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Material balance and indicators, Austria 1960-1997

Prepared for DG Environment and Eurostat by:
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Statistics Austria

eurostat

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Material balance and resource use indicators (DMI and DMC) for Austria 1960 - 1997

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Preface

As part of work to develop environmental accounting linked to national accounts and input-output tables, Eurostat is currently looking at **economy-wide material flow accounts and aggregate material balances**. These accounts provide aggregate descriptions of the material flows through economies and allow for the derivation of aggregate indicators of material use and material efficiency when compared to e.g. Gross Domestic Product (GDP). A preliminary basic layout of economy-wide material balances showing the aggregate indicators that can be derived from such accounts is presented overleaf.

This Working Paper presents the results of work by Statistics Austria on an economy-wide material balance for 1997 as well as a time series of resource use indicators such as Direct Material Inputs (DMI) and Direct Material Consumption (DMC) for 1960-1997. This report is an essential contribution to the development of economy-wide material flow accounts and balances. Eurostat distributes this report hoping that those wishing to implement economy-wide material flows can benefit from the Austrian experience.

Brian Newson
Head of Unit B1
National accounts methodology,
statistics of own resources

EUROSTAT DRAFT SCHEME FOR ECONOMY-WIDE MATERIAL BALANCES

Economy-wide material balance with derived indicators

(excludes air & water flows)

INPUTS (origin)	**OUTPUTS (destination)**
Domestic extraction	**Domestic processed output to nature**
Fossil fuels (coal, oil…)	***Emissions and wastes***
Minerals (ores, sand…)	Emissions to air
Biomass (timber, cereals…)	Waste landfilled
	Emissions to water
Imports	***Dissipative use of products***
DMI - direct material inputs	(Fertiliser, manure, compost, seeds..)
	DPO - domestic processed output to nature
Unused domestic extraction	
Mining/quarrying overburden	**Disposal of unused domestic extraction**
Soil excavation	Mining/quarrying overburden
Erosion	Soil excavation
TMI – total material input	Erosion
	TDO - total domestic output to nature
Hidden flows[1]) imported	
TMR - total material requirements	**Exports**
	TMO – ***total material output***
	Net Additions to Stock (NAS)
Note: terminology not yet fully standardised	Infrastructures and buildings
	Other (machinery, durable goods, etc.)
	Hidden flows exported

Source: Eurostat

This account allows derivation of key material use indicators for inputs (DMI, TMI and TMR), outputs (DPO, TDO and TMO) as well as calculation of aggregate material consumption indicators (NAS, DMC and TMC). DMC and TMC are calculated as follows:

- *DMC (domestic material consumption)* = Domestic extraction + Imports – Exports = DMI - Exports
- *TMC (total material consumption)* = Domestic extraction (used and unused) + Imports + hidden flows imported - exports - hidden flows exported

These indicators are linked by accounting identities. For example, TMI (total material input) = TMO + NAS; or NAS = DMC – DPO. It is important to have the indicators in a long time series in order to identify longer-term trends and isolate changes that are due to economic cycles.

[1] Hidden flows (or ecological rucksacks) are a measure of material flows that are 'hidden' behind the goods imported or exported. In the exporting country, hidden flows are the total material inputs (i.e. TMI) needed to produce the goods exported. In the importing country these hidden flows are a measure (as part of TMR) of the material flows that its imports induce in the exporting country. Hidden flows do not enter the importing (or leave the exporting) country. Rather, they are a way of converting the imported inputs of a country into a common basis of primary resource extraction, thus indicating the impact on other countries. In some studies the unused domestic extraction (e.g. mining overburden) is called 'domestic hidden flows' to underline that such flows are often without monetary value and thus not recorded in economic accounts. Standard methodologies for estimating hidden flows (in particular hidden flows exported) are only just developing.

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Summary

The extent of environmental degradation or pollution depends largely on the volumes of materials taken from the environment and subsequently returned to it in the form of waste or emissions. An earlier article (see Annex) presenting material input series concentrated on the first of these two aspects, in an attempt to decide how materials-efficient the socioeconomic system is.

This paper goes one step further and attempts to show to which categories of use material flows are ultimately to be allocated, to show how much goes to increase stocks, how much is returned to nature as waste and how much is reprocessed. Fresh data have recently become available for this kind of balance, and it is therefore worthwhile to put previous work on a firmer footing.

The second section of the paper uses some of the indicators derived from the material flow account to try to shed light on the relationship between the consumption of materials and economic performance, i.e. material productivity. It emerges that domestic consumption of materials rose by 92% between 1960 and 1997, whereas GDP increased by 231% over the same period, and thus material productivity rose by 72% during those years. This analysis, differentiated to show individual groups of materials, thus demonstrates that with mineral materials there is still a good deal of potential for savings to be made, whilst fossil fuels are now used much more efficiently.

Introduction

The political objective of sustainable development[2]) calls for the more sparing use of natural resources, a call prompted by two environmentally-relevant aspects of society's consumption of materials. On the one hand, there are fears about the future scarcity of resources. If there are no restrictions on their extraction from nature, supplies for the longer term will inevitably be at risk. It is possible to guard against this danger only if mankind is aware of how many renewable and non-renewable resources are being consumed and, on the basis of this knowledge, uses fewer non-renewable resources in the future, whilst exploiting renewable ones only to the extent that they can be renewed over the period of use. The second aspect is the fact that the use and extraction of raw materials have in themselves an effect on the environment, through the movement of large quantities of materials and the construction of the associated infrastructure, which seals the ground by building on it and destroys the landscape, and through the increased use of transport and the resulting emissions.

Material flow accounts may be considered a good indicator of various types of environmental deterioration which it would otherwise be difficult to measure in qualitative terms. They are sources of information on which sustainable development can be based. They are already being produced in various industrial countries (including Germany, Japan, the USA, the Netherlands and Austria). In Austria, the IFF[3]) social ecology unit produced the first material flow account for 1988, and a further account produced by the same institute for 1992 was included in the National Environment Plan. The methodology worked out by the IFF was the basis for all further accounts.

Statistics Austria ("STATISTIK ÖSTERREICH" - formerly Austrian Central Statistical Office), first produced material balances in 1998, in cooperation with the IFF, for the reference year 1996[4]). Now, following publication of input series for all three sub-sectors[5]), material balances for 1997 are appearing, and these are an improvement on the previous year as regards the use of data.

- The biomass balance has been improved by the use of supply balances for plant and animal products, and thus the output side of plant/animal production has been more fully represented (a broader spectrum covered and a greater degree of detail).

- New calculation methods for the volume of natural stone and of sand and gravel from the input series enable improvements to be made in the mineral balance compared with the previous year, with the

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[2]) Referred to, for example, in Agenda 21, the UN Conference on Environment and Development, Rio de Janeiro 1992.

[3]) Interdisziplinäres Institut für Forschung und Fortbildung [Institute for Inter-disciplinary Research and Continuing Education]

[4]) Statistische Nachrichten, Volume 11/1998, p.939 et seq. Materialflussrechnung Österreich 1996.

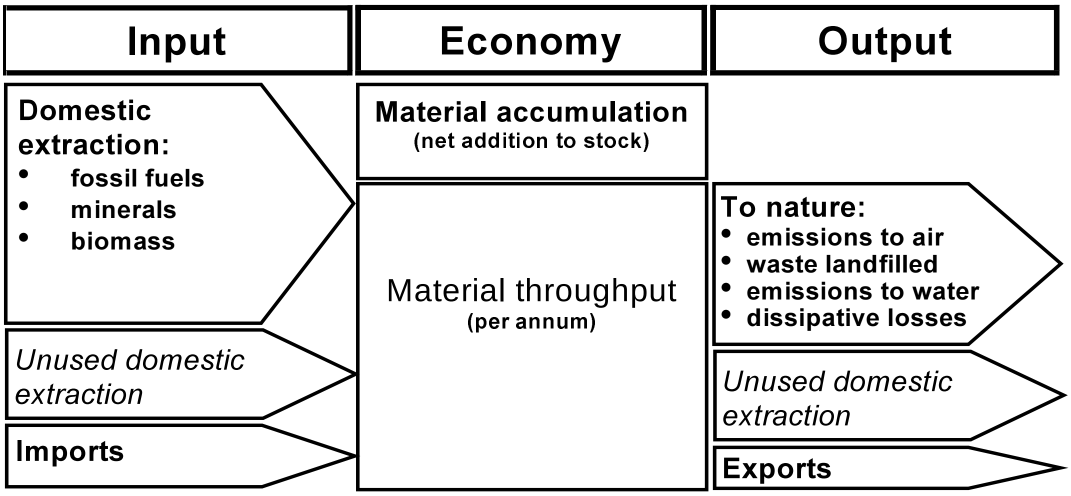
[5]) Statistische Nachrichten, Volume 2/2000, p.128 et seq. Materialflussrechnung für Österreich 1960-1997.

recalculation of the volume extracted producing a lower level which has affected not only the input series but also the balance items, in particular material accumulation (infrastructure).

- For the first time, only data from ÖSTAT's energy balance were used for the fossil fuels balance.

Methodology

The whole national economy is shown as a physical input-output system representing societal metabolism. The figure below[6]) shows in diagrammatic form the relationship between the individual flows of material.



Source: EUROSTAT

The input side covers primary extraction and imports. Imports are the mass of raw materials plus semi-manufactures and finished products.[7]) They are shown in terms of the weight of raw materials and products as they cross the Austrian national borders, and thus do not include any of the intermediate consumption of materials ("ecological rucksacks"[8])) arising when materials are extracted or products are manufactured in other countries. The materials which have entered the socioeconomic system are processed and used either to build up stocks (e.g. buildings) or, following consumption, are returned to the environment in some form or other. On the output side are emissions to the atmosphere, waste, dissipative losses (e.g. wear and tear on roads), specific applications (of farm manure, for example), losses during use and exports. All material flows are measured in millions of tonnes. In line with the conservation of mass principle, input equals output plus changes in stocks. The reference period is one year. A total balance is aggregated from three partial balances, or "individual accounts", which show the annual throughput of biomass, minerals and fossil fuels (petroleum, coal and natural gas). These partial balances are in turn all constructed according to the same plan, namely imports, primary extraction, processing, final consumption and exports. The system boundary is that of national accounts, and thus flows of materials can be compared with national accounts data.

Data used

The balances were produced for the year 1997. Where only older data were available in a few areas, the figures were taken over from the previous year, and any missing data were estimated. The following data sources were used to compile the three individual accounts:

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[6]) Taken from a Eurostat B1 paper - National accounts methodology, February 2000.

[7]) Since it was often difficult in practice to differentiate between raw materials and products consisting largely of those raw materials, certain product groups were included in the representation of material flows for the sake of completion.

[8]) "Ecological Rucksacks" are materials extracted but not used. See Adriaanse et al.: "Stoffströme: Die materielle Basis von Industriegesellschaften", Wuppertal Institut, Wuppertal 1998, English version "Resource flows: the material basis of industrial economies", World Resources Institute 1997.

Official statistics

- **Coal, petroleum and natural gas:** 1997 energy balances.

- **Mineral substances:** 1997 external trade statistics; 1996 and 1997 short-term economic statistics on the producing industries (production of physical assets); 1990 input-output table; net output values for the production of sand and gravel and natural stone by industry, large- and small-scale businesses.

- **Biomass:** 1997 external trade statistics; 1997 agricultural statistics (harvest statistics); 1997 short-term economic statistics (feedingstuffs processed by industry), animal and crop supply balances for 1997; material flow account - input series.

Other data

- **Coal, petroleum and natural gas:** Austrian Mining and Steel Handbook [Österreichisches Montanhandbuch] for 1998 (reporting year 1997; blast furnace consumption).

- **Mineral substances:** Austrian Mining and Steel Handbook for 1998 (reference year 1997); ÖSTAT and the Federal Environment Agency [Umweltbundesamt]: The environment in Austria in 1994, data and trends; Federal Environment Agency: Federal Waste Management Plan 1998 (reference year 1996).

- **Biomass:** BMLF: [Federal Ministry of Agriculture and Forestry]: Forest Report, Austria (felling), Federal Environment Agency: Federal Waste Management Plan 1998; Austropapier: Paper from Austria. Monthly magazine of the paper industry 4/1998.

Results

Individual accounts

Coal, petroleum and natural gas (fossil fuels)

The data for this account are taken mainly from the basic energy balance for 1997 and ÖSTAT's conversion balances. Starting with inputs (domestic extraction and imports), these three material flows are divided up by processing step (e.g. refineries, coking plants, blast furnaces, production of electricity and heating, petrochemical industry) or final consumption, storage and exports. The output side is also divided into products and emissions (emissions of carbon, hydrogen, nitrogen, oxygen and sulphur into the atmosphere, plus waste and ash).

For 1997, input of fossil fuels totalled just under 29 million tonnes, 88% of which (25 million tonnes) was imported. Around 33% of input is of crude oil, 21% coal and 25% gases, the remainder being petroleum products, plastic and plastic products. Total output amounted to 29 million tonnes, 27 million tonnes of this being emissions. The majority of emissions are of carbon (17 million tonnes) with the remainder divided between nitrogen, hydrogen, oxygen, sulphur and dust. Four million tonnes were exported, the majority of exports being plastics and plastic goods (2 million tonnes).

Minerals

The minerals for this group are mined (ores, salts, industrial minerals, clay) or quarried (sand, gravel and natural stone). Since there was a new basic calculation for sand and gravel and for natural stone in the case of domestic primary extraction, the figures cannot be compared with the previous year's. The data were taken from the mineral input series.[9]) Total input amounted to 109 million tonnes, 82% domestic primary extraction and the remaining 18% imports. 14 million tonnes, 13% of material throughput, were exported. The vast majority of mineral raw materials remain in the system as additions to stock (82 million tonnes, including the statistical difference). Only some 3 million tonnes are recycled (3% of total mineral output).

Biomass

The use of supply balances of animal and crop products to give biomass is a new departure. Material input amounted to 54 million tonnes, 72% arising in Austria and 28% imported. Domestic extraction can be divided into crop production and amounts arising from forestry. For animal production, there is only a very small amount from game.[10]) Imports consist primarily of timber and wood products, food, beverages and tobacco and other products from biotic materials.

Exports totalled 13 million tonnes, 14% of material throughput. 41% of the exports of biotic materials are wood and wood products, 34% other products, 23% food, beverages and tobacco and the remainder feedingstuffs.

Overall account

For 1997, 29 million tonnes of fossil fuels were extracted, 109 million tonnes of minerals and 54 million tonnes of biomass. This gives a total input of 191 million tonnes or per capita consumption of 24 tonnes of material. For the overall account, a comparison is possible with the 1992 results, provided a little caution is exercised: in that year, the total materials input was around 221 million tonnes, or a material throughput of approximately 29 tonnes per person per year. This overall comparison shows a clear reduction - around 18% - in total consumption over the past six years. Nevertheless, compared with other countries the consumption figures are very high, indicating the extent to which the quality of life in developed economies goes hand-in-hand with a high level of material consumption. Particularly high consumption volumes are associated with the resource-intensive construction industry, the eating habits of the population and the kind of energy used.

An analysis of up-to-date results also shows that on the inputs side a little over two-thirds of material throughput is extracted within Austria. The largest share of imports, namely 42%, is of fossil fuels. 16%, or around 31 million tonnes, of material input is exported, primarily mineral raw materials, timber and semi-finished and finished products.

Moving on to output flows, we see that around 68 million tonnes of material throughput are returned to nature in the form of emissions and waste. A further 31 million tonnes are "specific applications", i.e. spread as manure, etc. 87 million tonnes, including 82 million tonnes of minerals, accumulate for the long term in the form of structures and other fixed assets, thus contributing to an annual net increase in stocks.

Although there is a great deal of publicity nowadays to encourage recycling, at present only a very small share of material throughput, 5%, is reprocessed. Considering that roughly half of all waste comes from construction, it is open to question whether the recycling potential of materials is anywhere near exhausted. Only in agriculture are fairly large volumes, namely around 12% of total throughput (farm manure and harvest residues), reutilised.

See graphs 1 – 4 for details.

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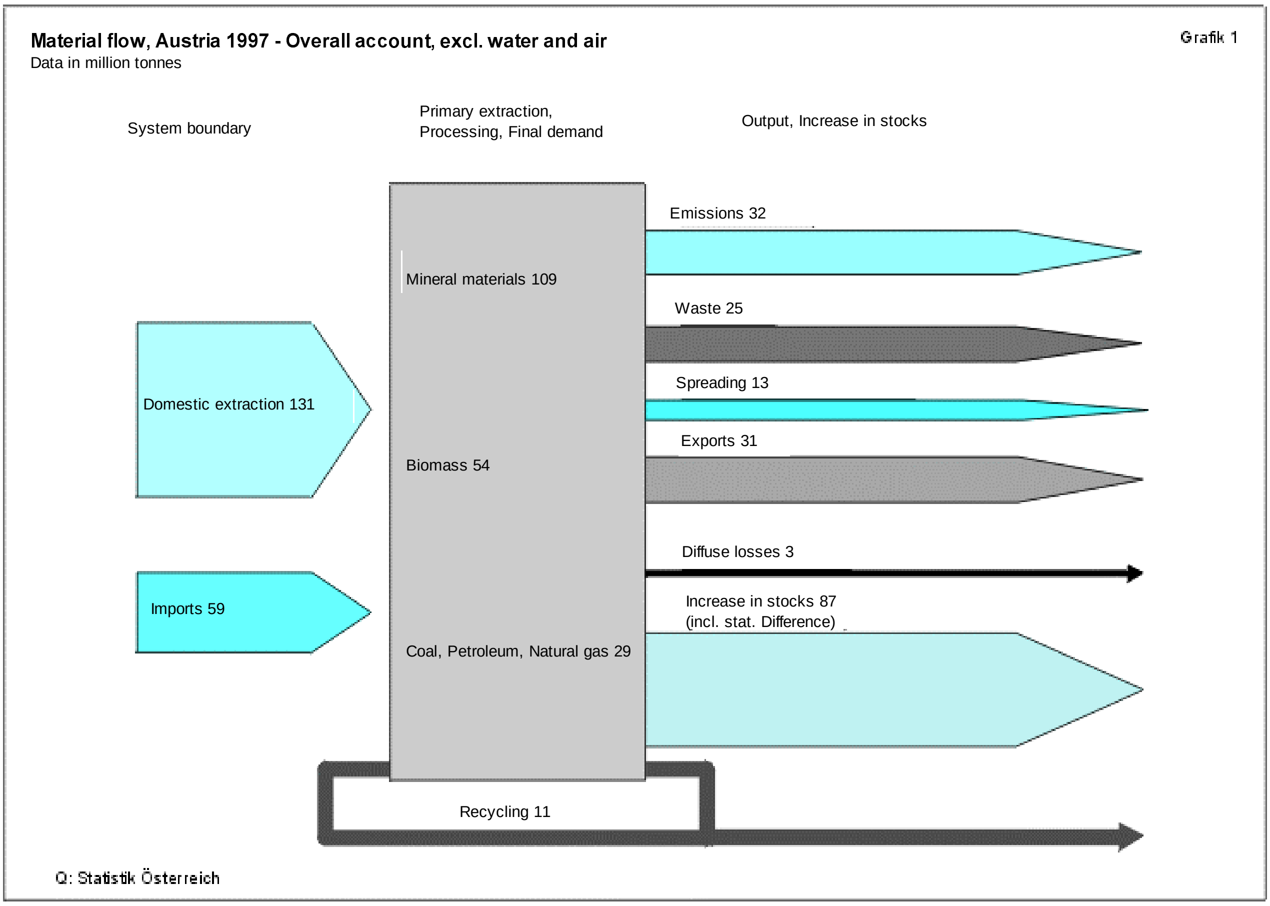
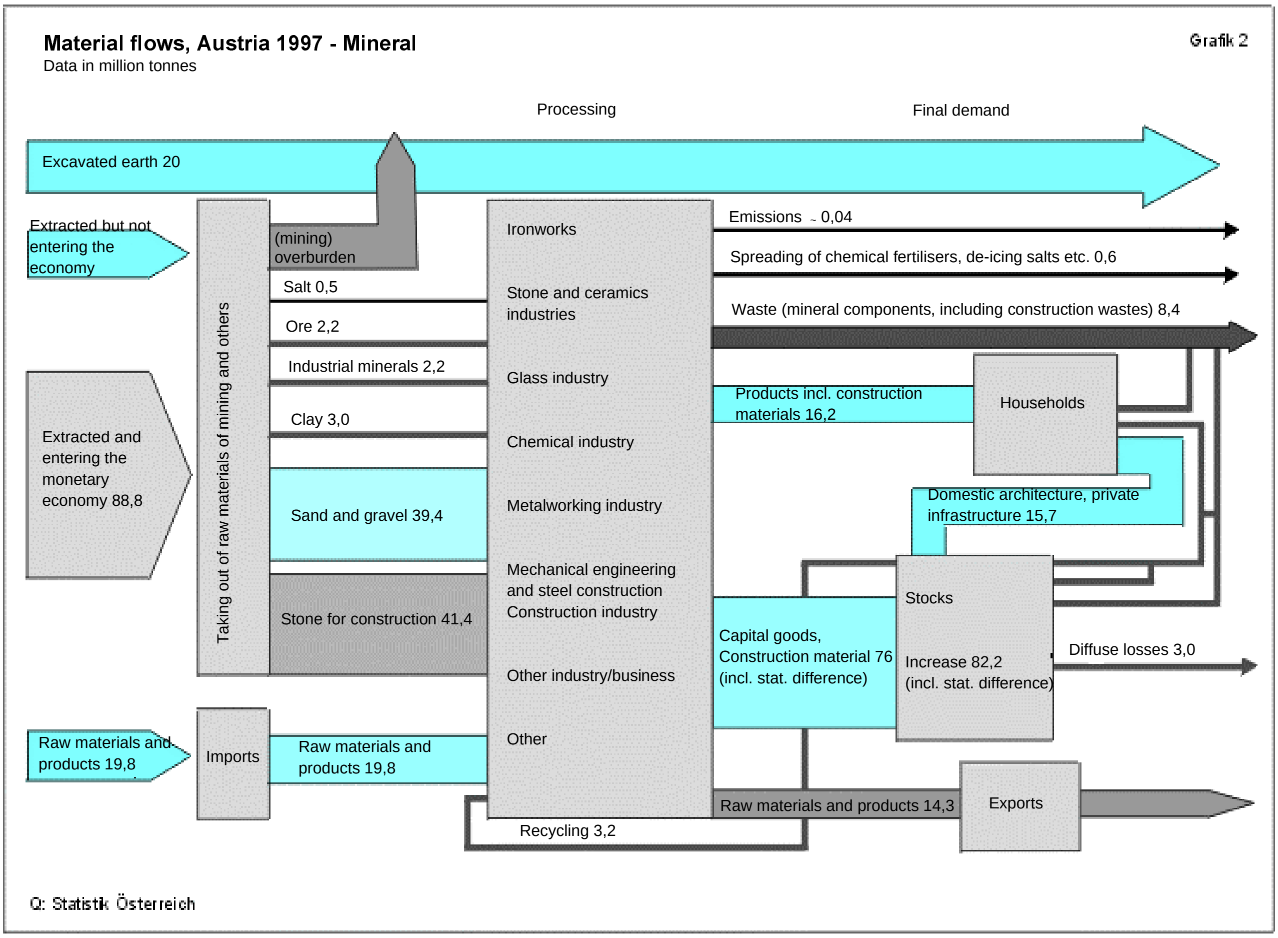
[9]) Statistische Nachrichten, Volume 2/2000, p. 128 et seq. Materialflussrechnung für Österreich 1960-1997.
[10]) The output of productive livestock is not primary extraction from nature, since it occurs within the system boundary assumed here.

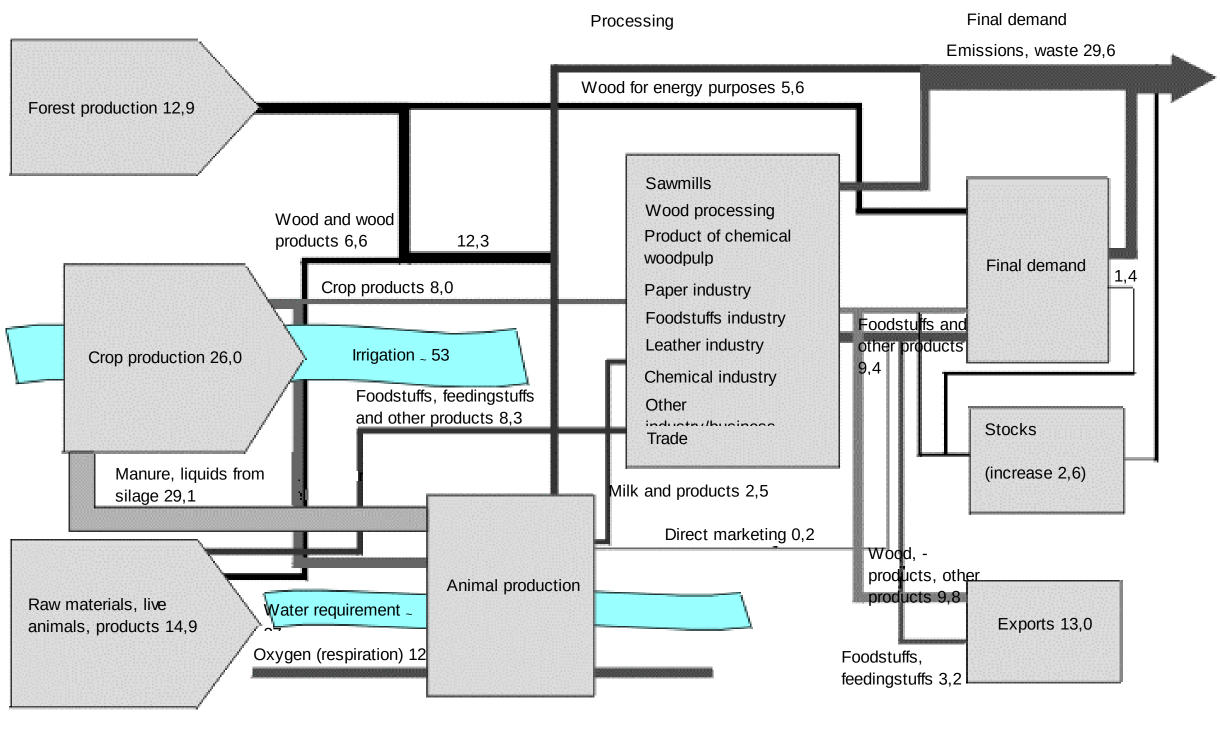

Material flow, Austria 1997 - Overall account, excl. water and air
Data in million tonnes
Grafik 1
System boundary
Primary extraction, Processing, Final demand
Output, Increase in stocks
Domestic extraction 131
Imports 59
Mineral materials 109
Biomass 54
Coal, Petroleum, Natural gas 29
Emissions 32
Waste 25
Spreading 13
Exports 31
Diffuse losses 3
Increase in stocks 87
(incl. stat. Difference)
Recycling 11
Q: Statistik Österreich


Material flows, Austria 1997 - Mineral
Data in million tonnes
Grafik 2
Processing
Final demand
Excavated earth 20
Extracted but not entering the economy
(mining) overburden
Extracted and entering the monetary economy 88,8
Taking out of raw materials of mining and others
Salt 0,5
Ore 2,2
Industrial minerals 2,2
Clay 3,0
Sand and gravel 39,4
Stone for construction 41,4
Raw materials and products 19,8
Imports
Raw materials and products 19,8
Ironworks
Stone and ceramics industries
Glass industry
Chemical industry
Metalworking industry
Mechanical engineering and steel construction Construction industry
Other industry/business
Other
Recycling 3,2
Emissions 0,04
Spreading of chemical fertilisers, de-icing salts etc. 0,6
Waste (mineral components, including construction wastes) 8,4
Products incl. construction materials 16,2
Households
Domestic architecture, private infrastructure 15,7
Capital goods, Construction material 76 (incl. stat. difference)
Stocks
Increase 82,2 (incl. stat. difference)
Diffuse losses 3,0
Raw materials and products 14,3
Exports
Q: Statistik Österreich

Material flow, Austria 1997 - Biomass

Data in million tonnes

Grafik 3

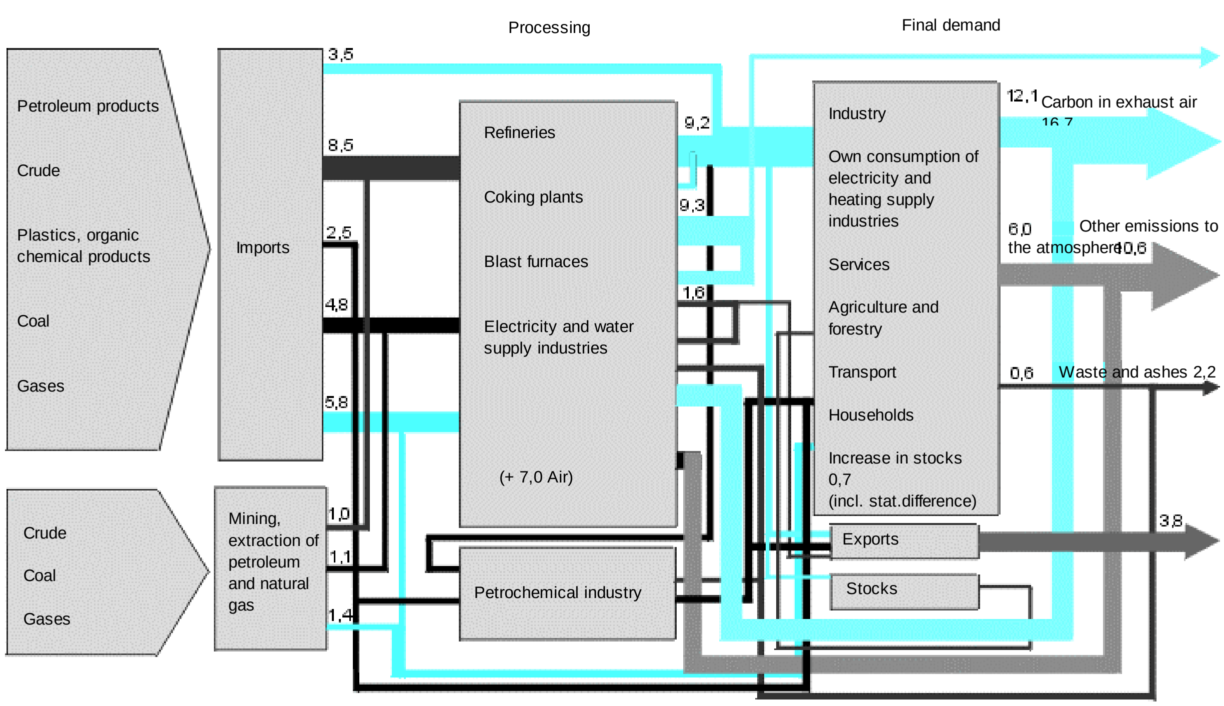


Q: Statistik Österreich

Material flow, Austria 1997 - Coal, petroleum, natural gas

Data in million tonnes

Grafik 4



Q: Statistik Österreich

Indicators derived from the material flow account

However important the detailed description of the individual input and output flows may be for an accurate analysis of a country's material balances, the main requirement is still simple answers to general questions on, for example, the kind and quality of a country's societal metabolism. For this purpose, indicators in the form of easily understandable and informative parameters are the appropriate data, in the same way as GDP growth rates or unemployment rates, for example.

Eurostat has considered how useful indicators[11]) may be derived from material flow balances. In principle, the starting point could be either the input or the output side of a material balance, since according to the conservation of mass principle the sums of the two sides must be equal. The paper on the input time series[11]) presented the "Direct Material Input" (DMI) indicator, i.e. domestic extraction plus imports, which shows a similar growth pattern in Austria to that of gross domestic product - more rapid growth in the 1960s and 1970s, with the trend flattening out after that. The indicator thus shows at a glance that up to now only small efficiency gains have been achieved in the use of natural resources.

The indicator provides more information, however, if exports are deducted from domestic extraction (DMC = domestic material consumption). This indicator shows only the volumes of materials consumed within the country, and is therefore not distorted by the often substantial export volumes, as may happen in small countries such as Austria, in particular. In general, the indicator is flatter and more suited to international comparisons within the EU, for example.

As the *Table* shows, the total material input indicator (DMI) rose 112% over the period 1960 to 1997, whereas the indicator reflecting the domestic consumption of materials (DMC) rose by only 92% *(Graph 5)*.

Gross domestic product (GDP) in real terms rose much more sharply over the same period (+231%). The widening gap between DMI and DMC is driven by the development of imports and exports in physical terms which increased much faster than GDP over the period (imports by 337% and exports by 339%) *(Graph 6*).

Material productivity expressed as DMI in relation to GDP increased by only 56% whereas material productivity expressed as DMC per unit of constant GDP shows a 72% increase between 1960 and 1997 (Graph 7).

Even more revealing, however, is a breakdown of the total period of almost 40 years into typical economic phases. Thus the period between the late 1960s and around 1980 may be termed a period of particularly high economic growth. The oil crisis of 1974/75 interrupted the growth trend briefly and led to a phase in which growth rates were roughly halved. Following the 1981 recession, there was a period of fairly moderate economic growth, with recovery beginning only after the 1993 slump. If the pattern of overall material consumption is looked at in parallel to these economic phases, the following interesting details emerge:

- During the 1960 to 1975 expansion phase, with an average annual growth rate of 6.2%, material consumption increased by 3.6% a year.
- During the following phase, 1975 to 1981, when average annual growth rates (3.2%) were roughly half of their previous levels, material consumption grew at roughly half the rate (1.8% per annum), in other words the change in the material consumption trend matched the change in the economic growth trend.
- In the following period, 1981 to 1993, when the economy was weaker, average growth rates were 2.7% a year in contrast to an increase in material consumption of only 0.4% a year, or an input trend noticeably below average.
- During the final phase, following the 1993 collapse, GDP growth rates were rather weak at + 2.2% per annum, but the increase in material consumption was roughly the same (+2.0% per annum).

If the material flow is divided up into its three major streams - biomass, minerals and fossil fuels - extremely interesting details emerge: there was only slight growth in the consumption of biomass over the period in

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[11]) Eurostat B1 National accounts methodology: Deriving resource use indicators from a material balance, February 2000.
[11]) Statistische Nachrichten,, Volume 2/2000, p.. 128 et seq. Materialflussrechnung für Österreich 1960-1997.

question (+8%), which is not surprising, since most of this flow (with the exception of wood) was used directly or indirectly as food. Compared with 1960, around 60% more fossil energy is consumed today. This is a much slower increase than the increase in GDP, which indicates that energy has been successfully "delinked" from economic growth . Per head of the population, the consumption of fossil raw materials is around 63% higher than in the first year taken into account. The largest increase in domestic materials consumption was in the minerals group (+182%), where the rise was only 15% slower than the rate at which the economy grew in just under 40 years. By the end of the period, per capita consumption (1997: 13.4 tonnes a year) was almost three times as high as in 1960 (4.8 tonnes). This is a particularly striking example of the overutilisation of natural resources. It is noticeable that the largest volumes of consumption per capita did not occur when economic growth was at its most dynamic, but in years when the economy was flat. It was only in 1975 that the tonnage figures moved into two digits. In the 1990s, the figures rose again, to average values of 12 to 13 tonnes per person, although there was no unusually dynamic growth in the economy over this period, either. In the case of minerals, therefore, the overall consumption pattern described can be seen particularly clearly. If we assume that most mineral material input goes into the building stock, then there is an obvious comparison to be made with the construction industry: whereas the economy as a whole - as described above - recovered quickly after the 1975 collapse, real value added in the construction industry remained virtually the same for the next ten years (growth rates are the exception and are offset by frequent periods of decline). It was not until the start of the 1990s that a clear upward trend emerged in the construction industry. This explains the pattern of minerals consumption described above.

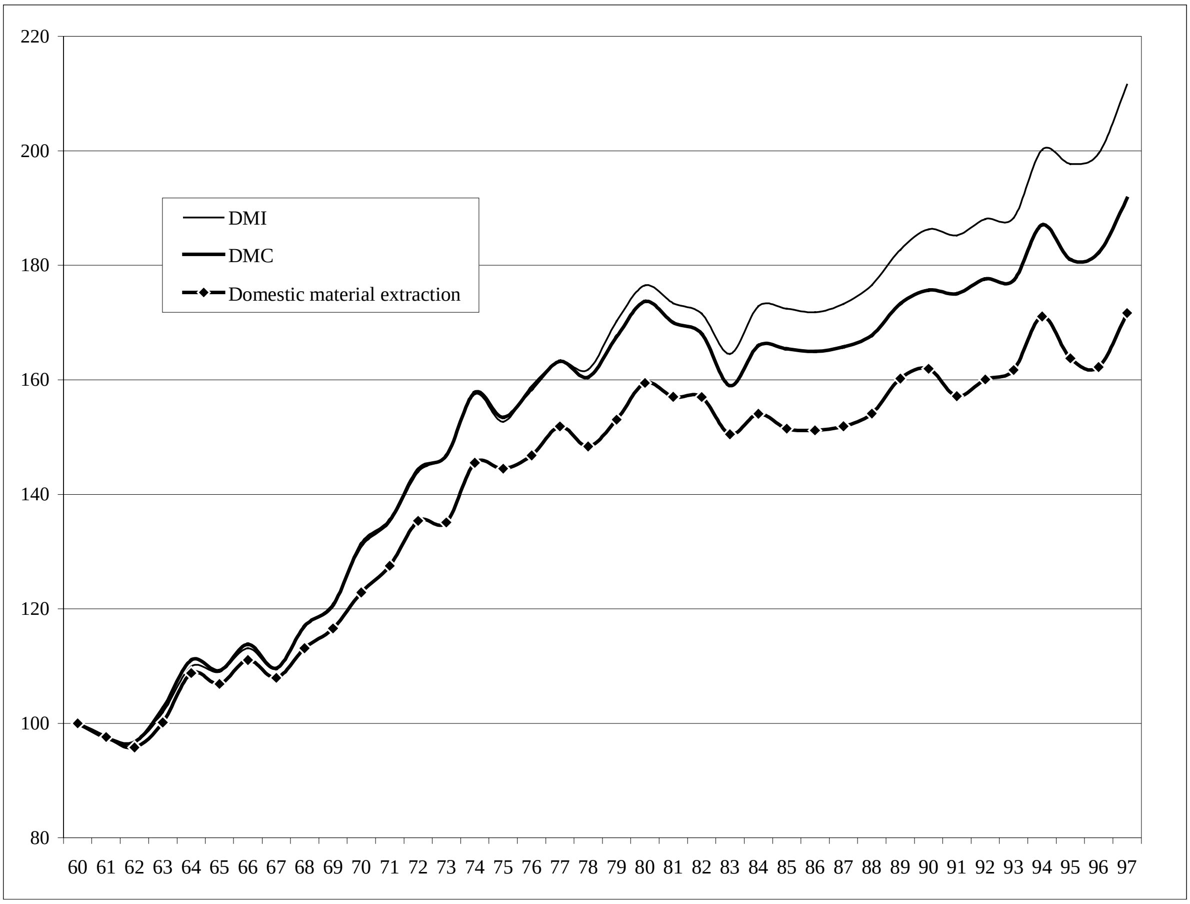
A further very useful indicator would be one which could be derived from the data on the output side of a material balance, namely one showing the material flows returned to nature (DPO = domestic processed output to nature). This would be a combination of emissions, waste and dissipative losses. Unfortunately, it is not yet possible to produce information of this kind, since no time series of material balances with output data are yet available.

Table: Indicators from material flow accounts 1960-1997

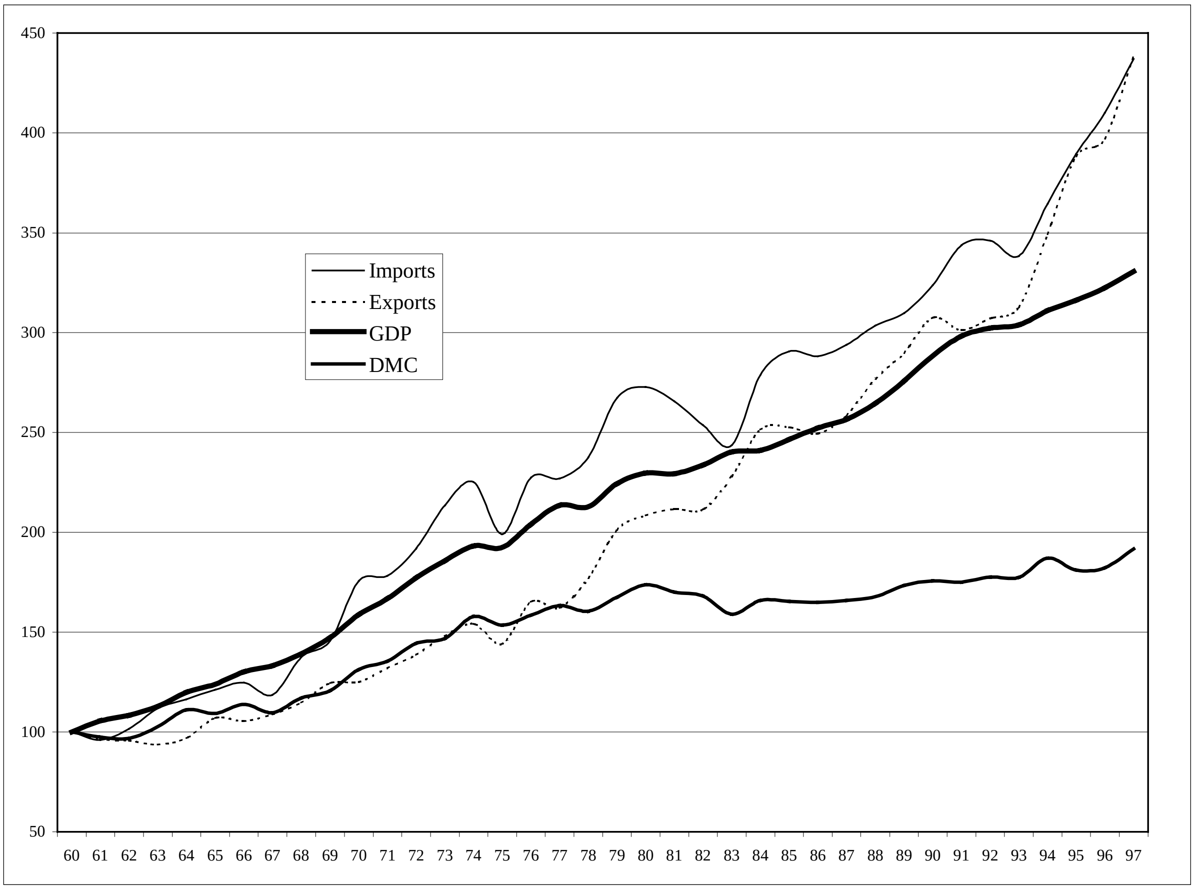
Year	Overall changes 1960=100			DMI 1960 =100			DMC 1960=100			DMI per capita, tonnes			DMC per capita, tonnes		
	DMI	DMC	GDP	Biomass	Mineral materials	Fossil fuels	Biomass	Mineral materials	Fossil fuels	Biomass	Mineral materials	Fossil fuels	Biomass	Mineral materials	Fossil fuels
1960	**100.0**	**100.0**	**100.0**	100.0	100.0	100.0	100.0	100.0	100.0	5.1	5.3	2.1	5.1	4.8	2.1
1961	**97.3**	**97.4**	**105.6**	93.7	101.6	94.9	93.4	103.3	94.9	4.8	5.4	2.0	4.7	4.9	2.0
1962	**96.6**	**96.7**	**108.3**	90.9	101.4	97.7	90.6	103.7	97.7	4.6	5.4	2.1	4.6	4.9	2.1
1963	**101.9**	**102.6**	**112.8**	93.7	107.7	105.8	93.6	111.2	105.8	4.8	5.8	2.2	4.7	5.3	2.2
1964	**109.9**	**111.1**	**119.8**	99.6	117.9	112.3	96.1	121.9	112.3	5.1	6.3	2.4	4.9	5.8	2.4
1965	**109.0**	**109.2**	**123.9**	92.9	118.9	118.9	85.9	122.2	116.5	4.7	6.4	2.5	4.4	5.8	2.5
1966	**113.1**	**113.8**	**130.1**	100.4	120.5	120.8	93.5	124.5	118.7	5.1	6.4	2.6	4.7	5.9	2.5
1967	**109.5**	**109.6**	**133.2**	101.4	114.2	112.5	94.2	117.5	110.3	5.2	6.1	2.4	4.8	5.6	2.3
1968	**116.8**	**117.0**	**139.1**	103.1	126.5	119.4	95.2	131.5	117.6	5.2	6.8	2.5	4.8	6.3	2.5
1969	**121.0**	**120.7**	**147.3**	101.8	136.4	121.7	92.5	142.1	120.0	5.2	7.3	2.6	4.7	6.8	2.5
1970	**130.8**	**131.3**	**158.7**	105.3	149.4	137.5	95.9	156.7	135.7	5.4	8.0	2.9	4.9	7.5	2.9
1971	**135.2**	**135.5**	**166.8**	102.0	162.8	136.8	93.0	170.6	134.7	5.2	8.7	2.9	4.7	8.1	2.8
1972	**143.9**	**144.3**	**177.2**	104.1	178.0	141.9	94.6	187.3	139.6	5.3	9.5	3.0	4.8	8.9	3.0
1973	**146.9**	**146.8**	**185.8**	108.5	174.6	159.1	98.2	183.2	157.0	5.5	9.3	3.4	5.0	8.7	3.3
1974	**157.5**	**157.8**	**193.2**	110.2	199.2	155.3	99.8	210.2	153.4	5.6	10.6	3.3	5.1	10.0	3.2
1975	**152.7**	**153.5**	**192.5**	110.8	192.7	144.1	101.2	204.4	142.7	5.6	10.3	3.0	5.1	9.7	3.0
1976	**158.9**	**158.4**	**204.0**	111.4	200.7	156.4	98.8	213.2	154.2	5.7	10.7	3.3	5.0	10.1	3.3
1977	**163.2**	**163.2**	**213.6**	114.3	209.7	148.1	102.0	223.4	146.2	5.8	11.2	3.1	5.2	10.6	3.1
1978	**161.8**	**160.4**	**212.8**	112.3	205.7	155.9	98.9	217.7	154.0	5.7	11.0	3.3	5.0	10.4	3.3
1979	**170.2**	**167.5**	**224.4**	116.9	217.6	162.6	101.5	229.1	161.1	5.9	11.6	3.4	5.1	10.9	3.4
1980	**176.5**	**173.7**	**229.6**	125.1	224.5	161.1	109.2	236.6	159.6	6.4	12.0	3.4	5.5	11.3	3.4
1981	**173.4**	**170.0**	**229.3**	123.5	220.6	156.0	107.8	231.6	154.4	6.3	11.8	3.3	5.5	11.0	3.3
1982	**171.5**	**168.0**	**233.7**	132.6	211.7	145.0	117.5	221.6	143.6	6.7	11.3	3.1	6.0	10.5	3.0
1983	**164.5**	**159.0**	**240.3**	123.1	206.9	136.5	106.1	215.5	134.9	6.3	11.1	2.9	5.4	10.3	2.9
1984	**172.9**	**166.0**	**241.1**	128.6	214.6	152.4	110.5	222.0	149.2	6.5	11.5	3.2	5.6	10.6	3.2
1985	**172.4**	**165.4**	**246.5**	133.3	206.6	156.4	115.5	213.5	150.3	6.8	11.0	3.3	5.8	10.2	3.2
1986	**171.8**	**165.0**	**252.3**	129.5	209.2	154.7	110.6	217.3	150.8	6.6	11.2	3.3	5.6	10.3	3.2
1987	**173.3**	**165.8**	**256.5**	130.7	210.7	155.1	111.6	217.9	151.8	6.6	11.3	3.3	5.7	10.4	3.2
1988	**176.6**	**167.8**	**264.6**	135.3	216.7	144.9	113.7	224.9	142.1	6.9	11.6	3.1	5.8	10.7	3.0
1989	**182.7**	**173.3**	**275.8**	136.1	229.7	146.6	113.0	238.8	143.7	6.9	12.3	3.1	5.7	11.4	3.0
1990	**186.3**	**175.7**	**288.4**	134.9	234.5	157.1	110.1	242.9	153.9	6.9	12.5	3.3	5.6	11.6	3.3
1991	**185.2**	**175.1**	**298.2**	128.0	237.4	159.1	105.4	245.8	156.2	6.5	12.7	3.4	5.3	11.7	3.3
1992	**188.1**	**177.6**	**302.2**	118.3	255.0	155.4	94.7	265.4	151.6	6.0	13.6	3.3	4.8	12.6	3.2
1993	**188.3**	**177.4**	**303.8**	123.4	252.4	151.7	100.4	261.9	146.7	6.3	13.5	3.2	5.1	12.5	3.1
1994	**200.2**	**187.1**	**311.0**	133.1	270.5	148.8	106.8	280.3	141.7	6.8	14.5	3.1	5.4	13.3	3.0
1995	**197.7**	**181.0**	**316.3**	134.6	258.7	157.5	106.7	261.8	150.9	6.8	13.8	3.3	5.4	12.5	3.2
1996	**199.6**	**182.2**	**322.5**	133.7	257.9	165.7	105.8	261.5	157.1	6.8	13.8	3.5	5.4	12.4	3.3
1997	**211.6**	**191.7**	**330.7**	139.1	280.1	169.0	108.1	281.9	159.4	7.1	15.0	3.6	5.5	13.4	3.4

DMI: (Direct Material Input) = Domestic extraction + imports
DMC: (Domestic Material Consumption) = Domestic extraction + Imports - Exports
GDP: Gross Domestic Product
Source: Statistik Österreich (ÖSTAT)

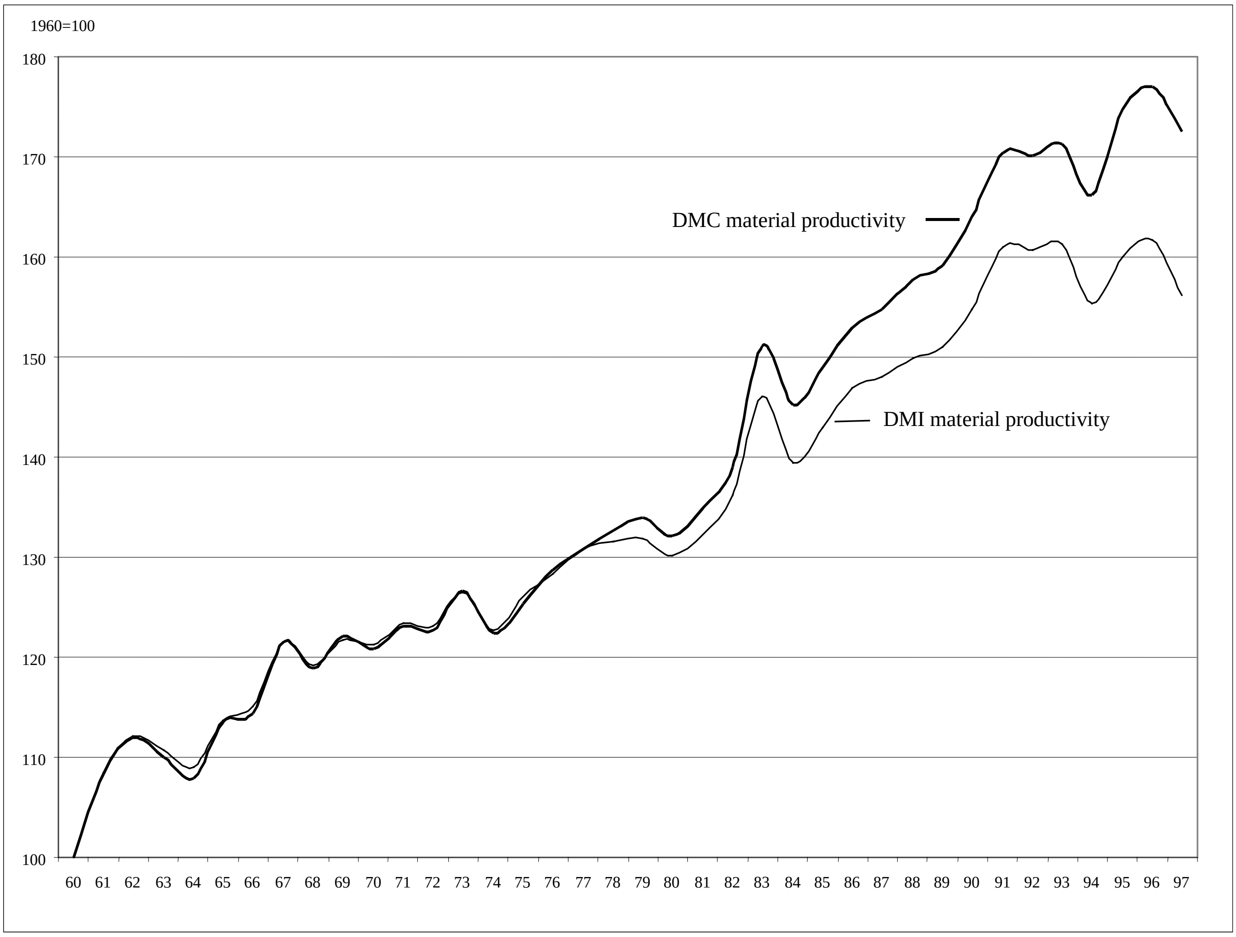
Graph 5: DMI, DMC and domestic material extraction, index 1960=100



Graph 6: DMI, DMC and domestic material extraction, index 1960=100



Graph 7: Material productivity, index 1960=100



ANNEX - Material flow account for Austria, 1960 to 1997

(Translation of an article published in Statistische Nachrichten Nr. 2/2000)

Summary

This paper discusses one aspect of an extension of national accounts to include more environment statistics in the form of a satellite account on "physical accounting". Satellite accounts set out to show the effects of socioeconomic activities on the environment, using a framework which is consistent with the national accounts but does not change the actual system. They are being produced in response to the criticism that national accounts do not adequately cover the negative external effects of economic development (environmental pollution). The whole subject of the natural resources which national economies extract from the environment has attracted a great deal of attention in connection with the demands of sustainable consumption and sustainable economic behaviour. The methodology for computing direct material input, the headline indicator, will be presented and the indicator calculated for the period 1960 to 1997. This will be the first publication of comprehensive data on the use of materials in Austria, as a time series in official statistics.

Introduction

Material flow accounts are one of the key areas of ecological accounting. They are produced as a satellite national account illustrating physical exchange processes involving society and nature or various national economies. They provide evidence of the quantities of material needed to underpin a national economy.

The present work concentrates on the input side of the material flows "mobilised" by socioeconomic processes, flows which are depicted in a time series for the period 1960 to 1997. Annual material input is the first parameter for the environmental pollution caused by society.

The groundwork was already in place. As long ago as 1994, the Institut für Interdisziplinäre Forschung und Fortbildung (IFF) - Soziale Ökologie calculated a time series[12]) for the Austrian economy's material input between 1970 and 1990. The methodology and time scale were subsequently[13]) extended (1960 - 1995), and a further development of the methodology made it possible to carry out a plausibility test on the input side for the input-output balance.[14])

The Statistics Austria also has a long history of physical accounting, producing a whole series of material flow accounts[15]). In 1998, the 1996 material balance for Austria was incorporated into official statistics[16]). The current project, aiming as it does to link statistical with scientific know-how, ties in with international projects. The German Federal Statistical Office produced a material input time series - for the old Länder - as long ago as 1994[17]). In 1997, the World Resources Institute produced a report on material input over time in four industrial countries (Germany, the Netherlands, Japan and USA) for the period 1995 to 1995.[18])

Methodology

We began with the idea that national accounts are input-output systems which metabolise with nature and with other national economies. This economic (or societal) metabolism enables national economies to organise their exchanges of materials and energy with nature. Materials are extracted from nature,

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12) A. Steurer, 1994. Stoffstrombilanz Österreich 1970 – 1990. "Soziale Ökologie" series, volume 34, Vienna: IFF own publication.
13) H. Schandl, 1997. Materialfluss Österreich. Die materielle Basis der österreichischen Gesellschaft im Zeitraum 1960 bis 1995. "Soziale Ökologie" series, volume 50, Vienna: IFF own publication.
14) H. Weisz, H. Schandl and M. Fischer-Kowalski 1999. OMEN – An Operating Matrix for Material Interrelations Between the Economy and Nature. How to Make Material Balances Consistent. In: R. Kleijn, S. Bringezu, M. Fischer-Kowalski and V. Palm, ed. Ecologizing Societal Metabolism: Designing Scenarios for Sustainable Materials Management. CML Report 148. Leiden: University Papers, pp. 160-165.
15) S. Gerhold. Several contributions to this periodical since 1990.
16) M.E. Wolf, B. Petrovic and H. Payer, 1998. Materialflußrechnung Österreich 1996. (Volume 11/1998), p. 939 ff.
17) Kuhn, Radermacher and Stahmer.
18) A. Adriaanse, S. Bringezu, A. Hammond, Y. Moriguchi, E. Rodenburg, D. Rogich and H. Schütz 1997. Resource Flows: The Material Basis of Industrial Economies. Washington: WRI.

processed, stockpiled in society (in the form of buildings, roads, vehicles and consumer durables) and finally, at the end of the chain, returned to nature in the form of waste and emissions. The metabolism of materials is a sweeping illustration of current environmental problems. The main topics of the environmental debate - waste and emissions - are but one minor aspect of what lies behind the annual flow of materials[19]).

A material flow account is a concrete expression of the idea of societal metabolism, quantifying the materials used, changes in stocks of materials and materials returned to nature. The accounts cover one-year periods. When a national materials balance is to be compiled, it is important first of all to delimit the boundaries of the system to be balanced, to draw the dividing lines between the national economy (society) and nature as well as between the national economy in question and other national economies. To this end, a distinction is made between the extraction of materials from nature on the country's own territory and external relations with other economies.[20])

Work on the material input time series focuses on three key criteria: the account must be theoretically sound, relevant to the policies in question and technically feasible. What do these criteria mean, exactly?

- The theoretical soundness criterion means that we must have a clear idea of the system boundaries (in time and space) of the social unit to be investigated (in this case the Austrian national economy), of the components of the system and of the difference between stocks and flows of materials (see above) and that, for complete balancing, the conservation of mass principle must be observed.
- The policy-relevance criterion means that the account must be compatible with other reporting systems. In particular, it needs to be based closely on national accounts, so that material indicators may be compared with monetary ones. The times series for material input must also be usable as a general source of information for integrated environmental policies. A further criterion is that links must be possible with other environmental information systems.
- The feasibility criterion refers to the possibilities offered and limitations imposed by the available data when it comes to a top-down account. It must be possible to compile a material input times series annually and reasonably quickly from statistics which appear regularly.

The present time series covers the input side of the materials balance for Austria, representing it in the form of quantities of materials used each year. The use of water and air was not covered. The account covers materials (other than water and air) which are either extracted from nature in Austria or imported from other economies. Thus the system boundary for the balance on the input side is described, a functional boundary between the Austrian economy and nature or between the Austrian economy and other national economies.

The annual material input is split into biomass, mineral materials, fossil materials and products. These highly aggregated groups of materials are compiled using a top-down approach, on the basis of existing and regularly available statistical data sources. The core data for the input side of the materials balance are agricultural statistics, mining statistics, certain components of industrial and commercial statistics and external trade statistics. Annual material input is calculated in line with the logic and criteria of national accounts, care being taken to ensure compatibility. This leads to problems in those areas where material flows which are not valued - or not fully valued - in economic terms are important from the point of view of volumes used, such as mineral raw materials in bulk or biomass which is grazed.

In such cases, we had to fall back on plausible estimates or secondary statistics, although we kept to the basic principle that the data sources used for the estimates must be available for several years at least. Thus the input-output table, for example[21]), which is available for three years (1976, 1983 and 1990), was suitable for a plausibility check on the partial aggregates in the times series. We did not use special studies for the times series if they had a single year reference year. The series presented here shows direct annual material input

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[19]) See on this subject the ideas of Jänicke 1995. Tragfähige Entwicklung: Anforderungen an die Umweltberichterstattung aus Sicht der Politikanalyse. In: S. Bringezu, ed: Neue Ansätze der Umweltstatistik. Ein Wuppertaler Werkstattgespräch. Berlin, Basel, Boston: Birkhäuser. pp. 9-25.

[20]) A material flow account could also be produced for a region, an economic sector or an individual business. The starting point in this case, too, would be a definition of the system to be balanced and its boundaries.

[21]) *Beiträge zur Statistik* „Input-Output-Tabelle 1990. Güter und Produktionskonten"; „ Input-Output-Tabelle 1983. Güter und Produktionskonten", two volumes ´Input-Output-Tabelle 1976. Güter und Produktionskonten", two volumes. The input-output table contains the monetary equivalents of physical production in ATS million.

and ignores the "ecological rucksacks"[22]) - meaning, where the extraction of raw materials is concerned, those quantities of materials which are "mobilised" in connection with direct material input but are not, in the end, used, such as the overburden from mining or the excavation of soil.

Basic data and calculation methods

The following section discusses the basic data and methods used to calculate the extraction of materials in Austria, divided into main aggregates: biomass, mineral materials and fossil materials, followed by material imports/exports.

Biomass

Agricultural harvest

Coverage of the harvest is based on ÖSTAT's agricultural report, which collects figures on quantities harvested each year. As Austria had to adjust EU statistics after joining the European Union, the coverage of vegetables and fruit has been much more detailed since 1994. Since 1983, there have been sharp falls in almost all groups (with the exception of cereals), but the reasons have varied: changes in the weather or in areas under cultivation may have been responsible. In the longer term, the quantities harvested depend on the utilisation of the land and productivity per hectare.[23])

Figures were collected for the harvests of the following crops:

- **Cereals:** This group includes winter wheat (from 1995 common wheat), spring wheat (from 1995 durum wheat), winter rye (and spring rye from 1990), spring rye (up to 1989), winter barley, spring barley, winter meslin, summer meslin, buckwheat (up to 1967), triticale (from 1995), oats and grain-maize. The cereals harvest as recorded in the statistics increased by 123.2% during the period under observation. Up to 1995, the straw harvest was also recorded separately for all kinds of cereal, but since 1996 this has not been the case. Prior to 1996, figures for straw covered the following kinds of cereal: winter wheat, spring wheat, winter rye (and spring rye), spring rye, winter barley, spring barley, winter meslin, summer meslin, triticale and oats. No explanation could be found for the sharp drop in the times series in 1995/1996 (-18.4%).
- **Root crops:** These include potatoes, sugarbeet, fodder beet, swede, fodder carrots and other root crops (up to 1965). Quantities harvested in Austria declined by 55.1%.
- **Vegetables:** These include kidney beans (up to 1974 and from 1995), cos lettuce (from 1995), Brussels sprouts (from 1995), garlic (from 1995), horse radish (from 1995), radish (from 1995), leek (from 1995), iceberg lettuce (from 1994), endive (from 1994), frisee (from 1994), lollo rosso (from 1994), radicchio (from 1994), zucchini (from 1995), lambs lettuce (from 1995), green leaf chicory (from 1995), celery (from 1995), sweet corn (from 1995), lentils (up to 1961), millet (up to 1974), garden peas (up to 1974), broccoli (from 1995), cauliflower (from 1995), Chinese cabbage (from 1964), cabbage, spinach (from 1987), carrots, red beet (from 1987), gherkins, asparagus (from 1995), parsley (root and leaves) (from 1967 to 1975 and from 1995), radishes (up to 1975, from 1995), Savoy cabbage (up to 1975, from 1995), kohlrabi (up to 1975, from 1995), head lettuce, onions, green peas, French beans, tomatoes and paprika (including pepperoni). As already mentioned, there has been a considerable improvement in the degree of detail of the vegetable survey since Austria joined the EU. Many of these kinds were grown in previous years, but were lumped together under combined headings in the old classification. Since 1960, there has been a 93.1% rise.
- **Other crops:** This category comprises horse beans (from 1986, up to 1994), oil squash (fruit with seeds), oil squash (dried seeds), winter rape for oil, sunflowers for oil (seeds), sunflowers, chicons,

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[22]) Schmidt-Bleek, Friedrich (1994): Wie viel Umwelt braucht der Mensch? MIPS – das Maß für ökologisches Wirtschaften. Berlin, Basel, Boston: Birkhäuser. As well as the "ecological rucksack" for raw materials, there is an "ecological rucksack" of products which includes the whole intermediate consumption of materials chain.

[23]) See Krausmann, F. 2000. Rekonstruktion der Entwicklung von Materialflüssen im Zuge der Industrialisierung: Veränderungen im sozioökonomischen Biomassemetabolismus in Österreich 1830 bis 1998. Final report of a study commissioned by the Breuninger Stiftung. Vienna.

hops, tobacco, soya beans (from 1990) and poppy. Here, there was a 122.3% increase during the period under consideration.

- **Fodder crops:** These include field beans (up to 1972, from 1987), feed peas (from 1986), green maize, pulse mixes, foxtail millet/common millet and bird rape (up to 1975) (and summer rape from 1990). Grain maize made up the largest share in this category, and the group as a whole showed an increase of 166.5%.
- **Catch crops:** These are buckwheat for seed, turnips (all kinds), summer fodder mix, fodder rape, sunflowers and maize for fodder, foxtail millet and other field crops. This category saw a 35.8% increase.
- **Clover and hay:** These include: red clover and other clover hay varieties, alfalfa hay, other clover, clover/grass hay, hay from ley grass farming, hay from meadows mown only once, hay from meadows mown two or three times, mountain meadows (up to 1972) and hay from litter meadows. Cultivation of these crops remained relatively stable over the period under consideration, with a negligible drop of 0.7% overall.
- **Fruit:** this covers summer apples, winter apples, cider apples, summer pears, winter pears, cider pears, cherries, sour cherries, damsons, greengages, cultivated plums, mirabelles, apricots, peaches, walnuts, pine strawberries, red and white currants, blackcurrants and gooseberries. During the period as a whole, 43.8% less fruit was harvested, but between 1990 and 1997, there was 27.8% growth.
- **Wine:** Overall, the wine harvest increased by 100.9% during the period under consideration.
- **Wood harvest:** In Austria, most of the wood harvested is covered in the annual statistics of the Federal Ministry of Agriculture and Forestry (felling statistics). Detailed studies, which include more accurate calculations and correct errors, in particular underestimates in the felling statistics, are available from the Bundesholzwirtschaftsrat [Federal Council for the Timber Industry] (Holzkurier No 48/1980) for 1926 to 1978, and from ÖSTAT for 1983 and 1988 to 1995.[24]) For years 1960 to 1978, wood input was calculated from Bundesholzwirtschaftsrat data (Holzkurier No 48/1980). The following headings were aggregated: total commercial timber and firewood from forest land, merchantable timber (coniferous and broadleaf) from non-forest land, from non-commercial kinds of wood and seedlings/saplings, together with merchantable firewood (coniferous and broadleaf) from non-forest land and from non-commercial kinds of wood, seedlings/saplings and branches. For 1983 and 1988 to 1995, the following headings from the ÖSTAT wood balance were aggregated: timber felled, other timber from forest land and other timber, and "reprocessed timber" was subtracted. For the remaining years, for which no wood balance was available, the additional estimates were calculated analogous to those from the wood balances for 1978 and 1983.

The unit in which the volumes of wood are shown is the cubic metre. These were converted to tonnes and standardised at 14% water content. Since different species of wood have different specific weights, a weighted average appropriate for the composition of the Austrian forests was taken as the conversion factor (see Table 1).

[24]) Gerhold, S. 1992. Stoffstromrechnung: Holzbilanz 1955-1991. Volume 8/1992, p. 651 ff.

Table 1: Wood conversion factors

Species	Percentage productive woodland	Dryweight per cubic meter of solid timber [kg/Vfm]
Picea abies/spruce	*62.2*	430
Abies alba/fir	*2.7*	410
Larix decidua/larch	*5.0*	550
Pinus/pine	*6.4*	535
Other coniferous wood	*1.5*	435
Fagus sylvatica/beech	*9.8*	680
Quercus/oak	*1.7*	680
Other hard wood	*5.2*	680
Softwood	*3.5*	490
Other/shrubs	*2.0*	490
Weighted average		487

Source: Haberl 1995, Species composition of Austrian forests according to the forest inventory 1986/90, dryweight per Vfm according to ÖNORM 3011, calorific value according to Lieth 1975.

- **Estimate of green fodder** (biomass input through grazing): The volume of biomass which is grazed off when animals eat roughage is not regularly documented in the statistics. In soil use statistics, three types of grazing are shown, by area: rough grazing, grazing on artificial pastures and grazing on alpine pastures. Green fodder was calculated as the net yield per hectare for rough grazing and grazing on artificial pastures.[25]). For alpine pastures, green fodder intake was calculated on the basis of the number of livestock units grazed on alpine pastures per year (alpine pasture survey), the average period of grazing and the average dry matter per livestock unit per day.[26]) The period of mountain grazing varies with the height of the pastures. Various studies[27]) suggest an average of ten days.
- **Honey, game and fish:** These three areas were not surveyed until 1992 (supply balances of crop/animal products). Since the volumes involved are very small, they have little effect on the overall picture of material input.

Mineral materials

These are aggregates of ore, salt, industrial minerals, clay, natural stone, sand and gravel.

- **Ore:** The data source is the Austrian *Montanhandbuch* [Mining Manual]. Of the seven ores at the start of the period (iron ore with micaceous iron oxide, tungsten ore, lead and zinc ores, copper ore, antimony ore and bauxite), there were only two left by 1997, namely iron ore with micaceous iron oxide and tungsten ore. Tungsten ore mining ceased in 1971 and restarted in 1974 in a new area. The same happened in 1993 (closure) and 1994 (reopening in a new area). In 1994, the mining of lead and zinc ores ceased. Copper ore was mined until 1976. In 1991, the antimony ore works were closed. The mining of bauxite ceased in mid-1964. During the period 1960/97, the extraction of ore in Austria fell by 44%.
- **Salt:** The source used was the primary production of evaporated salt, as recorded in industrial production statistics. This series has been in existence since 1977. Years 1960 to 1976 were extrapolated back using an appropriate factor (industrial salt-rocksalt/brine). Overall, there was a 111.5% increase.
- **Industrial minerals**: The source for these values is the Austrian *Montanhandbuch*. The group includes gypsum, anhydrite, barytes, graphite, oil shale, talc, kaolin, magnesite, feldspar, diatomite, trass and

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[25]) Schechtner 1963, quoted in Hohenecker 1980. Ernährungswirtschaftsplanung für Krisenzeiten in Österreich. Vierter Teilbericht: Futtermittelbilanzen für Österreich. Universität für Bodenkultur. Vienna. Buchgraber, Karl (1998): Nutzung und Konservierung des Gründlandfutters im österreichischen Alpenraum. Publications of the Bundesanstalt für Alpenländische Landwirtschaft, Gumpenstein, Volume 31. Irdning. Schlechter's 1963 values were used for 1959. The Buchgrabner 1998 values were used for years 1986 onwards. Between 1959 and 1986, the yield per hectare was interpolated linearly.

[26]) According to Hohenecker (1980) we can assume a daily intake of dry matter per livestock unit of 10kt (grass and herbage).

[27]) Hohenecker 1980, Brugger and Wohlfahrter 1983. Alp Wirtschaft Heute. Graz, Stuttgart: Leopold Stocker Verlag.

sulphur (extracted). No barytes has been extracted since 1981, and no diatomite since 1979. Overall, a 22.5% drop was recorded for this group during the period under consideration.

- **Clays:** This group consists of clay, illite clay and bentonite. The rise in quantities recorded was not a genuine increase, but was due to the increase in the number of workings to be inspected as a result of the 1990 *Berggesetznovelle* [Mining Act Amendment]. To correct for this, the data for 1960 to 1990 were grossed up using annual rates of change in the output of the tile industry (where clay is the main raw material). Since 1991, the sub-aggregates clay and illite clay have been covered. No bentonite has been mined since 1969. During the period under consideration, there was a 2.6% drop in clay extracted.
- **Natural stone:** In this area, too, the *Berggesetznovelle* led to breaks in the data series. As from 1991, dolomite, quartz and quartzite, basaltic rocks, limestone, marble and marl have been lumped together as natural stone. This aggregate includes both stone used as a raw material in the building industry (in the form of rough blocks or crushed or broken stone) and stone used as the basic product for industry. A comparison of values from the *Montanhandbuch* and the volume of output for the two-digit heading 271 (quarrying of natural stone) from the 1990 input/output table confirms that from 1991 the values given in the *Montanhandbuch* can be used. The series for 1960 to 1990 was calculated from the quantities of natural stone quarried (crushed and broken stone and preliminary screening material) in industry and large-scale businesses. These values, however, include neither the output of small-scale businesses nor the output of "competitors"[28]). In order to remedy this statistical under-reporting, key figures from the 1976, 1983 and 1990 input/output tables were used. On the basis of knowledge of the ratios of output volumes in industry and large-scale businesses to small-scale businesses and "competitors", total output volume was grossed up linearly from the output of industry and large-scale businesses for which information was available. The increase in the quarrying of natural stone, including cement and limestone raw materials, was 234.9%.
- **Sand and gravel:** Sand and gravel form the most sensitive area where data are concerned. Output volumes in industry and large-scale business are known but small-scale businesses are not known, even though they account for a large share of the quantities quarried. The *Montanhandbuch*, which is otherwise a reliable source of data, does not provide any useful information in this field. By converting output in monetary terms from the input/output tables, we can calculate total output volumes for three years, 1976, 1983 and 1990. In contrast to natural stone, however, the result of this conversion is implausible, namely a clear drop in output volumes between 1976 and 1990, a trend for which we could find no firm evidence, and so for the calculation of the times series, the output of small-scale businesses and "competitors" (from the 1990 input/output table) was grossed up to the volumes for industry and large-scale business output, which were known. With this input series, an increase of 277.3% was observed.

Fossil materials

Figures for the extraction of coal, petroleum and natural gas are based on the values in the Austrian *Montanhandbuch.*

- **Coal:** In years 1960 to 1967 and 1990 to 1995, both hard coal and brown coal were mined, and in other years only brown coal. Over the period under consideration, coal extraction fell by 81.5%.
- **Petroleum:** There was a 60.3% decline in the production of petroleum.
- **Natural gas:** Between 1960 and 1997, output of natural gas fell by 2.8%.

External trade

Imports are the second important component in the calculation of material input. In this case, we are able to use the very detailed, reliable basic data from external trade statistics, which are available for every year from 1947. For the whole period under consideration, data are broken down into three groups of materials (biomass, mineral materials and fossil materials) and into chemicals and other products. For exports, this has been possible only since 1964. The processing trade was not taken into account[29]). For both imports and exports, there were sharp rises in all groups, with the largest increase in exports of biomass.

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28) i.e. groupings of financial firms combining for a limited period for construction projects.
29) i.e. goods are imported/exported for finishing and returned to the country of origin.

Results

A look back at material input in Austria over the past four decades shows that even highly industrialised societies are confronted with extremely dynamic physical growth processes. In 1960, direct material input was 89.7 million tonnes, or 12.7 tonnes per capita. By 1997, this already high figure had risen to 185.4 million tonnes or 23 tonnes per capita. Thus the annual volume of materials used in the country doubled between 1960 and the present day.

Table 2 shows the average material input for ten-year periods, divided by group of materials. *Table 3* shows the dynamics of growth from one decade to another. By far the largest increase was between the 1960s and the 1970s, when average direct material input rose by 40%. All the partial aggregates (with the exception of biomass input) rose more during this period than any other. In contrast, the growth rate in average material input between the 1970s and the 1980s was "only" 14% and between the 1980s and the 1990s 12%.

Table 2: Average material input in Austria during the past four decades, million tonnes

	Mean values			
	1960-69	1970-79	1980-89	1990-97
Biomass	35.0	39.2	46.5	46.8
Mineral materials	43.1	71.2	81.0	96.4
Fossil materials	16.5	22.3	22.5	23.6
Products	1.8	3.7	5.7	7.9
Direct material input (DMI), total	**96.4**	**136.4**	**155.7**	**174.6**

Table 3: Relative growth in average material input, Austria, %

	Change in mean values		
	60s/70s	70s/80s	80s/90s
Biomass	*12.1*	*18.4*	*0.7*
Mineral materials	*65.1*	*13.8*	*18.9*
Fossil materials	*35.7*	*0.7*	*4.7*
Products	*98.2*	*55.4*	*38.6*
Direct material input (DMI), total	***41.5***	***14.1***	***12.1***

A comparison of average material input and population figures shows that annual per capita materials consumption was 13.3 tonnes in the 1960s, rising to almost 22 tonnes in the 1990s. Economic growth (represented as the change in GDP) followed a similar pattern to that of material input, with rapid growth in the 1960s but slower growth since the 1980s.

As an example of a highly industrialised country, Austria curbed the growth trend - both economic growth and the consumption of materials - following an extremely intensive growth phase in the 1960s and the 1970s. It is too early to say whether this is a temporary phenomenon or whether the figures are stable, although still high.

Table 4: Per capita direct material input (DMI), GDP and population in Austria, 1960-1997

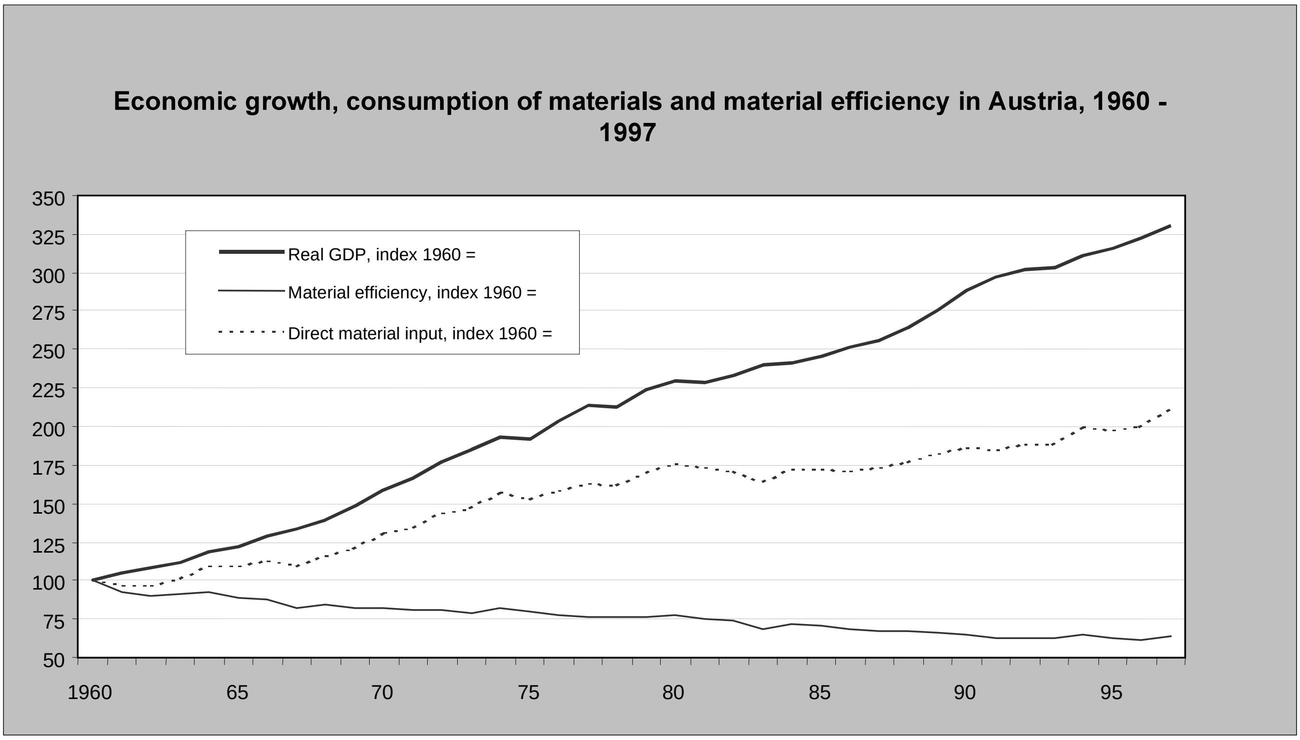
	Mean values			
	1960-69	1970-79	1980-89	1990-97
Per capita DMI, tonnes	13.3	18.1	20.5	21.9
Real GDP, ATS billion	627.4	993.3	1 271.8	1 592.0
Population, '000	7 248.9	7 552.0	7 587.0	7 956.9

Table 5: Increase in per capita direct material input (DMI), GDP and population in Austria, in %

	Change in mean values		
	60s/70s	70s/80s	80s/90s
Per capita DMI	*35.8*	*13.6*	*6.9*
Real GDP	*58.3*	*28.0*	*25.2*
Population	*4.2*	*0.5*	*4.9*

The key issue in the debate on environmental policies over the past decade has been whether the industrialised countries could manage to decouple the consumption of energy and materials from economic growth by making technological improvements and structural changes. The hope is that this will come about via improvements in efficiency, as recently expressed under the slogan "Factor four - wealth doubled and resource use halved"[30]). There would seem to be ample scope for the more efficient use of raw materials. Use of energy has been examined particularly thoroughly and it has been estimated that over 50% savings could be made through the introduction of technical improvements. However, there are factors which militate against the likely dematerialisation of industrial production and the way of life of industrial societies in the future. Improvements in resource efficiency are frequently more than offset by quantity effects. Resource efficiency is a function of economic growth and the consumption of resources. Thus the material efficiency indicator shows how many units of material were consumed to produce one unit of GDP. The concept of materials productivity crops up more frequently in economic discussions. This shows how many units of value added have been produced from a given unit of material.[31]) Have resources been used more efficiently in Austria over the past few decades?

Since the 1960s, material efficiency has risen by approximately 30%. In 1960, a material input of 174 kg was needed for each ATS 1 000 of value added, whereas today only 121 kg are required. This indicates that there has been some success during the past few decades in decoupling material consumption from economic growth. The Austrian national economy was even more materials-extensive at the start of the 1990s, however, producing ATS 1 000 worth of value added in 1991 and 1992 for only 112 kg of material input. Thus in the 1990s the physical economy became more dynamic again.[32])



Source: IFF Statistik Österreich: material input in kg per ATS 1 000 of value added.

The example of Austria also shows that more efficient use of materials has not led to a reduction in material input in absolute terms. This continues to increase even though, as in the 1980s, the rate of growth has slowed down. It is still too early to tell what effect the greater dynamism of the late 1990s will have on material consumption in the future.

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[30]) Weizsäcker, F.., A. B. Lovins und L. H. Lovins 1995. Faktor Vier: Doppelter Wohlstand – halbierter Naturverbrauch. The new report to the Club of Rome, Munich, Droemer Knaur.

[31]) Material productivity is the reciprocal of material efficiency.

[32]) Looked at another way, the figures for productivity growth of material input were ATS 5.75 per kg of material input in 1960 as opposed to ATS 9 in 1997.

Summary and outlook

This material flow account of an input times series for the Austrian economy between 1960 and 1997 results from a successful pooling of scientific and statistical know-how. The Institut für Interdisziplinäre Forschung und Fortbildung - Soziale Ökologie, which was one of the first institutes in Europe to develop material flow accounting, contributed its experience of methodology and its knowledge of ecological conditions and processes. As the producer of an enormous fund of data, ÖSTAT was able to contribute the knowledge it had acquired of the quality, informative value and methodology of data acquisition. But the main thrust of our work was to demonstrate that material flow accounting on a regular basis is simple and feasible.

Once material input accounting for Austria has been incorporated into ÖSTAT's regular programme, we plan three-yearly updates. International discussions have suggested that three years is an appropriate interval for this kind of work. This stock-taking could also be an opportunity to review the success of the ever-increasing efforts of environmental policymakers over the past few years to reduce the national economy's material input and/or to decouple the use of materials from economic growth by increasing efficiency.

In ÖSTAT's view, this work has shown that, as well as information on input flows, many data are available on the destination of material flows, i.e. the key building blocks for balances are in place. By widening the focus, we could increase the value of the experience gained with the material flow accounting system, since as well as depicting changes in the volumes of materials consumed, we could show who are the main consumers of materials, i.e. those who cause materials to be extracted from nature. The plan is therefore to produce a further paper setting out a balance for the three major flows of matter.

However, a clear distinction has to be made between the two aims from the point of view of the data involved. Whereas in theory we need only production data (or estimates of such data) for the calculation of the material input of a national economy, for a materials balance a key requirement is statistics on the use of raw materials. ÖSTAT compiled such statistics up to 1994, although their quality left something to be desired. But such statistics ceased to be collected when the programme of work was adapted to EU requirements and the Office suffered from an increasing shortage of resources. Since, however, input data are required to help solve many issues - including for input output statistics, for example - this data collection was resumed as from the 1997 reporting year, albeit in a somewhat changed form. In the future, therefore, we can count on a regular supply of data on the use of the most important material flows, and ongoing balances will be possible as well. With society's throughput of materials becoming an ever more serious issue, it is becoming increasingly important to extend in this way the range of information available.

Heinz Schandl - Helga Weisz (IFF) - Brigitte Petrovic (ÖSTAT)

Domestic removal of biomass, million tonnes

	Grain harvest	Straw harvest	Root crops, other crops	Vegetables	Other crops	Fodder crops	Catch crops	Clover and hay	Fruit harvest	Wine harvest	Green fodder estimate	Honey, game and fish	Wood	Total biomass
1960	2.24	3.08	8.34	0.24	0.10	1.54	0.53	7.50	1.28	0.09	1.28	-	7.38	33.59
1961	2.27	3.02	6.95	0.23	0.08	1.31	0.50	7.80	1.03	0.13	1.28	-	7.15	31.75
1962	2.31	2.96	6.91	0.21	0.08	1.31	0.00	7.63	0.77	0.10	1.28	-	6.85	30.40
1963	2.23	2.81	7.89	0.26	0.12	1.35	0.00	8.08	0.86	0.18	1.27	-	6.40	31.44
1964	2.35	2.80	7.87	0.26	0.14	1.47	0.86	8.42	0.86	0.28	1.28	-	6.73	33.32
1965	2.02	2.60	5.94	0.26	0.10	1.62	0.72	8.97	0.48	0.14	1.28	-	6.53	30.66
1966	2.64	3.24	7.53	0.29	0.13	1.66	0.00	9.07	0.75	0.15	1.25	-	6.93	33.63
1967	2.93	3.34	7.28	0.28	0.14	1.73	0.85	8.79	0.65	0.26	1.24	-	6.69	34.19
1968	3.04	3.30	7.52	0.29	0.14	1.89	0.93	8.85	0.72	0.25	1.25	-	6.53	34.71
1969	3.40	3.34	6.96	0.27	0.10	2.31	0.00	8.86	0.64	0.23	1.21	-	6.98	34.31
1970	3.07	3.22	6.76	0.28	0.11	2.55	0.93	8.84	0.67	0.31	1.23	-	6.88	34.84
1971	3.54	3.19	6.23	0.28	0.11	2.63	0.00	8.47	0.55	0.18	1.24	-	7.21	33.63
1972	3.31	3.14	6.18	0.30	0.11	2.74	0.63	8.85	0.37	0.26	1.25	-	7.20	34.34
1973	3.78	3.18	5.61	0.31	0.13	3.76	0.73	8.50	0.65	0.24	1.19	-	6.84	34.91
1974	4.03	3.34	5.50	0.32	0.15	3.67	0.70	8.71	0.68	0.17	1.22	-	6.68	35.16
1975	3.71	3.14	5.90	0.36	0.14	4.36	0.76	9.21	0.65	0.27	1.24	-	6.48	36.22
1976	4.27	3.56	5.28	0.27	0.14	4.62	1.08	7.15	0.63	0.29	1.18	-	7.51	35.98
1977	4.21	3.32	4.89	0.35	0.16	5.23	0.94	8.32	0.53	0.26	1.20	-	7.50	36.93
1978	4.63	3.27	4.02	0.34	0.18	5.46	0.79	8.12	0.59	0.34	1.22	-	7.29	36.24
1979	3.99	3.21	4.31	0.36	0.19	5.45	0.87	7.77	0.64	0.28	1.19	-	8.83	37.10
1980	4.83	3.81	4.45	0.40	0.25	5.35	0.84	8.04	0.65	0.31	1.22	-	9.17	39.33
1981	4.35	3.31	4.80	0.39	0.25	5.79	1.10	7.92	0.45	0.21	1.25	-	9.20	39.03
1982	5.03	3.76	5.13	0.37	0.21	6.58	1.15	8.38	0.81	0.49	1.28	-	8.93	42.11
1983	5.06	3.90	3.41	0.19	0.16	5.48	0.85	7.71	0.67	0.37	1.09	-	9.61	38.51
1984	5.35	4.16	4.12	0.25	0.20	6.06	0.85	7.40	0.70	0.25	1.11	-	9.97	40.42
1985	5.56	3.86	3.82	0.26	0.22	6.82	0.76	8.16	0.59	0.11	1.12	-	9.80	41.09
1986	5.11	3.63	3.02	0.26	0.32	6.51	0.88	7.57	0.72	0.22	1.18	-	10.19	39.62
1987	4.97	3.51	3.32	0.27	0.40	6.38	0.99	7.96	0.51	0.22	1.19	-	10.09	39.79
1988	5.36	3.97	3.19	0.30	0.47	5.76	1.03	7.83	0.78	0.35	1.19	-	10.77	41.00
1989	5.00	3.68	3.72	0.29	0.51	5.58	1.08	7.84	0.65	0.26	1.20	-	11.49	41.29
1990	5.29	3.83	3.45	0.30	0.44	4.48	0.95	7.07	0.56	0.32	1.13	-	12.58	40.40
1991	5.04	2.75	3.48	0.30	0.55	4.43	0.73	7.13	0.49	0.31	1.08	-	10.06	36.34
1992	4.32	2.16	3.46	0.24	0.59	3.70	0.36	5.54	0.48	0.37	1.07	0.01	10.75	33.06
1993	4.21	2.00	4.01	0.25	0.60	4.36	0.42	6.43	0.63	0.27	1.07	0.01	10.71	34.96
1994	4.44	2.32	3.26	0.28	0.70	4.32	0.71	7.05	0.55	0.22	1.14	0.02	12.54	37.54
1995	4.45	2.41	3.70	0.39	0.77	4.06	0.79	7.24	0.66	0.22	1.22	0.02	12.06	37.99
1996	4.49	1.97	3.96	0.40	0.21	4.02	0.73	6.77	0.59	0.21	1.23	0.01	13.11	37.70
1997	5.01	2.15	3.75	0.46	0.22	4.11	0.71	7.45	0.72	0.18	1.22	0.01	12.86	38.86

Extraction of mineral raw materials, million tonnes

	Ores (iron ore, tungsten ore, lead, copper, zinc and antimony ore)	Salt	Industrial minerals (gypsum, anhydrite, graphite, kaolin, talc, magnesite)	Clays	Natural stone (incl. cement and limestone raw materials	Sand and gravel	Total mineral materials
1960	3.92	0.25	2.83	3.13	12.37	10.44	32.95
1961	4.06	0.21	3.04	3.16	12.02	10.82	33.31
1962	4.14	0.23	2.83	3.19	11.80	10.94	33.13
1963	4.11	0.28	2.45	3.23	11.80	12.94	34.80
1964	3.91	0.29	2.80	3.26	12.75	16.70	39.70
1965	3.88	0.30	2.95	3.29	11.96	18.72	41.11
1966	3.84	0.32	2.95	3.32	12.77	18.32	41.53
1967	3.85	0.31	2.80	3.36	13.57	15.52	39.40
1968	3.90	0.34	2.71	3.39	13.09	19.94	43.37
1969	4.41	0.34	2.78	3.43	13.02	22.83	46.81
1970	4.43	0.40	2.76	3.60	15.34	24.34	50.87
1971	4.78	0.39	2.60	3.83	16.55	27.68	55.83
1972	4.72	0.41	2.66	3.86	17.26	32.19	61.08
1973	4.83	0.44	2.73	3.86	16.52	31.72	60.10
1974	4.85	0.44	2.72	3.88	18.22	38.08	68.18
1975	4.45	0.38	2.39	3.58	17.78	38.08	66.66
1976	4.55	0.47	2.12	3.15	17.94	40.90	69.13
1977	4.17	0.32	2.26	3.07	19.67	42.56	72.06
1978	3.59	0.32	2.21	2.90	20.27	40.84	70.13
1979	4.12	0.38	2.43	2.92	22.00	41.47	73.31
1980	4.39	0.41	2.69	3.56	23.27	42.08	76.40
1981	4.24	0.46	2.46	3.47	22.30	42.22	75.16
1982	4.62	0.43	2.30	3.27	23.86	37.44	71.93
1983	4.84	0.36	2.36	3.02	22.34	38.03	70.95
1984	5.01	0.42	2.60	3.16	22.53	38.19	71.91
1985	4.49	0.44	2.66	3.08	22.40	36.17	69.24
1986	4.04	0.49	2.44	2.98	23.82	36.88	70.65
1987	3.73	0.48	2.26	2.99	24.51	37.23	71.22
1988	3.01	0.41	2.48	3.36	26.44	36.46	72.17
1989	3.10	0.40	2.67	3.27	27.29	39.84	76.57
1990	2.95	0.39	2.58	3.50	27.00	42.04	78.44
1991	2.72	0.46	2.17	3.68	27.37	42.66	79.05
1992	2.24	0.46	2.32	3.72	32.45	43.72	84.91
1993	1.71	0.52	2.03	3.29	34.04	42.71	84.29
1994	1.65	0.52	2.36	3.23	34.83	46.71	89.31
1995	2.31	0.60	2.32	3.40	34.40	40.36	83.38
1996	2.23	0.60	2.08	2.94	35.46	39.41	82.70
1997	2.18	0.53	2.19	3.05	41.41	39.41	88.78

Extraction of fossil materials, million tonnes

	Coal	Petroleum	Natural gas	Total fossil materials
1960	6.11	2.45	1.11	9.67
1961	5.77	2.36	1.18	9.30
1962	5.81	2.39	1.24	9.44
1963	6.16	2.62	1.29	10.06
1964	5.86	2.66	1.34	9.86
1965	5.51	2.85	1.31	9.67
1966	5.30	2.76	1.42	9.48
1967	4.62	2.68	1.36	8.66
1968	4.18	2.72	1.23	8.14
1969	3.84	2.76	1.12	7.72
1970	3.67	2.80	1.44	7.90
1971	3.77	2.52	1.43	7.72
1972	3.76	2.48	1.49	7.72
1973	3.63	2.58	1.72	7.93
1974	3.63	2.24	1.67	7.54
1975	3.40	2.04	1.79	7.22
1976	3.21	1.93	1.62	6.77
1977	3.13	1.79	1.81	6.73
1978	3.08	1.79	1.83	6.69
1979	2.74	1.73	1.75	6.22
1980	2.86	1.48	1.44	5.78
1981	3.06	1.34	1.09	5.49
1982	3.30	1.29	1.00	5.59
1983	3.04	1.27	0.92	5.23
1984	2.90	1.21	0.96	5.07
1985	3.08	1.15	0.88	5.11
1986	2.97	1.12	0.84	4.93
1987	2.79	1.06	0.88	4.73
1988	2.13	1.18	0.96	4.26
1989	2.07	1.16	1.00	4.23
1990	2.45	1.15	0.98	4.57
1991	2.08	1.28	1.01	4.37
1992	1.75	1.18	1.09	4.02
1993	1.69	1.16	1.13	3.97
1994	1.37	1.10	1.03	3.50
1995	1.25	1.03	1.12	3.41
1996	1.11	0.99	1.13	3.23
1997	1.13	0.97	1.08	3.18

Imports, million tonnes

	Biomass	Mineral materials	Petroleum, coal, natural gas	Chemicals	Products	Total imports
1960	2.22	4.73	5.24	0.00	1.31	13.50
1961	1.80	4.96	4.84	0.00	1.36	12.96
1962	2.16	5.08	5.12	0.00	1.36	13.71
1963	2.12	5.79	5.70	0.00	1.47	15.08
1964	2.36	4.74	6.88	0.62	1.13	15.72
1965	2.60	3.68	8.05	1.23	0.79	16.35
1966	2.32	3.85	8.52	1.25	0.89	16.82
1967	2.11	3.63	8.10	1.30	0.88	16.01
1968	2.21	4.30	9.67	1.43	0.95	18.55
1969	2.17	4.59	10.42	1.48	1.00	19.66
1970	2.88	5.43	12.58	1.64	1.18	23.71
1971	2.89	5.49	12.67	1.66	1.37	24.07
1972	2.93	6.00	13.42	1.96	1.60	25.91
1973	3.95	5.69	15.78	1.81	1.59	28.83
1974	4.31	6.87	15.61	2.01	1.60	30.40
1975	3.45	5.95	14.26	1.61	1.61	26.88
1976	3.93	6.48	16.54	1.83	1.91	30.70
1977	4.01	6.96	15.36	2.19	2.13	30.64
1978	3.98	7.37	16.54	2.24	1.94	32.07
1979	4.76	8.68	18.02	2.53	2.10	36.09
1980	5.48	8.18	18.23	2.67	2.25	36.83
1981	5.20	7.95	17.76	2.79	2.15	35.85
1982	5.39	7.83	16.02	2.82	2.19	34.25
1983	5.56	6.99	15.12	2.95	2.27	32.91
1984	5.65	8.95	17.65	3.07	2.33	37.66
1985	6.64	8.59	18.20	3.36	2.44	39.24
1986	6.75	8.16	18.13	3.32	2.54	38.91
1987	7.00	8.16	18.39	3.44	2.69	39.68
1988	7.47	9.49	17.34	3.86	2.83	40.97
1989	7.44	9.96	17.63	3.76	3.03	41.83
1990	7.91	9.89	18.85	3.77	3.30	43.71
1991	9.50	10.38	19.35	3.72	3.46	46.41
1992	9.29	11.17	19.14	3.66	3.47	46.73
1993	9.24	10.81	18.64	3.63	3.38	45.69
1994	10.14	12.59	18.68	4.03	3.78	49.22
1995	10.23	14.09	20.06	4.17	4.04	52.59
1996	10.19	14.47	21.47	4.77	4.48	55.37
1997	10.96	16.73	22.01	4.32	4.98	59.00

Exports, million tonnes

	Biomass	Mineral materials	Petroleum, coal, natural gas	Chemicals	Products	Total exports
1960	0.13	4.14	0.00	0.00	2.97	7.24
1961	0.22	3.63	0.00	0.00	3.12	6.97
1962	0.24	3.43	0.00	0.00	3.24	6.92
1963	0.18	3.29	0.00	0.00	3.31	6.78
1964	1.39	3.55	0.00	0.00	2.07	7.01
1965	2.60	3.82	0.35	0.15	0.82	7.74
1966	2.59	3.63	0.31	0.16	0.94	7.63
1967	2.67	3.63	0.32	0.88	0.38	7.87
1968	2.96	3.58	0.27	1.07	0.42	8.30
1969	3.48	3.76	0.25	0.98	0.53	9.00
1970	3.48	3.75	0.26	0.95	0.61	0.00
1971	3.34	4.11	0.31	1.13	0.65	9.55
1972	3.53	4.27	0.33	1.18	0.72	10.03
1973	3.81	4.38	0.31	1.46	0.76	10.71
1974	3.84	4.55	0.28	1.62	0.87	11.15
1975	3.55	4.06	0.22	1.71	0.89	10.43
1976	4.67	4.12	0.34	1.76	1.07	11.96
1977	4.55	4.09	0.29	1.84	0.96	11.73
1978	4.93	4.49	0.28	2.06	1.06	12.82
1979	5.66	5.18	0.22	2.28	1.22	14.56
1980	5.84	5.25	0.22	2.41	1.36	15.09
1981	5.76	5.46	0.23	2.51	1.35	15.32
1982	5.57	5.45	0.21	2.61	1.46	15.30
1983	6.21	5.68	0.24	2.86	1.52	16.51
1984	6.63	6.40	0.48	3.11	1.57	18.20
1985	6.52	6.24	0.91	2.93	1.69	18.28
1986	6.91	5.95	0.58	2.91	1.70	18.05
1987	6.97	6.33	0.50	3.26	1.65	18.72
1988	7.90	6.25	0.41	3.60	1.89	20.04
1989	8.39	6.44	0.44	3.58	2.14	20.98
1990	9.02	6.89	0.47	3.44	2.43	22.26
1991	8.23	7.01	0.44	3.50	2.63	21.81
1992	8.55	7.08	0.57	3.44	2.58	22.22
1993	8.36	7.29	0.74	3.48	2.77	22.64
1994	9.58	7.91	1.06	3.88	2.85	25.28
1995	10.15	9.66	0.98	3.87	3.44	28.11
1996	10.15	9.49	1.28	4.16	3.66	28.74
1997	11.25	10.97	1.44	4.32	3.77	31.74