OFFICE FOR NATIONAL STATISTICS

UK MATERIAL FLOW REVIEW

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Contents

1 - Introduction

Background

The Office for National Statistics is responsible for updating and maintaining the Material Flow Account for the United Kingdom. The accounts are published biannually as part of the UK Environmental Accounts. The latest version was published in *Environmental Accounts* [1] in November 2004 and covered periods 1970 to 2003 (ONS, 2004).

The accounts provide a comprehensive and coherent framework for the recording of material flows in the UK, and for the calculation of a range of resource productivity indicators. It is intended that some of the indicators, most likely domestic material consumption, will be included in the revised set of sustainable development and sustainable consumption and production indicators compiled by the Department for Environment, Food and Rural Affairs (Defra).

There are, however, a number of areas where the data, methodology and factors used in the accounts could be improved. In particular, there are some concerns about the completeness, timeliness, international comparability, policy relevance and accuracy of the estimates.

The review follows from a proposal made to Eurostat in June 2002 for a jointly funded review of the accounts. The ONS Investment Board approved the proposal in September 2002 and the contract with Eurostat was signed in October 2002.

Purpose

It is hoped that this work will help the Office for National Statistics meet its objectives by producing statistics which are more accurate and more relevant to the formulation and monitoring of economic and environmental policies regarding resource use.

In particular it is the aim of this report to highlight areas in which the accounts have been improved as a result of research prompted by this report and where possible to make recommendations for future development of the Material Flow Accounts.

These aims are in line with recently published OECD recommendations by The Council on Material Flows and Resource Productivity[2], which states that member countries "take steps to improve information on material flows, including its quality and relevance for environmental management." (OECD, 2004).

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[1] Office for National Statistics (2004), *Environmental Accounts* , November 2004

[2] Organisation for Economic Co-operation and Development (2004), Recommendation of the Council on Material Flows and Resource Productivity, April 2004

Structure of review

The review looked at five different issues related to the compilation of the Material Flow Accounts. These are completeness, timeliness, international comparability, policy relevance and the accuracy and coverage of the indirect and hidden flows.

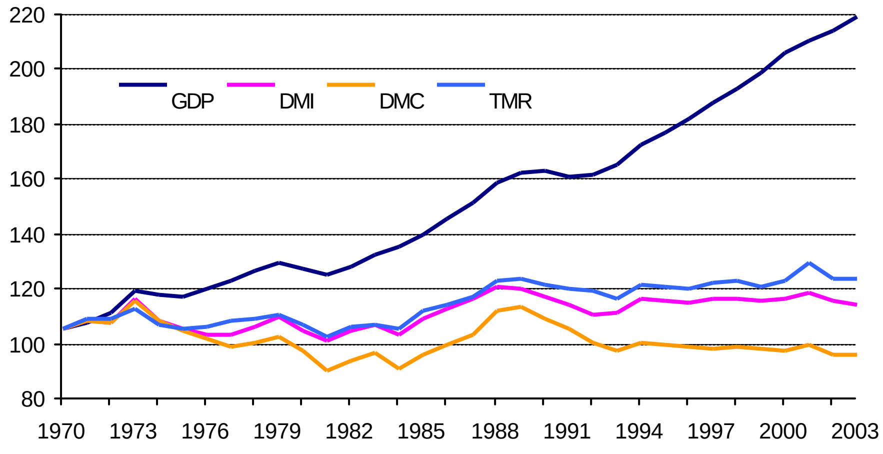
Current position

The UK Material Flow Accounts were originally compiled by the Wuppertal Institute on behalf of the then Department for Environment, Transport and Regions now the Department for Environment, Food and Rural Affairs (Defra). The initial accounts were published in 2002 in the report entitled *Total Material Resource Flows of the United Kingdom* (obtainable from Defra). A summary report entitled *Resource use and efficiency of the UK economy* (Defra 2002) is published on the Defra website.

The accounts are now compiled and published by the ONS annually and provide a limited dataset focusing on the input and consumption side of the accounts from 1970 onwards. The key indicators currently published are:-

Direct Material Input (domestic extraction + imports)
Domestic Material Consumption (domestic extraction + imports – exports)
Total Material Requirement (direct material input + indirect and hidden flows)

UK material flows, 1970-2003



Source: ONS Environmental Accounts

To date it has not been possible to compile output indicators of sufficient quality for publication because of the limited availability of information of landfilled waste and emissions to water. Although the situation is improving in respect of waste (more details are contained in the chapter on completeness), availability issues are still a problem for emissions to water. For this reason, the review has concentrated on improving estimates of the published indicators. However, the development of output indicators is discussed in the chapter on recommendations.

2 - Concepts and definitions

The following chapter on concepts and definitions was taken from Eurostat's "Economy-wide material flow accounts and indicators - A methodological guide" hereafter referred to as "The Guide".

Material inputs and outputs

The focus of economy-wide MFA and balances is on the economy's metabolism, i.e. on the flows between a given economy and the environment. Therefore, the system boundary is defined:

1. by the extraction of primary (i.e., raw, crude or virgin) materials from the national environment and the discharge of materials to the national environment;
2. by the political (administrative) borders that determine material flows to and from the rest of the world (imports and exports). Natural flows into and out of a geographical territory are excluded.

Inputs from the environment refer to the extraction or movement of natural materials on purpose and by humans or human-controlled means of technology (i.e. involving labour). Output released to the environment means that society loses control over the location and composition of the materials.

Only flows are counted that cross the system boundary at the input side or at the output side. Material flows *within* the economy are not presented in economy-wide MFA and balances. Therefore, inter-industry deliveries of products, for example, are not described. Also, flows within the economy may be instrumental for estimating primary input flows, for example when data on primary extraction are lacking. In the following, several borderline cases are presented that have to be settled by convention. The national accounts and the Pressure-State-Response framework offer useful guiding principles for these borderline cases. In general, economy-wide MFA should be consistent with the national accounts, and materials recorded as inputs or outputs should generally belong to the Pressure (rather than State) category.

The domestic production of livestock is considered a process *within* the economy, and the domestic harvest of plant biomass as feedstuff for this livestock, including the plant biomass directly taken up by grazing livestock, as well as imported feedstuff, are counted as inputs.

Fertiliser used on agricultural land is defined as an output to the environment because dispersion and decomposition processes within soil and subsequent emissions are difficult to measure and can hardly be considered as completely under human control.

Material stocks and the system boundary

There are some material stocks for which compilers have to determine whether they should be treated as part of the economy or of the environment. Cases in point are controlled landfills and cultivated forests. These decisions have an impact on the input and output flows that are recorded in the accounts. When controlled landfills are included within the system boundary, the emissions and leakages from landfills rather than the waste landfilled must be recorded as an output to the environment. For cultivated forests, the nutrients taken up by the trees rather than the timber harvested would be recorded as an input.

The Guide recommends treating forests and agricultural plants as part of the environment in economy-wide MFA and the harvest of timber and other plants as material inputs. Treating forests and agricultural plants as part of the economy would require to include the bio-metabolism of these plants in the accounts. This extension is laborious, difficult to underpin with actual data and probably does not increase the information content of the accounts.

In the Guide, waste landfilled is considered an output to the environment but compilers are free to choose the treatment they prefer. If controlled landfills are included within the system boundary, the classifications of outputs and stock changes presented in the Guide (must be adapted. It is recommended to show waste landfilled as a separate category of stock changes so as to facilitate international comparison of data.

Residence versus territory principle

Economy-wide material flow accounts and balances should be consistent with the national accounts. The national accounts define a national economy as the activities and transactions of producer and consumer units that are resident (i.e. have their centre of economic interest) on the economic territory of a country. Some activities and transactions of these units may occur outside the economic territory and some activities and transactions on the geographical territory of a country may involve non-residents. Standard examples for illustrating this difference are tourists or international transport by road, air or water. Due to such activities the environmental pressures generated by a national economy may differ from the environmental pressures generated on a nation's geographical territory. Trans-boundary flows of emissions through natural media (e.g., emissions to air or water generated in one country but which are carried by air or rivers and impact on another country) are not part of economy-wide MFA.

For physical accounts to be consistent with the national accounts means the application of the residence (rather than territory) principle. Hence, in principle, materials purchased (or extracted for use) by resident units abroad would have to be considered material inputs (and emissions abroad material outputs) of the economy for which the accounts are made. Likewise, materials extracted or purchased by non-residents on a nation's territory (and corresponding emissions and wastes) would have to be identified and excluded from that nation's economy-wide MFA and balances. Current knowledge suggests that the most important difference between residence and territory principle results from fuel use and corresponding air emissions related to international transport including bunkering of fuels and emissions by ships and international air transport as well as to fuel use and emissions of tourists. This should be kept in mind for physical input-output tables because the differences would be concentrated on the road, air and water transport industries (divisions 60, 61 and 62 of NACE Rev. 1) and households.

The significance of international transport and tourism activities and in particular the net balance of emissions and energy use by resident units abroad and non-resident units on a nation's territory will differ across countries. If the net balance is assumed to be significant, emissions and energy use by non-residents on national territory and by residents abroad will be.

Terminology

Three dimensions (pairs of distinction) are used to characterise categories of material flows and indicators. These are:

- the territorial dimension to indicate the origin and destination of flows: *domestic* <–> *rest of the world (ROW);*
- the product-chain or life-cycle dimension to indicate whether flows are directly observed or calculations of up-stream material requirements: *direct* <–> *indirect;*
- the product dimension to indicate whether flows enter (any) economic system or not: *used* <–> *unuse*d. This pair is only used for inputs. For outputs, the distinction *processed* <–>*non-processed* is used, i.e. flows stemming from an economic system or not.

The first two dimensions refer to flows in relation to the entity (the economy) for which the accounts are made. The third dimension refers to the flows only. Domestic flows are materials that are extracted from, or released into, the national environment. Direct flows are materials physically entering the national economy (i.e., the system for which the accounts are made) as an input. Indirect flows are material flows for the production of a product that have occurred up-stream in the production process.

"Used" refers to an input for use in any economy, i.e. whether a material acquires the status of a product. All direct flows are also used but not all used flows are direct. Some are indirect, e.g. the raw materials used in the rest of the world to produce products that are then imported by the economy for which the accounts are made. Unused flows are materials that are extracted from the environment without the intention of using them, i.e. materials moved at the system boundary of economy-wide MFA on purpose and by means of technology but not for use. Examples are soil and rock excavated during construction or overburden from mining.

Definitions

Direct (used) material inputs are defined as all solid, liquid and gaseous materials (excluding water and air but including e.g. the water content of materials) that enter the economy for further use in production or consumption processes. The two main categories are raw materials domestically extracted and imports. The sum of these two categories constitutes one of the indicators derived from the accounts, the Direct Material Input (DMI). Deducting exports from this indicator results in the Domestic Material Consumption (DMC).

Unused domestic extraction are materials extracted or otherwise moved on a nation's territory on purpose and by means of technology which are not fit or intended for use. Examples are soil and rock excavated during construction, dredged sediments from harbours, overburden from mining and quarrying and unused biomass from harvest. Agricultural soil that is eroded is not moved on purpose but may be included as an optional memorandum item.

Outputs to the environment are defined as all material flows entering the national environment, either during or after production or consumption processes. Outputs include emissions to air and water, waste landfilled as well as materials dissipatively used (e.g., fertiliser or thawing materials). Outputs also include the disposal of unused domestic extraction.

In the Guide, *indirect flows* are defined for economy-wide material flows only, i.e. they only refer to imports and exports. In a PIOT framework, indirect flows can also be compiled for material flows within the economy.

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

The term 'hidden flow' has been used to signify the movements of the unused materials associated with the extraction of raw materials (i.e., for use), both nationally and abroad (see e.g. Adriaanse et al. 1997). In the Guide hidden flows are defined, in line with most of the current practices, as a synonym for unused extraction. Unused domestic extraction may therefore be called 'domestic hidden flows'. The indirect flows of unused extraction abroad associated to imports may be called 'foreign hidden flows (associated to imports)'.

3 - Completeness

A detailed analysis of data availability for the UK Material Flow Accounts is presented in Annex A. The annex contains information on the individual products, data availability and the data source. The review also considered a number of areas where the completeness of the accounts could be improved.

Waste arisings and recycling

Waste landfilled and waste water from private households, industry and commerce are included in the material flow accounts as outputs. Outputs to the environment are defined as all material flows entering the environment, either during or after production or consumption processes. Included is the disposal of unused domestic extraction. Outputs to the environment can be classified further into processed and unprocessed outputs. Unprocessed outputs correspond to the disposal of unused domestic extraction (equal to unused domestic extraction on the input side). Processed outputs are the result of production or consumption processes. Processed outputs to the environment are classified into:

- Emissions and waste flows;
- Dissipative use of products and dissipative losses of materials.

Waste data is recorded in the UK material flows, but it is not included in any published datasets, as output indicators are not currently published due to concerns about their overall quality. The ONS will seek to maximise the use of available data with the ultimate goal of compiling the indicator Domestic Processed Output.

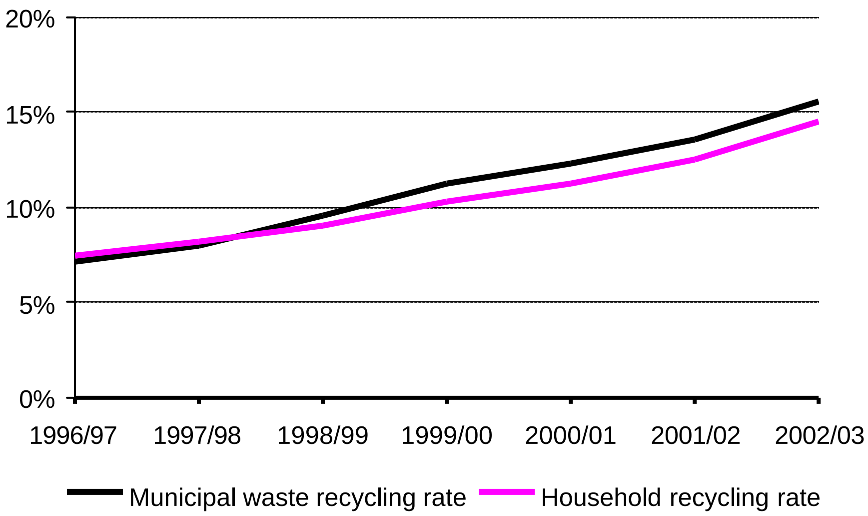
Waste data in the UK currently used in the Material Flow Accounts is based on data for England only. A UK figure is determined by grossing up using a factor of 1.129, based on likely waste arisings in Scotland, Wales and Northern Ireland. ONS has identified potential sources of data for Scotland, Wales and Northern Ireland, which could be used to assess waste more accurately at the UK level. These sources will be explored further in consultation with Defra. It is hoped that these improvements in data sources will lead to publication of a Domestic Material Output account in the future. In addition, Defra is currently considering the results of a consultation on proposals for a new three-year strategy for improving data on waste. The proposals for delivering more accurate, complete, timely and consistent data on all types of waste are set out in the consultation document which can be found at http://defraweb/corporate/consult/wip-data/index.htm

Current Eurostat advice states that "it is not recommended making recycling accounts part of the standard set of economy-wide MFA at present[3]" (Eurostat, 2001). The Guide cites problems

[3] Eurostat (2001), *Economy-wide material flow accounts and derived indicators: A methodological guide, European Communities*, 2001, p47

associated with establishing good data sources and a consistent definition and measurement of recycled material as the main difficulties. However, waste and recycling are important policy issues and the latest municipal waste arisings and recycling data, as published by the Department for Environment, Food and Rural Affairs (Defra) in their annual Municipal Waste Survey[4] (Defra, 2004), has been recorded as a memo item within the accounts. The devolved administrations also produce recycling and re-use statistics which may also be processed in the accounts enabling the compilation of a UK figure. Results for England only are shown below. The coverage, treatment, and presentation of recycling are also discussed in the chapter on recommendations.

Recycling and recovery rates in England
as a percentage of municipal waste arisings



Source: Defra

Emissions to water

Relevant emissions data has not been incorporated into the Material Flow Accounts, as data for the whole of the UK are not available. Information on emissions to controlled waters in England and Wales are recorded in the Environment Agency's Pollution Inventory. The Pollution Inventory holds information on annual emissions from large industrial sites regulated by the Environment Agency that fall in the following sectors:

- Fuel and power production
- Mineral industries - this includes cement, asbestos, glass fibre, ceramic and glass manufacturing
- Chemical industries
- Metal production and processing
- Waste disposal and recycling - waste incineration, waste recovery plants and fuel from waste stations
- Other industries - these include paper, pulp and board manufacturing, and tar and bitumen activities
- Sewage treatment works – introduced in stages according to size of population served

[4] Department for Environmental, Food and Rural Affairs (2004), *2002/03 Municipal Waste Management Survey*, August 2004

- Sites authorised to use radioactive materials – on a voluntary basis

Environment Agency and other UK stakeholders are considering the future development of a national inventory for emissions to water, which would allow comparison between emissions reported to the Pollution Inventory and those emitted from other sources within the UK.

Information on the disposal at sea of sewage sludge, solid industrial waste and dredged material comes from the Centre for Environment, Fisheries & Aquaculture Science. Data on the disposal of industrial waste and sewage sludge is available up to 1995 and 1998 respectively, after which disposal at sea was banned. Information on dredged material is available up to 2000, after which an average is used. More up to date data on dredged material is expected in the summer of 2005.

Material for construction purposes

It was felt the accounts might be under estimating the amount of material used for construction purposes by not including an estimate of on-site extraction of raw materials. ONS contacted the Quarry Products Association (QPA) to review the extent to which the current source, the Minerals Year Book, covered material for construction purposes that is extracted on-site and found that this material is not included in Minerals Year Book data.

These materials, for example aggregates and clays, are extracted on-site during the course of construction activity but are not generally recorded by contractors because as no financial transactions take place in their acquisition they fall outside the usual commercial processes. However, the view of the QPA is that contractors will aim to maximise use of such materials on site.

Hidden flows

“Hidden” flows record the amount of unused material translocated during the extraction process. For example, before a mineral can be extracted surrounding soil has to be removed. Hidden flows are distinguished from waste material because they never enter the economy, in comparison waste is classified as material discarded that has economic value. Hidden flow estimates were originally interpolated using co-efficients based on the German economy and supplied by the Wuppertal Institute. The Lawson report (see Annex B) has gone some way to improving these estimates however information is scarce and more research is required to build a system of co-efficients that accurately reflect the UK situation (see chapter on recommendations).

4 - Timeliness

The accounts are based upon four main data sources (agricultural statistics, the Minerals Year Book, trade statistics and atmospheric emissions data), supplemented by a number of ad hoc and non-annual data sources. The ONS has tried to determine the optimal point in the year for updating the accounts on an annual basis. Where data sources are not annual, methods have been developed to interpolate and extrapolate figures.

Direct material input

Agriculture, forestry and fishing data are updated using information from the Food and Agriculture Organisation of United Nations (FAO). The FAO update their databases throughout the year, however, experience suggests that most of the data required are available by end June.

Data on ores, minerals and fossil energy carriers are sourced to the United Kingdom Minerals Year Book. The Minerals Year Book is published by the British Geological Survey each August.

Imports and exports

Her Majesty's Customs and Excise (HMCE) are the source for data on imports and exports. These data are available annually from the HMCE website and are updated every September.

Domestic Material Output

Dissipative flows

These data are compiled in four blocks; livestock population, fertilisers, pesticides and seeds.

Data for livestock and seeds are available from the FAO for all years, with regular updates on their website. Data is missing for certain components and periods, but this should not seriously effect the quality of the account (see annex A for further details). Therefore, the inclusion of annual updates of these estimates in the UK Material flows account is possible.

Data for pesticides and fertilisers are available up to 1999 and 2000 respectively from the FAO website. Annual updates should be possible with rolling average estimates used for the later years currently unavailable from the FAO. The Department for Environment, Food, and Rural Affairs has been suggested as alternative data source and will be investigated.

Emissions to water

Information on releases to controlled waters in England and Wales for the period 1998-2003 are sourced from the Environment Agency's Pollution Inventory. The data cover emissions of 15 substances[5] to controlled waters (sea, river and estuary) and sewer from Agency regulated processes in England and Wales. Information on dredged material is available up to 2000, after which an average is used. More up to date data on dredged material is expected from the Centre for Environment, Fisheries & Aquaculture Science in the summer of 2005.

Waste landfilled

Data on Construction and Demolition waste is available from Defra for the years 1997, 1998 and 1999 based on a study by the Office for the Deputy Prime Minister and the Environment Agency. Data from a 2001 and 2003 survey on arisings and use of construction and demolition waste by the ODPM may help to provide estimates for more recent years.

Data on Industrial and Commercial waste is only available for 1998. The source for this data is the National waste production 1998 survey by the Environment Agency, also published in summary by Defra. A further survey, covering England and Wales, was carried out for 2002 and results are expected in spring 2005.

Data on municipal waste for England is available in Defra's annual Municipal Waste Survey from 1996 onwards. Data for other parts of the UK are available from National Assembly of Wales (NAW), Scottish Environmental Protection Agency (SEPA) and the Department of Environment Northern Ireland (DoENI).

Interpolation and extrapolation

From 1975, most data required for the current range of UK Material Flows estimates are available. Where gaps do exist, typically in the years 1970-1975, their importance to the overall account is low. However, attempts have been made to fill the data gaps that exist in this and later periods by interpolation and extrapolation. It is intended that this will reduce the impact of artificial step changes, caused by missing data, and improve the overall coherence of the accounts.

The data-filling excise subsequently undertaken took a number of different approaches. Firstly all available data were identified and input. If data were unavailable, the data source was directly approached. For instance, Customs and Excise were contacted with a view to obtaining data for periods where gaps exist, mainly in the period 1970 - 1987. On contacting Customs and Excise regarding the possibility of providing the data using their Overseas Trade Statistics (OTS), it became clear that the financial and time costs involved in obtaining the data were prohibitive.

In circumstances where there was no alternative source, three different data filling methods were used, depending on the particular circumstances. Thus, where a time series was erratic a three-year

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[5] Arsenic, benzene, cadmium, chloroform (trichloromethane), chromium, copper, ethylene dichloride (1,2-dichloroethane), lead, mercury, naphthalene, nickel, nonylphenols, octylphenols, tributyltin (TBT) compounds and zinc.

moving average was applied. If a time series remained broadly unchanged, the value for the last year of available data has been used. Finally, if time series showed an obvious trend, data for the missing years were extrapolated from the series trendline.

This process has resulted in minor revisions to the Domestic Material Input, Domestic Material Consumption and Total Material Requirement in certain years. However, these revisions do not exceed 1 million tonnes in any given year.

Conclusion

Given the constraints imposed by data availability it was decided that the optimal processing time for UK Material Flows is in time for the autumn edition of the Environmental Accounts. This allows the use of the maximum amount of new data for publication at the earliest opportunity. If data is unavailable at time of processing the most appropriate of the three data filling methods outlined above should be applied.

5 - International comparability

There is a body of international work, in the form of accounts and guidance, which has grown in parallel with the UK account. Thus, there is a need to identify the areas where the UK account diverges from wider international practice, to adopt such practices as standard where appropriate, and to develop adjustments for the purposes of international comparisons where the divergence from international standards is justified. Particular issues here concern the treatment and accuracy of estimates of soil erosion, biomass extracted through grazing, adjustments for the water content of products, and the calculation of the so-called balancing items.

Soil erosion

Estimates for soil erosion associated with agricultural activity are compiled but these are not included in the hidden flow estimates that form part of the material flow account. The assumptions made in the compilation of the estimates are as follows:

- Erosion is restricted to arable land and permanent crops, erosion is not estimated for permanent pastures;
- In total, without further differentiation, 50 per cent of the arable and permanent crop land is subject to erosion;
- For 10 per cent erodible land, the average erosion rate is 13 tonnes per hectare per annum;
- For 90 per cent erodible land, the average erosion rate is 2 tonnes per hectare per annum;
- The average erosion rate for winter cereals is twice the 90 per cent rate for other crops, i.e. 4 tonnes per hectare per annum;
- Harvesting of sugar beets and potatoes induces additional erosion of 2 tonnes per hectare per annum.

Soil erosion from arable land — **Million tonnes**

	1998	**1999**	**2000**	**2001**	**2002**	**2003**
Erosion for 10% of erodible land excl. winter cereals	2.4	2.3	2.4	2.5	2.4	2.4
Erosion for 90% of erodible land excl. winter cereals	3.4	3.3	3.4	3.5	3.3	3.4
Erosion by harvest of potatoes	0.3	0.4	0.3	0.3	0.3	0.3
Erosion by harvest of sugar beets	0.4	0.4	0.3	0.4	0.3	0.3
Erosion from winter cereals land	5.1	4.7	5.0	4.5	4.9	4.9
Erosion for total erodible land	**11.6**	**11.0**	**11.5**	**11.3**	**11.2**	**11.3**
Average erosion rate in tonnes per hectare	3.7	3.7	3.7	3.7	3.7	3.7

Biomass extracted through grazing

The mass of biomass extracted through animal grazing is derived by multiplying the area of grassland and permanent pastures by yield coefficients for each type of pasture. The annual biomass yields per pasture type are as follows:

Rotation grassland - 8.5 tonnes per hectare

Permanent grassland - 3.3 tonnes per hectare

Rough grazing - 2.6 tonnes per hectare

The yield rates were recommended to the ONS by Helga Weisz from the IFF Klagenfurt.

Biomass from animal grazing

Permanent Pasture (million hectares)	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Rotation grassland	1.3	1.2	1.2	1.2	1.2	1.2
Permanent grassland	5.3	5.4	5.3	5.4	5.3	5.3
Rough grazing	5.9	5.9	5.8	5.9	5.8	5.8
Biomass from grazing (million tonnes)						
Rotation grassland	11.1	10.4	10.4	10.4	10.4	10.4
Permanent grassland	17.6	17.7	17.4	17.7	17.6	17.6
Rough grazing	15.2	15.3	15.0	15.3	15.2	15.2
Total	**44.0**	**43.4**	**42.8**	**43.4**	**43.2**	**43.2**

Water content of products

Paragraph 5.01 of the Eurostat guide (Eurostat, 2001) states "*Material inputs and outputs are counted with their reported (fresh) weights. This weight includes water contained in the materials (for example, the water content of timber, cereals and other biomass but also the water content of e.g. lignite or sand). It is possible to make supplementary accounts in dry weight (and it is necessary to identify the water content of material flows for establishing a full balance). For some special cases where reported data must be complemented by estimates (e.g. fodder plants taken up by grazing livestock) it is recommended to convert these into a weight that is equivalent to that of products typically reported in statistics so as to render reported and estimated data comparable. This involves using a 'standardised water content'. For most bulk biomass materials (timber, cereals, hay) such standardised water content will be around 15% of total product weight*[6]*.*"

The UK's estimates of biomass from animal grazing are already in fresh weight as they are derived from the annual yields of pasture and grazing land, therefore no adjustment is needed. No adjustments are made to account for the water content of timber either domestically extracted or imported. If other countries do adjust for water content, the UK estimates will be under recorded in comparison. UK domestic extraction of timber amounted to 7 million tonnes in 2003 while imports amounted to 20 million tonnes. Adding an additional 15 per cent for water content will increase domestic extraction by just over 1 million tonnes (0.2 per cent) and direct material consumption by 4 million tonnes (0.6 per cent).

Memorandum items for balancing

The Eurostat guide recommends the introduction of balancing items to ensure that the mass of inputs and outputs do actually balance. These balancing items are only used for balancing purposes and are not included in any indicators derived from the accounts themselves. The guide identifies memorandum items for both the input and output sides.

[6] Eurostat (2001), *Economy-wide material flow accounts and derived indicators: A methodological guide, European Communities*, 2001

Memorandum items for balancing

Material inputs	Material outputs
Oxygen for combustion Oxygen for respiration Nitrogen for emissions from combustion Air of other industrial processes	Water vapour from combustion From water content of fuels From hydrogen content of fuels Water evaporation from products Water content of biomass Water content of other materials Respiration of humans and livestock CO_2 Water vapour

Combustion memorandum items

Estimates of oxygen for combustion and hydrogen and water content of combusted fuels are derived using a detailed breakdown of fuel type and information on hydrogen and water content of the fuels themselves.

Hydrogen and water vapour content of fuels **Content %**

Fuel type	H - content	H_2O - content
Coking Coal	4.7	1.9
Other Bituminous Coal & Anthracite	4.7	1.9
Sub-Bituminous Coal	4.7	1.9
Lignite/Brown Coal	1.9	59.3
Peat	4.5	24.2
Oven and Gas Coke	0.8	1.8
Patent Fuel and BKB	4.2	1.9
Crude Oil	12.0	0.0
Natural Gas Liquids	14.4	0.0
Refinery Gas	21.5	0.0
Ethane and LPG	17.7	0.0
Motor Gasoline	14.4	0.0
Aviation Gasoline	15.0	0.0
Jet Fuel	15.0	0.0
Other Kerosene	15.0	0.0
Gas/Diesel Oil	13.3	0.0
Heavy Fuel Oil	11.7	0.5
Naphtha	14.4	0.0
Petroleum Coke	0.8	1.8
other Products	10.6	0.0
Natural Gas	23.0	0.0
Gas Works Gas	23.0	0.0
Coke Oven Gas	19.8	0.0
Blast Fumaces	0.3	0.0
Solid Biomass and Animal Products	5.0	15.5
Gas/Liquids from Biomass + Wastes	19.8	0.0

Annual volumes of fuels consumed were obtained from the International Energy Agency[7] website. The emission of hydrogen and water are derived by multiplying the annual fuel consumed by the level of hydrogen and water in each fuel type. For example, in 1999 the UK consumed approximately 46

[7] www.iea.org

million tonnes of bituminous coals with a hydrogen content of 4.7 per cent and a water content of 1.9 per cent. Therefore, emissions of hydrogen amounted to 2.2 million tonnes and water 0.9 million tonnes. To enable aggregation of total water vapour, the hydrogen is multiplied by 9 to convert it to water equivalent. This results in a water equivalent of 39.2 million tonnes and an overall water vapour total of 40.1 million tonnes.

Oxygen needed for combustion is derivable by multiplying total emissions of water vapour by 16/18.

The UK has not compiled any combustion memorandum items since 1999. As the UK is yet to compile an output account, there is no current need for balancing items.

Respiration memorandum items

The UK compiles estimates for oxygen inputs for respiration and CO_2 and water vapour outputs from respiration based on fixed coefficients.

Coefficients for human respiration **Tonnes per capita per annum**

Memorandum item	Coefficient
Oxygen for respiration	0.26
CO_2	0.30
Water vapour	0.35

The above coefficients are then multiplied by the appropriate annual population estimation to derive the balancing items for human respiration. The coefficients specified by the Wuppertal Institute come from Matthews et al. 2000[8] (Matthews, 2000).

Coefficients for livestock respiration **Tonnes per head per annum**

Livestock	O_2 per year	H_2O per year	CO_2 per year
Cattle	2.45	3.38	2.92
Sheep	0.20	0.27	0.24
Horses	1.83	2.53	2.19
Pigs	0.25	0.35	0.30
Chickens	0.01	0.02	0.01
Ducks	0.01	0.02	0.01
Geese	0.01	0.02	0.01
Turkeys	0.01	0.02	0.01

The above coefficients are then multiplied by the appropriate livestock numbers, taken from the Food and Agriculture Organisation (FAO) website, to derive the balancing items for livestock respiration. The coefficients are derived from Matthews et al. 2000.

Human and livestock respiration estimates are available for the period 1970 to 2003.

[8] Matthews et al. (2000), *The Weight of Nations - Material outflows from industrial economies*

Conclusion

The UK's material flow accounts were originally compiled by the Wuppertal Institute and therefore generally follow the guidelines spelt out in the Eurostat guide. Stefan Bringezu, Stefan Moll and Helmut Schutz from the Wuppertal Institute formed part of the Eurostat Task Force that drafted Eurostat's guide. The accounts appear to deviate from the guide in the treatment of the water content of products. If other countries follow Eurostat's guidelines and add an additional 15 per cent for the water content of dried timber, in comparison, the UK's timber accounts would be under recorded. Adding an additional 15 per cent for water content will increase domestic extraction by just over 1 million tonnes (0.2 per cent) and direct material consumption by 4 million tonnes (0.6 per cent).

The UK currently publishes estimates for domestic material input, domestic material consumption and total material requirement with no estimates for domestic output. Comparing data availability for the UK with that for other countries suggests that while the UK does not produce a complete material flow account the range of data available are broadly comparable with most other countries that currently produce material flow accounts.

6 - Policy relevance

Economy-wide MFA and balances complement and supplement other environmental datasets and accounts. For example, foreign trade or production statistics as well as environmental statistics and environmental accounts for forests, sub-soil assets, water or air emissions provide great detail on individual material flows and related environmental issues. Organising such existing datasets in a consistent accounting framework, the main purposes of economy-wide material flow accounts and balances are to:

- provide insights into the structure and change over time of the physical metabolism of economies;
- derive a set of aggregated indicators for resource use, including for the EU-level initiative on Headline Indicators and the United Nations' initiative on Sustainable Development Indicators;
- derive indicators for resource productivity and eco-efficiency by relating aggregate resource use indicators to GDP and other economic and social indicators;

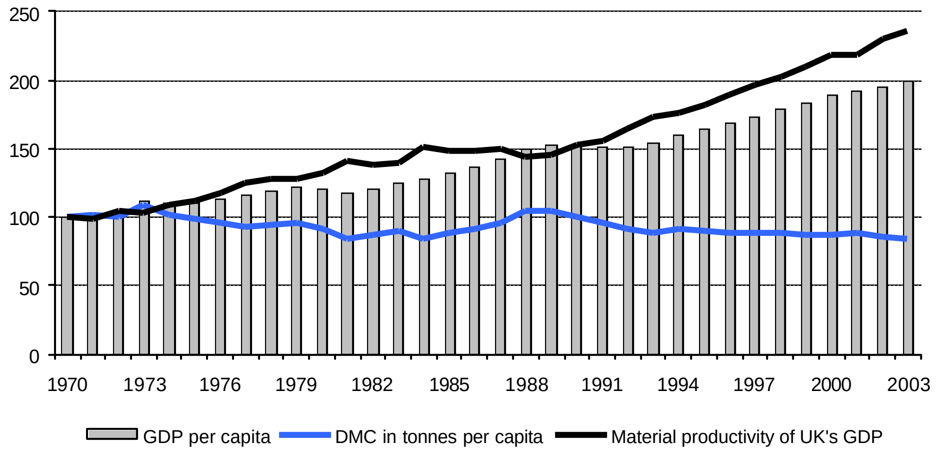
Indicators for flows of materials through the economy feature prominently on the political agenda in the context of concepts such as 'factor 4 or 10' or 'eco-efficiency'. The objective of the natural resource strategy in the 6th Environment Action Programme is defined as "*ensuring that the consumption of resources and their associated impacts do not exceed the carrying capacity of the environment and breaking the linkages between economic growth and resource use*".

Sustainable development - National

Resource productivity indicators are an important policy instrument as they enable Government to determine the success or failure of moves towards sustainable development. Data from the accounts can be used to measure resource productivity. An analysis of resource productivity has now been incorporated into the material flows; this shows evidence of that material use is becoming decoupled from economic growth. Further analysis will be required to see whether this is connected to the increasing importance of the service industry in the UK and the increase in imports associated with the decline in the UK manufacturing industry.

Material productivity 1970 to 2003

Index 1970 = 100



Source: ONS Environmental Accounts

In May 1999, the Government published *A better quality of life: a strategy for sustainable development for the UK* [9](SD, 1999a). It brought the environment, social progress and the economy alongside each other at the heart of policy making. The strategy also identified a set of headline and core indicators to be used to report on progress towards the goal of sustainability. In the December of the same year the UK government published *Quality of life counts (QOLC 1999)* (SD, 1999b)[10], which contained indicators for a strategy for sustainable development to provide a baseline assessment from which progress might be judged. Indicator A1 focused on UK resource use.

Then in 2001, the Government published a report on resource productivity, *Resource productivity: making more with less* [11](PIU, 2001). Chapter 3 of the report specifically looked at how best to measure resource productivity through various means such as material flow analysis, environmental space, ecological footprints, human appropriated net primary production, assimilative capacity and the asset balance of environmental capital. The reported stated that "*It is crucially important that we have a full understanding of the role that natural resources - particularly those subject to the most pressures - do play in the economy. It is recommended that the ONS, DEFRA, DTI and HM Treasury work together on a programme of work to improve this understanding. The programme will need to be focused on the development of the economy into the future, as well as on the present, exploring the implications for resource use and resource productivity.*"

In September 2003, the Department for the Environment, Food and Rural Affairs and the Department of Trade and Industry circulated a joint consultation paper on a set of sustainable consumption and production indicators (Defra, 2003). Indicator 5 was specifically on material use and compared the

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[9] Sustainable Development (1999a), *A better quality of life: a strategy for sustainable development for the UK*, May 1999

[10] Sustainable Development (1999b), *Quality of life counts*, December 1999

[11] Performance and Innovation Unit (2001), *Resource productivity: making more with less*, November 2001

change in Gross Domestic Product since 1990 with Total Material Requirement, Direct Material Input and Domestic Material Consumption (as shown in the chart on page 7). Unlike issues such as air quality and levels of atmospheric emissions, the Government has not set any specific resource use targets for the UK. There is, however, a commitment to promote continual improvements in resource efficiency.

The UK Government's last annual report, *Achieving a better quality of life* (SD, 2004)[12], was published in March 2004 and provided an update of UK progress and action to achieve sustainable development. The Sustainable Development Commission also published their independent report on how the UK been doing, *Shows Promise. But must try harder* (SDC, 2004)[13]. Both recognise that although progress has been made, there is still much to do. In April 2004, Defra in partnership with other Government departments and the devolved administrations, launched a UK-wide consultation entitle *Taking it on*[14], looking at how to take on the challenge of sustainable development. The consultation paper sought to gain the views and ideas of businesses, trade organisations, academia and local authorities. The consultation period ended in July 2004.

Also, in April 2004 the Organisation for Economic Co-operation and Development (OECD) agreed a recommendation for member countries to develop and promote the use of their material flow accounts at both the macro and micro level. There was also a call for further linking of environmental and economic data and the development of common methodologies and measurement systems[15].

In October 2004, the Environmental and Sustainable Development unit of Eurostat presented proposals for a resource productivity indicators at the Joint Working Group meeting in Luxembourg. The initial proposals focused on the construction of an indicator based on constant price GDP divided by Domestic Material Consumption. Following a subsequent meeting of the MFA Task Force, Eurostat are consulting on proposals to collect MFA data through a set of standard tables. These tables comprise productivity indicators, resource intensity indicators, MFA indicators per capita and domestic extraction and import use at a NACE 2-digit level.

Other areas of policy interest

A description of other areas of policy relevance and how they have been addressed by the current review follows:

Data on re-use and recycling, although not central to the account, have been incorporated into the database as memo items. While information on recycled material does not feed directly into the material flow accounts, it does directly affect the extraction and use of virgin raw materials. Work

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[12] Sustainable Development (2004a), *Achieving a better quality of life*, March 2004

[13] Sustainable Development Commission (2004), *Shows promise. But must try harder*, April 2004

[14] Sustainable Development (2004b), *Taking it on: developing UK sustainable development strategy together*, April 2004

[15] Recommendation of the Council on Material Flows and Resource Productivity, OECD, 21 April 2004, p3

done for Defra by the Wuppertal Institute in 2002 (Defra, 2002) suggested that one tonne of recycled material saved just over three tonnes of natural resources. Additional analysis of recycled or re-used material, particularly by the construction industry, will give some indication of domestic extraction/imports avoided. Information on construction and demolition waste has been collected for England and Wales through a survey by the Office for the Deputy Prime Minister for periods 1999-2000 and 2003.

A study of the use of sand and gravel by Statistics Sweden (Statistics Sweden 1999) estimated that re-use and recovery of sand and gravel from house demolition amounted to around 290,000 tonnes in an average year. Re-use of sand and stone amounted to 144,000 tonnes while recovery of sand and gravel from concrete was 144,000 tonnes and recovery from light concrete 5,000 tonnes.

There is strong academic and policy interest to increase the level of detail within the accounts so that flows within the economy can be understood e.g. in tracking specific toxic substances through the economy. However, substance flow analysis is not possible with material flow accounts, which only record materials as they cross the system boundary i.e. environment to economy (inputs) or economy to environment (output). Most of these material flows are in the form of raw or semi-manufacture materials as opposed to the products themselves. However, intra-economy flows are possible, through the use of physical input-output tables.

Associated with these approaches is life cycle analysis, which tracks the environmental costs of a product from “cradle to grave”. The material flow accounts are specific to material input from or output to the environment in any one year whereas life cycle analysis measures the environmental performance of a product from its production until the end of its life. However, although desirable there are resource constraints and data availability issues that mean further disaggregation is not possible at the current time.

While the material flow accounts record the mass of material input into the economy and output to the environment it does not necessarily show the full environmental impact of their production and disposal. Domestic extraction of biomass may come from sustainable sources such as cultivated forests or otherwise. For imports, no distinction is made between imports from sustainable or unsustainable sources. No allowances are made for the transportation of imports e.g. atmospheric emissions associated with importing coal from South America or fresh fruit from Spain. While the presentation of the output indicators while show the level of waste and emissions to air and water, it will not give a clear indication of the environmental cost of soil erosion, atmospheric pollutants or landfilled waste

Data on material flows associated with trade needs to be classified in a way that ensures maximum comparability with estimates of the flows from domestic extraction. The imports of raw materials as well as finished or semi-finished manufactures have hidden flows associated with their extraction and manufacture. Estimating those flows presents difficulties as information on unused extraction in the exporting country is not available. This leaves us with two options. Option one is to estimate hidden flows using UK ratios while option two looks at using the ratios for other countries when and where available.

Better information on the impact of production abroad will enable a better understanding of the effects of changes in the manufacturing base and the increased demand for imports. There is increasing policy interest in the relocation of production as it disguises the global impact of the UK economy.

Physical Input Output tables (PIOT's) are seen by some as the ultimate goal of material flows. Some countries have developed PIOT's, however, they are difficult to develop due to resource and data limitations. Eurostat's methodological guide states "The implementation of PIOT is a time-consuming and labour-intensive task. The work can be accomplished only if input-output experts and experts in environmental statistics and accounting co-operate. For a detailed PIOT, the costs will probably be comparable with those of compiling an input-output table in monetary units. PIOT data are very detailed and as such not very useful for policy makers. Therefore, summary tables and analytical uses (e.g. indirect effects, decomposition analyses) are absolutely essential to justify the compilation work and to communicate the results of PIOTs.". As the Guide says, when there is a clear analytical use it may be worth considering the compilation of PIOT tables. This may be worth considering for UK if such a need is identified e.g. for energy consumption and their associated emissions.
Currently the ONS has no current plans to produce PIOT's although the Stockholm Environment Institute, based at the University of York, have been working on them as part of the Resource and Energy Analysis Programme (REAP)[16]. The ONS's work programme could however change if the demand for PIOTs existed and resources were available to conduct such development work.

Statistics Denmark produced Physical Input-Output Table for Denmark in 1999 (Gravgaard Pedersen 1999) presenting products and materials for 1990 and air emissions for 1990-92. The publication contained summary tables for all commodities as well as detailed tables for various commodities such as animal and vegetable products, chemical products, plastic products and energy products. Atmospheric emissions were then sourced to consumption groups and other final demand categories. The final chapter looked at the emission content of foreign trade and whether foreign trade placed an emissions burden on Denmark or the rest of the world. Similar analysis of the net burdening of UK foreign trade may justify the need for atmospheric PIOTs.

In 1997, the German Office of Statistics presented the first detailed Physical Input-Output Table for the former West Germany, based on data of the year 1990. Subsequent analysis has looked the direct and indirect resource use for intermediate and final demand and issues on resource productivity and

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[16] Development of Physical Accounts for the UK and Evaluating Policy Scenarios: Resource and Energy Analysis Programme (REAP), http://www.york.ac.uk/inst/sei/IS/REAP_SEI.pdf

labour productivity e.g. integrated input-output analyses of material flows and labour in order to discover target-conflicts between the ecological, social and economic dimension of sustainability.

7 - Hidden flows

“Hidden” flows, materials translocated by the process of extraction but not actually used, are a significant element of the accounts but are extremely difficult to measure. This review assessed how accurate the estimates used in the accounts were and looked for alternative sources of estimates.

A report “UK Material Flow Accounts: Review of indirect flow coefficients,” has been produced for the ONS by the University of Manchester. This looks at the coefficients used to determine UK hidden flows. In particular, it focuses on flows associated with mining and quarrying, which form the largest volumes in the material flow accounts. In addition, the University of Manchester (UoM) considered the feasibility of establishing revised estimates of hidden flows relating to the production of agricultural biomass and manure and finally it reviewed the importance of flows such as excavation, dredging, soil erosion, forestry operations, land filling and land reclamation. A full version of the university’s report can be found in Annex B.

Impact of the review of hidden flow coefficients

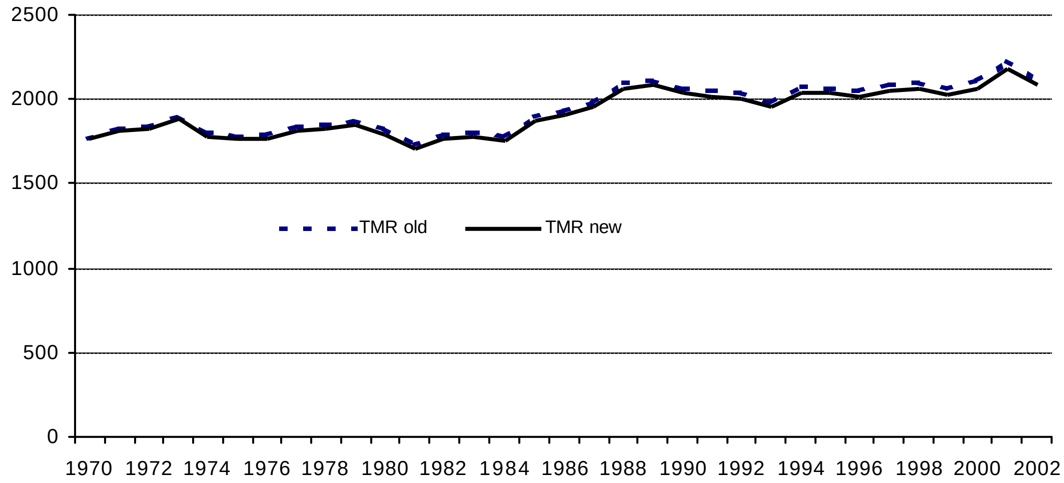
Hidden flows comprise raw materials translocated by the process of extraction but not actually used in the production of goods and services. These movements are also known as unused indirect flows. Hidden flows may be as a result of extraction activities within the UK economy or associated with the extraction of raw materials in other countries that are then imported into the UK economy. Examples of hidden flows are unused extraction from mining and quarrying (also known as overburden), discarded material from harvesting (e.g. wood harvesting losses such as timber felled but left in the forests) and soil and rock moved as a result of construction and dredging.

The focus of the hidden flow review was to look at the hidden flow coefficients associated with domestic extraction. Prior to the review, the coefficients used were those recommended by the Wuppertal Institute, who set-up the original material flow spreadsheets used by the ONS. The Wuppertal Institute had in turn used coefficients taken from an article published in the *Journal of Industrial Ecology (JIE[17])* by Ian Douglas and Nigel Lawson (Douglas and Lawson, 2000). The coefficients published in *JIE* article did not specifically relate to extraction in the UK but were more global in coverage. The Wuppertal Institute did not consult either author before using the *JIE* coefficients. The review undertaken by the UoM team in 2003 specifically looked at hidden flows associated with UK extraction alone. The review looked to cover hidden flows from biomass (agricultural harvest, timber, animal grazing and fishing), mineral extraction and fossil fuel extraction. The review went on to make some further recommendations to improve the overall account. There follows an analysis presenting the impact of the new coefficients on a product by product basis and identifies the extent of the revisions brought about by their implementation.

[17] Douglas, I. and Lawson, N. (2000), Journal of Industrial Ecology, *The Human Dimensions of Geomorphological Work in Britain*, March 2000

Total Material Requirement incorporating original and revised coefficients

Million tonnes



The overall impact of the new coefficients is to reduce the UK's Total Material Requirement (TMR) by 2.2 per cent in 2002 but has little effect prior to 1990. The 2.2 per cent fall equates to 41 million tonnes. The main drivers behind the fall are the lower levels of hidden flows associated with the domestic extraction of hard coal, crushed stone and sand and gravel. The main upward revision is to the residues of agricultural harvest where coefficients are now applied to products that previously had no hidden flow coefficients.

Summary of impacts on main indicators

Revisions to hidden flows

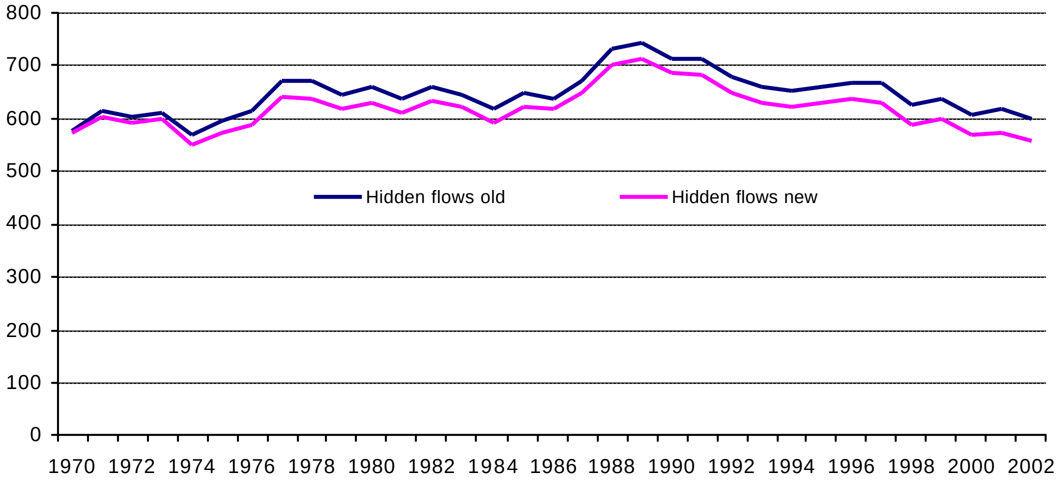
Million tonnes

	1970	1975	1980	1985	1990	1995	1997	1998	1999	2000	2001	2002
from domestic extraction (excluding soil erosion)	-3	-22	-31	-25	-26	-32	-38	-36	-40	-38	-45	-41
Of which from												
Unused biomass	9	7	10	11	10	10	11	11	11	10	9	10
Fossil fuels	-19	-26	-39	-38	-46	-41	-42	-36	-38	-34	-35	-33
Minerals and ores	8	-3	-1	5	9	-1	-6	-9	-12	-15	-18	-16
Soil excavation and dredging	0	0	0	-1	-1	-1	-1	-1	-1	-1	-2	-3
Production of imports	0	0	0	0	0	0	0	0	0	0	0	0

Overall, the impact of these revisions is to lower the levels of hidden flows in all years. An upward revision to unused biomass is more than offset by generally lower levels of unused extraction for both fossil fuels and minerals and ores. The chart below tracks the impact of these revisions over the period of the accounts.

Total hidden flows from domestic extraction

Millions of tones



The new hidden flow coefficients were incorporated into the Material Flow Accounts for the autumn 2004 edition.

1. Biomass - Residues from harvest

Residues from biomass comprise agricultural waste from the harvesting. The table below shows the old coefficients used in the compilation of the UK MFA, the suggested coefficients from the UoM, the coefficients used in the production of the report and the date of their implementation.

Coefficients

	Old coefficients	UoM Coefficient	Coefficient used in report	Implemented from
Barley(summer)	0.24	0.46	0.46	1970
Barley (winter)	0.40	0.46	0.46	1970
Maize	0.31	0.46	0.46	1970
Mixed Grain	0.31	0.63	0.46	1970
Oats	0.35	0.46	0.46	1970
Rye (winter)	0.34	0.63	0.46	1970
Rye (summer)	0.53	0.63	0.46	1970
Triticale	0.31	0.63	0.46	1970
Wheat(summer)	0.35	0.46	0.46	1970
Wheat (winter)	0.33	0.46	0.46	1970
Potatoes	0.03	0.63	0.03	1970
Peas, dry	0.59	0.63	0.63	1970
Pulses n.e.s	0.73	0.63	0.63	1970
Linseed	0.46	0.63	0.46	1970
Mustard seed	0.50	0.63	0.46	1970
Rapeseed (winter)	0.36	0.63	0.46	1970
Rapeseed (summer)	0.40	0.63	0.46	1970
All other forms of vegetation harvesting (including agriculture and forestry)[1]	None	0.63	0.63	1970
Sugar Beets	0.01	0.54	0.54	1970
Maize for Forage + Silage	0.31	0.63	0.31	1970
Leguminous n.e.s [1], for Forage + Silage –red clover	0.10	0.63	0.10	1970
Leguminous n.e.s [2], for Forage + Silage – luceme	0.17	0.63	0.17	1970
Cabbage for Fodder Production	None	0.63	0.01	1970
Pumpkins for Fodder Production	None	0.63	0.01	1970
Turnips for Fodder Production	None	0.63	0.01	1970
Beets for Fodder Production	0.01	0.63	0.01	1970
Hops	None	0.63	0.63	1970

[1] Asparagus, cauliflower, cabbages, carrots, chillies and peppers, cucumbers and gherkins, leeks, lettuce, mushrooms, onions

[2] Shallots, dry onion, green peas, tomatoes, apples, cherries, gooseberries, grapes, pears, plums, strawberries and all other berries.

Comments and sources

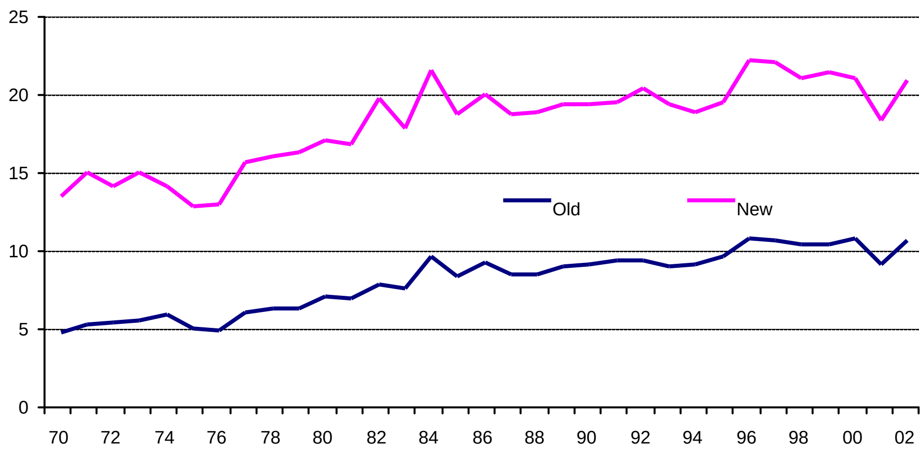
The old coefficients were sourced from *Geisler, G., 1970, Pflanzenbau in Stichworten, I. Die Kulturpflanzen, Verlag Ferdinand Hirt, Kiel* (Geisler, 1970), however there were many products that were not given a coefficient, namely all those listed in footnote 1 at the bottom of the table. In an attempt to introduce some consistency, the same coefficients were used for all cereal products and for all fodder products. The existing coefficients were retained for potatoes and silage, as the suggested coefficient of 0.63 seemed too high.

Impact of the new coefficients

The new coefficients were introduced from 1970 and result in an increase in the hidden flows, mainly due to the application of coefficients to the products listed in footnote 1 of the table. Hidden flows in 2002 are now estimated to be 20.4 million tonnes compared to the existing estimate of 10.1 million tonnes. Chart 1 shows the change in level of hidden flows from 1970. The new coefficients were introduced for the full period as no coefficients existed for many of the agricultural products

Chart 1 - Hidden flows for agricultural harvest residue

Million tones



2. Fossil fuels - Hard coal

The hidden flows arising from the extraction of hard coal covers both coal from deep mined and coal opencast sites.

Coefficients

	Old coefficients	UoM coefficient	Coefficient used in report	Implemented from
Coal-deep mined	0.35	0.56	0.56	Phased in from 1970
Coal-opencast	17.5	15	15	1970

Comments and sources

The old coefficients are from '*UK Minerals Yearbook*' and the new coefficients are from the UoM review, where their source is UK Coal Mining Ltd.

Impact of the new coefficients

The effect of the new coefficients is to reduce the level of hidden flows from coal excavation by 32.8 million tonnes in 2002, a reduction of 14 per cent. Whilst the coefficient for deep mined coal has risen, the level of extraction has fallen considerably due to the closure of most of the deep mines. UK Coal stated that improved mining techniques have enabled the exploitation of less productive mines, which has resulted in the gradual increase in the ratio of waste produced. Coal extraction has shifted more towards opencast mining and it is the reduction in the opencast coefficient that drives the overall fall in the hidden flows.

Chart 2 - Hidden flows for hard coal

Million tones

3. Minerals - Barite

The hidden flows cover the extraction of barite.

Coefficients

	Old coefficient	UoM coefficient	Coefficient used in report	Implemented from
Barite	1	No waste	0	Phased in from 1980

Comments and sources

The old coefficients for barite was fixed at 1 while the new coefficients is zero. The UoM review states that barite is produced together with fluorspar and that the hidden flows are implicitly included in the coefficient for fluorspar. The UoM source is MI Great Britain Limited. The recommendation of the UoM review is to gradually phase in the new coefficient from 1980 following the decline of the industry in the period.

Impact of the new coefficient

The new coefficients have been phased in from 1980. The effect of the new coefficients in 2002 is to reduce the hidden flows from 59 thousand tonnes a year to zero.

Chart 3 - Hidden flows for barite

Thousand tones

4. Minerals - Clay

The hidden flows cover the extraction of ball clay, china clay, fire clay, common clay and shale, bentonite and Fuller's earth.

Coefficients

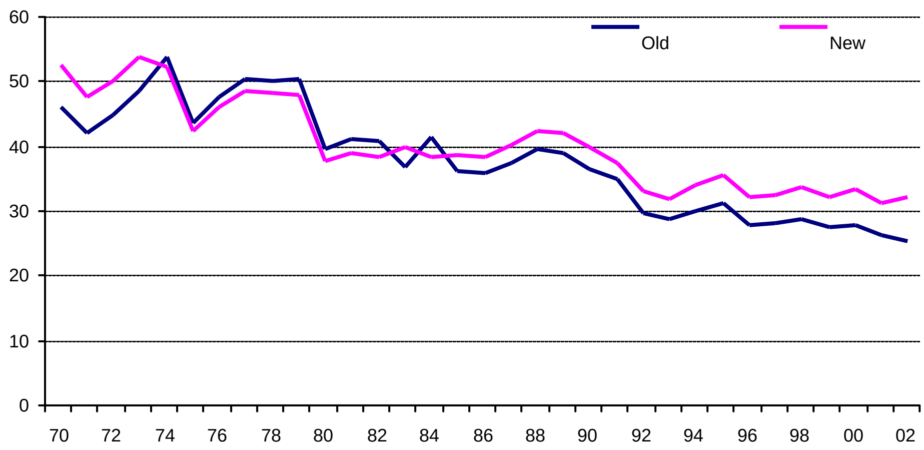
	Old coefficients	UoM coefficients	Coefficients used in report	Implemented from
Ball clay	No coefficients	9 (ball clay only)	9	1970
China clay	8	6.5	6.5	Phased in from 1970
Bentonite	3	No waste	None	1970
Fuller's earth	3	0.125	0.125	1970
Common clay and shale	**Included in total construction clay** 0.5	Average 0.6 to 0.8 of production	0.7	2002
Fire clay	No coefficients	Waste accounted for in opencast coal mining	None	No change

Impact of the new coefficients

The overall effect varies from year to year but the general effect is to increase the hidden flows in most years. Hidden flows are 6.8 million tonnes higher in 2002 using the new coefficients, an increase of 30 per cent.

Chart 4 - Hidden flows for clay, bentonite and Fuller's earth

Million tonnes



5. Minerals – Crushed stone

The hidden flows cover the extraction of chalk, igneous rock, limestone and dolomite, sandstone and slate.

Coefficients

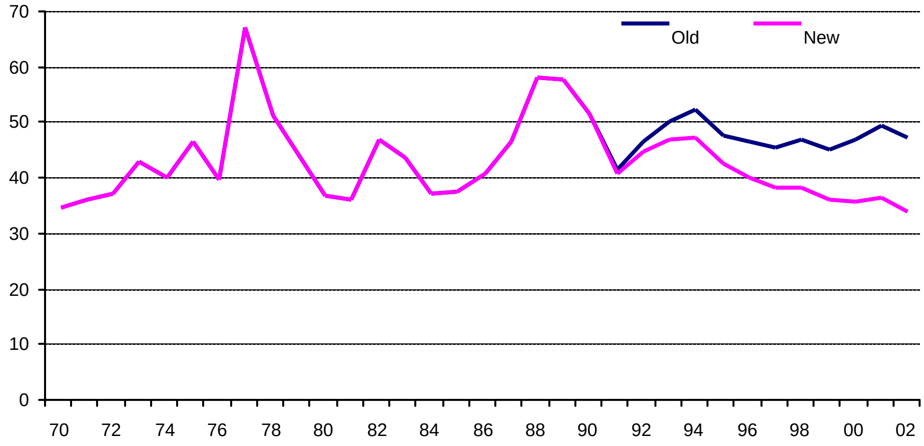
	Old coefficients	UoM coefficients	Coefficients used in report	Implemented from
Chalk	0.2	0.15	0.15	Phased in from 1990
Igneous rock	0.2	0.15	0.15	Phased in from 1990
Limestone/Dolomite	0.2	0.15	0.15	Phased in from 1990
Sandstone	0.2	0.15	0.15	Phased in from 1990
Slate	19	10 (District Slate)	10 (District Slate)	Phased in from 1990

Impact of the new coefficients

The new coefficients are phased in from 1990 as it was felt that working practices changed in the lead up to the introduction of the Review of Mineral Permissions Act 1995. The new coefficients reduce the estimated hidden flows by 12 million tonnes, a reduction of just over 25 per cent in 2002.

Chart 5 - Hidden flows for crushed stone

Million tonnes



6. Minerals – Fluorspar

The hidden flows cover the extraction of fluorspar.

Coefficient

	Old coefficient	UoM coefficient	Coefficient used in report	Implemented from
Fluorspar	1	0.275	0.275	Phased in from 1980

Comments and sources

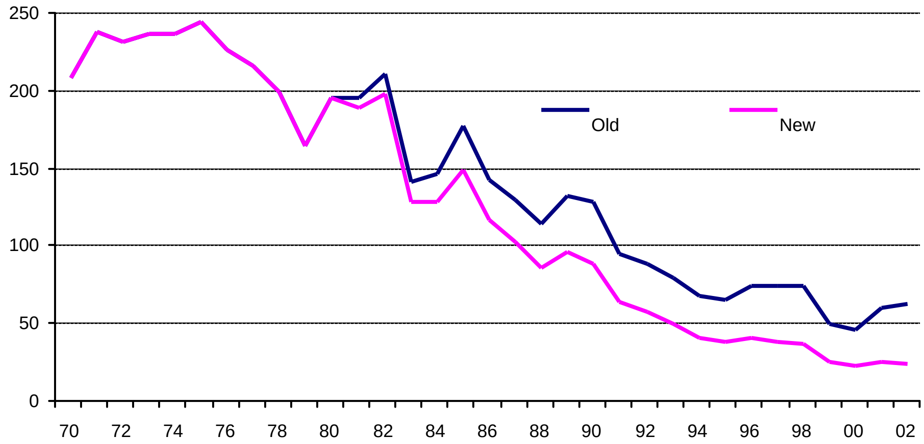
The old coefficient came from the *Douglas and Lawson (2000) JIE* article*.* The new coefficient for fluorspar comes from the MFA review, which sources the coefficient to *BGS Commissioned Report CR/03/157C.* The MFA review suggested coefficients in the range of 0.25 to 0.3, so we have taken the median of the figures, which is 0.275. The coefficient has been phased in from 1980 when the industry began to decline.

Impact of the new coefficient

The new coefficient has been phased in gradually from 1980. It reduces the estimates of hidden flows by 38 thousand tonnes, a reduction of just over 73 per cent in 2002.

Chart 6 - Hidden flows for fluorspar

Thousand tonnes



7. Minerals – Gypsum

The hidden flows cover the extraction of gypsum.

Coefficient

	Old coefficient	UoM coefficient	Coefficient used in report	Implemented from
Gypsum	0.2	1.2	1.2	1970

Comments and sources

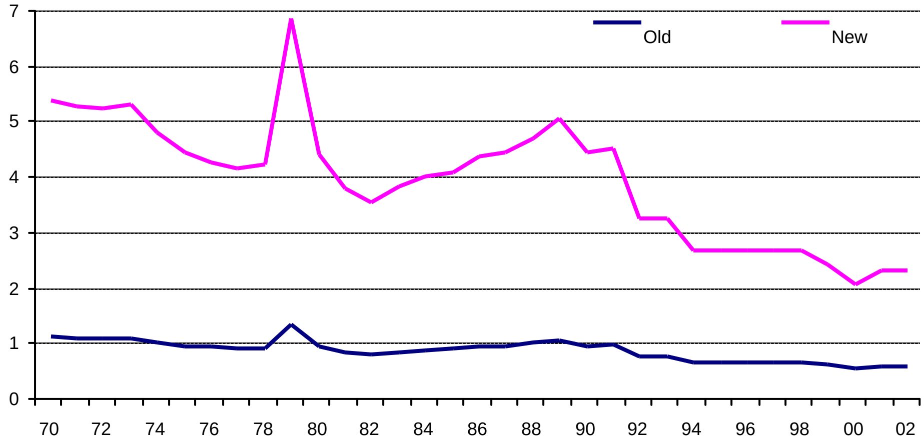
The old coefficient came from the *Douglas and Lawson (2000), JIE* article*.* The new coefficient for gypsum comes from the MFA review which in turn sources the coefficient to British Gypsum Ltd. The coefficient has been introduced from 1970 as the old coefficient related to global gypsum production rather than UK specific.

Impact of the new coefficient

The new coefficient has been introduced from 1970. The new coefficient increases the estimated hidden flows by 1.7 million tonnes, an increase of 500 per cent throughout the time series.

Chart 7 - Hidden flows for gypsum

Million tonnes



8. Minerals – Potash

The hidden flows cover the extraction of potash.

Coefficient

	Old coefficient	UoM coefficient	Coefficient used in report	Implemented from
Potash	0	2	2	1973

Comments and sources

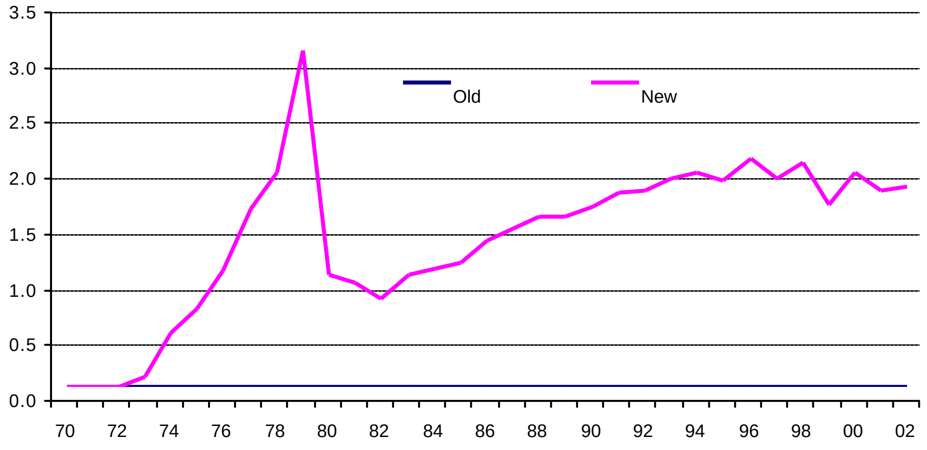
The old coefficient came from the *Douglas and Lawson (2000) JIE* article. The new coefficient for potash is suggested in the MFA review and comes from Cleveland Potash Ltd. The coefficient is introduced from 1973, as there was no significant potash as working prior to that period.

Impact of the new coefficient

The new coefficient has been introduced from 1973. The new coefficient introduces hidden flows where there were none previously. Total hidden flows are estimated at 1.8 million tonnes.

Chart 8 - Hidden flows for potash

Million tonnes



9. Minerals – Sand and gravel

The hidden flows cover the extraction of sand and gravel.

Coefficient

	Old coefficient	UoM coefficient	Coefficients used in report	Implemented from
Sand and Gravel	0.38			
Sand and Gravel : Land	-	0.25	0.25	Phased in from 1990
Sand and Gravel : Marine	-	0.08	0.08	Phased in from 1990
Silica sands	-	0.75	0.75	Phased in from 1990

Comments and sources

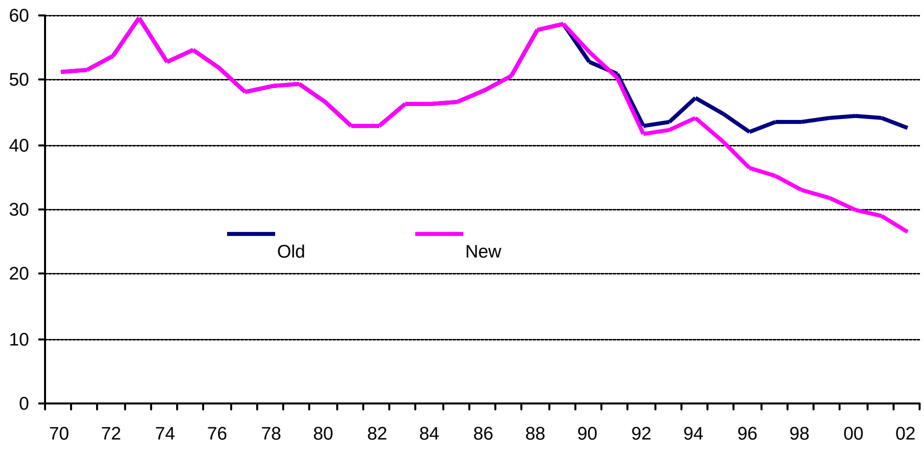
The old coefficient for sand and gravel came from the *Douglas and Lawson (2000), JIE* article. Three new coefficients were recommended in the review and these replace the original single sand and gravel. The new coefficient is phased in from 1990 as it was felt that working practices changed in the lead up to the introduction of the Review of Mineral Permissions Act 1995.

Impact of the new coefficient

The new coefficients have been phased in from 1990. The overall impact is to reduce the hidden flows by 40 per cent in 2002. The new hidden flows associated with sand and gravel are estimated at 23.8 million tonnes, a reduction of 16.1 million tonnes. Chart 9 presents the data in aggregated form to allow comparison with existing data.

Chart 9 - Hidden flows for sand and gravel

Million tones



10. Minerals – Talc

The hidden flows cover the extraction of talc.

Coefficient

	Old coefficient	UoM Coefficient	Coefficient used in report	Implemented from
Talc	0.2	1.2	1.2	1970

Comments and sources

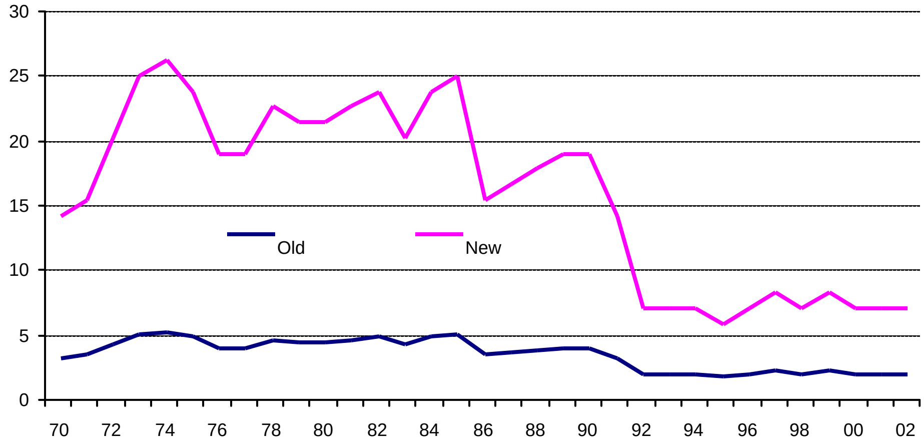
The old coefficient for talc came from the *Douglas and Lawson (2000), JIE* article. The new coefficient comes from the MFA review, which sources the coefficient to Alexander Sanderson & Sons.

Impact of the new coefficient

The new coefficient has been introduced from 1970. Its impact is to increase the level of hidden flows 5 thousand tonnes to 6 thousand tonnes in 2002.

Chart 10 - Hidden flows for talc

Thousand tonnes



11. Ores - Lead

The hidden flows cover the extraction of lead ore.

Coefficient

	Old coefficient	UoM Coefficient	Coefficient used in report	Implemented from
Lead ore	31	0	0	Phased in from 1970

Comments and sources

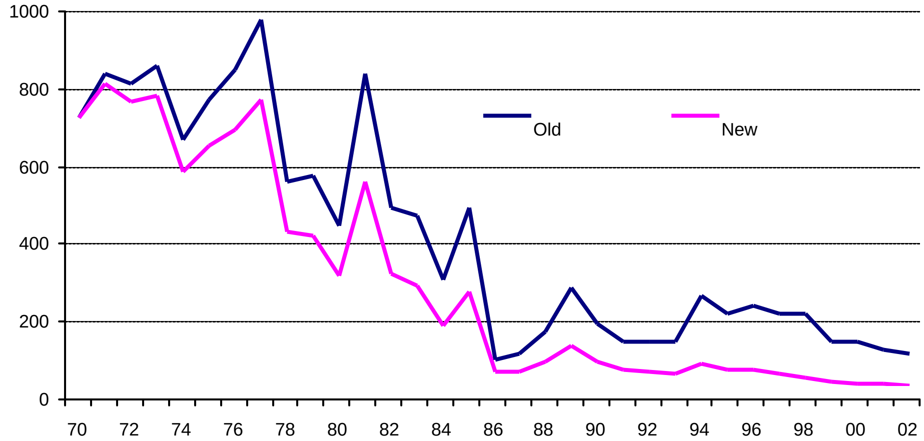
The old coefficient for lead ore came from the *Douglas and Lawson (2000) JIE* article. The new coefficient is suggested in the MFA review, where it states that lead production is done in association with the extraction of fluorspar and therefore already implicitly included.

Impact of the new coefficient

The new coefficient has been phased in from 1970. Its overall impact is to reduce the hidden flows to zero in 2002. The old coefficient of 31 resulted in hidden flows of 80 thousand tonnes in 2002.

Chart 11 - Hidden flows for lead ore

Thousand tones



12. Ores - Iron

The hidden flows cover the extraction of iron ore.

Coefficient

	Old coefficient	UoM Coefficient	Coefficient used in report	Implemented from
Lead ore	4.2	0	0	Phased in from 1970

Comments and sources

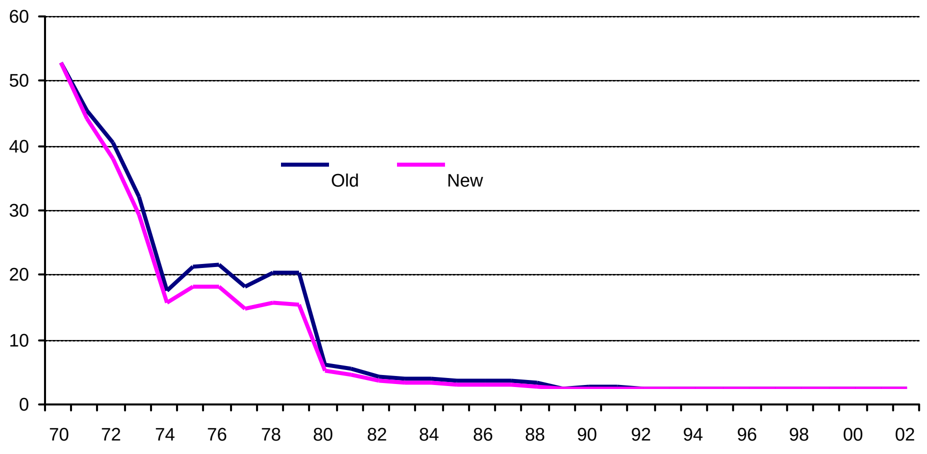
The old coefficient for lead ore came from the *Douglas and Lawson (2000) JIE* article*.* The new coefficient is suggested in the MFA review, where it suggests that there should have no coefficient of iron ore. There is only one mine in the UK producing iron ore and it estimates its hidden flows to be zero.

Impact of the new coefficient

The new coefficient has been phased in from 1970 in line with the MU MFA review recommendations. Its overall impact is to reduce the hidden flows to zero in 2002 compared to 2 thousand tonnes using the old coefficient.

Chart 12 - Hidden flows for iron ore

Million tones



8 - Recommendations from the review

Publication

Publication of the Material Flow Account by the ONS will continue to form part of the UK Environmental Accounts with an optimum publication date of the November of each year. Estimates will be for T-1, where T is the current year.

Compilation of output indicators

The published data focuses on material input and consumption through the presentation of indicators such as direct material input and domestic material consumption. No data or indicators are published for material output despite the availability of much of the information. New information from the Environment Agency should improve the availability of commercial and industrial waste information. The Department for Environment, Food and Rural Affairs (Defra) have recently consulted on a Waste Data Strategy which would deliver more complete, timely and accurate waste data across all waste streams, see http://defraweb/environment/waste/wip/data/index.htm The ONS will seek to maximise the use of all available waste and emissions information with the aim of compiling output indicators such as Domestic Processed Output.

Compilation of Eurostat's standard tables

Eurostat have circulated proposals for the collection of material flow data through a set of standard tables. Much of the information is already available for core indicators such as Direct Material Input and Domestic Material Consumption. However, Eurostat's request for imports allocated to economic branches and to the categories of final demand will require development of the existing imports dataset.

Recycling and re-use

While information on recycled material does not feed directly into the Material Flow Accounts, it does directly affect the extraction and use of virgin raw materials. Work done for Defra by the Wuppertal Institute in 2002 (Defra, 2002) suggested that one tonne of recycled material saved just over three tonnes of natural resources. Additional analysis of recycled or re-used material, particularly by the construction industry, will give some indication of domestic extraction/imports avoided. Information on construction and demolition waste has been collected for England and Wales through a survey by the Office for the Deputy Prime Minister for periods 1999-2000 and 2003.

Better analysis of published datasets

Consultation with several users has identified the need for better analysis of the already published data, particularly the impact of foreign trade. Defra intend to use domestic material consumption as a decoupling indicator and will use the analysis to gain a greater understanding of the composition and drivers of UK resource use. The ONS will consult with Defra to clarify the full extent of the analysis required.

Better analysis of resource use

The current published information gives no indication of the final consumer. Analysis of resource use is likely to become a standard data requirement of Eurostat if and when they introduce a NAMEA[18] type analysis of the Material Flow Accounts. Eurostat data requirement is likely to be at a NACE two-digit level as opposed to the complete 93-industry breakdown used for energy and atmospheric emissions.

Maintenance of the hidden flow coefficients

The ONS should endeavour to maintain the accuracy of the hidden flow coefficients identified by the University of Manchester. The ONS should evaluate the options open to it in maintaining the coefficients. The proposal put forward by the University to add a hidden flow question to the Annual Minerals Raised Inquiry (AMRI) was rejected by the AMRI Steering Group as impractical on the grounds that it would place too great a burden on the respondents. The establishment of a hidden flow database was proposed at a recent material flow task force meeting in Luxembourg.

Other development suggestions

Other suggestions are put forward in the University of Manchester's report including work on physical input-output tables and a look at spatial and temporal distinctions.

[18] National Accounts Matrix incorporating Environmental Accounts (NAMEA).

9 - References

British Geological Survey (2004), *United Kingdom Minerals Yearbook 2003*, Nottingham, ISBN 0-85272-473-3 available at http://www.bgs.ac.uk/mineralsuk/statistics/uk/ukmy.html

Department for Environmental, Food and Rural Affairs (2002), *Resource use and efficiency of the UK economy*, June 2002, available at http://www.defra.gov.uk/environment/statistics/waste/research/download/mfaressum.pdf

Department for Environmental, Food and Rural Affairs (2004), 2002/03 Municipal Waste Management Survey, August 2004, available at http://www.defra.gov.uk/environment/statistics/wastats/archive/mwb200203.pdf

Department for Environmental, Food and Rural Affairs and Department for Trade and Industry (2003), *Sustainable Consumption and Production Indicators: Joint Defra/DTI consultation paper on a set of "decoupling" indicators of sustainable development*, September 2003, available at http://www.defra.gov.uk/corporate/consult/scp-indicators/consultdoc.pdf

Douglas, I. and Lawson, N. (2000), Journal of Industrial Ecology, *The Human Dimensions of Geomorphological Work in Britain*, March 2000.

Eurostat (2001), *Economy-wide material flow accounts and derived indicators: A methodological guide,* Luxembourg, Office for Publications of the European Communities, 2001 ISBN 92-894-0459-0 available at http://epp.eurostat.cec.eu.int/cache/ITY_OFFPUB/KS-34-00-536/EN/KS-34-00-536-EN.PDF

Geisler, G. (1970), *Pflanzenbau in Stichworten, Teil I. Die Kulturpflanzen,*. Hirth-Verlag, Keil, Germany

Gravgaard Pedersen, O. (1999), *Physical input-output tables for Denmark,* Statistics Denmark

Matthews at al. (2000), *The Weight of Nations - Material outflows from industrial economies* , World Resources Institute, Washington DC ISBN 1-56973-439-9 available at http://pdf.wri.org/weight_of_nations.pdf

Office for the Deputy Prime Minister (2001), *Construction and demolition waste survey for England and Wales 1999-2000*, available at http://www.odpm.gov.uk/stellent/groups/odpm_planning/documents/pdf/odpm_plan_pdf_606686.pdf

Office for National Statistics (2004), *Environmental Accounts* , November 2004, available at http://www.statistics.gov.uk/downloads/theme_environment/EANov04.pdf

Organisation for Economic Co-operation and Development (2004), Recommendation of the Council on Material Flows and Resource Productivity, April 2004, available at http://www.oecd.org/dataoecd/3/63/31571298.pdf

Performance and Innovation Unit (2001), *Resource productivity: making more with less*, November 2001, available at http://www.number-10.gov.uk/su/resource/downloads/resource-productivity.pdf

Statistics Sweden (1999), *A material account for sand and gravel in Sweden*, October 1999.

Sustainable Development (1999a), *A better quality of life: a strategy for sustainable development for the UK*, May 1999, The Stationery Office, London, ISBN 0-10-14345-9 available at http://www.sustainable-development.gov.uk/uk_strategy/content.htm

Sustainable Development (1999b), *Quality of life counts* , December 1999, The Stationery Office, London, ISBN 0-10-14352-9 available at http://www.sustainable-development.gov.uk/sustainable/quality99/index.htm

Sustainable Development (2004a), *Achieving a better quality of life*, March 2004, available at http://www.sustainable-development.gov.uk/ar2002/

Sustainable Development (2004b), *Taking it on*, *developing UK sustainable development strategy together,* April 2004, available at http://www.sustainable-development.gov.uk/taking-it-on/consult/document/pdf/consult.pdf

Sustainable Development Commission (2004), *Shows promise. But must try harder*, April 2004, available at http://www.sd-commission.org.uk/news/resource_download_search.php?attach_id=SMDOB79-7JQMZFE-1OHI1PA-UFRDL3I

Annex A

Completeness - Data availability in the UK material flow account

Contents

Page

Domestic Extraction - Agriculture

Product	Availability (Dec 2004)	Source	Comments
Cereals			
Barley	1961-2003	FAO website	
Maize	1970-1980	FAO website	Category removed from the FAO website
Mixed grain	1961-2003	FAO website	
Oats	1961-2003	FAO website	
Rye	1961-2003	FAO website	
Triticale	1985-2003	FAO website	
Wheat	1961-2003	FAO website	
Roots + tubers			
Potatoes	1961-2003	FAO website	
Pulses			
Peas (dry) and pulses not elsewhere specified	1961-2003	FAO website	
Oil crops			
Linseed	1984-2003	FAO website	
Mustard seed	1961-1987	FAO website	Set to zero from 1988
Rapeseed	1961-2003	FAO website	
Vegetables + melons			
Chillies and peppers green	1989-2003	FAO website	
Onions + shallots	1981-2003	FAO website	
Leeks and other alliac vegetables	1989-2003	FAO website	
All other vegetables	1961-2003	FAO website	Carrots, cabbages, cauliflowers, mushrooms, peas, etc.
Fruits			
Apples	1961-2003	FAO website	
Berries not elsewhere specified	1961-2003	FAO website	
Cherries	1961-2003	FAO website	
Currants	1961-2003	FAO website	
Fresh fruit not elsewhere specified	1961-1979	FAO website	Set to zero from 1988
Gooseberries	1961-2003	FAO website	
Grapes	1989-2003	FAO website	
Pears	1961-2003	FAO website	
Plums	1961-2003	FAO website	
Raspberries	1961-2003	FAO website	
Fresh stoned fruit not elsewhere specified	1969-1979	FAO website	Set to zero from 1988
Strawberries	1961-2003	FAO website	
Fibre			
Flax fibre and tow	1992-2003	FAO website	
Other crops			
Sugar beets	1961-2003	FAO website	
Maize for forage and silage	1971-1998	No current data source	Between 1998-2002 rolling averages of the previous 3 years data have been used to bring the data up to date.

Domestic Extraction - Agriculture cont.

Product	Availability (Dec 2004)	Source	Comments
Other crops cont.			
Leguminous not elsewhere specified for forage and silage	1966-1994	No current data source	Between 1995-2002 rolling averages of the previous 3 years data have been used to bring the data up to date
Cabbage for fodder production	1968-1994	No current data source	Between 1995-2002 rolling averages of the previous 3 years data have been used to bring the data up to date
Pumpkins for fodder production	Not available	No current data source	
Turnips for fodder production	1966-1994	No current data source	Between 1995-2002, rolling averages of previous 3 years data have been used to bring the data up to date
Beets for fodder production	1966-2002	FAO website	Latest data estimated using rolling averages of the previous 3 years data.
Hops	1961-2003	FAO website	

Domestic Extraction - Forestry & fishing

Product	Availability (Dec 2004)	Source	Comments
Forestry			
Roundwood, roundwood (C) and roundwood (NC)	1961-2003	FAO	
Fisheries			
Total fish catch and total marine fish catch	1961-2001	FAO	From 2002, rolling averages of previous 3 years data have been used to bring the data up to date
Shrimps + prawns	1961-2002	FAO	Data for 2003 have been estimated

Domestic Extraction - Minerals & ores

Product	Availability (Dec 2004)	Source	Comments
Ores			
Iron Ore	1970-2003	UK Minerals Yearbook	2003 data is provisional
Tin Ore	1970-2003	UK Minerals Yearbook	Set to zero from 1999
Lead Ore	1970-2003	UK Minerals Yearbook	2003 data is provisional
Minerals			
Barite	1970-2003	UK Minerals Yearbook	2003 data is provisional
Clays			
Fire clay	1970-2003	UK Minerals Yearbook	2003 data is provisional
Fuller's Earth	1970-2003	UK Minerals Yearbook	2003 data is provisional
China clay	1970-2003	UK Minerals Yearbook	2003 data is provisional
Ball clay and Potter's clay	1970-2003	UK Minerals Yearbook	2003 data is provisional
Crushed stone			
Chalk	1970-2003	UK Minerals Yearbook	2003 data is provisional
Igneous rock	1970-2003	UK Minerals Yearbook	2003 data is provisional
Limestone (excluding Dolomite) and Dolomite (excluding Limestone)	1970-2003	UK Minerals Yearbook	2003 data is provisional
Silica stone and Granister	1970-1989 no data for 1979,1980 and 1985	UK Minerals Yearbook	Categories not in MYB
Sandstone	1970-2003	UK Minerals Yearbook	2003 data is provisional
Slate	1970-2003 no data for 1991	UK Minerals Yearbook	2003 data is provisional
Calcspar	1970 - 2002, no data for 1987, 1994-96, 1999-2000	UK Minerals Yearbook	
Chert and Flint	The data for is available between 1970-2002, no data for 1982, 1988, 1989, 1991-92, 1994-96.		
Feldspar/China stone	1970-2003	UK Minerals Yearbook	2003 data is provisional
Flourspar	1970-2003	UK Minerals Yearbook	2003 data is provisional
Gypsum	1970-2003	UK Minerals Yearbook	2003 data is provisional
Potash	1970-2003	UK Minerals Yearbook	2003 data is provisional
Salt			
Rock salt	1970-2003	UK Minerals Yearbook	2003 data is provisional
Salt from brine	1970-2003, no data for 1971, 1972 and 1991	UK Minerals Yearbook	2003 data is provisional
Salt in brine	1970-2003, no data for 1971, 1972 and 1991	UK Minerals Yearbook	2003 data is provisional

Domestic Extraction - Minerals & ores cont.

Product	Availability (Dec 2004)	Source	Comments
Sand and Gravel			
Sand and Gravel: land	1970-2003	UK Minerals Yearbook	2003 data is provisional
Sand and Gravel: marine	1970-2003, no data for 1991	UK Minerals Yearbook	2003 data is provisional
Special sands			
Glass making	1970-1974		These categories no longer in MYB
Moulding	1970-1974		These categories no longer in MYB
Other silica sands	1970-1974	UK Minerals Yearbook	These categories no longer in MYB
Talc	1970-2003	UK Minerals Yearbook	2003 data is provisional

Domestic Extraction - Fossil energy carriers

Product	Availability (Dec 2004)	Source	Comments
Hard Coal			
Deep-mined coal	1970-2003	UK Minerals Yearbook	2003 data is provisional
Opencast coal	1970-2003	UK Minerals Yearbook	2003 data is provisional
Other types of coal	1970-2003	UK Minerals Yearbook	2003 data is provisional
Crude Oil			
Crude oil: onshore and Crude oil: offshore	1992-2003	UK Minerals Yearbook	No on/off shore split given so these estimated. **Note**: The totals for crude oil extraction are available for all years between 1970-2003
Condensates and other: Onshore and Condensates and other: Offshore	1992-2003	UK Minerals Yearbook	No on/off shore split given so these estimated. **Note**: The totals for Condensates are available for all years between 1970-2003
Natural Gas			
Onshore and Offshore	1970-2003	UK Minerals Yearbook	No on/off shore split given so these estimated
Colliery	1970-2002	UK Minerals Yearbook	Latest data estimated using a rolling average of the previous 3 years data
Peat	1970-2003	UK Minerals Yearbook	2003 data is provisional

Direct Processed Output - Dissipative flows

Product	Availability (Dec 2004)	Source	Comments
Manure			
All livestock	1970-2003	FAO website	Includes; cattle, sheep, horses, pigs and poultry
Mineral fertilisers			
Nitrogenous, phosphate and potash	1970-2001	FAO website	To bring the data up to date rolling averages of previous 3 years data have been use for latest years
Pesticides			
Insecticides, herbicides, fungicides, etc.	1970-1999	FAO website	To bring the data up to date rolling averages of previous 3 years data have been use for latest years.
Seeds			
Linseed	1983-2003	FAO website	
Pulses not elsewhere specified	1986-2003	FAO website	
Triticale	1985-2003	FAO website	
All other seed	1970-2003	FAO website	Barley, rye, potatoes, wheat, oats, peas, etc.

Direct Processed Output - Emissions to water

Product	Availability (Dec 2004)	Source	Comments
Dredge material and sewage sludge			
Zinc, lead, copper, chromium, nickel, cadmium and mercury	1985-1997	Centre for Environment, Fisheries & Aquaculture Science	For 1998 and 1999 rolling averages of previous 3 years data have been used to bring the data up to
Release to controlled waters	1998-2003	Environment Agency	

Direct Processed Output - Emissions to air

Product	Availability (Dec 2004)	Source	Comments
Atmospheric emissions			
Greenhouse gases, acid rain precursors, etc.	1990-2002	National Environmental Technology Centre	Carbon dioxide, methane, nitrous oxide, sulphur dioxide, ammonia, nitrogen oxides, particulate matter, carbon monoxide, volatile organic compounds, benzene 1-3, butadiene, lead, cadmium, mercury, arsenic, chromium, copper, nickel, selenium, zinc

Direct Processed Output - Waste landfilled

Product	Availability (Dec 2004)	Source	Comments
Construction and Demolition waste	1997, 1998 and 1999 2001, 2003	ODPM and Department for Environment, Food and Rural Affairs (Defra)	Survey t repeated every two years
Industrial and Commercial waste	1998-1999	Environment Agency/Defra	Survey repeated in 2002
Municipal Waste	1996-2003	Defra, National Assembly for Wales, Scottish Environmental Protection Agency and Department for Environment Northern Ireland	Data presented in financial year format

Imports and Exports

Imports and exports

Product	Availability (Dec 2004)	Source	Comments
All imports and exports	1970-2003	HM Customs and Excise website	

Data sources and links

Centre for Environment, Fisheries & Aquaculture Science - The Centre for Environment, Fisheries & Aquaculture Science website holds information on fish stocks and catches for UK fishing grounds, dredging activity around the UK and the emissions of certain metals to water?
http://map2.cefasdirect.co.uk/isea/

Department for Environment, food and Rural Affairs (Defra) - The Defra website contains a wide range of environmental statistics. Information on landfilled waste is available from the Defra website at http://www.defra.gov.uk/environment/statistics/waste/index.htm

Environment Agency - The Environment Agency provide information on emissions to controlled waters and waste. Information on emissions to controlled waters in England and Wales for 1998-2003 can be found at http://www.environment-agency.gov.uk/commondata/103601/pi_summ_proc_03v3prot_862571.xls

HM Customs and Excise - The HM Customs and Excise website contains detailed information on all recorded exports and imports under *UKtradeinfo*. The data are free once registered.
http://www.uktradeinfo.com/

National Environmental Technology Centre - The National Environmental Technology Centre (Netcen) compile the UK's National Air Emissions Inventory and provide National Accounts consistent data to the ONS for compilation of the Environmental Accounts. http://www.netcen.co.uk/

UK Minerals Yearbook - The UK Minerals Yearbook is published annual, usually between March and July of each year, by the British Geological Survey. The latest edition *UK Minerals Yearbook 2003* has data up to and including 2003. *UK Minerals Yearbook 2003 (*Hillier J A, Chapman, G R, Highley D E) ISBN 085272473X. http://www.bgs.ac.uk/mineralsuk/statistics/uk/ukmy.html

United National Food and Agriculture Organisation - Data on agricultural production, etc. are obtained from the United National Food and Agriculture Organisation website free of charge. Data availability varies with estimates frequently required for the latest periods.
http://www.fao.org/waicent/portal/statistics_en.asp

Annex B

UK MATERIAL FLOW ACCOUNTS: REVIEW OF INDIRECT FLOW COEFFICIENTS

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Greater Manchester Geological Unit

Report to the Office for National Statistics

November 2003

THE UNIVERSITY of MANCHESTER

Contents

Chapter 1 - Review of current methodology and functionality of existing data

The main focus of this document is the precision and accuracy of means of estimating the hidden flows due to mining and quarrying in the United Kingdom. This chapter sets out the most significant recent literature on that problem and provides a list of some general works that provide background data on the problems of materials flows generally. This is a rapidly emerging interdisciplinary field in which key work is being done by professionals ranging from geologists to economists.

Mine and quarry waste and overburden: studies relevant to UK production

Bringezu, S. and Schütz, H. 2001a *Material use indicators for the European Union, 1980-1997. Economy-wide material flow accounts and balances and derived indicators of resource use. Working Paper No. 2/2001/B/2 prepared for DG Environment and Eurostat.* European Commission, Luxembourg.

> Establishes a framework and method description for drawing up aggregate material balances nationally. Methodological guide concludes that priorities for future work should include collection of generic coefficients and the implementation and maintenance of a database with coefficients for indirect flows. Domestic material input flows give country specific ratios for hidden flows, with all UK hidden flows referenced from Douglas, I. and Lawson, N. 2001, with the exception of coal (1.25 to 6.2 tonnes per tonne from 1970 to 1997) and crude oil (0.006 tonnes per tonne for offshore extraction) which were taken from the database of the Wuppertal Institute database. A universal hidden flow ratio for peat was taken from Douglas, I. and Lawson, N. 1997.

Bringezu, S. and Schütz, H. 2001b *Total material resource flows for the United Kingdom.* Department of the Environment, Transport and Regions Contract EPG 1/8/62. DETR, London.

> Uses methodology developed by Adriaanse , A., Bringezu, S., Hammond, A., Moriguchi, Y., Rodenburg, E., and Schütz, H. (1997) in *Resource flows: the material basis of industrial economies.* World Resources Institute, Washington, D.C. Excludes soil erosion and hidden flows for precious stones and metals in data covering Total Material Requirements for the UK. No individual figures or sources for mine and quarry waste and overburden included in the report.

The ONS material flow statistics database references hidden flows as hereunder:

- Crushed stone and slate, sand and gravel: Klinnert 1993 (Klinnert, C. 1993 *Acquisition of statistical data on mineral raw materials.* Unpublished report for the Wuppertal Institute).
- Potash: Cleveland Potash Company (reference to Douglas I. and Lawson, N. 2001 for comparison).

- Salt and talk: German hidden flow coefficients (reference to Douglas I. and Lawson, N. 2001 for comparison).
- Lead: US Bureau of Mines 1993 (reference to Douglas I. and Lawson, N. 2001 for comparison).
- Crude oil: UN and UK Energy Statistics Yearbook (reference to Douglas I. and Lawson, N. 2001 for comparison).
- Construction clay (common clay and shale): Klinnert 1993 coefficients (reference to Douglas I. and Lawson, N. 2001 clay and ball clay for comparison).
- Clay, china clay, ball clay, fullers earth, bentonite, gypsum anhydrite, fluorspar, iron ore: Douglas, I. and Lawson, N. 2001
- Clay, domestic total clay summary: average hidden flow co-efficient used but no source quoted.
- Peat: Douglas, I. and Lawson, N. 1997
- Natural gas: US-DOE: Energy Technology Characterization Handbook 1983
- Hard coal, barites, feldspar: no source given.

Douglas, I. and Lawson, N. 1997 An earth science approach to assessing the disturbance of the earth's surface by mining. *Mining and Environmental Research Network Research Bulletin No. 11/12, 1997 Special Edition,* 37-43

Individual multipliers to assess global figures for waste and overburden for all minerals listed in the United Nation's Department of Economic and Social Affairs, Statistics Division *Industrial Commodity Statistics Yearbook- production statistics*. The estimates are for global production, but include UK estimates for aggregates and building stone, coal, oil, clays, slate and peat. Multipliers derived from a world-wide literature review, including case studies, and consultation with the UK minerals industry and other academic and specialist researchers.

Douglas, I. and Lawson, N. 2000 The human dimensions of geomorphological work in Britain. *Journal of Industrial Ecology, 4(2),* 9-33

Individual multipliers for all commodities listed in the British Geological Survey's *United Kingdom Minerals Yearbook.* Multipliers derived from Douglas, I. and Lawson, N. 1997.

Eurostat 2000 *Economy-wide material flow accounts and derived indicators. A methodological guide.* Office for Official Publications of the European Community, Luxembourg.

Detailed terminology, definition, concept and methodology for hidden and indirect flows. No actual data or sources of data for hidden and direct flows, including mine and quarry waste and overburden.

Schandl, H. and Schulz, N. 2000 *Using material flow accounting to operationalise the concept of society's metabolism. A preliminary MFA for the United Kingdom for the period of 1937 – 1997.* ISER Working Papers. Paper 2000-3. University of Essex, Colchester.

Discussion on methodological basis for inclusion of hidden flows in MFAs. No individual figures for mine and quarry waste and overburden shown, but draws on Douglas, I. and Lawson, N. 1997.

Sherlock, R.L. 1922 *Man as a geological agent*. Witherby, London.

Assessment of the total quantities of materials moved by man in Great Britain between 1895 and 1913. Empirical evidence of coal mine and quarry wastes. Volumes of material excavated in Cornwall and Devon (copper and tin) used as a guide for other minerals. Difficulty in estimating quantities (net) caused by changes in the compilation of published statistics. Output from quarries below 20 ft. (6 m) in depth were still being ignored in the annual reports on Mines and Quarries issued by the Home Office.

Sheerin, C. 2002 UK material flow accounting. *Economic Trends 583,* 53-61.

No figures or sources of hidden flows given, but reference made to Wuppertal Institute's research for DETR and ONS and to standards set by Eurostat (see Eurostat, 2000).

United Nations Economic Commission for Europe 1992 *The environment in Europe and North America: annotated statistics.* United Nations, New York, 81.

Statistics covering generation of waste during all phases of the material cycle, from extraction of raw materials to consumption. Mining and quarrying wastes for selected countries. U K estimates of annual averages in the late 1980's. Limited surveys and ad hoc data.

Major texts in the field

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Chapter 2 - Updated data on hidden flows and wastes due to mining and quarrying

To evaluate ways in which the hidden flows and wastes due to mining and quarrying could be assessed more accurately and be updated annually, the project team contacted a wide range of authorities and enterprises in the mining sector, including the British Geological Survey and the British Aggregates Association. This chapter presents the results of that enquiry and provides new figures and coefficients for the hidden flows and wastes in the UK mining and quarrying industry.

Data Sources for mine and quarry production statistics

Annual production data are collated by the British Geological Survey and are published in the United Kingdom Minerals Yearbook. The principal sources of annual production data are:

- The ONS's Annual Minerals Raised Inquiry (AMRI)
- The Aggregate Minerals Survey for England and Wales
- The Quarry Products Association
- The Coal Authority

All the data sources are given in the United Kingdom Minerals Yearbook.

Appraisal of current hidden flow data

Coal- deep mined

The methodology applied in the derivation of data on hidden flows is unclear.

The majority of deep coal mining in the UK is currently undertaken by UK Coal Mining Ltd.

As at 2002, hidden flows of + 56% of production.

Source: Mr. Patrick O'Brian, Director of Mining, UK Coal Mining Ltd. who can be consulted annually.

Coal- opencast

Methodology applied in the formation of data on hidden flows is unclear.

UK Coal Mining Ltd are also the major operator of opencast coal sites in the UK

As at 2002, waste and overburden applicable to production:

- *England 16:1*
- *Wales 18:1*
- *Scotland 13:1*

UK hidden flows (based on 2002 production) =15:1(+1500% of production)

NB all waste and overburden during opencast operations is replaced in the same void, but this does result in environmental change (see Douglas and Lawson, 2000).

Source: Mr. Patrick O'Brian, Director of Mining, UK Coal Mining Ltd. who can be consulted annually.

Coal- other

Coal recovery: reworking of existing tips and lagoons. Accounted for above, thus no coefficient required.

Natural gas, oil and condensates

The current methodology in the statistics appears sound

Iron ore

The single working iron ore mine in the UK producing in excess of 50 tons per annum is Egremont Mining Co in Cumbria who mine known measures with nil hidden flows.

Fluorspar

All UK processing is at Cavendish Mill, Derbyshire.

Hidden flows of + 25-30% of production

Source: BGS Commissioned Report CR/03/157C

Barytes

Primarily produced in conjunction with Fluorspar with the exception of Foss Mine, Aberfeldy where virtually no waste occurs.

Source: Mr N Butcher, Project Geologist, MI Great Britain Ltd.

Lead

UK lead production is in association with the extraction of Fluorspar and Barytes, thus no co-efficient should be applied.

Aggregate quarries including sandstone, limestone, chalk and igneous rock.

Percentages of waste at aggregate (hard rock) quarries are estimated to vary from less than 5% to over 25%.

Hidden flows of + 15% of production.

Source: Mr. Peter Huxtable, General Secretary, British Aggregates Association

Sand and Gravel Quarries.

Percentages of waste at land based sand quarries are estimated to vary from less than 5% to 40% and in certain limited cases to 50%

Hidden flows of + 25% of production.

Source: Mr. Peter Huxtable, General Secretary, British Aggregates Association

Marine won sand

Waste from marine sand extraction is almost impossible to quantify. It is returned to the sea and hence never becomes a waste issue. Sea movements (coastal drift and tide) are also likely to redistribute any discarded fine material back in to the location, and form from whence it was extracted. Percentages of material returned to the sea are estimated at between 5% and 10%.

Hidden flows of + 7.5% of production.

Source: Mr. Peter Huxtable, General Secretary, British Aggregates Association

Common Clay and Shale

Used in the production of bricks. Overburden/interburden coefficients are always estimated to assess the economic viability of extraction. In the UK, the waste coefficient is between 80 and 140%, with some pits producing as little as 20% waste.

Hidden flows for all 160 +UK pits = average of + 60%-80% of production

Source: Mr. Peter Haslam-Brunt, Quarry Manager, Ibstock Brick Ltd, Chesterton who can be consulted annually.

Slate

Lake District quarries average recovery rate is 10%, thus 10:1, and is up to 30:1 for slate block production. Two Lake District quarries now have facilities to crush waste for aggregate production as and when a local market exists. Thus average for Lake District Slate = 3:1 (+ 300%).
Source: Mr. Mike Dickinson, Director of Quarries, Burlington Slate Ltd. who can be consulted annually.

North Wales quarries average between 12:1 and 15:1 and principally produce roofing and architectural products, with virtually no sales as fill.
Source: Mr. Andy Carson, Quarry Manager, McAlpine Slate Ltd. who can be consulted annually.

Hidden flows for UK slate production average 10:1 (+1000% of production)

Ball Clay

Used in the production of ceramic products. Ratio of overburden and interburden is very variable from quarry to quarry. The mineral is selected during excavation resulting in a national average of waste and overburden equating to

Hidden flows for ball clay ratio 9:1(+ 900% of production)

Calcspar

Can be included with limestone in aggregates and building stone (paragraph 9). Virtually no production waste.

China Clay

China clay workings are restricted to Cornwall and Devon. Ratio waste and overburden/china clay recovery during extraction is 9:1, but some waste (typically rock) is recovered and sold as aggregate. Thus:

Hidden flows for china clay ratio 6.5:1(+ 650% of production)

Sources: BGS Commissioned Report CR/03/157C

Mr. F. Hart, Chief Chemist, Goonvean Ltd.

China Stone

Used in the production of Royal Doulton pottery. The mineral is hand selected during excavation of China Clay. Thus,

No hidden flows.

Source: Mr. F. Hart, Chief Chemist, Goonvean Ltd.

Fireclay

Fireclays are mainly confined to coal-bearing strata and production is almost entirely confined to opencast coal sites. Whilst primarily used in the production of bricks, pipes and tiles, it is increasingly being used as capping material in the restoration of landfill sites. The waste is thus accounted for in opencast coal mining (see section 2).

Source: David Waghorn, Senior Geologist, Greater Manchester Geological Unit.

Fuller's earth

Used to produce Bentonite. No waste is produced, but overburden removal equates to:

Hidden flows of + 12.5% of production

Sources: David Waghorn, Senior Geologist, Greater Manchester Geological Unit.
BGS Commissioned Report CR/03/157C

Gypsum

All Gypsum in the UK is produced in underground mines with nil waste production, with the notable exception of Kilvington (Jerico) opencast operation where the ratio of waste/overburden to production is 10:1. Thus,

Hidden flow applicable to all UK production in 2002 = + 120%

The UK production of Gypsum is enhanced by the availability of Desulphogypsum from Drax and Ratcliffe on Soar Power stations. This source is felt to be unsustainable and, in the event of reduction, it will result in increased production at Kilvington.

Source: Dr. Noel Worley, British Gypsum Ltd. who can be consulted annually.

Peat

No waste produced but overburden is removed. Thus

Hidden flows of + 25% of production.

Source: David Waghorn, Senior Geologist, Greater Manchester Geological Unit.

Potash

All deep mined at Boulby mine, Cleveland. Waste comprises salts and clay.

Hidden flows of + 200% of production

Source: Mr. David Pybus, Senior Geologist, Cleveland Potash Ltd., Cleveland, who can be consulted annually.

Rock Salt

Underground production, principally in Cheshire and Northern Ireland, for highway de-icing. All processing is carried out underground without producing waste.

Source: David Waghorn, Senior Geologist, Greater Manchester Geological Unit.

Salt from brine

Controlled solution mining, in Cheshire, principally for the chemical industry. Insoluble waste from the purification process amounts to

Hidden flows of + 3% of production

Sources: David Waghorn, Senior Geologist, Greater Manchester Geological Unit.

BGS Commissioned Report CR/03/157C

Silica sand

Sourced during the surface excavation of sands for aggregates, used principally for glass making and as foundry sand, thus waste and overburden part of sands for aggregates (see section 2).

Source: David Waghorn, Senior Geologist, Greater Manchester Geological Unit.

Talc

Production in Shetland only, vertical faults with some side-wall removal.

Hidden flows of + 120% of production

Source: Mr. Owers, Director, Alexander Sandison & Sons, Shetland who can be consulted annually.

Annual updating of hidden flow coefficients

The Annual Mineral Raised Inquiry (AMRI) is an annual statutory survey of the output and value of all mine and quarry operations in Great Britain, with the exception of deep-mined coal. It is undertaken by the Office for National Statistics on behalf of the Office of the Deputy Prime Minister and the Department of Trade and Industry. The ONS maintains its own register of mineral operators but uses the British Geological Survey's Directory of Mines and Quarries for updating purposes. After consultation with industry and the British Geological Survey, we recommend that the AMRI form is modified to include provision for the collection of data reflecting hidden flows. We therefore suggest inclusion of the following questions in each category:

1) Quantity of overburden/interburden, and other waste rock, moved during operations in the last 12 months. Please include all overburden removed during operations, even if this material is subsequently to be used for replacement in voids or for restoration works.
2) Quantity of non-saleable material (waste) resulting from extraction and processing operations in the last 12 months. Please include all non-saleable material removed during operations, even if this material is subsequently to be used for replacement in voids or for restoration

works. Do not include material stored on site for future sale as either primary or secondary product.

Comments

- Some sources and methodologies applied in the current ONS data are unclear.
- The current data quotes comparison with a 2000 study by Douglas and Lawson which contains the author's 1997 estimates of coefficients applicable to global production, unless otherwise stated.
- The Quarry Producers Association (QPA) was reluctant to give direct access to its members. The reason given was that members are already overburdened with official questionnaires and, in any event, individual quarries rarely retain waste statistics.
- The QPA state that most waste and overburden remains within the confines of the quarry and is not always measured.
- Some operators see the Aggregates Tax as a handicap to the exporting of waste as low grade fill.
- Fines in statistics. Certain groups of aggregates, for example limestone, possess different properties depending on their location in the UK. Processing operations can result in the production of stockpiles of fines for which there are no markets or are unsuitable for restoration purposes. These materials are thus included in the estimates for waste.
- The Annual Minerals Raised Inquiry (AMRI) is used to collect data on all mining and quarrying operations in Great Britain, with the exception of deep-mined coal. AMRI covers opencast coal although the figures are not published and are probably incomplete. There is a separate survey of minerals in Northern Ireland and data on all coal mining operations are available from The Coal Authority.

Findings

The current hidden flow data files require updating to reflect the results of the above survey.

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Chapter 3 - Assessment of feasibility of establishing estimates of hidden flows relating to the production of processed goods for import and export

To make an adequate assessment the hidden flows relating to the production of processed goods for import and export requires adding to the detail in the general model of the materials flow of an economy (Fig. 4.1) which clearly indicates both the place of foreign hidden flows associated with imports and the domestic hidden flows associated with exports.

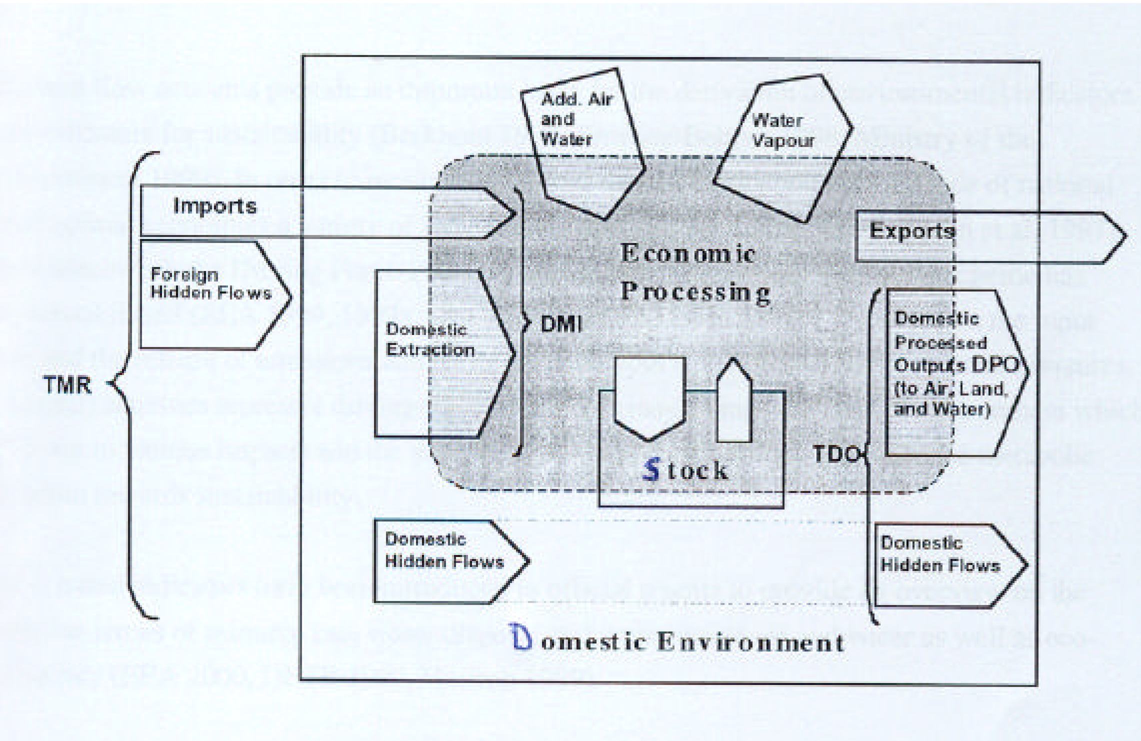

Fig. 3.1 Economy wide materials flows (after Matthews et al., 2000).

Imports

In the analysis of Finnish materials flows, the hidden flows for imported products are accounted for on a life cycle basis by converting finished products, semi-manufactured products and raw materials into raw equivalent weights. This conversion includes all material losses and usage, which do not enter the product's weight and the energy consumption during each production and transportation chain. The hidden flows of resource extraction and infrastructure creation and maintenance are also recognised and included in imported products at each production phase (Juutinen and Viitanen, 2000).

The foreign hidden flows occur in widely diverse environments, affecting contrasted landscapes and different cultures and economies. The very diversity of geological conditions in which minerals are exported mean that the hidden flow coefficients in mined materials imported to the UK will differ greatly depending on the source of the imports. For example, UK coal imports in 2000 included 8.5 million tonnes of coking coal, over half of it from Australia and most of the rest from Canada and the USA. The main sources of imports of steam coal, mostly for use in power generation and industry, were Columbia (39 per cent) and South Africa (32 per cent) with smaller volumes from Australia, Poland, the USA and elsewhere. Such diverse sources are clearly recognised by Bringezu and Schütz (2001a) who use different coefficients for hard coal for the countries supplying coal to the UK (Table 3.1). These values are taken from the Wuppertal database, but it is difficult to know how they were derived. Douglas and Lawson (2002) suggest a global multiplier of 4.89 for hard coal (the mean of 0.2-0.9 for deep mining and 10-22 for opencast operations). This may be a more appropriate figure to use for other countries. These Wuppertal coefficients have been widely used in other countries (Hammer and Habacek, 2003; Juutinen and Viitanen, 2000) and thus good independent international comparators for countries that export to the UK are difficult to find.

Table 3.1 Hidden flow coefficients for hard coal and brown coal

Country	Hard coal coefficient	Brown coal coefficient
Australia	10.6	7.4
Russia and former USSR	5.1	
Canada	18.9	
Colombia	12.0	
South Africa	3.8	
USA	6.3	
Poland		7.4
Czech Republic		6.6
Other countries	0.9	3.2

Source: Bringezu and Schütz (2001)

For other minerals, the same problems apply. Generally for the minerals that dominate the world economy, the Wuppertal database is the main source used. It has been adopted by the World Resources Institute. The problems associated with minerals that are co-located, often in the same hydrothermal vein deposits, with other minerals are also dealt with well by Bringezu and Schütz (2001a).

The hidden flows caused by production of imported agricultural products in their country of origin are less clearly set out. Fig 2.12 in the final UK materials flow report (Bringezu and Schütz (2001b) shows considerable soil erosion in varying amounts associated with foreign resource extractions. Why the soil erosion in 1982 should be half that in 1998 when the biomass extracted is nowhere nearly as different is unclear. This is important because even though the UK may be managing its own farmland more sustainably it may be drawing some of its biomass consumption from unsustainable managed land overseas. Basically, there is a great danger in using over simplified coefficients to estimate the soil erosion associated with imported commodities. One guide to materials flow analysis suggests that “detailed erosion models, taking account of slope, exposure to wind and crop types may be used when available” (European Commission, 2000). Many experts on erosion consider that such models are full of assumptions. To be of any use, they require data on rainfall, which is notoriously variable at any one place from season to season and year to year. A more detailed review of soil erosion is included in Chapter 5.

The whole issue of hidden agricultural flows in imported goods needs greater investigation. Some detailed life cycle analyses ought to be undertaken for specific agriculture and forestry products. From these, better, generalised coefficients might be developed.

Marine fisheries are a special case. The Food and Agriculture Organisation (FAO) estimates that some 27 million tons -- equivalent to more than one third of current global food fish production -- is caught and discarded every year (Speer, 1995). Most fishing gear is not very selective and varying amounts of non-target species of fish and other marine life are generally caught along with the target stock. Among the most notorious fisheries in this area are shrimp fisheries: in portions of the Gulf of Mexico it is estimated that for every one pound of shrimp caught, 10 pounds of other species are caught and discarded. In addition, limited storage capacity on large and small vessels leads to the discard of less valuable species.

Table 3.2 Environmental effects of fishing and responses by the New Zealand fishing industry

Fish ecology	Fishery	Status of information	Trend	Management responses
Disruption of predator-prey relationships	Potentially all wild fisheries	Very limited	Unknown	
Fish bycatch and discards	Trawl, longline and gill net fisheries	Some information on volume, no data on ecosystem effects	Unknown	
Dumping of fish processing waste	Hoki, Squid	Little data on waste volumes none on effects	Reduced dumping in some areas as more vessels process fish meal on-board; increase in other areas	Squid and Hoki Code of Practice

FAO estimates that up to 10 per cent of total food fish supplies are lost due to poor handling, processing and lack of protection against pests and spoilage (Speer, 1995). These observations suggest the 25 per cent waste coefficient applied by Bringezu and Schütz (2001a) may be an underestimate. However the data on which these statements is based is uncertain. Table 3.2 shows some of the uncertainties about fish waste volumes and trends found in a detailed New Zealand examination of the consequences of marine fishing. More detailed examination of losses in marine fishing is required, particularly in view of the rapid depletion of world fish stocks.

Exports

In making their summary of exports, Bringezu and Schütz (2001a) account for imported metals in exports by transferring hidden flow (used/unused) coefficients of imported ores, concentrates, or metals to the accounting of the appropriate hidden flows for exports. The point here is to distinguish the area to which the hidden flows are assigned. If China imports iron ore from Australia to make steel, and then manufactures car parts that are sent to the UK to be put into cars that are sold in the USA, then the hidden flows that are associated with those cars have to be divided appropriately between Australia, China and the UK. The USA in this case would have responsibility for some mining hidden flows in Australia, some coal, limestone and energy-related hidden flows in China, and some manufacturing-related hidden flow in the UK. To avoid double accounting, should we perhaps consider that hidden flows only arise at the source of extraction of raw materials? This issue is best tackled using a life cycle approach to materials consumption in manufacture, but in today's global economy manufacturers are likely to change the sources of the inputs fairly frequently, in response to exchange rates and market conditions, in order to achieve the lowest possible costs consistent with their quality standards. Such a life-cycle analysis would also take into account the final destination of the car when scrapped. The old car could be exported to another country or the scrap metal sold for reprocessing elsewhere. Other parts could become landfill waste at the final destination.

The difficulty might be that although we know the total import of, say, car parts, we don't know which car parts from which country are in the cars exported to the USA. All that can be done is to say of all the car parts brought into the UK, a certain percentage is exported from the country to other countries. Thus the coefficient for hidden flows related to iron ore extraction that gets applied to exports cannot easily be that of the country from which iron ore was obtained for a specific product, but only an average value.

This whole part of national materials flow accounting requires closer scrutiny. Probably the application of simple coefficients to exports year after year is too crude to reasonably reflect what actually happens.

Conclusions

Many data problems arise with foreign hidden flows affecting imports. As the overall analysis of UK materials flows shows that between 1970 and 1999 the UK was a net importer in terms of hidden flows associated with imported or exported commodities (Bringezu and Schütz, 2001b), it is increasingly important, socially and politically, that the extent of the environmental impacts of foreign material flows to the UK is known. It is suggested that this issue be examined in depth, at least for the 10 most important commodities in mass and in value coming into the UK. Such an investigation might include the hidden flows of hard coal mining, gold production, timber extraction and certain food commodity production systems. Fishing hidden flows, both in marine fish capture and in aquaculture deserve special attention in view of the lack of good data and the rapid changes in the status of both forms of fish supply to consumers.

One way of dealing with the hidden flows related to exported goods is to use physical input-output tables (PIOT). However, the quantities in those tables are only as good as the data supplied to enter in them. Applying the technique to the material flows of Finland, Mäenpää. and Muukkonen (2001) found that PIOT provide a powerful comprehensive and consistent data set for analysing the linkages between economy and nature. They are a useful framework for the presentation of Data on raw material use, wastes and emissions. However, packaging, discharges to water bodies and the use of water itself were not included in their preliminary version. They also note that the contributions of the biological metabolism of livestock and humans should be included in the PIOT. It helps to explain the marked discrepancy in the material balance of agriculture and the large amount of manure produced by farm animals. Such an approach leads to identification of gaps in the environmental statistics and ensures that all the biogeochemical processes and exchanges involved in the metabolism of nations get considered when analysing materials flows. Considerable effort ought to be devoted to establishing them. However, data sources for hidden flows require prior attention if the PIOT are to be realistic.

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Chapter 4 - Coefficients for agricultural biomass and manure

The agricultural chemicals applied to the farm are seen as manufactured products from raw materials whose hidden flows will have been accounted for elsewhere in agricultural statistics. However, these inputs to agriculture have important residues that are significant in terms of their effects on the environment. Chemical releases from agriculture have become major problems both through non point source pollution of rivers and greenhouse gas emissions, especially of nitrogen and methane. With their importance for river water quality and climate change, environmental statistics ought to address these waste flows from agriculture. The first step in any such consideration is to assess ways of quantifying the mass or volume of the different types of by-product and waste.

While some of the nutrient losses from agricultural chemicals are associated with soil erosion, which is considered in Chapter 5, others are dissolved in water, carried into groundwater bodies where they may remain for many years before discharging through springs and seepage to lakes, rivers and the coastline. Gases released by organic processes from both crop residue decomposition and animal activities on farms, disperse through the prevailing winds to other parts of the country and are often "exported" to neighbouring countries.

Agricultural inputs: arable

Organic products produce residues that can be composted, left on the soil or returned to the environment in some way. The residues can also enter the waste stream where they occur in processing plants, retail premises or individual households. The difference from minerals is that the produce may be part of a complex cycle of growth, extraction, organic waste arising, waste decomposition and return to environment in some way over a period of months or years, depending on the material. Rock derived materials decompose and decay over decades, centuries and thousands of years

In the arable agricultural food chain, by-products (many termed waste) arise at different stages of the process and take different forms (Table 4.1). Many of these by-products have other uses, but by no means all by-products are reused. Much organic waste is returned to the land, but a considerable amount is disposed of in other ways. To be consistent with the way mining overburden is treated in this report, it would be appropriate to say that all material that is harvested, i.e. removed from the place where it is grown, and is re-deposited on the land, either in the same field or elsewhere, is part of the "hidden" flows of agricultural production.

Table 4.1 Agricultural and food-chain sources and types of by-products that may be considered as potential waste

Sources of agricultural by-products/waste	Types of agricultural by-product/waste
Farmers	Stem and leaf waste
Food growers	Cleaning and washing wastes
Food processors	Sorting waste and culls
Canneries	Peeling and coring waste
Packers and packaging manufacturers	Stone fruit waste
Frozen food producers	Milling waste
Food dehydrators	Waste water screenings
Restaurants	Brewing industry waste
Retailers	Sugar industry bagasse and beet pulp
Households	

An alternative view is to suggest that what does not leave the farm is not part of the materials flow. Thus if the farmer tops, shells or washes vegetables and retains the wastes, that remains part of the organic biomass of the farm and is not part of the agricultural materials flow. However, as most environmental statistics are compiled at the national, regional or local government unit level, the farm boundary distinction may not be quite so relevant.

Methodologies for assessing the hidden flows in crop production

1 Using the net primary productivity concept

The concept of "human appropriation of net primary productivity" (HANPP) has been used to assess how much of potential plant growth is turned to human use and to waste (Vitousek et al., 1986; Wright, 1990; Haberl, 1997, 2002). Calculating HANPP requires data on:

a) The annual productivity of potential vegetation (that which would be there if there were no human interference)

b) The annual productivity of the plant biomass that occupies the ground in that year (usually a complex mosaic of different types of land use)

c) The amount of biomass harvested each year.

Although good data exist on the net primary productivity (NPP) of above ground vegetation, that for below-ground biomass is poor and usually unreliable. The subsurface standing crop is not only difficult to measure, but varies seasonally. Thus most of the information on NPP relates to the above ground standing crop only. As harvesting of root crops and tubers is usually the only type of farm production that disturbs the root zone, except in these cases, it may be sufficient to deal with the above-ground biomass only.

The advantage of this measure is that because it relies on annual agricultural harvest statistics and on remote sensing of the state of the vegetation, measures for each year can be obtained, albeit after considerable work.

2 Calculating the by-products and wastes from crop production

A second approach to agricultural residues is to establish how much of the harvested material is left behind in the field. Leaves, stems and roots of cereal grains, left in the field after grain harvest, comprise from 50 to 75 per cent of the total cereal biomass produced by a season's grain crop. This cereal stubble that is left to accumulate on the ground reduces soil erosion by buffering the impact of raindrops and reducing wind speed at the soil surface. Cereal stubble also increases the water available in the soil for plant use by enhancing rainfall infiltration and reducing evaporation losses. Cereal straw accumulation and incorporation in the long term increases organic matter inputs into the soil, reduces the loss of plant nutrients and increases soil biological activity. Each type of residue makes different contributions to this process. Cereal residues added to the soil decompose to release nutrients they contain.

The indices suggested by various authorities are highly variable (Table 4.2). The values for wheat and sugar beet in the Technical Annex (Bringezu and Schütz, 2001) and in Kouikos and Diamantidis (1998) are similar but the lack of confirmed values for other crops and wide differences in straw:grain ratios between cereal crops make further evaluation necessary. Clearly yields and harvesting techniques vary greatly from area to area and are affected greatly by natural factors, such as climatic variability, and by human input factors, such as fertilisers. Thus assessments of the unused portions of harvested crops are bound to vary widely.

Table 4.2 Multipliers for agricultural by-products and wastes

Commodity	Factor reported in the Technical Annex to "Total Material Resource Flows of the United Kingdom"	Kouikos and Diamantidis, 1998 Ratio of by-product yield (t odm/ha) to average crop yield	Bauder, 2000 Straw:grain ratio	Environmental signals 2000 Environmental assessment report No 6
All forms of vegetation harvesting (including agriculture and forestry)				0.63
Wheat	0.46[1]	0.54	1.7	
Barley	0.46		1.5	
Oats	0.46		2.0	
Maize	0.46	1.31		
Oilseed rape		1.0		
Sunflower		3.16		
Potato				
Sugar beet	0.54	0.47		

1The Technical Annex applies a single multiplier to all cereals

3 Agricultural mass balance modelling

In their model of a total mass balance for European agriculture, Gerlagh and Gielen (1999) argue that EU data show that the cereal production of 205 million tonnes (Mt), provides 31 Mt for net exports, 107 Mt for fodder, 42 Mt for human consumption; 15 Mt for industrial purposes, and 6 Mt for seeds. Of the 42 Mt used by people, 11 Mt of cereals are wasted during the preparation of the 31 Mt actually consumed by people. This multiplier of approximately 35 per cent of cereals becoming hidden flows may be an underestimate as it only considers harvested material, not the residues left in the fields. Further work is needed to improve the multipliers for individual crops under UK conditions, especially to include important crops like oilseed rape and potatoes, and to discover the differences between the various cereal crops.

Agricultural hidden flows: pastoral

The huge movement of farm animals through livestock marketing, seasonal changes in pastures and the transport to slaughter houses, both within the country and overseas, means that animals carry the growth from grazing in one place to another, thus the waste they produce and the waste created when they are slaughtered is not just a function of the biomass and chemicals consumed on the last farm or feedlot on which they were kept. It is necessary to establish whether slaughtering of animals is more concentrated in some parts of the country than others.

Calculation of manure production in Europe (Gerlagh and Gielen, 1999) suggests that per animal yields of dry matter range from 2.5 tonnes per cow to 0.01 tonnes per chicken (Table 4.3).

Table 4.3 Manure production in Western European agriculture

Animal	Manure production per animal per year (tonnes) wet matter	Manure production per animal per year (tonnes) dry matter
Cattle	13.30	2.50
Sheep and goats	1.00	0.20
Pigs	1.10	0.13
Chickens	0.02	0.01

Source: Gerlagh and Gielen, 1999

Estimates of greenhouse gas emissions from farm animals suggest production of 3.1 Mt per year from manure, mainly as a result of anaerobic processes that occur during the storage of wet manure (Table 4.4). The nitrogen available in manure in Western European agriculture is about 12 Mt, some 7 Mt of which is related to cattle raising and 2.5 Mt to sheep and 2.5 Mt to pigs (Gerlagh and Gielen, 1999).

Table 4.4 Western European methane emissions related to manure by animal type and management system in 1990

Animal type	Methane emission Mt	Management system	Methane
Dairy cattle	1.1	Pasture/grazing	0.1
Other cattle	0.9	Liquid slurry	2.7
Pigs	0.9	Solid storage	0.1
Poultry	0.1	Lagoon/daily spread	0.0
Other animals	0.1	Other	0.1
Total	3.1	Total	3.1

Source: Gerbens 1999

Table 4.5 Livestock on agricultural holdings, June 2001 **Thousands**

	Total cattle herd	Dairy cows	Beef cows	Sheep and lambs	Pigs	Total fowls	Laying hens	Total poultry
United Kingdom	10,602	2,251	1,708	36,716	5,845	164,074	29,895	180,077

Source: Defra

The total UK herd of some 10 million cattle (Table 4.5) could imply 130 Mt of wet manure per year and the release of some 0.3 Mt of methane (multiplying the cattle numbers by the per capita outputs in table 5.3 and the UK proportion of the European herd of about 80 million by the European agricultural methane value in Table 4.4). This quantity is about one-third of the total methane emissions due to UK Agriculture (Table 5.6). The relationship between the European and UK methane statistics requires further examination. Critical appraisal of all these statistics is necessary before reliable coefficients can be calculated.

Soil erosion by grazing animals, particularly by sheep in the uplands is dealt with in Chapter 5.

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Chapter 5 - Importance of flows such as excavation, dredging, soil erosion, forestry operations, landfilling and land reclamation

This chapter sets out to identify importance of flows that occur directly and indirectly in activities that disturb the ground surface, from cuttings and embankment construction along motorways to the soil erosion of farmland and in managed forests and the deliberate deposition of material in landfills or for land reclamation from the sea or the reshaping of old mining and industrial areas. It also provides comments in the inclusion in materials flow analyses of recycled products and emissions to the atmosphere and some introductory ideas on the environmental impact of hidden flows.

Excavation (cut and fill) during construction of transport infrastructure and urbanisation

The environmental impact of increases in urbanisation and transportation infrastructure can be measured in terms of land usage (land covered in concrete) and also in terms of materials moved during excavation (cut and fill). These earth movements also constitute a permanent change in landform. The current figure of 132 Mt for on site cut and fill in the environmental accounts is an average annual figure based on mid 1990’s projections of increases in urbanisation between 1981 and 2016 and does not include estimations for cut and fill during the construction of transport infrastructure or other major civil engineering projects, such as tunnels or airport runways. Another important construction activity that uses large quantities of material is the construction of flood defence works along rivers and coastlines. Any generalised figure for the total mass of material moved by all these construction, land filling and reclamation activities has to be treated with caution. The masses involved may show considerable variation from year to year depending on the number of major projects requiring large quantities of excavation or fill.

Possible sources of useful data that can help provide estimates of construction related activity are:

- The National Statistics Land cover account, Great Britain 1990 to 1998, which has a comparison between 1990 and 1998 stock of “built up areas and gardens”.
- The National Statistics collection of historical construction data relating to contractor’s work only.
- Data supplied by the Office for the Deputy Prime Minister (ODPM) to National Statistics giving the results of land use change data collected by Ordnance Survey, in particular estimates of change to residential use, for England and regions. Includes percentage of new dwellings built on previously-developed land, densities, and changes to residential use within Green Belts and within Flood Risk areas. Full results, including changes to other urban uses and to rural uses and changes at county level, will be added to the ODPM website later this year.

- Department for Environment, food and Rural Affairs (Defra) published statistics on the previous use of land changing to residential use from 1992 – 2002, and showing the previous uses. Information relates to map changes recorded by Ordnance Survey as at the end of 2002, where the year of change has been estimated by surveyors from available information.

The methodology of these studies requires more detailed investigation than is possible under this review. For example, planning related data can be suspect because it invariably relates to planning applications granted and not to actual plans completed. Updating of mapped data will be time/space variable and there are problems in interpreting remote sensing and photographic data. Means of gaining representative samples of the tonnage of material shifted per unit length of roads of different types, of accounting for the materials shifted in major projects such as the construction of airport runways or the Channel Tunnel, and of establishing the mass of waste landfilled exist (Table 5.1), but much more refinement is need in relating these to house construction, other forms of urban development and other types of infrastructure establishment.

Table 5.1 Examples of masses of excavation related to specific infrastructure projects

Construction activity	Mass of material excavated Mt
Manchester Airport second runway	7.0
Channel Tunnel	20.0
London Underground Jubilee Line Extension	3.5
Thames Water London Ring Main	1.0
Conway Tunnel (A55)	10.0
A417-A419 dual carriageway (Cirencester)	(0.123 per km) 3.2
M65 (Blackburn)	(0.458 per km) 9.6

Source: Douglas and Lawson, 2002

Dredging and sediment transfers.

In the UK, approximately 40 million tonnes of dredged material are annually disposed of to the marine environment at estuarine and offshore sites licensed by Defra. Typically, about 80 per cent of the material arises from maintenance dredging, mostly muddy sand. The current total for the wet tonnes dredged at sea in the UK statistics is a Wuppertal Institute estimate based on an average of the available data. Current figures for sewage sludge and dredged material dumped at sea emanate from the Centre for Environment, Fisheries and Aquatic Science, a consultancy. Dredging at sea is usually a response to patterns of sedimentation by tidal and riverine action and is a human adjustment of coastal sediment budgets. Recording the quantities of materials removed from rivers and estuaries is important because of both the transfer of materials and the possible pollutant contained therein.

- Defra provide statistics for the annual amounts of both wet and dry dredged material dumped at sea. These statistics also include figures for various heavy metals dumped at sea, up to and including 2000.
- Defra provide annual estimates of direct inputs from land based sources to coastal waters and separate estimates of riverine inputs: suspended particulate matter, metals, nutrients and organic substances, up to and including 2001.

Table 5.2 Variation in dredging effort in or near selected UK marine SACs

Marine Special area of conservation	Port	Total estimated amounts of material dredged m^3 per year
Fal and Helford (England)	Falmouth	3,000-4,000
	Penryn	
	Truro	
Morecambe Bay	Barrow	
(England)	Fleetwood	1,270,000 – 2,670,000
	Heysham	
	Lancaster	
Pembrokeshire Islands	Milford Haven	50,000
(England)	Pembroke Dock	
Plymouth Sound and Estuaries	Cattewater Harbour	None
(England)	Millbay Docks	
	Sutton Harbour	
	Dockyard Port of Plymouth	Very small amounts of maintenance dredging per year
Severn Estuary	Avonmouth	
(England/Wales)	Bristol	
	Cardiff	3,460,000
	Barry	
	Newport	
	Sharpness	
	Gloucester	
	Watchet	
Strangford Lough	Strangford	1,500
(Northern Ireland)	Portaferry	

Marine aggregates

Marine aggregates are an important UK resource, with 22 to 26 Mt being extracted annually (Seaman, 2003). An average of 3.5 Mt per year is landed solely for coastal defence, mainly for beach restoration and replenishment. The Crown Estate collects statistics for all licensed dredging in the area of its jurisdiction out to the 12-mile limit (Table 5.3). Vessels are fitted with automatic monitors to measure their activity. Data from beyond the 12 mile limit may have to be obtained from individual companies, but the total quantity in the table is almost the same as Seaman's total quoted above. At present it is unclear what proportion of the marine aggregate supply comes from outside the 12-mile limit, but future resources towards the centre of the English channel have been identified.

Table 5.3 Crown Estate Regional Dredging Statistics from 1 January 2002 to 31 December 2002

Tonnes

Dredging Area	Permitted Removal	Actual Removal
Humber	4,650,000	3,023,227
East Coast	12,575,000	9,011,323
Thames	3,700,000	1,647,795
South	11,175,000	5,756,644
South West	3,191,000	1,467,122
North West	1,384,999	482,270
Rivers and Miscellaneous	N/A	545,302
Total	36,675,999	21,933,683

Source: Crown Estates

Waste land filling and land reclamation

ONS use figures supplied by Defra for industrial and commercial waste and from the Defra for municipal and household waste in their environmental accounts. The statistics for municipal solid waste arisings and disposal are considered robust, but those for industrial and commercial and construction and demolition waste require scrutiny. Recycling is increasing (see Table 5.4 for the reduction in the percentage of waste landfilled 1989-2001) and therefore the proportion of waste arising that is recycled ought to be considered separately to avoid double counting. Regional waste statistics are readily assembled for household waste from county and unitary authorities, but controlled waste and special waste is likely to be transported long distances to special disposal sites. It should also be noted that a considerable amount of household waste travels interregionally by train (e.g. from Greater Manchester to North Lincolnshire). Should the arising be located to the region in which they occur and the quantity landfilled to the other region? 8000 t of slate waste per day are planned to be moved by rail from the waste tips at Blaenau Ffestiniog in North Wales to Manchester and the West Midlands in England. Some of the transported waste may come from the old waste tips, thereby emphasising that a temporal difference in arisings and deposition as well as a spatial difference may occur. More attention to this issue is required.

Interregional waste traffic also raises the issue of the waste associated with imports. Some waste occurs from imported food (e.g. the peelings of imported potatoes may be composted and returned to the environment in the UK, but the waste foliage associated with their cultivation may remain in Cyprus or Egypt). Clear criteria for splitting the destinations of the waste associated with imports are needed.

Land reclamation includes restoration and even the translocation of natural wildlife habitats. Between 1990 and 1995 in England over 30 habitat translocations were undertaken, including heathlands, chalk downland and wet meadows totalling some 85000 m^3 of soils and vegetation, with material being moved up to 20 km. During two three or four month periods of 1998 and 1999, approximately 10,000 tonnes of mud (per year) was used for saltmarsh creation at Titchmarsh Marina, Walton on the Naze, Essex. Good statistics on all the different forms of earth movement for land restoration are hard to find. This is clearly an area for further research.

Table 5.4 Household waste statistics for the Lancashire County area (including Blackpool and Blackburn with Darwen

Tonnes per year

	1989-90	1990-92	1992-93	1993-94	1995-96	1996-97	1997-98	1998-99	1999-00	2000-01
Total waste tonnage	587575	-	651145	667907	659145	668893	726006	730791	785994	805666
Total waste landfill tonnage	575823	-	621843	607127	584002	579261	618557	625557	665737	682263
% waste landfilled	98	-	98.5	90.9	88.6	86.6	85.2	85.6	84.7	84

Emissions

Table 5.5 UK carbon dioxide emissions by source **Million tonnes (carbon)**

	1970	1980	1990	1995	2000	2001
Industry	96.6	76.7	65.5	58.1	56.3	58.0
Transport	20.5	25.7	39.1	39.7	41.8	41.6
Domestic	54.3	48.7	41.8	38.6	39.5	41.6
Services	14.3	13.5	13.2	13.1	10.6	10.6

Source: Defra

Defra has statistics on emissions of carbon dioxide, nitrous oxide and methane that can be related to general sources. The relative importance of the different sources is changing with a general decline in industrial emissions, but an increase in emissions from transport and little change in emissions from agriculture. Diffuse emissions from agriculture account for about 40 per cent on national methane and nitrogen emissions, but it remains difficult to get precise statistics on how, where and when they are produced.

Table 5.6 UK methane emissions by source **Million tonnes**

	1980	1990	1995	1999	2000	2001
Coal mines	1.140	0..735	0.464	0.286	0.245	0.223
Landfill	0.889	1.131	0.938	0.626	0.552	0.487
Agriculture	1.006	1.034	1.008	1.005	0.971	0.914
Gas leakage	0.354	0.398	0.374	0.349	0.336	0.343
Other sources	0.430	0.362	0.277	0.237	0.220	0.229
Total emissions	**3.819**	**3.661**	**3.062**	**2.503**	**2.323**	**2.195**

Source: Defra

Forestry Operations

Forestry woodfuel include biomass not harvested or removed from logging sites in commercial hardwood and softwood stands as well as material resulting from forest management operations such as pre-commercial thinnings and removal of dead and dying trees. Up to 50 per cent of the above ground biomass may be left behind after forestry operations. Wood is the most commonly used biomass fuel for heat and power, and unwanted woody waste is a by-product of many forestry operations. Using these materials for electricity generation recovers their energy value while avoiding landfill disposal.

Table 5.7 UK timber production 2001-02 **Thousands of cubic metres overbark standing**

	Conifers			Broadleaves	Total
	(Forestry Commission)	(Non- Forestry Commission)	Total		
2001	5,140	3,480	8,630	710	9,340
2002	5,210	3,630	8,840	690	9,530

Source: Forestry Facts and Figures 2003

Forestry woodfuel includes under-utilised logging brash, poor quality commercial trees, dead wood and other non-commercial trees that need to be thinned. Forest thinning is necessary to help some forests regain their vigour, but for smaller woodlands the cost of removing the wood cannot be recovered through timber sales. Therefore a large supply of woodfuel is currently unmarketed but could be converted to biomass power or biofuels.

Present potential resource in the absence of competing markets

The total potential operationally available woodfuel in Britain during the present forecast period of 2003-06, in the absence of competing markets, is 3.1 million odt y^{-1}. The main sources are small roundwood followed by sawmill co-product (potential to contribute around 1.03 and 0.86 million odt y^{-1} respectively) with arboricultural arisings providing about 14% of the total. Approximately equal quantities are available in England and Scotland but the composition is substantially different. Arboricultural arisings form the major element in England though sawmill co-product, small roundwood, and branches are all significant components. In Scotland and Wales, small roundwood and sawmill co-product are the dominant resources with all other potential resource streams playing only a minor part. Unless establishment of fast growing species such as short rotation coppice increases substantially, it will remain a minor component of the potential woodfuel mix.

Table 5.8 - Current potential operationally available woodfuel resource in the absence of competing markets by country

Thousand oven dry tonnes y^{-1}

Product	Scotland	England	Wales	Britain
Stemwood 7-14cm diameter	606	298	128	1032
Poor quality stemwood	113	94	70	278
Stem tips	12	14	5	31
Branches	116	225	68	410
Sawmill conversion products	404	290	166	859
Arboricultural arisings	22	456	14	492
Short rotation coppice	0.6	16	0.2	17
Total	**1,268**	**1,382**	**449**	**3,119**

Source: Forestry Commission

Present potential resource taking account of existing industries

The potential GB resource that could be made available to new woodfuel projects without serious disruption to existing wood-using industries is estimated to be 1.26 million odt y^{-1}. Assumptions on market availability are:

10% of the small roundwood

100% of poor quality stemwood, stem tips and branches

10% of sawmill co-product

100% unmarketed arboricultural arisings

100% of material from clearance of utilities and roadside maintenance

80% of short rotation coppice in England, i.e. all coppice other than that established under the Energy Crop Scheme, and 100% short rotation coppice in Scotland and Wales.

Table 5.9 Current potential operationally available woodfuel resource in the presence of competing markets by country

Thousand oven dry tonnes y^{-1}

Product	Scotland	England	Wales	Britain
Stemwood 7-14cm diameter	61	30	13	103
Poor quality stemwood	113	94	70	278
Stem tips	12	14	5	31
Branches	116	225	68	410
Sawmill conversion products	40	29	17	86
Arboricultural arisings	18	313	10	341
Short rotation coppice	0.6	13	0.2	14
Total	**356**	**707**	**180**	**1,263**

Source: Forestry Commission

Soil erosion in material flows

Components of soil loss

Particulate and dissolved matter

Normally soil loss is discussed in terms of the mass of soil particles removed per unit areas per unit time, usually in t km^{-2} y^{-1} or kg ha y^{-1}. The dissolved component can change with the transport of the soil material downslope. Substances can be lost from particles and other substances may be precipitated on to the surface of particles. Normally field measurements at the plot scale of soil erosion only deal with solid matter, whereas river measurements usually report both dissolved solids and particulate loads. Sometimes particulate loads are divided into suspended sediment and bed load. Quite often bed load is estimated from suspended load measurements.

Sources of soil erosion

Soil loss from arable agriculture

Soil erosion is usually thought of as loss from ploughed fields. All the classic images of the dust bowl relate to soil loss from ploughing and cultivation. Probably the soil erosion estimates used in the USA and Germany relate to estimates of total erosion from arable agriculture in the countries concerned.

Soil loss from grazing animals

Grazing animals are a major factor in soil erosion in the uplands of the UK. Sheep have had major impacts on erosion of the moorlands and probably contribute to much degradation of upland peat areas.

Soil loss from forestry activities

Drainage for afforestation of upland areas has led to higher rates of soil loss than before. Some good data on such soil loss rates are available, but data are required on the annual amount of new afforestation.

Soil loss from unsealed roads and tracks

Both agricultural and forestry activities use unsealed roads and tracks, often in steep country, which are liable to erosion. Few data are available for the length of such eroding tracks or for soil loss from them.

Soil loss from construction activities

Construction disturbs the ground surface and exposes soil to the erosive action of wind and water. The periods of exposure in any one place are usually short and the amount of soil lost depends on both the nature of the soil and the magnitude of erosive events (high winds, heavy rain) during that period of exposure. Data for erosion in newly urbanising areas of the UK are available, but will be difficult to apply generally with confidence.

Soil loss from mining and quarrying

By exposing both cut surfaces and waste tips to erosive agents, mining and quarrying may contribute to soil loss. However it might be argued that the soil lost in already accounted for in the calculations of overburden removal and mining waste.

Soil loss from recreational activities

Increasingly countryside and peri-urban recreation is leading to soil erosion in intensively used sites and along footpaths. Some particular activities, such as off-road vehicle use and motorcycle scrambling, locally produce intense soil erosion, but the total area so affected is small. Footpath erosion in upland National Parks, together with sheep grazing, is believed to cause 75 per cent of the erosion in the hills (McHugh et al., 2002).

Soil loss from derelict land

Many areas of derelict land have patches of bare soil that are liable to erosion. It may be possible to calculate the fraction of the known total area of derelict land that is actively eroding and to get a figure for the average annual soil loss from such areas.

Variability of soil erosion in time

Soil is lost in discrete erosive events, such as brief periods of high winds or major rainstorms.

Inter-annual variability

Soil loss rates from individual fields or headwater catchments vary widely from year to year. Long-term soil loss rates are more meaningful but are not easily obtained. How do these considerations relate to ONS' reporting of annual material flows?

Extreme natural events

Rare events carry disproportionately large amounts of eroded soil. Data on these extreme event loads are not readily available, save for a few long-term studies. It is important to identify these extreme values.

Periods of disturbance

Periods of land-use change, such as change from agricultural to urban use or grazing to forestry, are often critical for soil loss. Probably the only way to incorporate these into a calculation is to consider how much such change occurs in an average year. Ideally, we need to know the amount of such conversion for every year, but even then its impact on soil erosion will depend on the nature of the affected soils, the part of the country it is in and the techniques used to reduce erosion during the conversion process.

The sediment yield problem

Soil removal

Soil erosion is the detachment and transport of soil particles. Any individual particle may be simply removed from its original position and re-deposited a centimetre or more further downslope. Other particles may be transported all the way from their original position to stream channels. Thus, in terms of availability of soil for arable agricultural production, eroded soil in the same field is still available for productive use, that carried to rivers is not.

Soil deposition

Eroded soil can be deposited at many sites within a river catchment system, anywhere on the slope above the stream, on the flood plain, in the stream channel, by overbank flood flows and in any reservoir or behind any weir in the river channel.

Catchment sediment budgets

An elegant way of examining how eroded soil gets transported through river systems is to use the catchment sediment budget which identifies and links sediment sources and places of sediment deposition. Quine and Walling (1992) examined 13 sites in southern England by use of Caesium 137 and found a sediment delivery ratio of 27-86 per cent. The sediment budget of the river Severn was calculated by Chernobyl - derived radionuclides. The result was that only 24 per cent of the sediments were deposited in the floodplains and about 75 per cent contributed to the output by the river.

Actual soil erosion figures to use?

The key issue is the precise soil loss figure to use. We must clarify whether we are solely concerned with arable agriculture and loss from productive fields or with some other dimension of the soil erosion problem. Two sets of reasonably reliable data are available from small scale plot studies in many locations of erosion in arable fields, essentially in the south-east of England (Evans, 1990) and in the grazing and peatland areas of the uplands of England and Wales (Mc Hugh et al., 2002). The mean values obtained from those investigations are set out below (Tables 5.8 and 5.9), but there is wide variation from year to year in erosion, partly depending on the number and magnitude of heavy rainfalls.

Table 5.8 Soil loss by rill erosion from fields in England

Mean results of plot experiments			
	1982	**1983**	**1984**
Area of fields affected by rilling %	6.10	8.50	8.30
Area of rilled soils in fields %	12.60	17.20	9.00
Volumes of soil eroded m^3 $ha^{-1}yr^{-1}$	2.72	2.99	1.60

Source: Evans, 1990

Evans' work (1990) suggests that if the erosion due to rilling on arable fields is added to that by surface wash, then the mean annual soil loss from arable fields in lowland England will be less than 2.8 t ha^{-1} yr^{-1} or less than 3.68 Mt per year for the whole arable area. In 2003 the Environment Agency website reported that recent research has estimated that 2.2 million tonnes of soil per year are lost from 26,300km2 of arable land in England through erosion by water.

For the uplands, erosion data are scarcer, but McHugh et al. (2002) emphasise that sheep grazing is a major factor in upland erosion and thus agricultural productivity should include an erosion estimate for that caused by sheep as well as that from arable land.

Table 5.9 Soil loss by surface wash from arable land in lowland England

Soil and crop/ ground cover	Soil eroded by surface wash $m^3\ ha^{-1} yr^{-1}$	Soil eroded $t\ ha^{-1}\ yr^{-1}$ assuming bulk density is 1.4.
Bedfordshire		
Sandy soil under resown grass	0.78	1.09
Medium loam under winter cereals	0.32	0.45
Clay under cereals	0.27	0.38
Chalky medium silt under winter cereals	0.25	0.35
Kent		
Bare medium loam between apple trees	0.32	0.45
Somerset		
Medium and light silts	0.37	0.52
Tamar Valley (Devon-Cornwall)		
Bare soil	1.00	1.40
Ploughed soil	0.15	0.21
Oilseed rape	0.10	0.14
Suggested general maximum for lowland arable land	0.3	0.42

Source: Evans, 1990

Environmental impact of hidden flows

The hidden flows can have great environmental and social consequences. Old, poorly regulated landfills can become “chemical time bombs” within which there is a build-up of gases that may explode. Leachates from old landfills may escape to adjacent groundwater and rivers. The Aberfan disaster reminded everyone of the possibly tragic consequences of unstable tips of mining waste. However, many hidden flows are less visually apparent but equally dangerous to human and environmental health. Possibly the greatest problems are linked to nitrogen in the environment. While it is necessary to apply nitrogen to increase crop yields, it is often added in excess and this wreaks havoc with our health and that of our land, air, and water. The excess nitrogen enters the air, creating smog and small particles that cause respiratory ailments in people. It also falls back to the surface as acid rain, corroding buildings, harming plants, and acidifying lakes and streams. In addition, it drifts higher in the atmosphere in a form that adds to global warming as well as stratospheric ozone depletion. Excess reactive nitrogen also flows directly from the land into rivers and then to the coastal oceans where it causes numerous problems, including oxygen-starved coastal waters that cannot support many forms of marine life. Much is now known about nitrogen release and the pathways it takes through soils, rocks and streams to rivers and the coastline in the UK, but quantifying the rate at which it flows through these pathways is difficult. Sometimes nitrogen takes 10 years or more to pass through groundwater systems from the field where it is applied to the springs from which urban water supplies are drawn.

This type of diffuse impact of hidden flows is becoming a critical problem. Environmental accounts need to try to encapsulate the magnitude of some of them, but a careful blending of the latest science and data on the levels of application of agricultural chemicals are need. This requires much careful work.

Opportunities for re-using the material in hidden flows require further exploration. Even though landscape restoration has become a fine art, there are still waste streams that need new end uses and new destinations, particularly the fine "soil material" emerging from municipal waste and the sludge from sewage treatment. Urban renewal supplies large quantities of construction and demolition waste much of which is used on site, but much more of which could be recycled. The materials flows accounting approach to urban and industrial metabolism has already indicated the potential for using crushed concrete instead of natural aggregates. Most asphalt planings are already re-used in road construction and maintenance. However, the analyses do not look at the land that could be saved from disturbance and the off-site effects that could be avoided if less natural aggregate were used. These indirect hidden flows and costs need attention. Perhaps materials flow accounting should pick up how these re-use activities reduce "hidden flows" over time.

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Chapter 6 - Future research agenda

Problems remain in how hidden flows are defined. Many of the interpretations of hidden flows are ambiguous. In many cases, deliberate discard of materials by human action is merely aiding natural processes of nutrient cycling. For example, harvesting results in a loss of biomass, such as leaves, branches, trunks, that are left on-site to decay. They are part of the natural nutrient circulation and hence help rather than harm nature. It is also questionable if material flows for the soil improvement of agricultural land, such as earth moving by harrowing, should be registered as use of natural resources. Earth moving in cultivated areas does not involve the use of virgin natural resources and the operation improves the quality of land (Juutinen and Mäenpää, 1999).

A further issue concerns materials that are imported but enter the stocks. Should the hidden flows of imports include the materials of machines, equipment and buildings used in their production and how should they be divided between products? The problem is critical if the hidden flows involved in the transportation of imports are included in the Total Material Requirement (TMR). Large material flows are usually involved in building the transportation infrastructure. The TMR method has not yet developed an accepted standard practice in dealing with long-lasting material flows.

Research implications

1. Classification of 'material flow' and 'hidden flow'

The generally accepted definitions suggest that:

- Material input: where substances come from the 'natural' environment i.e. without direct economic value, into 'use' i.e. the economic environment.
- Hidden flow: materials which are moved or disturbed but which are not used i.e. have no economic value.

This definition needs closer scrutiny because:

- There is growing awareness of the material cycles affecting and involved in all human activity.
- A key implication of the goal of 'resource efficiency' is to move the economic boundary, so that waste with zero or negative value becomes a 'resource' with positive value.
- A further implication is that materials will be extracted from former wastes or disturbed land.

2. Establishing reliable coefficients

The review in the preceding chapters suggests reasonable confidence in the hidden flows associated with most forms of mineral production, especially from large-scale commercial enterprises. Imports are not always treated so carefully, unless the characteristics of mining in the major supplier countries are well known. As agriculture is now one of the major sources of pollutants entering natural waters and the atmosphere, particular attention is needed to the residues from specific cereal and other crops, to manure production and to other forms of animal waste. Soil erosion from arable land is not the only form of soil erosion that occurs as a result of materials flows and the consequences of overgrazing in the uplands require special attention. As soil erosion is a process driven by climatic variables such as rain and wind, it is not constant from year to year and an effective way of linking the influence of climate on soil erosion to the areas under different forms of land use is needed to get a meaningful answer to the year-to-year variation in soil erosion.

The forestry sector also requires careful attention, as biomass harvesting on an industrial scale, especially for power generation by biomass burning, can lead to a decline in soil nutrient status and environmental impoverishment. Soil erosion in forestry operations tends to be high due to operations using machinery on steep slopes. The data available to calculate coefficients are at present inadequate and a more comprehensive approach is required.

The need for attention to the coefficients in the fishing industry was set out in Chapter 4.

3. Physical input-output table (PIOT) systems of accounts

As set out in Chapter 3 PIOT provide a powerful comprehensive and consistent data set for analysing the linkages between economy and nature. The methodologies are quite well-developed, but having accurate data to fill all the appropriate cells in the tables will remain a problem while some of the coefficients for hidden flows are unreliable. A second factor is the ability of the PIOT designers to think of all the linkages and pathways involved. Physical scientists studying pollution recognise that they cannot always recognise all the possible pathways a contaminant may take through the different components of a river basin and its associated soil and groundwater system. Likewise materials flow analysts need to think about all the opportunities for re-use of “waste” materials and the way in which different components and outputs of a manufacturing process may be disposed of.

4. Spatial hierarchy

At present in the accounting system there is no distinction between material flows which travel 0.01 mm and 1000km, except that of the economic boundary, i.e. that costs will usually dictate that zero value material travels the least possible distance. This is not necessarily the case: where processing is carried out at a distance from extraction, as transport costs reduce, it will be ‘economic’ for material to be carried further.

This suggests some kind of hierarchy:

- Disturbance
- Small movement
- Movement in proximity to extraction
- Movement on site
- Movement in the region / country
- International movement

Such a hierarchy suggests that we need to be able to establish regional systems of materials flow accounts.

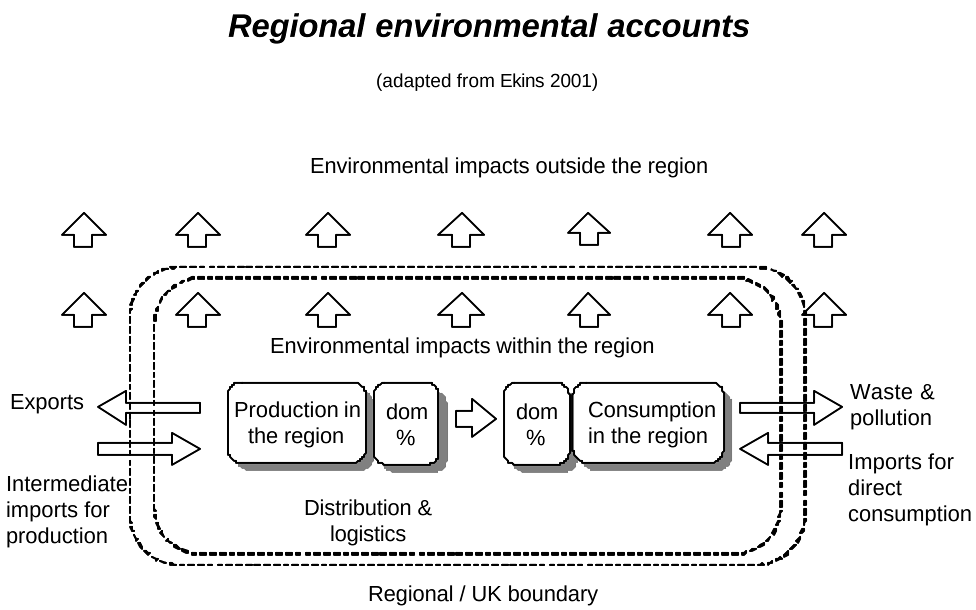

Fig 6.1 A possible framework for regional material flow accounts.

Many authors have worked on urban metabolism, from the classic study of Hong Kong to modern work on Stockholm. However boundary issues have meant that most studies have had to assume that cities that are not totally separate physically (on islands) or administratively, consume most materials at the same rate per capita as the rest of the country.

In the national context, it is particularly important to identify the hidden offshore flows associated with imports that affect life and the environment in other countries.

5. Temporal hierarchy

Again there is no distinction in the accounts between materials that are separated at source or the point of extraction and become hidden flows at that time and those materials that may take 100 years to finally become part of the urban system waste stream. Construction and demolition waste is a good case. A time hierarchy would look at scales from nanoseconds to millennia.

In any one locality or city, there may be periods of urban renewal when large waste flows are created through demolition and reconstruction, although the landfill and aggregates taxes are increasing incentives to used crushed demolition waste on site. Recycling opportunities for demolition waste depend on the waste being in the right place at the right time, at least until such time as organised stores of such waste are established in accessible locations. The closure of a railway for example changes the track ballast from a stock to a waste that may have some potential for re-use. While on the national scale, such temporal lags may not be too significant in the total materials flow, they may become significant in the budgets for small areas and cities.

6. Economic hierarchy

An issue arises over the moment when material becomes an economic good. In cut and fill operations on a major road development, the earth moved to build a cutting is waste, and thus a “hidden flow”, but does it become an economic resource when it is dumped further down the road to create an embankment? In this report all the shifted material is lumped together as “hidden flow” material, but if the material from the cutting were not available a cost would be involved in getting material from a quarry where it would clearly bee seen as part of an economic materials flow.

7. Information management

The diversity of flows that could be measured is extremely large. Many are neither easy nor practical to measure. There is thus a need to prioritise the derivation of coefficients. With crushed stone accounting for around 150 Mt of the UK materials flows and domestic potash only 0.9 Mt, it is much more important to get the hidden flow coefficient for crushed rock correct than that for potash, although for imports the value of diamonds, gold and copper are such that large hidden flows are involved for small quantities of traded materials.

An agreed hierarchy of importance should be developed and the coefficients for those commodities whose total hidden flows are going to be the largest will have to be dealt with first. If there are commodities for which the possible magnitude of hidden flows is not known (diamonds may be such a case), attention should also be paid to them.

In any system developed for the UK, there should be some coordination and compatibility with other accounting systems such as those of Eurostat.

Mineral extraction data could be approached more comprehensively through a simple matrix focusing on the ‘discard’, i.e. to ask operators ‘how much material goes to waste’ as suggested in Chapter 2. However, it might also be approached in a more analytic way, by looking closely at the different kinds of flows and drawing appropriate boundaries, in the light of the comment above (Fig. 6.2):

For agricultural inputs: arable, grazing and forestry, the difference from minerals is that the organic matter produced is part of a complex nutrient flow to which any residues left on site will return. Clear decisions need to be made about how we established the boundaries of biomass hidden flows in terms of their impact on the sustainability of land management operations.

Fig. 6.2 Possible matrix for the analysis of flows related to minerals extraction

Environmental cycles	Factors of production	Physical flows	'Use' - Input to economic system	Processes
	Construction, transport etc off site			
Landscape change etc	Construction, transport etc on site			
		Material Extracted	>>>>>>>>>>>	Sorting / processing
Direct soil erosion etc		Waste material from washing & grading	Storage for eventual use	Wastes / vapour etc from processing
Moisture cycles etc		Tailings from sorting & gradings	Storage for eventual use	Recycling of grey water
Substance flux		Overburden moved		
		Soil disturbed		

8. Production & consumption

Attention is needed to the issue of hidden flows from the destruction of discarded urban stock and infrastructure. How for example do we deal with redundant infrastructure and industrial dereliction, abandoned mines and quarries that eventually undergo restoration? Presumably they are treated as construction and demolition waste in the year of clearance and rebuilding. Some sites, such as former industrial coking and coal chemical by-product plants, take many years to clear. They may also contain residual chemicals in holding areas such as tar lagoons that may continue to be present long after all the other infrastructure is removed. These industrial wastes are still potential flows into the environment, either when they are finally removed or when they leak and release substances to drainage channels or groundwater bodies. Attention should also be given to the hidden flows balance if landfill mining becomes more prevalent than it is now.

Conclusion

As with many branches of human enquiry, as new forms of scientific endeavour develop, the easily tackled issues get dealt with first. This is the case with the hidden flows in materials flow. Some confidence can expressed in the data for domestic minerals and municipal waste flows, but more difficult but significant areas such as the agricultural and biomass coefficients and those associated with many imported materials require further attention. Several definitional problems remain for which it would be good to have agreed European or international standards.

References

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