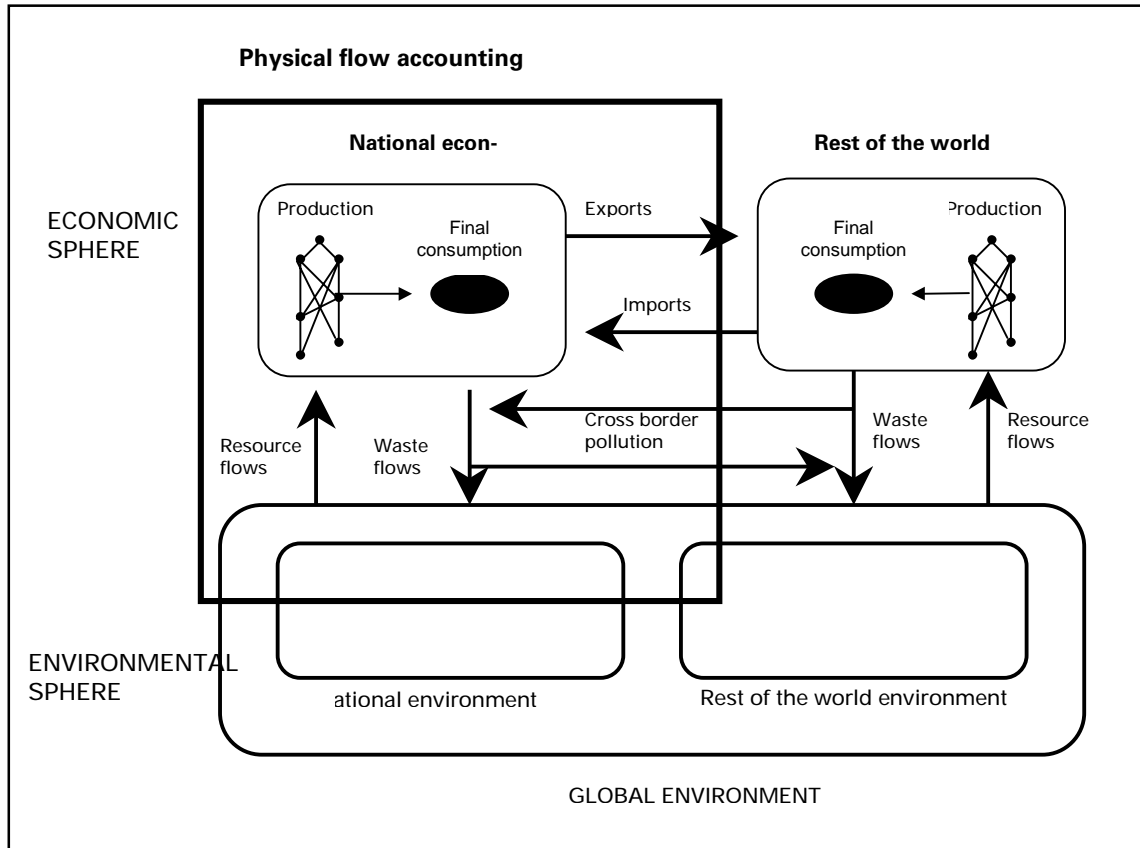
There are counted only flows that cross the system boundary. That means flows from national environment to the economy, flows between national and the rest of the world economy (imports and exports), and flows from the economy to national environment or to rest of the world environment.

Material flows within the economy are not presented in MFA, although they are described in Physical Input-Output Tables (PIOT). There are neither considered natural flows that take place within the environment, or between national and the rest of the world environment (across frontier flows).

4.4 CONCEPTS, DEFINITIONS AND CLASSIFICATIONS

Material flows from national environment to the economy are called input flows, and they refer to the extraction or movement of natural materials on purpose and by humans or human-controlled means of technology.

Output flows released to the environment means that economic system or society loses control over the location and composition of the materials.

Flows classification

Material flows can be grouped depending on the dimension used to characterise categories of material flows and indicators. Attending to the territorial dimension to indicate the origin and destination of flows, they are classified into ***domestic and rest of the world flows***. If it is beard in mind the product-chain or life-cycle dimension, there are two types: ***direct and indirect flows*** to indicate whether flows are directly observed, or they are obtained as a calculation of up-stream material requirements.

The product dimension indicates whether flows enter the economic system or not, and divides flows into ***used and unused***. This classification is only used for inputs. For outputs, terms ***processed and not processed*** are used to determine flows stemming from an economic system or not.

Combining the three dimensions leads to five categories of inputs relevant for economy-wide MFA:

Material input categories

Product-chain	Used or unused	Domestic or rest of the world	Term used
Direct	Used	Domestic	Domestic extraction (used)
Not applied	Unused	Domesti	Unused domestic extraction
Direct	Used	Rest of the world	Imports
Indirect (up-tream)	Used	Rest of the world	Indirect (input) flows associated to imports
Indirect (up-tream)	Unused	Rest of the world	

Materials extracted or mobilised on purpose and by means of technology which are not fit or intended for use are named ***hidden flows***. For materials extracted or moved on a nation's territory, these hidden flows are "unused domestic extraction".

Output flows can be classified into:

Material output categories

Product-chain	Processed or not	Domestic or rest of the world	Term used
Direct	Processed	Domestic	Domestic processed output to nature
Not applied	Not processed	Domesti	Disposal of unused domestic extraction
Direct	Processed	Rest of the world	Exports
Indirect (up-tream)	Processed	Rest of the world	Indirect (output) flows associated to exports
Indirect (up-tream)	Not processed	Rest of the world	

Indirect flows are defined only for economy-wide material flows, and they only refer to imports and exports. They are the material requirements associated to the production of a product or raw material.

On the input side, indirect flows are defined as up-stream material input flows that are associated to imports but are not physically imported. On the output side, indirect flows are up-stream material input flows associated to exports but not physically exported. Therefor, indirect flows are the "cradle to border" inputs necessary to make a product available at the border for import or export, excluding the mass of the product itself. Two types of indirect flows are distinguished: used and unused. Indirect flows can only be calculated after the accounts for direct (used) materials have been completed.

For economy-wide MFA, two components of indirect flows are distinguished:

Up-stream indirect flows expressed as the Raw Material Equivalents (RME) of the imported or exported products. The RME is the used extraction that was needed to provide the products.

Up-stream indirect flows of unused extraction associated to this RME.

5 Indicators and balances derived from the accounts

5.1 MFA DERIVED INDICATORS

A set of indicators can be derived from the material flow accounts so as to provide an aggregate picture of the "industrial metabolism". These indicators can be grouped into input, consumption and output indicators. More indicators could be derived from the accounts, by setting the boundaries of the accounts differently or by compiling indicators per material group.

It is not yet clear which of the indicators will be considered the most relevant and useful in the longer term. Only future use in analysis can provide a sound basis for such recommendations. The choice of the most relevant indicators will depend on the policy focus and on proven usefulness and applicability of indicators in policy analysis. At this stage, only a set of criteria for the selection of indicators can be offered:

– Ease of understanding the meaning of an indicator.

– Ease of compilation.

– Data availability.

– Compatibility with the national accounts.

– Potential for policy uses.

– Completeness of the indicator.

Resource use and efficiency has emerged as a major issue for long-term sustainability and environmental policies at the EU member states level. Objectives include to increase substantially the resource efficiency of the economic system, thereby reducing the use of natural resources and related negative impacts on the environment. Two main themes have been identified as policy relevant: the total quantity used and the efficiency in use. Domestic Material Consumption (DMC) or Total Material Requirement (TMR) were considered good indicators to describe those issues.

At present it appears that good candidates for core indicators would be the input indicators Direct Material Input (DMI) and Total Material Requirement (TMR), as well as the consumption indicators Domestic Material consumption (DMC) and, maybe, Total Material Consumption (TMC).

5.2 MAIN ACCOUNTING BALANCES

Direct material inputs are all solid, liquid and gaseous materials that enter the economy for further use, either in production or consumption processes; and they are classified by their origin into domestic extraction (used) and imports. If exports are subtracted from direct material inputs, the result will be ***domestic material consumption***, which measures the total amount of material directly used in an economy.

Adding unused domestic extraction and indirect flows associated to imports to direct material inputs, ***total material requirement*** will be obtained. It measures the total "material base" of an economy. Subtracting exports and indirect flows associated to exports, the result is ***total material consumption***, which represents the total material use associated with domestic production and consumption activities.

Domestic processed output is defined as the total weight of materials, extracted from the domestic environment or imported, which have been used in the domestic economy before flowing to the environment. These flows occur at the processing, manufacturing, use, and final disposal stage of the production-consumption chain. Adding the disposal of unused domestic extraction, there is obtained ***total domestic output*** to nature. Finally, ***total material output*** measures the total of material that leaves the economy, both to the environment and to the rest of the world (exports).

Economy-wide material balance with derived resource use indicators

INPUTS (origin)	OUTPUT (destination)
Domestic extraction Fossil fuels (coal, oil…) Minerals (ores, sand…) Biomass (timber, cereals…)	**Emissions and wastes** Emissions to air Waste landfilled Emissions to water
Imports	**Dissipative use of products and losses** (fertiliser, manure, seeds; corrosion…)
Direct material inputs (DMI)	**Domestic processed output to nature (DPO)**
Unused domestic extraction From mining/quarrying From biomass harvest Soil excavation	**Disposal of unused domestic extraction** From mining/quarrying From biomass harvest Soil excavation
Total material input (TMI)	**Total domestic output to nature (TDO)**
Indirect flows associated to imports	**Exports**
Total material requirements (TMR)	**Total material output (TMO)**
	Net additions to stock Infrastructures and buildings Other (machinery, durable goods
	Indirect flows associated to exports

6 Material flow accounts estimation for Spain. Statistical data sources

The Spanish Mining Statistics published by the Directorate-General for Energy and Mine Policy of the Ministry of Economics is the statistical source used to estimate most of the direct flows relative to domestic extraction of fossil fuels, minerals, ores and quarrying products.

With regard to biomass, the Agricultural Statistics of the Ministry of Agriculture, Fisheries and Food allows to estimate biomass from agriculture, forestry, hunting and inland fishing. Data from sea fishing biomass were obtained from the FAO statitics.

Imports and exports data were estimated from Foreign Trade Statistics of the Tax Office, which offers detailed information about imported and exported products by raw material, product type, etc. in physical units. Those data have been classified according to EUROSTAT Combined Nomenclature, so they can be related to domestic production.

On the outputs to the environment side, waste landfilled and waste water data were calculated from the statistical survey over industry and services waste generation, and the survey over municipal solid waste collection and processing; both published by the National Statistical Institute (INE). As for emissions to air, NAMEA emission and energy accounts are the most suitable source, as they follow the residence principle. In this case there have been used the air emissions accounts published by INE.

Hidden flows and indirect flows associated to imports and exports are probably the most difficult to establish. They have been estimated from a set of default coefficients published by the Wuppertal Institute, corresponding to each imported or extracted material. Only imported raw materials and semi-manufactured product have been taken into account. For unused domestic extraction, those coefficients have been completed with data from the Spanish Mining Statistics, and they have also been contrasted with waste statistics to prove their reliability.

For unused biomass from harvest, three aspects have been considered: sea fishing discarded by-catch, which represents 25% of the catch according to Greenpeace; wood harvesting losses, from Wuppertal Institute data; and soil losses from agriculture harvesting, which have been calculated from the Agricultural Statistics of the Ministry of Agriculture, Fisheries and Food; and estimations made in the Spanish Forestry Plan.
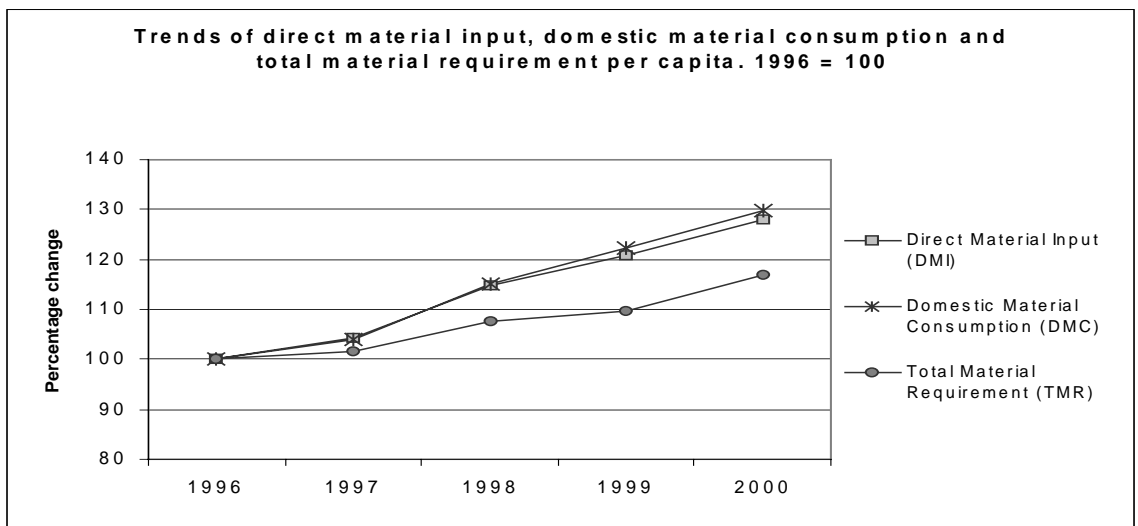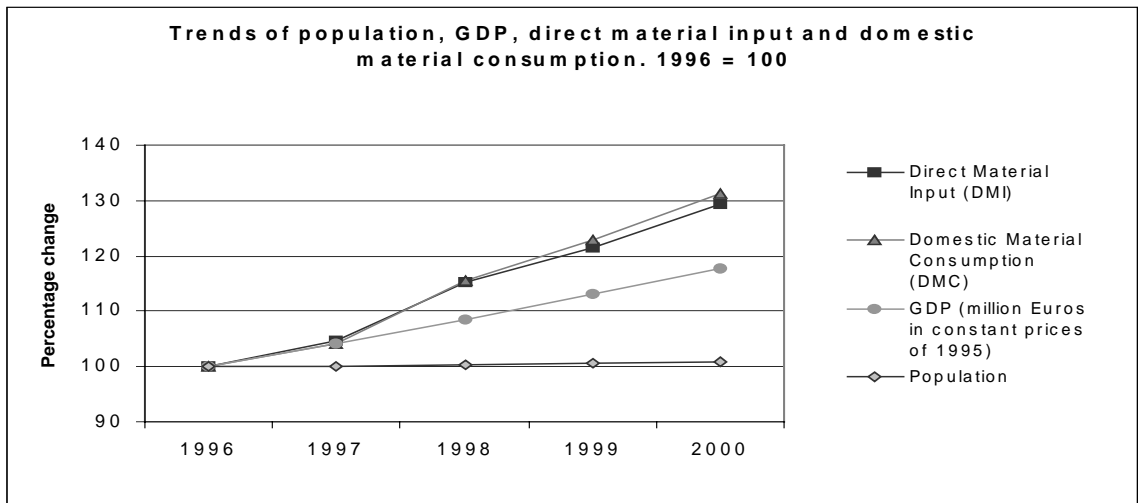
7 Preliminary conclusions

Traditional economic system has measured contribution of factors of production, work and capital through their productivity. Data provided by national accounts allow to a detailed research of their productivity evolution over time, and how the introduction of new technologies in the production system has permitted to obtain high growth rates. However, factor of natural resources has been scarcely contemplated in economic analysis and in national accounts development, what shows the scarce interest of economic analysts for these issues.

Nowadays, the new concept of sustainability requires to take this factor into consideration at the same degree as the others, work and capital, in economic development framework. Therefore, natural resources use should be measured, as work and capital, through per capita or productivity terms indicators.

In this sense, direct material input per capita seems to correlate with GDP per capita. Material consumption could also be an appropriate indicator, specially for small economies with a higher dependence on international trade, as it neutralises the effect of economic size on trade.

Preliminary results of this work for Spanish economy show that differences between GDP per capita and material input per capita have increased in the brief period 1996-2000. There could be deduced that on that period a higher proportion of natural resources have been used by production or consumption processes. Those differences are shown in following graphics.

Trends of population, GDP, direct material input and domestic material consumption. 1996 = 100

Trends of direct material input, domestic material consumption and total material requirement per capita. 1996 = 100

Apparently, direct material input and total material requirements per capita are also correlated. Main differences due to hidden and indirect flows, which are included in TMR as it measures the real material weight of an economy. In principle, input indicators measure used or mobilised materials to support economic activities (including production for export), and are highly related to each country's means of production.

he development of indictors which measure **material efficiency or productivity** (GDP unit per material indicator unit) or **material intensity** (material indicator unit per GDP unit) has huge significance to compare natural resources use with economic growth. Using efficiency or productivity terms tend to be more common among economists and for comparison with other economic indicators, whereas intensity tends to be more commonly used by environmentalists.

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Following graphics show how both indicators change over 1996-2000 period. In 1996, one material input tonne generated 763 Euro of GDP, whereas in 2000 it generated only 694 Euro; which means a fall in resources productivity of 9%. Al the same time, in 1996, 1.310,61 material tonnes were introduced in the economic system to produce one million Euro of GDP. In 2000 there are required 1.439,03 tonnes.

Material efficiency: direct material input, total material input and total material requirement. GDP units at constant prices per tonne

Material intensity: direct material input, total material input and total material requirement. Tonnes per GDP at constant prices