Materials Use and Induced Energy Demand: an Input-Output Analysis

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Paper to be presented at the
Intermediate International Input-Output Meeting
on Sustainability, Trade and Productivity
July 26-28, 2006, Sendai, Japan

Abstract:
This paper explores the relationship between materials use and energy demand and the potential of input-output analysis to illuminate this relationship. A significant part of energy demand in developed countries is due to the provision of material goods to society, which involves complex networks of production and distribution activities that all need energy. Material efficiency improvement strategies aiming at redesigning these networks, e.g. by more efficient materials use, product reuse and recycling or materials substitution, could therefore indirectly also reduce energy consumption. To assess the overall potential of material efficiency improvement for reducing energy demand, a first step is to estimate how much energy is needed for the provision of material goods. A few studies based on detailed process analysis have aimed at highlighting this issue, but have remained partial. Input-output analysis offers possibilities for a more comprehensive picture, though at a higher aggregation level. In this paper a calculus is proposed for a comprehensive assessment of energy demand induced by the supply of material goods. It includes materials use at the various levels of intermediate and final demand, the complete supply chains from resource extraction to the distribution of commodities and also considers energy demand related to imported commodities. An application of this calculus to the case of Germany shows that almost 50 % of total energy demand are induced by materials use. The contributions of the various economic sectors to this result are highlighted. To outline priority areas for material efficiency improvement from an energy perspective, the results are further disaggregated to groups of material goods, which are differentiated by characteristics such as material properties, product life spans or final uses. The paper concludes with a discussion of the approach.

1 Materials use, material efficiency and energy demand

In industrial countries a significant share of total energy consumption is used to provide society with material goods. Each material good travels through a complex chain of processes until it is in the hand of the final user. This process chain or product life cycle usually starts with resource extraction, contains various manufacturing steps and finally the product is distributed to the user through trade and transport activities. After having been used - sometimes in several consecutive use phases - it turns into waste that is either disposed of or recycled. Each of these steps requires energy or influences energy demand. Industrial manufacturing processes directly need energy, though their energy intensity varies strongly according to the basic materials involved. Material characteristics such as specific weight or volume can influence energy demand in the distribution phase. For some goods they also play a role in the use phase. Vehicle weight for instance, which is highly determined by materials composition, has a strong influence on fuel demand. The duration of the use phase determines the time of replacement and thus the level of manufacturing needed for product replacement. Finally the choice of the disposal route can also lead to additional energy demand for collecting and treating waste or reduce energy demand via incineration, recycling or reuse of products and parts. Thus energy consumption is indirectly affected by the way material goods are produced, used and disposed of.

Usually the main focus of energy conservation strategies is laid on improving the efficiency of energy conversion and energy use. But energy consumption can also be reduced by improving the efficiency of the materials system. Several generic options for improving material efficiency exist, which can address the manufacturing, the use as well as the waste management phases of a product life cycle. Their applicability and potential for material efficiency improvement (MEI) strongly depend on the specific material or product characteristics. These options can be classified as follows, though they are actually interdependent (see Nathani/Jochem, 2004 or Worrell, 1995 for further characterisations):

- more efficient use of materials in manufacturing, thus directly reducing materials use (e.g. reducing paper density);
- more efficient use of final products (e.g. double sided printing and copying of paper);
- materials substitution (e.g. use of light weight materials in cars, thus reducing fuel demand in the use phase);
- recycling and reuse of production waste and discarded products or product parts at different levels (e.g. plastics recycling or reuse of copying machine parts), thus reducing the production level of virgin materials, of new products or product parts;

- design of more durable goods, thus extending product lifetime and reducing the production of new products needed for replacement;
- material efficient product substitution, which can also comprise the replacement of material goods by services or more efficient combinations of services and material goods (e.g. car sharing).

In the field of industrial ecology these groups of measures and their potential environmental benefits have been extensively studied (see e.g. articles in the Journal of Industrial Ecology). Several studies have focused on the links between the materials and the energy system and the potential of material efficiency improvement for saving energy or reducing CO_2 emissions (e.g. Worrell et al., 1995; Gielen, 1998; Jochem, 2004). Most of these studies are based on bottom-up, technology-based methods like process chain analysis or material flow analysis (MFA), in which networks of interlinked processes for delivering materials or final products are analysed. Some have concentrated on certain product groups (e.g. packaging materials, see Hekkert et al., 2000a, Hekkert et al., 2000b) while others have provided overviews for the major basic materials (e.g. Gielen, 1999 or Kram et al., 2001). These studies show that material efficiency improvement can make significant contributions to energy conservation.

In this context it is of interest how large the overall contribution of MEI options to reducing energy demand could be. Due to the enormous complexity of the materials system this question is difficult to answer. A first step towards an answer would be to estimate the total amount of energy used for producing and delivering material goods. This is the focus of the paper at hand.

An analysis of existing studies has shown some results for indicators related to energy demand such as CO_2 or greenhouse gas emissions and fossil fuel depletion. Gielen (1998) analysed the cradle-to-gate[1] CO_2 emissions for the most energy-intensive bulk materials in Western Europe with a MFA approach. According to this estimate CO_2 emissions amount to approximately 900 Mt or 25% of total Western European CO_2 emissions. In a more recent similar study Phylipsen et al. (2002) estimated the environmental impacts of the production of a similar set of basic materials and compared them to total environmental impacts in Western Europe. The necessary environmental impact information was taken from a life cycle assessment database. They included the materials' life cycles up to manufacturing of the basic materials as well as recycling and waste disposal. Further processing of the materials to the final products, distribution and the use phase were not considered. For the impact categories 'climate change' and 'fossil

1 The term cradle-to-gate refers to system boundaries that include in a life cycle sense all process steps from resource extraction to the manufacturing of the respective material or product. The related term cradle-to-grave additionally includes the downstream steps further manufacturing, distribution, use and waste management.

fuel depletion‘ that are related to energy consumption they reported shares of 16 % and 28 % respectively. These studies have the advantage of covering many energy-intensive materials with great detail. Still they remain partial since they do not consider the further processing of basic materials into final products and trade and transport of these final products.

Input-output analysis allows for a more comprehensive estimation of energy demand induced by the supply of material goods – though on a higher aggregation level - and thus offers a different and complementary perspective on this issue. In this paper an adequate calculus for illuminating the relationship between materials use and energy demand is proposed and applied to the case of Germany.

In the following section the calculus is presented. Section three contains the results of the calculations for Germany. Section four concludes with a summary and a discussion of the approach.

2 A calculus for the estimation of energy demand induced by the supply of material goods

The aim of the calculus is to cover the use of material goods or materials on all levels of the economy. The approach follows three steps. In the first and crucial step it is necessary to determine the demand for material goods and related activities (e.g. trade and transport) at the various levels in a way that double counting is avoided. In the second step the total, i.e. direct and indirect production output needed to meet that demand is calculated by using the Leontief inverse and finally the energy demand related to that output is quantified.

The sectoral structure of an input-output table allows to discriminate sectors producing material goods from the other sectors. Essentially these are the primary sector, the resource extraction sectors (excluding the extraction of energy carriers), the manufacturing industries, the construction industry and finally trade and transport services (excluding passenger transport). At the first level the demand for goods provided by these sectors, which has to be determined, includes final demand. At the second level materials are needed as inputs for the production of all the non-material goods, i.e. predominantly energy and services. At the next level material goods as inputs for the non-material inputs for non-material final demand have to be captured and so on (see Figure 1). By following this scheme demand for materials in the economy can be covered comprehensively. Materials as inputs to production of materials are covered in the next step, where output in the total supply chain of the materials determined in the first step is calculated.

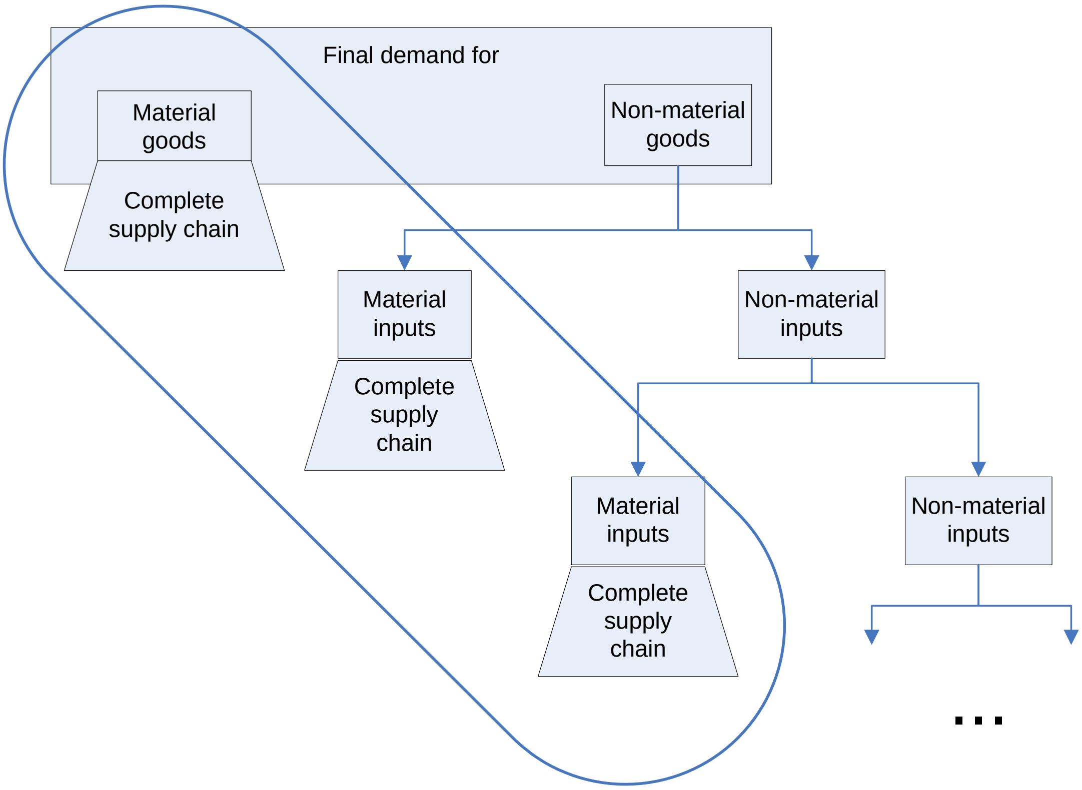

Figure 1: The use of material goods at the different economic levels

With regard to the system boundaries of the analysis, the energy demand of a country can be viewed from two perspectives, a production-oriented and a consumption-oriented perspective. These two perspectives differ with regard to the allocation of energy demand in the producing sectors. In the production-oriented perspective the domestic energy used for the production of goods in a country is counted. In the consumption oriented perspective the energy used for producing the goods consumed in a country is recorded, regardless of the origin of the products consumed. In this case the energy demand in foreign countries for manufacturing the imported goods has to be included. In the present work - as in several other input-output based studies - this is done by assuming domestic production relations for the imported goods.

In developing the calculus we can start with final demand for domestic material goods and the related trade and transport services. Regarding transport services, we have to seperate transport of final demand goods from passenger transport which has no relation to the use of material goods.

Final demand for domestic material goods and related distribution services is calculated as

$$Y_m^{dom} = H_m \cdot (Y^{dom} - Y_{pt}^{dom}) \tag{1}$$

with H_m: a diagonal matrix filtering the sectors that produce or distribute material goods (i.e. including trade and transport sectors); for sectors producing material goods the value on the diagonal is equal to one and otherwise zero

Y_m^{dom}: matrix of domestic final demand

Y_{pt}^{dom}: matrix of domestic final demand for passenger transport services

Final demand for non-material goods then results as

$$Y_{nm}^{dom} = Y^{dom} - Y_m^{dom} \tag{2}$$

At the next level we have to include the material inputs for the production of non-material final demand goods. These are calculated as

$$V_{m,1}^{dom} = H_m \cdot A \cdot Y_{nm}^{dom} \tag{3}$$

with A: the standard domestic input coefficient matrix

The second-round material inputs for first-round non-material inputs then follow as

$$\begin{aligned} V_{m,2}^{dom} &= H_m \cdot A \cdot (A \cdot Y_{nm}^{dom} - (H_m \cdot A \cdot Y_{nm}^{dom})) \\ &= H_m \cdot A \cdot ((I - H_m) \cdot A \cdot Y_{nm}^{dom}) \end{aligned} \tag{4}$$

The material inputs of the following levels follow the same scheme. We therefore can express the total use of material goods on all levels of the economy as

$$\begin{aligned} V_{m.tot}^{dom} = & Y_m^{dom} \\ & + H_m \cdot A \cdot Y_{nm}^{dom} \\ & + H_m \cdot A \cdot [(I - H_m) \cdot A \cdot Y_{nm}^{dom}] \\ & + H_m \cdot A \cdot \{(I - H_m) \cdot A \cdot [(I - H_m) \cdot A \cdot Y_{nm}^{dom}]\} \\ & + ... \end{aligned} \tag{5}$$

We can rewrite this expression as

$$\begin{aligned} V_{m,tot}^{dom} = & Y_m^{dom} \\ & + H_m \cdot A \cdot [Y_{nm}^{dom} + (I - H_m) \cdot A \cdot Y_{nm}^{dom}) \\ & \qquad + (I - H_m) \cdot A \cdot (I - H_m) \cdot A \cdot Y_{nm}^{dom}) \\ & \qquad + ...] \\ = & Y_m^{dom} + H_m \cdot A \cdot [\sum_{n=0}^{\infty} ((I - H_m) \cdot A)^n] \cdot Y_{nm}^{dom} \end{aligned} \tag{6}$$

Similar to the derivation of the Leontief inverse we can express the power series as an inverse, provided the inverse of $[I - (I - H_m) \cdot A]$ exists:

$$V_{m,tot}^{dom} = Y_m^{dom} + H_m \cdot A \cdot [I - (I - H_m)A]^{-1} \cdot Y_{nm}^{dom} \tag{7}$$

The domestic gross output induced by this use of material goods on all levels is then calculated by premultiplication with the Leontief inverse:

$$X_{m,tot}^{dom} = (I - A)^{-1} \cdot V_{m,tot}^{dom} \tag{8}$$

Finally domestic energy demand follows as

$$E_{m,tot}^{dom} = \hat{e} \cdot X_{m,tot}^{dom} \tag{9}$$

with $\hat{e}$: the diagonalised vector of sectoral specific energy intensities, calculated for each sector by division of energy demand by gross output.

The use of material goods also induces gross production and energy demand in foreign countries through the use of imported goods.

The total demand for imported material goods is the sum of

- material goods directly imported for final demand, and
- imported material inputs used in the production of domestic non-material goods on the various economic levels

In order to capture the total output effect abroad we need to add to this demand the imported inputs used in the production of domestic final demand material goods.

Similar to equation 6 the resulting demand for imported goods can be formulated as

$$\begin{aligned} V_{m,tot}^{imp} = {} & Y_m^{imp} + A^{imp} \cdot Y_m^{dom} + (H_m \cdot A^{imp} \cdot Y_{nm}^{dom}) \\ & + H_m \cdot A^{imp} \cdot [(I - H_m) \cdot A \cdot Y_{nm}^{dom}] \\ & + H_m \cdot A^{imp} \cdot \{(I - H_m) \cdot A \cdot [(I - H_m) \cdot A \cdot Y_{nm}^{dom}]\} \\ & + \ldots \end{aligned} \tag{10}$$

which - provided the inverse of $[I - (I - H_m) \cdot A]$ exists - again can be reformulated as

$$\begin{aligned} V_{m,tot}^{imp} &= Y_m^{imp} + A^{imp} \cdot Y_m^{dom} + \{H_m \cdot A^{imp} \cdot [\sum_{n=0}^{\infty} ((I - H_m) \cdot A)^n] \cdot Y_{nm}^{dom}\} \\ &= Y_m^{imp} + A^{imp} \cdot Y_m^{dom} + \{H_m \cdot A^{imp} \cdot [I - (I - H_m) \cdot A]^{-1} \cdot Y_{nm}^{dom}\} \end{aligned} \tag{11}$$

with A^{imp}: the input coefficient matrix of imported commodities, calculated by division of imported inputs by gross outputs.

Assuming domestic production patterns also for production in foreign countries, the output induced in foreign countries yields as

$$X_{m,tot}^{imp} = (I - A^{tot})^{-1} \cdot V_{m,tot}^{imp} \qquad (12)$$

with $A^{tot} = A + A^{imp}$

Again assuming domestic energy intensities for foreign production, energy demand in foreign countries induced by the use of imported material goods on all levels is calculated as:

$$E_{m,tot}^{imp} = \hat{e} \cdot X_{m,tot}^{imp} \qquad (13)$$

3 Application of the calculus to the case of Germany

The above mentioned approach was used to determine the energy demand related to materials use in Germany. As a database for the calculations the German input-output table for the year 2000 with an aggregation level of 71 sectors (StBA, 2004) further aggregated to 68 sectors, was used (see Table 2 in the annex). The database for the calculation of the sectoral energy intensities was supplied by the German Federal Statistical Office (Mayer, 2006). Every sector’s energy demand is calculated as total final energy inputs minus total outputs of energy conversion. Thus for sectors involved in energy conversion only conversion losses and own use are included.

The calculations were not only performed for material goods as a whole, but also for several subgroups. The aim was to identify the energy relevance of groups of material goods that would be suitable for different material efficiency strategies. In this respect the following subgroups are distinguished:

- foodstuffs, which are used up by consumption and for which material efficiency measures are not suitable (apart from measures regarding packaging)
- other short-living material goods, which are also either used up by consumption (e.g. pharmaceuticals or detergents) or have a rather short product life span (e.g. paper products)
- longer-living material goods (e.g. technical devices), which generally are more complex and have a longer life span and thus are potentially suitable for higher-level material efficiency measures such as product reuse, intensification of use or increase of product lifetimes.
- trade and transport services for the distribution of the material goods,
- material goods, that are recyclable due to their material properties (e.g. paper- or metal-based goods),

- material goods, that are not recycled, either because they are dissipated into the environment after their use (e.g. foodstuffs or fertilisers) or because they have not been subject to recycling for other reasons (e.g. collection costs).

Table 2 in the annex contains the allocation of IO sectors to these categories of material goods. At the aggregation level of an input-output table, with the IO sectors representing heterogenous product groups, this classification of material goods necessarily remains fuzzy. Thus in some cases the allocation is ambiguous. This also holds for the group of material goods as a whole. Some sectors' outputs combine material goods and services, e.g. the construction sector that was included in the set due to its material and energy intensity or the hotel and restaurant sector that was not included, since the relevance of food as material seemed rather small compared to the relevance of services. In some cases the distinction between short and long living goods also was ambiguous. The chemical industry (excluding parmaceuticals) manufactures rather long-living commodities such as synthetic fibres as well as short-living commodities such as cosmetics or pesticides. In some cases the lifespan is unclear, e.g. in the case of plastics or paints. An analysis of chemical products for final use, which can be assigned unambiguously, suggests a dominance of short-living goods. Therefore chemicals have been allocated to this group. Another sector that is difficult to allocate is the heterogenous sector "Furniture and other manufactured goods", that was allocated to the subgroups of long-living and non-recycled goods. Due to these ambiguities the results for the subgroups should be seen as rough indications.

In the year 2000 total final demand in Germany equalled approximately 2.5 trillion euros, of which almost 60 % were material goods, the rest being energy carriers, water and services (see Table 1). Approximately 90 % of final demand were produced domestically. Table 1 also contains information on the subgroups of material goods considered in this analysis.

From the production perspective total domestic energy demand in 2000 amounted to almost 14.4 EJ, of which around 3.8 EJ are direct final energy demand in private households and an additional 1.5 EJ are related to the supply of this amount of energy, mainly conversion losses. The calculation results show that 7 EJ or almost 50 % of total energy demand are related to the provision of material goods (Figure 2). Approximately 6.5 EJ are induced by final demand for material goods and roughly 0.5 EJ by material inputs to non-material goods on the various levels of the economy (see Table 3 in the annex). Thus, with over 90 % of energy demand induced by the use of materials, final demand for material goods and the connected supply chains are dominant. The contribution of material goods as intermediate inputs to the production of non-material goods is below 10 %. Not included in this value is the use of material goods as capital goods in the production of non-material goods, since capital goods belong to final demand.

Table 1: Composition of final demand 2000 in Germany

	Domestic production	Imports	Total	Shares of total final demand
	Mill. Euro	Mill. Euro	Mill. Euro	
Material goods	1'216'974	250'461	1'467'435	59%
Non-material goods	1'007'982	19'122	1'027'104	41%
Total	2'224'956	269'583	2'494'539	
Shares	89%	11%		
Subgroups of material goods				
Foodstuffs	111'050	23'571	134'621	5%
Other short-living goods	118'765	23'268	142'033	6%
Long-living goods	713'511	203'509	917'020	37%
Trade and transport	273'648	113	273'761	11%
Recyclable mat. goods	750'990	209'012	960'002	38%
Non-recyclable mat. goods	192'336	41'336	233'672	9%

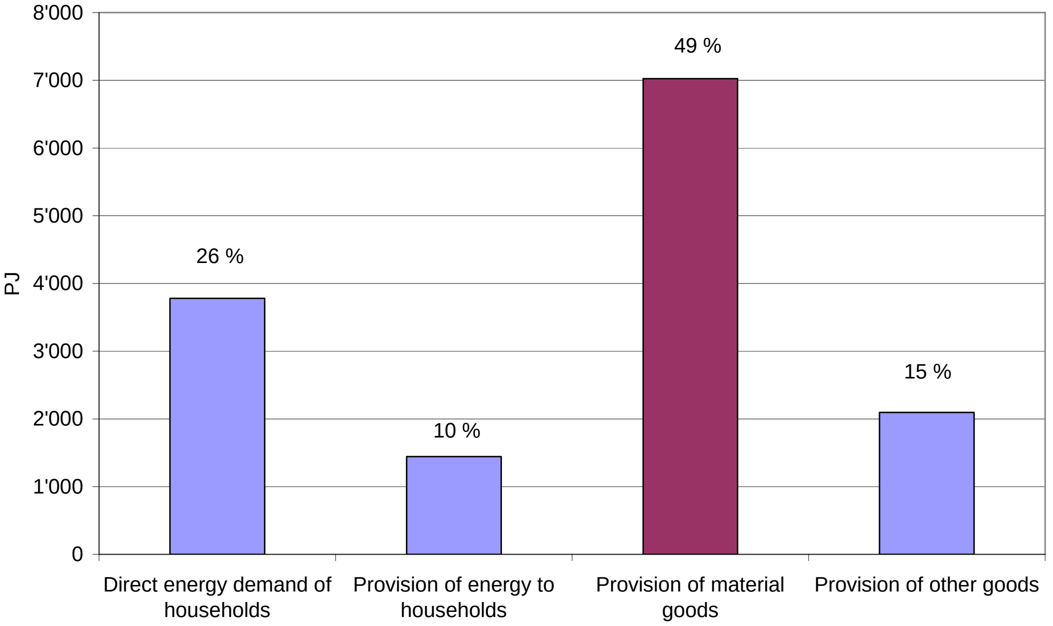

Figure 2: Breakdown of total domestic energy demand from a production perspective

The relevance of material goods for capital formation can be highlighted by an allocation of energy consumption to the categories of final demand. Figure 3 shows that 17 % of total energy demand is induced by materials needed for investment purposes. Exported goods account for the major share with approximately half of total domestic energy consumption assigned to material goods. This result is mainly due to the export of energy-intensive chemicals and steel-based goods (e.g. automobiles and machinery). Private consumption is responsible for a share of 29 %, whereas the relevance of government consumption is negligible with only 4 % of the total.

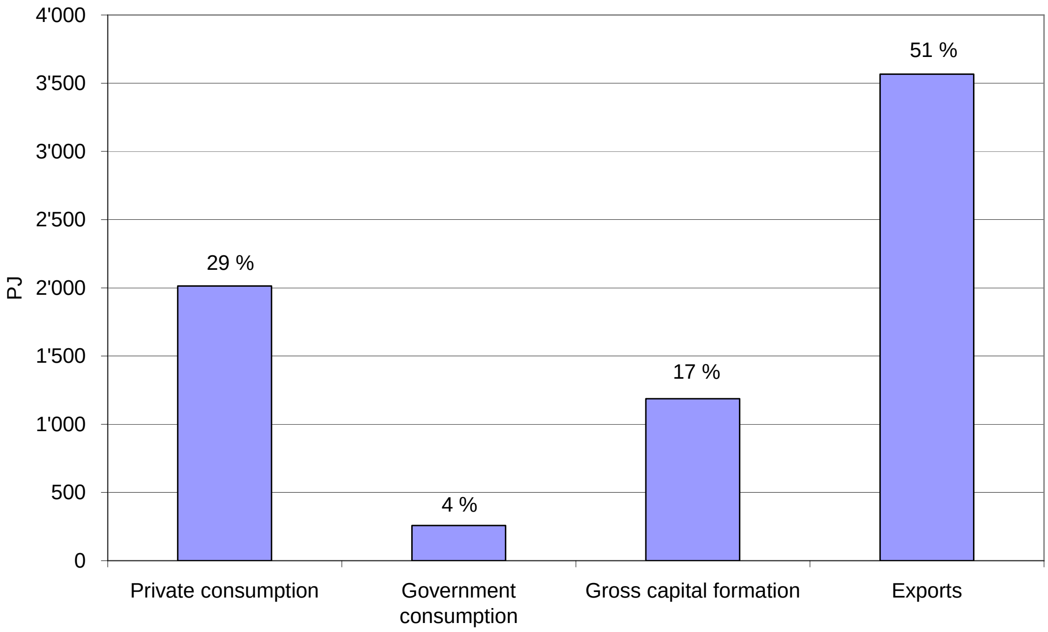

Figure 3: Allocation of energy demand induced by material goods to categories of final demand (production perspective)

The large share of energy demand induced by the export of material goods underlines the high importance of foreign trade in current supply chains. Therefore it is also necessary to consider the supply chains of imports to gain a comprehensive picture of energy consumption induced by the use of material goods. This is done with the above mentioned consumption oriented perspective.

From this perspective total energy demand induced by consumption in Germany also equalled 14.4 EJ in 2000. Of this value 5.9 EJ or 41 % can be attributed to the supply of material goods (Figure 4). The direct energy demand of private households and the energy needed for the supply of that energy are roughly equal to the shares in the production perspective. The other goods are responsible for 22 % of total energy demand.

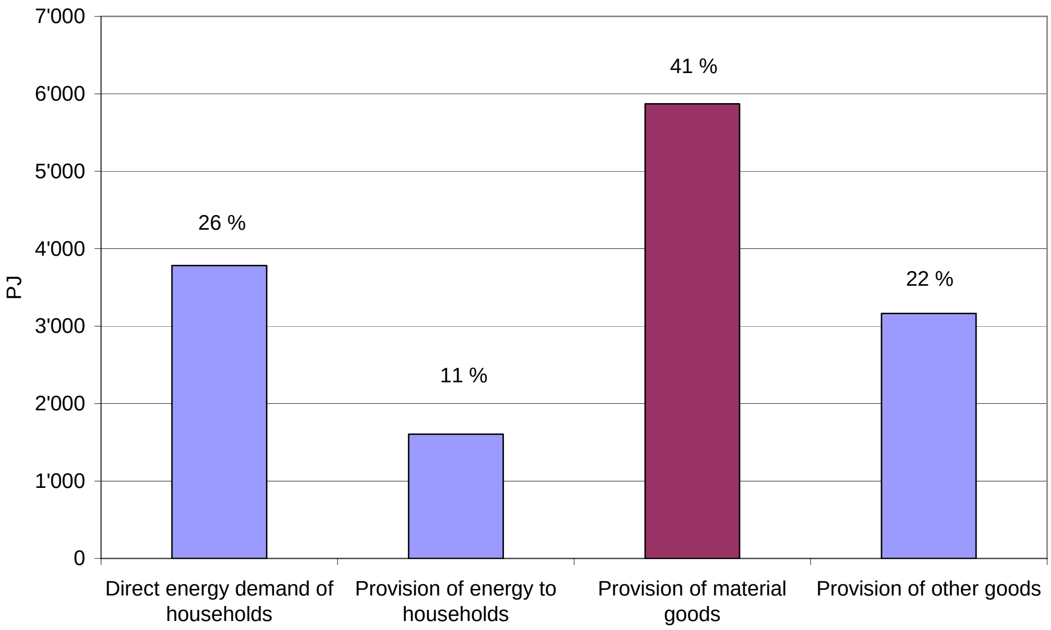

Figure 4: Breakdown of total domestic energy demand from a consumption perspective

The allocation of energy demand induced by materials use to final demand components show that private households are responsible for more than 50 % (about 3400 PJ, see Figure 5). Equipment and construction investment induce approximately 1000 PJ each, whereas 400 PJ are due to government's use of material goods. Figure 5 also highlights that a significant share of energy consumption occurs outside domestic boundaries. In total 41 % of the energy demand is needed for the production of imported goods. Imports have a high relevance for private consumption and especially for equipment investment, whereas material goods for government consumption and for construction investment mainly trigger domestic energy demand. The results from the consumption perspective also confirm the above mentioned finding that almost 90% of the energy demand occurs in the supply chains of final demand material goods, whereas 10 % are caused by material inputs for the production of non-material goods.

Figure 6 contains an overview of energy demand induced inside and outside of Germany by different categories of material goods, which gives an indication of the amount of energy that can be targeted at by different material efficiency measures. Note that the sum of the contribution of the individual categories is larger than the total for material goods as a whole due to double-counting. Yet the results do indicate the relevance of the various categories of material goods.

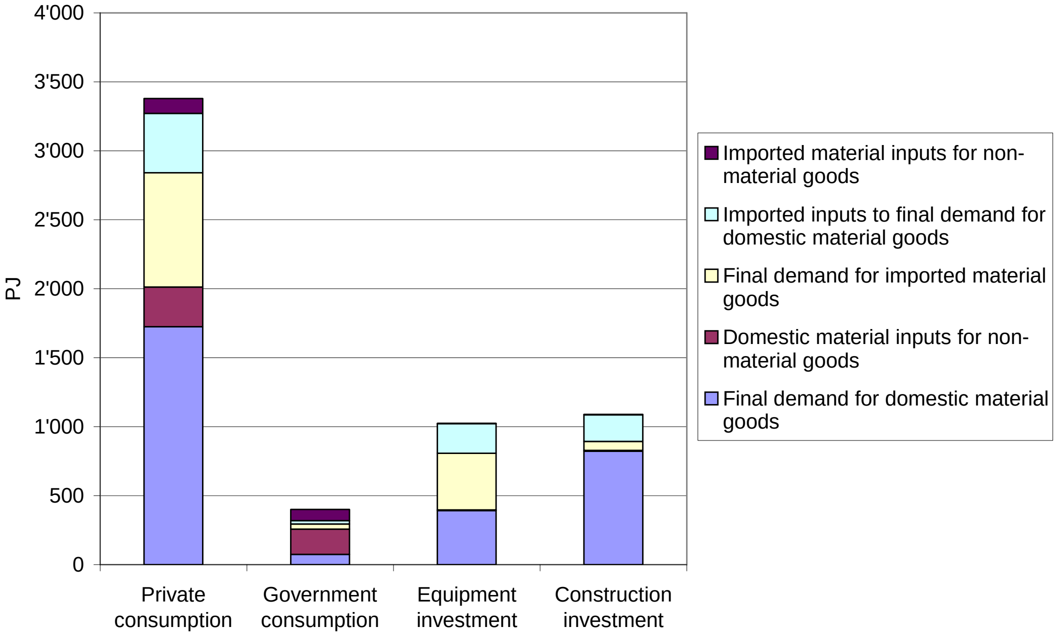

Figure 5: Allocation of energy demand induced by material goods to categories of final demand (consumption perspective, excl. net inventory change)

The major share of energy demand with almost 3400 PJ is needed for the supply of long-living material goods. Thus, material efficiency strategies aiming at remanufacturing or reuse, extending product lifetime or intensification of use may have a large energy saving potential. Foodstuffs which - apart from the packaging - are dissipated into the environment after use - are associated with an energy demand of about 900 PJ. Other short-living material goods are responsible for approximately 1400 PJ. The results further show that the distribution of goods, i.e. trade and transport also have a significant impact on energy demand with almost 1250 PJ. About 70 % of this value can be attributed to trade and transport of final demand material goods. The rest is needed for trade and transport of intermediate goods. With regard to the potential of recycling, materials that are potentially recyclable account for an energy demand of 3600 PJ, whereas non-recyclable or currently non-recycled material goods are responsible for an energy consumption of almost 2000 PJ.

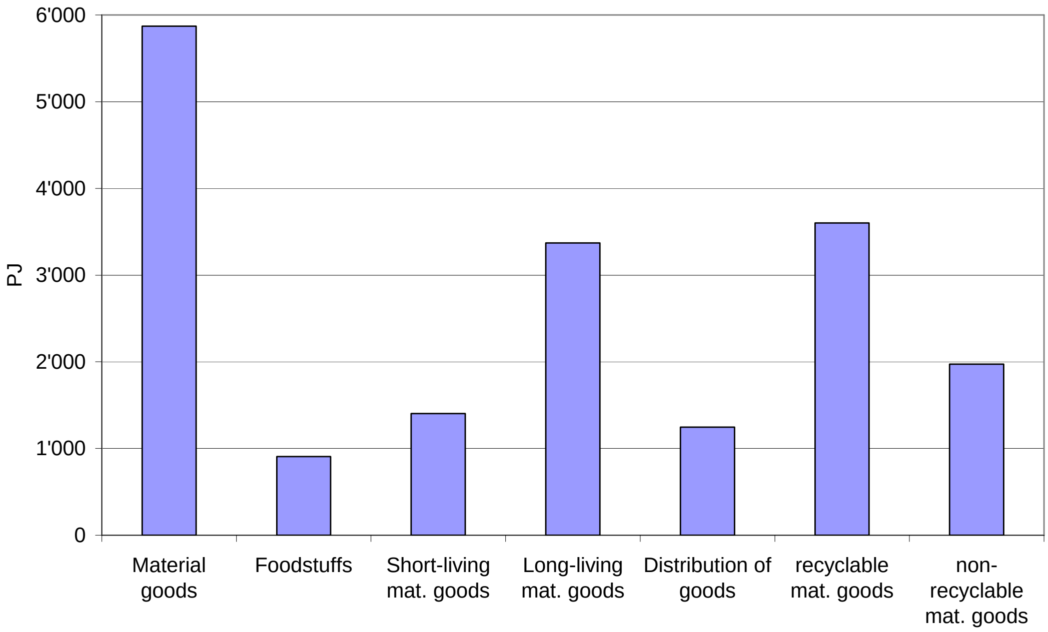

Figure 6: Energy consumption induced by different categories of material goods

4 Summary and conclusions

A significant share of energy consumption in industrialised countries is needed to provide society with material goods. Thus, strategies aiming at improving the efficiency of the material supply system can contribute to reducing energy demand. To assess this energy saving potential a first step is to estimate the total energy consumption induced by the supply and use of material goods. In this paper an appropriate calculus based on input-output analysis is proposed, that captures the use of material goods at the different levels of the economy and calculates the induced output and energy consumption. This approach was applied to the case of Germany.

Based on data for the year 2000, the results show that almost 50 % of total energy consumption in Germany or 7000 PJ are needed for the production and supply of material goods. Exported goods, which are relatively energy intensive, account for half of this value. Goods for private consumption are responsible for another 29 %, capital investment for about 17 % and government consumption for approximately 4 %.

From a consumption perspective, i.e. excluding exports, but including imports, the relevance of material goods is lower with about 5900 PJ or 41 % of total energy demand. Here private consumption is responsible for more than half of this value and capital investment for about one third.

An analysis of various subgroups of material goods that are suitable for different material efficiency improvement strategies has shown that about half of the energy consumption linked to the use of material goods is needed for long-living products. Thus, material efficiency strategies aiming at remanufacturing or reuse, extending product lifetime or intensification of use may have a large energy saving potential. Trade and transport of material goods has also turned out to cause significant energy consumption with over 1200 PJ. With regard to the recyclability of materials the results indicate that energy demand related to recyclable materials is significantly higher than that related to non-recyclable materials. Yet the latter account for an energy consumption of almost 2000 PJ.

From a methodological point of view the proposed calculus has proven useful to explore the relationship between materials use and energy demand from the perspective of input-output analysis. It can easily be adapted to analyse the relevance of other product groups for economic or energy related indicators (e.g. the relevance of services). Furthermore, if additional data is included into the input-output model, the scope of analysis can be extended to other indicators, e.g. environmental or social indicators.

Annex

Table 2: Allocation of commodity groups to categories of material goods

NACE code	Commodity group	Material goods	Food, bever-ages, tobacco	Short-living goods	Long-living goods	Trade and transport of goods	Recy-clable goods	Non-recycla-ble goods
01	Agricultural products	x	x					x
02	Forestry products	x		x				x
05	Fishing products	x	x					x
10, 12 - 13	Coal; Uranium, thorium and metal ores							
11	Crude petroleum and natural gas							
14	Other mining and quarrying products	x						
15.1 - 15.8	Food products	x	x					x
15.9	Beverages	x	x					x
16	Tobacco products	x	x					x
17	Textiles	x			x		x	
18	Wearing apparel; furs	x			x		x	
19	Leather and leather products	x			x		x	
20	Wood and wood products	x			x		x	
21.1	Pulp and paper	x		x			x	
21.2	Paper products	x		x			x	
22.1	Publishing products	x		x			x	
22.2 - 22.3	Printing products and re-corded media	x		x			x	
23	Coke, refined petroleum products and nuclear fuels							
24.4	Pharmaceuticals	x		x				x
24 (w/o 24.4)	Chemical products (w/o pharmaceuticals)	x		x				x
25.1	Rubber products	x			x		x	
25.2	Plastic products	x			x		x	
26.1	Glass and glass products	x			x		x	
26.2 - 26.8	Other non-metallic mineral products	x			x		x	
27.1. - 27.3	Iron and steel	x			x		x	
27.4	Non-ferrous metals	x			x		x	
27.5	Casting of metals	x			x		x	
28	Fabricated metal products	x			x		x	
29	Machinery and equipment n.e.c.	x			x		x	
30	Office machinery and com-puters	x			x		x	
31	Electrical machinery and apparatus n.e.c.	x			x		x	
32	Radio, television and com-munication equipment	x			x		x	
33	Medical, precision and optical instruments, watches and clocks	x			x		x	

NACE code	Commodity group	Material goods	Food, beverages, tobacco	Short-living goods	Long-living goods	Trade and transport of goods	Recyclable goods	Non-recyclable goods
34	Motor vehicles, trailers and semi-trailers	x			x		x	
35	Other transport equipment	x			x		x	
36	Furniture; other manufactured goods n.e.c.	x			x			x
37	Secondary raw materials	x			x			
40.1, 40.3	Electrical energy, steam and hot water							
40.2	Gas							
41	Water and water services							
45.1 - 45.2	Site preparation, buildings, civil engineering	x			x			
45.3 - 45.5	Building installations and other construction work	x			x			
50	Car trade and garages	x				x		
51	Wholesale and commission trade services	x				x		
52	Retail trade and repair services	x				x		
55	Hotel and restaurant services							
60.1	Railway transport services	x				x		
60.2 - 60.3	Other land transport services	x				x		
61	Water transport services	x				x		
62	Air transport services	x				x		
63	Supporting transport services; travel agency services							
64	Post and telecommunication services							
65	Banking services							
66	Insurance and pension funding services							
67	Auxiliary financial services							
70	Real estate services							
71	Renting services of machinery and equipment							
72	Computer and related services							
73	Research and development services							
74	Other business services							
75.1 - 75.2	Public administration and defence services							
75.3	Compulsory social security services							
80	Education services							
85	Health and social work services							
90	Sewage and refuse disposal services, sanitation services							
91	Membership organisation services n.e.c.							
92	Recreational, cultural and sporting services							
93 - 95	Other services							

Table 3: Domestic and foreign energy demand induced by the provision of material goods in Germany

	Private consumption	Government consumption	Gross capital formation	Total domestic final demand	Exports	Total final demand
	PJ	PJ	PJ	PJ	PJ	PJ
Final demand for domestic material goods	1'725	74	1'177	2'976	3'534	6'510
Domestic material inputs for non-material goods	287	183	10	481	32	513
Final demand for imported material goods	829	38	497	1'364	890	2'254
Imported inputs to final demand for domestic material goods	430	25	402	857	1'590	2'447
Imported material inputs for non-material goods	107	81	5	193	16	209
Total domestic energy demand	2'013	257	1'187	3'457	3'566	**7'023**
Total foreign energy demand	1'365	144	905	2'414	2'495	4'909
Total energy demand	3'378	401	2'092	**5'871**	6'061	11'932

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