Policy review on decoupling: development of indicators to assess decoupling of economic development and environmental pressure in the EU-25 and AC-3 countries

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Executive Summary

Aims and scope

This study has been conducted within the framework of the EU Thematic Strategy on the Sustainable Use of Natural Resources (Resource Strategy), which is currently in development. The objective of the Resource Strategy is described in the 6th Environmental Action Programme 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"*. This objective has different aspects. Not exceeding the carrying capacity of the environment refers to an absolute limit - however difficult to define - to the extraction and consumption of resources. It also clarifies the reason for the second objective, breaking the linkage between economic growth and resource use: reducing or avoiding environmental impacts. Breaking the linkage between economic growth and resource use, or decoupling, is a relative target, in line with Factor Four ideas and suchlike. In all, the following characteristics apply to decoupling as understood in the 6th EAP:

- decoupling is applied at the level of (supra)national economies
- the aim is reducing environmental impacts at a continued economic growth
- the target is the use of materials or resources
- decoupling is relative, but the underlying idea is sensitive to absolute limits.

The question that is the subject of this study is how to measure decoupling and how to monitor progress on the decoupling road. For monitoring, indicators or measurements are required that encompass the abovementioned characteristics: these indicators should be applicable at the (supra)national level, they should indicate a total level of environmental impacts, related to the use of materials or resources, and should enable creating time series in order to monitor progress. In earlier studies, the Domestic Material Consumption over GDP (DMC/€) has been put forward as such an indicator. DMC measures the material resources which are directly consumed within a national economy and are put forward as indicators, however indirect, for environmental pressure. The reasoning behind this is that in the end each kilogram of material entering an economy has to come out at some moment as waste or emissions.

While this is undoubtedly true, it is at the same time true that there are large differences in environmental impacts between different resources or materials. A kilogram of sand does not have equal impacts as a kilogram of copper, or meat, or coal. The potential environmental impacts of the different materials or resources should be considered as well as the weight or volume of their use. In the end, it is the environmental pressures and impacts respectively which should be decoupled from economic growth, not their use per se. In this study, we attempted to develop an indicator combining information on material flows with information on environmental impacts. This indicator we called EMC, Environmentally weighted Material Consumption. In addition, a first attempt was made to define an indicator for land use at the same basis, i.e. to be used as a measure for decoupling. These indicators are applied for the 25 EU countries and 3 Candidate countries. Time series are made for the former EU-15 countries from 1990 - 2000, and for the newly accessed and candidate countries from 1992 - 2000. The results are compared with the DMC for the same countries and time period. This sheds some light on the discussion with respect to the extent to which the DMC indeed can be regarded as a proxy for environmental pressure.

Next to indicator development, this study focuses on explaining these indicators. Both for the DMC and the EMC explanatory variables were defined and tested. Policies affecting material flows have been identified and an assessment has been made of their influence. Moreover, correlations were made between DMC and EMC. In this way, we hope to shed some light on the reasons for differences between countries for both variables, as well as on the debate over the usefulness of DMC as an indicator for environmental pressure.

Refining DMC

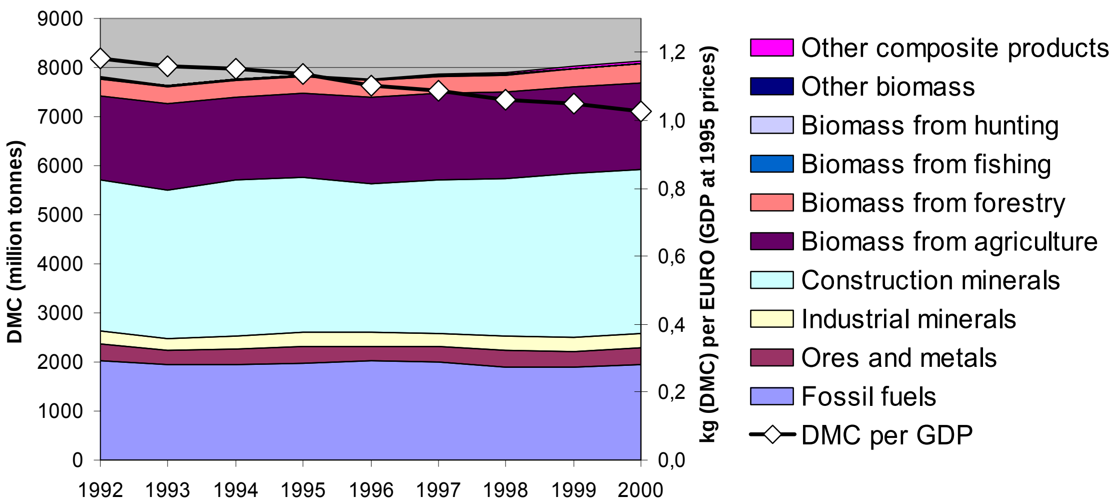
In previous studies, Material Flow Accounts have been drafted for EU and ACC countries and MFA-based indicators, such as DMI and DMC, have been derived from them. In this study, these MFA accounts have been refined for better cross-country comparability based in particular on plausibility checks for the two dominating material groups (in terms of quantity) which are construction materials and green biomass for ruminants' fodder.

DMC results

The result of the refining process is a consolidated database of DMC for the 28 countries included in this study. DMC, DMC/capita, DMC/€ and DMC broken down into categories of materials are available for a time period of 1990 - 2000 for the former EU-15 countries, and 1992 - 2000 for the other countries (AC-13, which are the ten newly accessed EU countries plus the three candidate countries Bulgaria, Romania, and Turkey). Between countries, there are large differences. On average, Eastern European countries have a slightly lower DMC/capita. There are some very high scoring countries, especially Finland, Ireland and Estonia. When regarding developments over time, a slightly up-going trend can be seen for the average DMC/capita, while the DMC/€ is clearly decreasing, as shown in the figure below. This shows that the EU economy has become more eco-efficient in terms of its direct materials consumption. Most of the 28 countries also show this trend, with different rates of improvement. However, two important points should be considered in this context:

- the absolute amount of direct materials consumed (DMC) has not decreased but even slightly increased over the 1990s (see figure below), indicating that absolute decoupling of material use from economic growth has not been achieved (but relative decoupling);
- potential shifts of the EU's resource requirements to foreign economies are not sufficiently reflected in the DMC indicator which accounts for direct materials only and neglects indirect material flows associated with imported and exported commodities. To overcome this bias, the material flow database would have to be further developed towards indicating the EU's global Total Material Consumption (TMC) which could be a matter of future studies.

DMC and DMC per GDP: EU-25 + AC-3 countries



In this figure, the contribution of the main material groups to the absolute level and trend of DMC can also be detected. A contribution to this process of relative decoupling came from a slight absolute reduction of the direct materials consumption of fossil fuels (obviously favoured by a substitution of low-energy coal by high-energy gas as results for the EMC below indicate). Contrary, the DMC of biomass had slightly increased and the DMC of construction materials had increased even more, with the overall effect of a slight increase of the total DMC (by 4% while GDP had increased by 20%). Obviously, increased domestic use of construction materials mainly prevented a development towards absolute reduction of the EU's direct material consumption.

Developing EMC

The idea behind the environmentally weighed material consumption indicator, EMC, is quite simple: *multiply the material flows with a factor representing their environmental impact*. Material flows are available through DMC and the accompanying MFA account. To specify the environmental impacts of a material, a Life Cycle Impacts approach is taken. For every considered material, an estimate is made of its contribution to environmental problems throughout its life cycle. This includes not only the impacts related to the material itself, but also the impacts of auxiliary materials, energy used for its extraction and production, emissions of impurities and pollutants included in the material during use or waste treatment, etcetera. Energy use in the consumption phase is not allocated to the materials' chains. We consider this energy use - for example, petrol in cars or electricity for computers - to be related to products rather than materials. It is difficult to allocate the use of energy to the individual materials a product is composed of, and quite often the energy use is hardly related to these materials. Energy use in the consumption phase however is not excluded from the EMC: it is included in the chains of fossil fuels, and any change due to shifts to less energy-intensive products will be visible in the EMC.

The established impacts in this way provide the total cradle-to-grave impact per kg of the material. This impact factor then is multiplied with the number of kilograms of this material being consumed to obtain an idea of the environmental impact of the consumption of the material. Summated over all materials, a picture emerges of the potential environmental impact of the material consumption of a national economy.

This simple idea, when put in practice, proves not to be that simple. There are some obstacles that must be taken:

Double-counting

We cannot just use DMC for the material flows related to consumption, because the impact factor relates to cradle-to-grave chains. For example, DMC contains imported fertiliser, but also the crop that is harvested for which this fertiliser is used. In the cradle-to-grave chain of the crop, the impacts of the fertiliser are already accounted for. If fertiliser appears separately in the account and is also multiplied with an impact factor, there is a double-counting. We excluded double-counting by excluding materials that are used solely for the production of other materials from the DMC. Their impacts however are included in the impact factors, which means they are not just left out.

Resources vs. finished materials

DMC is built up out of raw materials, finished materials and products. Cradle-to-grave impact factors refer to finished materials. This means, that the import or extraction of raw materials has to be translated into finished materials. For example, extracted sand is not just used as sand, but partly enters the chain of other materials such as concrete or glass. All these materials have different impacts. Therefore we used additional information about the fate of resources, assigning the raw material sand to its finished materials sand, concrete and glass. Products are excluded from the EMC. It has proven to be too elaborate to specify the material composition of each product being imported or exported. Since the amounts are small compared to the flows of materials, the error made by this may not be too large.

Included and excluded materials

The idea is to include as many materials as possible. Two restrictions are made: (1) information on the materials consumption should be available, and (2) information on the environmental impact of the material should be available. The first restriction proved to be the most limiting. For a number of smaller-scale materials it proved impossible to arrive at sufficiently credible materials balances. For DMC, this doesn't matter since the amounts are small. For the EMC this can be a problem, since small-scale materials sometimes have a very high impact potential per kg.

Weighting

We used the ETH-database, an established LCA database, for the Life Cycle Inventory (LCI). The LCI was aimed at specifying all environmental interventions in terms of extractions and emissions of 1 kg of each material. The results of the LCI were translated with LCA software (the CMLCA program) into contributions to 13 different impact categories. Thus, each material scores on global warming, acidification, human toxicity etc., in terms of potential impacts, expressed in equivalents. For global warming, for example, all emissions are added in terms of CO_2-equivalents. By multiplying these factors with the consumption flow and adding all materials, a picture arises of the contribution of the material consumption of a national economy to 13 environmental problems. This implies there is not just 1, but 13 indicators of environmental impact potential. This could be an acceptable end result, but not in this case: when the aim is to arrive at one single indicator for environmental impact, these 13 indicators must be aggregated. This issue of weighting is controversial in the LCA community and restricted under the ISO standard for LCA. Several schemes exist to attach relative weights to environmental problems, based on different starting points, but none is generally accepted. We decided to add the 13 impact categories based on an equal weighting, as an illustrative example, not as a political choice.

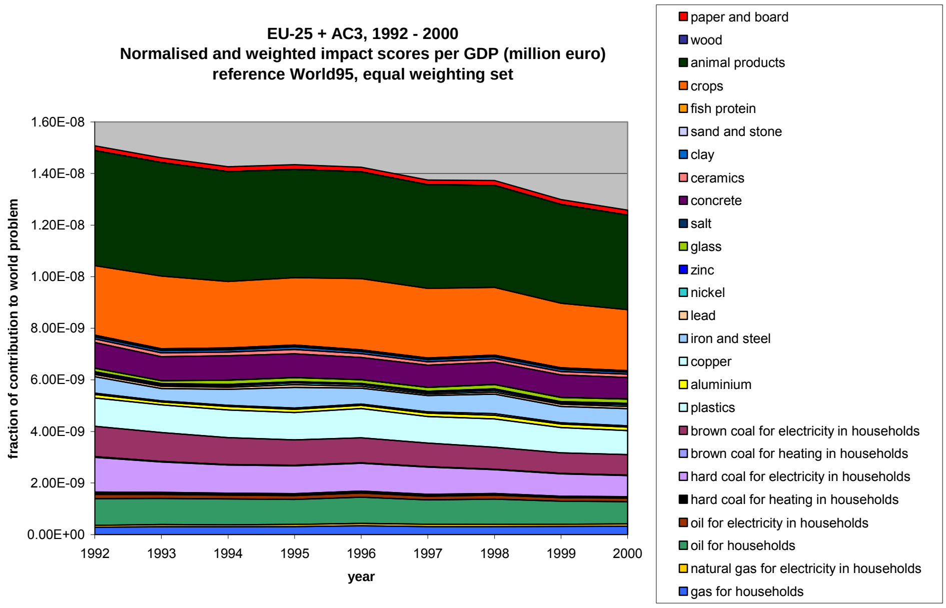
Interpretation problems

The uncertainties of basic MFA data and the derived DMC also apply to the EMC. Additional uncertainties and restrictions arise from the use of LCA data. The LCA process data are averages for Western Europe, implying that on the one hand differences between countries are not expressed, while on the other hand efficiency improvements over time that do not result in a lower materials consumption (such as the application of end-of-pipe technologies) cannot be seen. The LCA database is updated once a decade rather than once a year. Basic assumptions in the LCA database with regard to recycling and allocation are difficult to detect and may be open for improvement. Regarding the LCA impact assessment data, there are large differences in quality between the different impact categories. While global warming potentials are based on internationally agreed studies, large uncertainties exist in the impact categories related to toxicity. The LCA Impact Assessment methodology is not well developed for land use and waste generation. Depletion of resources of a biotic nature, e.g. wood and fish, is not included at all; at this moment there is no consensus on how to derive impact factors. Despite these omissions and uncertainties, the addition of LCA data in our view is still relevant, bringing the MFA based indicator a step further in the direction of potential impacts. Both for MFA and LCA databases, improvements should and probably will be made over time, allowing for more reliable indicators. Both research and development areas are alive and many experts are working on it, which ensures a highly dynamic development field.

EMC results

The result of applying the EMC methodology to the 28 countries included in this study shows, in the first place, that there are large differences between countries. The levels of EMC/capita and EMC/€ vary a factor 2 - 5. The most important explanation lies in the differences between the structures of the economy. Countries with a relatively large or intensive agricultural sector have the highest EMC score. These are different from countries with a high DMC, excepting Ireland. It is, however, difficult to attach a meaning to those differences. Should a country change its economic structure, or copy other countries? This is at least open to debate. While country comparisons suffer from interpretation problems with regard to the absolute value of EMC, the interpretation of time series within a country is less problematic. Given a certain structure of the economy, a development towards a less impact intensive economy can be regarded as positive. Here, too, are clear differences between countries. Some countries show a clear decrease in their EMC/capita, others a clear increase, yet others remain quite stable. The largest increase is visible in Southern European countries as Portugal, Spain and Greece. For the 28 countries in total, the EMC/capita is quite stable. The EMC/€ however shows a clear down going trend over time, as shown in the figure below. Most countries also show this trend, with different rates of improvement. This means that the EU economy is becoming more eco-efficient.

EMC/mln € of GDP, 1992 - 2000, EU-25 + AC-3

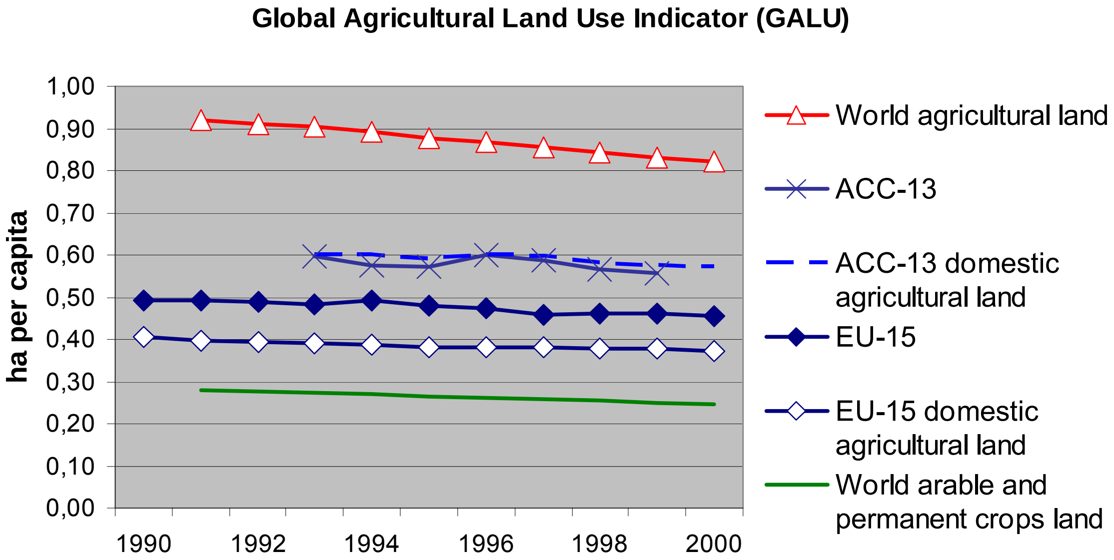


In this figure, the contribution of the different materials can also be detected. The largest contribution to this process of relative decoupling seems to originate from a reduction in the use of coal. This is replaced by gas, which has a lower impact potential.

Developing a land-use indicator

One of the objectives of this study was, to make a start with the development of a land-use indicator that can be used as a measure for de-coupling on the level of national economies. Land use is a very important aspect from a sustainability point of view, and land-use intensity therefore a relevant indicator for eco-efficiency. Since no such indicator exists yet, we started this task with some observations of aspects to address. We attempted to define a land-use indicator related to consumption, similar to DMC and EMC, and on a similar basis: the land use required to fulfil a nation's material needs. The concept of land use related to consumption has some similarities to the well-known Ecological Footprint. This, too, is a measure for land use related to consumption on the national level. The land-use indicator as proposed here is more clear-cut in that sense that it does not contain any "virtual" land use elated to the adsorption of pollutants, but only "real" land use. It is therefore not an overall indicator of environmental pressure, only insofar related to land use. Land use has another dimension: the intensity of use. On the one hand, it could be stated that the more Euro's are made with an hectare of land, the better it is, since the overall land use would be less. However, the more intensively land is used, the less room there is for multifunctional land use and for nature. Extensively used land, such as for example for forestry, leaves many opportunities for ecological values while these are almost absent in built-up land. So far, this aspect has been signalled but not included in the land-use indicator. In future, attention need to be given to this aspect as well. Another aspect is the nature of land as a resource. Land is not used up or consumed, it can be used indefinitely and its use can be changed.

In theory, the land-use indicator is calculated as: domestic land use + foreign land use for imported materials - domestic land use for exported materials. Thus, a picture emerges from the land used, anywhere in the world, for the consumption in a specific country. We name the indicator Global Land Use, in abbreviation GLU. In practice, data availability constitutes a real problem. Even for domestic land use, comparability between countries is limited and datasets are incomplete. Outside the EU the problems are even larger. Only the sub-category Global Agricultural Land Use (GALU) we were able to specify, be it with the help of some assumptions of our own. The figure below shows the GALU for the former EU-15 and ACC-13 in comparison with the world's availability of agricultural land in total and arable land plus permanent crops land in particular. From this picture, it seems that the global agricultural land use of the EU and ACC is in line with agricultural land available for each human being in the world. However, several arguments (as discussed in the main report) speak rather for an orientation towards the global availability of arable land and permanent crops land instead of total agricultural area. With this reference, the EU's and ACC's GALUs would rather exceed global limits on a per capita basis. Furthermore, the global per capita availability of both agricultural land and arable land and permanent crops land, is declining more rapidly than the GALUs of EU and ACC. Also, the agricultural land use intensity (in terms of fertilizer and pesticides use etc.) should be taken into consideration as well. This may put the EU's global agricultural land use into a different perspective than the mere hectares per capita show.



Underlying to this figure, an interesting difference between EU-15 and ACC-13 was observed. Whereas the EU-15 have always required a net surplus of agricultural land abroad, the ACC-13 have rather been net providers of agricultural land for the rest of the world (and most probably in particular for the EU-15). Future studies may show the status and development of agricultural land use of the extended EU-25 and beyond on the global scale, aiming at integrating qualitative aspects of land use as well.

Explanatory variables for DMC and EMC

A number of socio-economic and physical variables have been investigated as explanatory variables for both DMC and EMC. We performed an extensive regression analysis. Overall, the variation in these variables explains roughly 60-65% of the variation in both DMC and EMC per capita. Most important variables are related to the level of income in a country (GDP) and the structure of the economy. Richer countries tend to have higher levels of DMC and EMC per capita, but the increase due to economic growth is more profound in the EMC than in the DMC. A 1% economic growth results, in the long-run, in an increase in the EMC of almost 0.6% and in an increase in the DMC of 0.4%. As this is smaller than 1%, there is some relative decoupling. The higher figure for the EMC indicates that economic growth results in a higher increase in environmental impacts from resource consumption than in resource consumption measured in weight (as the DMC).

The structure of the economy is another important variable: the DMC is mainly influenced by the share of construction activities in an economy, whereas the EMC is influenced by both the construction activities and the agricultural sector. Other variables that have an influence on the DMC and EMC are related to both the growth in the dwellings per capita and the renewable energy input in an economy. More dwellings result in higher resource consumption, while a larger share of renewables in electricity production results in lower resource consumption. The DMC is furthermore influenced by a number of policy variables, such as energy prices and spendings on education. The price elasticity for motor fuel prices is in the long-run -0.16%, which is in line with other empirical studies.

While this analysis gives some insight in the factors that influence the resource consumption in a country, they provide little insight in which countries have been successful in reducing their resource consumption and which countries have been less successful. In order to address that question we investigated the differences in resource efficiency between countries. As stated above, countries differ by almost a factor 5-9 in their resource efficiency, either measured as DMC/€ or EMC/€. However, a large part of these differences can be attributed to the measure of GDP that is used. So far in the report, nominal GDP figures have been used that convert the national income figures of each individual country to Euro, using official exchange rates. However, these exchange rates do not reflect the amount of goods consumers can buy in their resident country, but rather what they can buy in the Euro zone. As the price level in Central and Eastern Europe is much lower than in Western Europe, these exchange rates do not truly reflect the amount of goods consumers can buy from their wages. Therefore, a measure of Purchasing Power Parities is often used in international comparisons between countries, especially if consumption related activities are to be compared. When taking Purchasing Power Parities as exchange rates, the differences in resource efficiency are reduced by more than half. The remaining variation is mostly influenced by differences in the structure of the economy and the level of GDP. Such influences are typically conceived as being outside the scope of the policy maker, Moreover, improvements in the structure of one economy may come at the expense of the structure of another economy and it is difficult to assess whether such changes are to the benefit of the environment or whether they are not. If we correct the resource efficiency for differences in the structure of the economy and the level of GDP, one may come at the part of resource efficiency that may be affected by differences in policies and consumer lifestyles. This analysis provided the insight that the United Kingdom, Romania and Sweden have typically better than average performance both in their levels of EMC/€ and evolvement of EMC/€ over time. Denmark and Latvia are here singled out as countries that typically performed worse than average for these two indicators. Romania and the United Kingdom are also identified as the countries that perform well with respect to their resource efficiency (both in levels and evolvement over time) of DMC/€. Finland, Bulgaria, Cyprus and again Denmark are here singled out as countries that perform worse than average with respect to their levels and changes in DMC/€.

Further investigation into why these changes occur between countries proved to be cumbersome. Typically, the DMC and EMC treat the economy as a black box and measure only the inputs and outputs into an economy. To reveal later what actually has been going on in the economy in terms of driving forces is not possible without going into the individual material account of these countries and conducting case-studies. The analysis on changes in resource efficiency over time indicated that former communist countries tend to have higher improvements in their resource efficiency and that countries that have implemented policies oriented on recycling of municipal waste tend to have higher reductions in resource use relative to GDP over time.

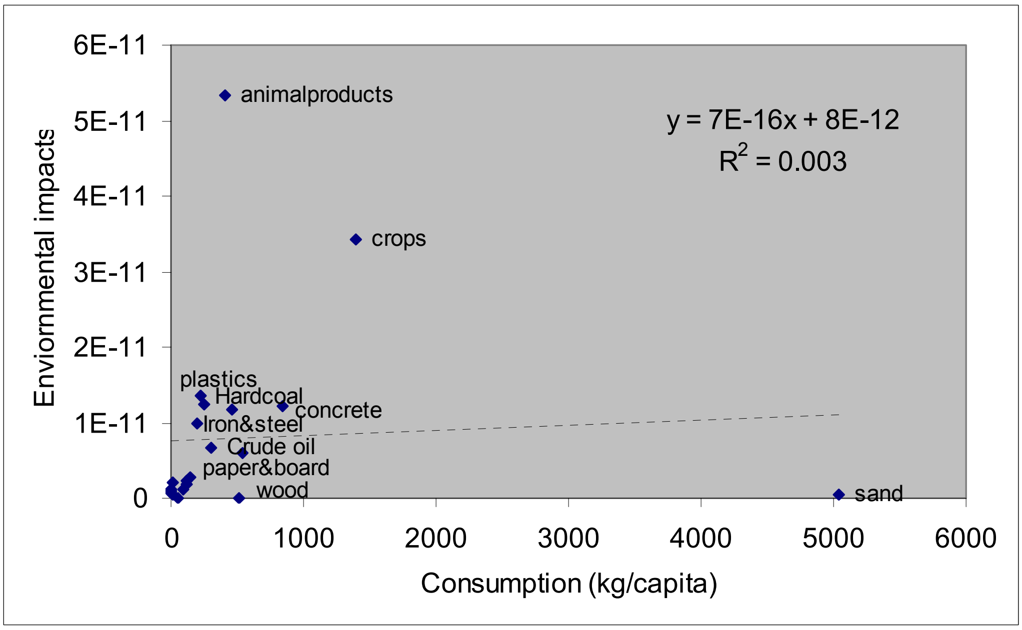
Next to these explanatory variables, the influence of a number of national and EU policies has been investigated. A general conclusion that can be drawn from the policy analysis is that currently policies for materials or products still mostly act by weight. Only some of the instruments under IPP explicitly act by environmental impact, for example by stimulating the use of renewable energy or certified wood. There is a tendency, however, to move toward policies acting by environmental impacts, for instance in the area of packaging. Next to this, sectoral policies of course address emissions and environmental impacts more directly, but those are mostly tied to locations.

As to the performance of individual countries some remarks can be made. In general, a clear distinction is seen between the older and the new Member States. To a lesser extent, there is a distinction between northern Europe and southern Europe. The UK was identified above as a country that performs well with respect to their resource efficiency corrected for the structure of the economy and the level of GDP. From the policy analysis it appears that this might be related to the use of the tax instruments in energy policies which are more stringent than in Western Europe for energy prices related to households. Interestingly, Denmark, and also Sweden, is almost always at the “top of the list”. This is more striking as the indicator of the EMC indicated that Denmark is also the country with one of the largest environmental burdens from resource consumption and Denmark performed poorly both for the DMC/€ and the EMC/€ when corrected for the structure of the economy and the level of GDP. Portugal and Greece are often at the bottom of the list (not taking into account the new MS).

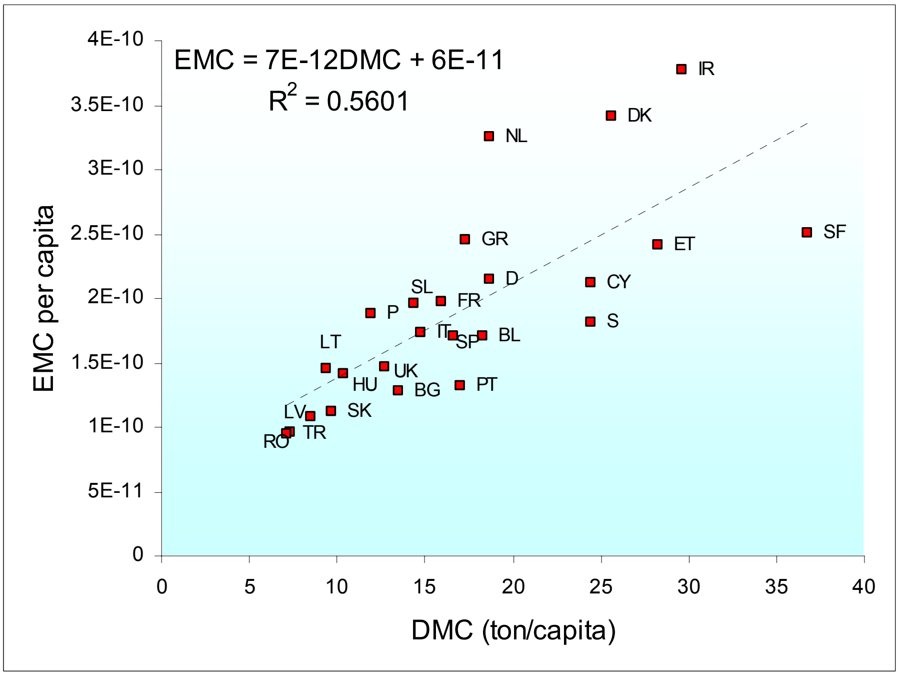
The differentiation in east-west and north-south is probably mostly due to differences in the structure of the economy, rather than to policy variables. We could find no reason why Romania performs so well in the corrected resource efficiency figures.

Correlation between DMC and EMC

In this study, we have investigated the relation between DMC and EMC at different levels. At the most detailed level, the level of individual materials, there seems to be no relation whatsoever between the weight of a certain material and its impacts. The figure below shows this.



At the aggregate level a different picture develops. When plotting the EMC-DMC relation for the different EU and AC countries there appears to be a correlation between the two, which is - although not extremely high - significant. This probably implies that the composition of material consumption does not differ that much between countries which are to a certain extent comparable in terms of their market structure and have extensive trade flows with each other. There are some outliers, however, which seem to be related especially to the economic structure and presumably to the influence of agriculture in these countries.



Over time, the correlation is also visible. The way a national economy uses materials, in terms of its technical coefficients, changes only slowly as the result of capital replacements and technological innovation or technological breakthroughs. This implies that given a certain input of materials and a certain economical structure, the output in terms of waste and emissions is more or less fixed. Structural changes and really significant improvements in efficiency only happen over a longer period of time. For shorter periods of ca. 10 years, the output seems to be determined by the input and therefore the DMC can be a valid approximation of environmental pressure, at the aggregate level and within national economies. On the long run, however, changes occur and the relation may no longer be valid.

What does this mean for the expendability between EMC and DMC? If they indicate the same thing, using just one of them seems sufficient. It could be argued that, since environmental impacts are what we are interested in, the EMC as the indicator that measures this should be used. On the other hand, DMC is easier to calculate and surrounded with less uncertainty, therefore an argument could be made to use DMC. To take this argument one step further, both DMC and EMC correlate with GDP/capita. By the same reasoning, we could use GDP/capita as a proxy for environmental pressure. Yet, since we are interested in measuring the decoupling between economic growth and environmental pressure, GDP/capita cannot be used in this way. In the same line of reasoning, it may also be interesting to see whether a decoupling between materials use and environmental impact potential might occur. For that reason, it still makes sense to measure both.

The application of the EMC and DMC may also differ. The DMC may be used as a "headline" indicator in a given time-period for the environmental pressure from materials consumption for individual countries or for comparing countries with a largely similar economic structure. However, if actual policies are put in place for reducing the environmental impacts from resource consumption, DMC is not appropriate as there is no linkage between environmental impacts and the underlying consumption in terms of kilograms. Also if the natural resource strategy is to contain long-term goals, like a Factor 4 in 25 years, one may question whether on such a long time-frame the changes in impacts will still correlate with the kilograms.

Set of indicators

A separate task of this study has been to identify a limited set of mass flow and land use indicators, and assess whether one or more of those indicators could be used for benchmarking. The indicators that have been regarded in this study are the following:

- variants of Domestic Material Consumption, DMC: DMC, DMC/capita, DMC/€, DMC/km^2 and DMC broken down into categories of materials
- variants of Environmentally Weighted Material Consumption, EMC: EMC, EMC/capita, EMC/€, EMC/km^2; EMC broken down into categories of materials; EMC per individual material; EMC per impact category
- variants of Global Land Use, GLU: GLU, GLU/capita, GLU/€, GLU/km^2 (not available at this moment), GLU broken down into categories of land use. At this moment, only agricultural land use can be specified sufficiently.

These indicators have been judged by a number of criteria. A very important criterion has been the indicative value. To assess the indicators on this criterion, we attempted to define the meaning of the indicators. If the definition is easy and clear-cut, the meaning of the indicator can be assumed to be clear. The next question is then, whether the indicator is relevant: clear or not, are we interested in its message?

DMC variants

The DMC can be defined as: "the annual consumption of "new" materials within a national economy". DMC is therefore a measure for the physical basis of a national economy. The indicative value, however, is indirect. Not the consumption itself, but its implications are indicated by DMC. DMC measures net additions to stock and generated waste and emissions, since every import or extraction that is not exported is either added to stock or becoming waste. By the same reasoning, DMC is a proxy for present and future waste and emissions, since all materials added to stock have to come out as waste or emissions at some moment in time. However the indicative value is still indirect. Not the physical basis, the stocks themselves, or even the present and future waste streams are the issue, but the potential environmental pressure related to them. As stated above, it appears that there is a significant correlation between the DMC on the one hand and the EMC on the other, both between countries and over time. On an aggregate level, therefore, DMC could indeed be used as a proxy for environmental pressure, at least on the short term. Although no absolute target or desired level can be defined, the meaning of the indicator is clear in a relative sense: less is better.

Both the DMC/capita and the DMC/km^2 roughly have the same meaning, but are options to make the DMC indicator comparable between countries. The DMC/capita could be regarded as a measure for environmental pressure of consumption. The DMC/km^2 is a little closer to indicating environmental pressure as such, since population (and therefore, environmental pressure) density is important. Countries with a dense population score higher on such an indicator. Such countries often can be more eco-efficient (see below) and even might have a lower DMC per capita, but nevertheless the environmental pressure can be high.

The DMC per € of GDP is another option to ensure comparability between countries. This can be regarded as an eco-efficiency or materials intensity measure: the amount of materials related to the making of (or spending of) one Euro. Again, less is better, because "less" means more eco-efficient and less material-intensive.

The DMC can be broken down into a small number of categories of resources. As an account, the more detailed it is the better, since more possibilities of analysis are available. However, the relation with environmental pressure on this level is less clear. Bulk-materials for construction, for example, are very important in weight but not in environmental pressure. For metals, it is the other way round. As is shown in Chapter 4, there is no relation at all between a specific material's volume of use and its environmental impact potential. As a proxy for environmental pressure, the DMC can therefore only be used on the aggregate level. This is true for all DMC variants, and especially for the DMC/€. On an aggregate level, the DMC/€ makes sense, but disaggregated the relation with income is meaningless. The contribution of each material to the GDP is different per kg of material. It would make sense if the GDP could be attributed to the different (groups of) materials. This can be an interesting task for the future.

EMC variants

The EMC can be defined as: "the global environmental impact potential of cradle-to-grave chains of "new" materials annually consumed in a national economy". It adds an environmental dimension to the DMC and therefore is a much more direct indicator of environmental impacts. It also adds a cradle-to-grave aspect to the DMC and therefore includes the impact potential of those parts of the chain that are located outside the nation. The environmental impact potential of consumption thus is a global impact potential. In that respect - though not in others - this measure resembles the Ecological Footprint, which also takes the consumption as the starting point and specifies cradle-to-grave chains related to this consumption. The EMC needs no further interpretation or correlation. Like DMC, it is a relative indicator (less is better). Its expression is not in kg but in fraction contribution to the worldwide environmental impact potential. Its absolute value therefore also has some meaning as well, although still in a relative sense. On the other hand, EMC is a "virtual" measure: while DMC counts actual material flows, EMC is a construct only dimly related to actually observed environmental impacts.

The EMC per capita means the same but is a measure that is comparable between countries, unlike the EMC itself. A translation into EMC per km^2 is meaningless when the land surface of the country is used and trivial when the land surface associated with the cradle-to-grave chains is used, if such data would have been available. Therefore the EMC/km^2 is cast aside on grounds of doubtful indicative value.

The EMC per € of GDP can be regarded as an eco-efficiency indicator, comparable to DMC/€. This indicator is a measure for the impact intensity of a Euro made, or spent. "Less is better" again seems to be applicable.

The total EMC is built up out of the EMCs per environmental impact category, which in turn are built up out of the EMCs per material for this impact category. The EMC therefore is also available at a more detailed level. The interpretation is easier, or at least more comfortable, at the level of the individual impact categories: the contribution of the chains of materials to, for example, global warming or human toxicity. This is less vague and ambiguous than the "total environmental pressure" and avoids problems with the relative weighing of the impact categories. At this level, the indicator has its largest indicative power. Environmental impact categories which are doubtful, either because of lack of data or because the impact category is not yet well-established in the LCA framework, can just be ignored or left out. EMCs per material within the impact categories are equally well interpretable, but suffer from uncertainty problems in the basic data (see 7.2). EMCs per group of materials, comparable to the categories of materials in DMC, could be a better option.

The breaking down of the EMC/€ into (groups of) materials leads to nonsensical results. The reasoning is comparable to that in Section 7.1.1, where similar conclusions are drawn for the breaking down of DMC/€.

Global land use variants

The global land use indicator, as developed in this study, can be defined as: "Global land use related to the annual consumption of "new" materials by a national economy". It can be used in a relative sense, less is better, but can also be related to an absolute value, i.e. the amount of land available on Earth. In principle, it can be a powerful indicator. In practice there are large problems with data availability. Agricultural land has been the only category for which sufficient data were available. Apart from that, it is difficult to relate these categories to the categories of materials used in the DMC and EMC. Biomass seems to be the only material category for which this is possible. The built-up area can be related to the other categories, since they will be mostly used there. However, land required to produce these materials is difficult to include. The GL is therefore would not be completely comparable to DMC and EMC. In all, the development of a global land use indicator is still in its first stages.

Comparability between countries

Comparability between countries can in principle be reached by using the indicators per capita, per € or per km^2. As mentioned above, not all combinations make sense. The per capita indicators seem most robust against becoming meaningless. The per € indicators are powerful measures of eco-efficiency, but only at an aggregate level. The per km^2 indicators are doubtful in their meaning; only for DMC these seem to make sense as a proxy for environmental pressure.

Another issue is what such a comparison means and what conclusions can be drawn from it. It has become apparent that the differences between countries are due mostly to the structure of the economy. This influences both DMC and EMC. A country with a large mining sector is bound to have a higher DMC, while countries with an intensive agricultural sector have a high EMC. Although it can be concluded that such countries have a worse environmental performance, it does not follow automatically that countries with mining sectors should close their mines or abandon their agriculture. It could be much worse, on a global level, if mining or agriculture were shifted to other places. Other aspects are population density and level of wealth. This can be seen most clearly by comparing Eastern European countries with the richer former EU-15 countries. The EMC/capita is lower for the Easter European countries, but the EMC/€ is much higher. This can be corrected to some extent by not using GDP but GDP corrected for purchasing power potential. However, differences between countries remain and cannot be interpreted directly in terms of where to go. This limits the usefulness of the indicators to monitoring; they cannot be used directly as steering variables.

These deliberations do not play a role when monitoring progress over time within a country, or within the EU as a whole. Given a certain structure of the economy, a development over time towards a less material and impact intensive economy can be regarded as positive. Therefore the use of time series does not cause interpretation problems.

Useful indicators for measuring decoupling at the level of (supra) national economies are, presently:

- DMC/capita and DMC/km^2, as descriptions of the physical economy and as proxy for emissions and waste, at the aggregate level.
- EMC/capita, as an approximation of the impact potential of consumption of national economies
- DMC/€ and EMC/€, as eco-efficiency indicators for materials intensity, respectively impact intensity of a national economy
- EMC/capita and EMC/€ broken down into separate impact categories, indicating the contribution of consumption to those impact categories and enabling to relate with environmental problems oriented policy
- EMC/capita broken down into categories of materials
- GALU/capita, only for agricultural biomass production.

All can be used in a relative manner (less is better), and therefore are in principle open to non-specific targeting or benchmarking.

Conclusions, discussion and recommendations

For the EU, MFA accounts including DMC are currently estimated and up-dated by Eurostat based on standardised methods. Eurostat is encouraging Member States to establish MFA accounting in their statistical programmes and so is the OECD. Further efforts will have to be put into the methodological harmonisation of MFA accounts so as to improve the statistical cross-country comparability. To enlarge the potential of use of the MFA databases, it could be recommended not to limit the accounts to the transboundary flows. Including recycled flows and production would increase the usefulness of the MFA database for all kinds of analyses. On an aggregate level DMC can be used as a proxy for environmental pressure. Hence, it seems the most readily available indicator to monitor resource use and resource productivity.

One of the major challenges of this study was the development of the environmentally weighted material consumption indicator, the EMC. Although many uncertainties, data gaps, methodological problems etc. have been encountered, we have been able to define and apply EMC. The next step is to assess whether the EMC indicator is ready for use.

On the positive side, the basic idea is simple - just adding an environmental weight to the material flow data - and the methodology builds entirely on existing tools and databases. An additional advantage of using LCA data is that this facilitates the link with a product policy. There are also some aspects that limit its potential at the moment. One important problem is that of the weighting between environmental impact categories. So far, every aggregate measure of environmental pressure or impact has suffered from this problem with regard to its acceptance. It may be kept in mind that the most influential measure for economic performance, GDP, also suffers from this problem: it is made up of different sub-indicators, which are aggregated arbitrarily. Nevertheless it is accepted as an indicator for welfare and is used for monitoring and even targeting. Many people have worked many years on its development. The same will probably be true for an indicator of overall environmental performance, to which we hopefully have made a contribution.

Other aspects limiting its potential for use refer to the mentioned uncertainties, data gaps and methodological issues. To develop the EMC further, the following activities are recommended:

- The LCA database used in this study has in the meantime been updated. It is recommended to derive new impact potentials with the help of this updated database
- In order to have a representative state of the art of technologies in the EU, a regular update of the LCA database is actually required. This is a major task for the LCA community.
- Not all relevant materials are included in the LCA databases. It is recommended to expand the database with materials related to agriculture, and with a number of secondary materials esp. metals.
- The LCA methodology does not allow assessing the problem of depletion of renewable resources. This is a very serious environmental problem indeed. If LCA is unable to deal with it, it is recommended that a separate indicator is developed for that, comparable to the effort undertaken in this study to define a land use indicator.
- There are differences between countries which are not visible from a general LCA database. For a sensible application of the methodology in the different countries, country-specific studies are required. Per country it can be determined whether the average LCA data are valid or new country-specific processes have to be defined. This will especially be relevant for industries with little transboundary flows, such as for example the construction industry.
- Using the DMC system boundaries for the EMC has proven to be difficult and even awkward. The system boundaries of apparent consumption seem to be more convenient and meaningful. It is recommended to develop the EMC further using the boundaries of apparent consumption. Additional data have to be collected from production statistics. With the help of these data, it may be possible to draft sufficiently reliable material balances for a more complete set of materials. An additional advantage is that apparent consumption enables to include recycled materials, which is at present not the case. Recycling appears only indirectly in DMC and therefore also EMC, as a reduced demand for "new" materials.
- The use of the EMC for policy purposes should be carefully considered. Its use for monitoring developments puts different requirements to an indicator than the use for targeting, or even for

identifying options for policies. The EMC in its present state could be used for monitoring, especially with the improvements as indicated above. In that view, it is also recommended to perform a robustness analysis of EMC, to see to what extent the uncertainties and data gaps could influence the outcomes.

- The EMC broken down into the different impact categories is more robust, because the tricky problem of weighting is avoided. Also, it is possible to make a distinction between more and less reliable impact categories. For the more reliable categories, general targeting (Factor Four, or suchlike) could in principle be possible. The underlying information for the individual materials could be used, as one of many necessary pieces of information, for more specific policies. It should not be allowed to live a life of its own.
- The link between a resources and a product angle should be made explicit. One of the repeatedly recurring issues refers to energy in the use phase of the life-cycle. In the EMC, energy in the use phase is represented in the chain of fossil fuels. It is therefore not invisible, but it is not attributed to the other materials. In our view, energy in the use phase can be attributed to a product, not to the materials the product is made from. From a product or service perspective, such as used in IPP, this is a very important aspect. A resource and a product perspective in our view should be additional, not mutually exclusive.

The other new indicator investigated in this study, the Global Land use indicator, is presently not applicable. Too many data are lacking and too little harmonisation in statistical categories exist at the moment. The LCA land use data, although they would be ideally suited to the indicator's purpose, appear to be insufficiently reliable. For the moment, only the Global Agricultural Land Use is specified. Further development of this indicator is recommended.

The analysis on the driving forces for resource use has delivered the following conclusions and recommendations:

- There is a large variation in resource and impact efficiency between countries.
- Resource or impact efficiency of the DMC or EMC is better measured in terms of Purchasing Power Parities than in terms of nominal exchange rates. This reduces the variation between countries and may give a better expression of what consumers can buy from their incomes.
- There is an epistemological advantage in using resource efficiency over resource productivity as resources themselves do not generate value added if no labour were put into the extraction and refining of resources. While this is recognized in the field of energy economics (energy efficiency is the target variable instead of energy productivity), the field of resource economics sometimes sticks to the concept of resource productivity.
- The most important driving forces for differences in resource as well as impact efficiency relate to the level of GDP and the structure of the economy. While indirectly one may hope that a natural resource strategy may result in changes in the economic structure, there will be no environmental gains if such changes are not accompanied by equivalent changes in the structure of consumption (lifestyles). For that reason, it might be wise to periodically correct the resource efficiency for changes in the structure of production and to identify countries that have performed well over time in improving their resource efficiency.
- It proved to be difficult to exactly trace back the reasons for improved resource efficiency over time. We found especially that they related poorly to policy variables that we have chosen in this study, except for the recycling of municipal waste. More efforts should be devoted towards revealing strategies that can help in reducing resource consumption over time and identifying successful policies that help to achieve the goal of decoupling environmental impacts of resource use from economic growth.

The DMC and EMC indicators developed and applied in this study are highly aggregated indicators, which may serve the purpose to provide an overview on the development at the macro level (national or EU) with regard to material consumption and related environmental impacts. In the past other attempts have been made to define comprehensive indicators for environmental pressure. They are sometimes highly appealing, but also suffer from generalisations, abstractions and simplifications. This makes their meaning doubtful and their relation with any real environmental impact hazy. Nevertheless there is a clear demand for such aggregated indicators. How to measure de-coupling without such an indicator? Its counterpart, the all-encompassing economic indicator, the GDP, has the same problems. Nevertheless GDP is generally used. Therefore it seems to be not just a matter of scientific soundness but also of political acceptance.

It is recommended to carefully consider the purpose for which the indicators will be used. A distinction can be made between monitoring and benchmarking on the one hand, and targeting or preparation of policy measures on the other. Past developments at the aggregate level can be monitored by such indicators, and if there is agreement on the desired direction of the indicator (less is better) benchmarking at the aggregate level - although more controversial - is also possible. For instance, benchmarking is possible for aggregate DMC and EMC with regard to eco-efficiency (Factor X improvement over a period of Y years) at the level of countries or the EU as a whole. The indicator then can be used to see whether or not the target is reached, again as a monitoring tool. For the preparation of specific policy measures, however, additional and more detailed information and specific indicators are required, especially at the level of sectors. Policy measures designed to control individual materials require much more detailed studies regarding the flows and applications of such materials.

In that view, it is also recommended to do a careful check on the indicative value. Is "less" indeed "better" in all cases, or can we imagine instances where this may not be true? Again, there may be a difference between DMC and EMC due to the fact that they indicate different things. And again, there may be a difference depending on the scale level of observation. For individual materials, less might indeed be better. When substitution is involved and we have to look at more materials at the same time, this is not automatically true. This is the same at the EU and national level: since substitution may occur, less is not automatically better. On the other hand, the correlation between DMC and EMC indicates that it could be concluded that over the past ten years, "less" materials consumption might indeed be translated into "better" for the environment. Nevertheless, a check as recommended above could be very useful to obtain more insight in this matter.

1. Introduction

Resource flows link the economy with the ecosystem and form the bridge between human activities and environmental impacts. The use of resources on the one hand leads to wealth and economic growth. On the other hand, it leads to problems related to resource availability, and to the generation of waste and emissions. In many countries as well as in the EU, decoupling of economic growth and resource use has become a policy objective. Over the years, there has been a debate of what exactly is meant by the term "decoupling". It has been understood as "dematerialisation", i.e. an economic growth linked to a reduced throughput of mass. It has also been understood as de-linking economic growth from environmental pressure. It has been used at the level of companies (making more money with less raw materials), at the consumer level (a shift from products to services), and at the level of national or even supra-national economies. On that level, a distinction is made often between "absolute" and "relative" decoupling, relative decoupling implying a reduced throughput or environmental pressure per unit of GDP, and absolute decoupling indicating a declining throughput or environmental pressure over a growing GDP.

The 6th Environmental Action Programme (6 EAP) (European Commission, 2002) also has addressed the issue of the use of natural resources. The objective for the thematic strategy on the sustainable use of natural resources (Resource Strategy) is described 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". This objective has both an "absolute" and a "relative" compound. Not exceeding the carrying capacity of the environment refers to an absolute limit - however difficult to define - to the extraction and consumption of resources. It also clarifies the reason for decoupling: reducing or avoiding environmental impacts. Breaking the linkage between economic growth and resource use is a relative target. In all, the following characteristics apply to decoupling as understood in the 6th EAP:

- decoupling is applied at the level of (supra)national economies
- the aim is reducing environmental impacts at a continued economic growth
- the target is the use of materials or resources
- decoupling is relative, but the underlying idea is sensitive to absolute limits.

Within the framework of the 6 EAP Resource strategy some studies have been conducted. One is the so-called Zero study (Moll et al., 2003). In this study, data have been collected on the use of resources in the EU-15 countries and processed into a number of indicators. Another, similar study has been commissioned by Eurostat (Eurostat, 2002). Finally, the Topic Centre on Waste and Material Flows (EEA, 2003), has provided information on material flows in EU and AC countries. From these studies, an analysis can be made of the pattern of resource use of countries. It appears that there are clear differences even within the EU. According to the Technical Annex to the call for tender, the Domestic Material Consumption over GDP (kg DMC/€) seems to be preliminarily adopted as an indicator for the material intensity of a national economy.

The available database also gives rise to a further need for analysis, and partly to an expansion, in three directions. In the first place, an analysis of the causes of the substantial differences between the countries is required. Are these due to statistical fluctuations or related to certain driving forces of material use? Such an analysis may form the basis for country-specific policies. Secondly, an expansion of the DMC indicator is required. There are some doubts regarding the indicative value of DMC and other mass based indicators for environmental pressure, since there is no direct correspondence between weight or volume and potential environmental impacts. Thirdly, there is a need for the definition and elaboration of an additional indicator for land use. Land is considered a key resource and is insufficiently expressed in any indicator related to the use of material resources. Land use can also be indicative of the "rucksack" that is associated with the consumption of materials.

Elaborating on these three issues is necessary for further refinement of an indicator for resource productivity that can be used for policy making at the EU level. These three issues therefore form the core of this study. This report is the first interim report of the study. It contains the results of the analysis of the DMC data set in Chapter 2. It contains progress reports, with methodological issues and interim results, on the other issues. A progress report on the explanation of differences between DMCs of countries due to socio-economic factors or the influence of policies is presented in Chapter 3. Chapter 4 contains the progress report on the methodology of connecting materials to environmental impacts, the derivation of indicators from that and the first results of the application of the methodology. In Chapter 5, finally, the progress on the identification of land use intensity in the EU and AC countries is presented.

2 MFA database for DMC: Review of the comparability of data, explanations, solutions, and results

2.1 Introduction

The scope of this section is, to analyse and discuss material flow data related to Domestic Material Consumption (DMC) for the EU-15 and its Member States (MS) and its Accession and Candidate Countries (ACC-13) with respect to comparability across countries. This task is performed with the aim to improve the interpretation and policy use of material intensity and resource use indicators on international level.

The comparability of materials flow data across countries was found to be critical with respect to five major points:

1. Basic statistical data may be wrong, misleading, incomplete and/or inconsistent over time and across countries;
2. Official statistics do not report the total weight of materials but only specific contents;
3. Statistical data in time series reveal individual gaps or different references;
4. International statistics have to be used instead of specific national statistics;
5. Data required to account for material indicators are not available from statistics.

In this study, the material flow databases for the EU-15 and MS, and of the ACC-13, were submitted to critical (re-)examination and reviewed for every single country with respect to major potential limitations that hinder international comparability of the derived material flow indicators DMI and DMC. This is described in detail in Annex 2.

In the annex, it is also described which solutions we chose in order to overcome the identified data problems. This includes in particular general plausibility checks for construction minerals and green fodder for ruminants which were developed in this study, and applied in order to improve data comparability on international level.

The outcomes are consolidated material flow databases for the EU-15 and Member States (MS) for 1990 to 2000, and of the Accession and Candidate Countries (ACC-13) for 1992 to 2000. This work was build upon extensive experience gained at Wuppertal Institute during recent and ongoing work in this field, in particular on material flows accounting for EU-15 and Member States (Bringezu and Schütz 2001a, 2001b, Eurostat 2001b, Schütz 2002, 2003), in comparison with recent and ongoing activities of EUROSTAT (Eurostat 2002), and on MFA for ACC-13 (Moll et al. 2002, Wuppertal Institute: this study). Furthermore, we analysed and included specific national data sources and studies on economy-wide MFA being available so far (Austria: Schandl et al. 2000, Gerhold and Petrovic 2000; Denmark: Pedersen 2002 and personal communications, Statistical Office Denmark online database; Finland: Mäenpää and Juutinen 1999, and personal communications Mäenpää, Thule Institute; Germany: Schütz 2003 and database of Wuppertal Institute; Italy: Barbiero et al. 2003 and personal communications Femia, ISTAT; The Netherlands: Matthews et al. 2000 and database of CML; Portugal: Monteiro 2003 and personal communications Romao, Statistics Portugal; Spain: Statistics Spain 2003; Sweden: Isacsson et al. 2000; UK: Bringezu and Schütz 2001c and Office for National Statistics online database; Czech Republic: Scasny et al. 2003, and personal communications Kovanda, Charles University Prague; Estonia: Statistics Estonia data provided by Matti Viisimaa, KKM Info- ja Tehnokeskus - Estonian Environment Information Centre, personal communication on 3 March 2002; Poland: Schütz et al. 2002). We also contacted official statistical offices and other institutions in individual countries in case of missing or obviously critical data.

Based on the acquisition and analysis of material flow data described in detail in Annex 2, this study provides a revised and consolidated database for DMI and DMC of EU-15 and MS 1990 to 2000 and of ACC-13 1992 to 2000. Still, it is recommended to establish national MFA studies by national authorities and experts with deeper insight into specific sources of data and information. This refers to countries' datasets which are not based on national specific studies as indicated above. These countries should be encouraged to establish respective MFA datasets based on harmonized methodological guidelines ensuring cross-country comparability. The recent re-establishment of the Eurostat task-force on economy-wide MFA and its major envisaged outcome, i.e. a harmonized practical guideline on how to establish economy-wide material flow accounts including standard accounting tables, should contribute to this end (see also following chapter 2.2 on methodology).

The data for domestic extraction in EU and MS and in ACC-13 are provided in this study at the highest level of detail available.

Data for imports and exports of the EU and MS are in general provided at the HS-CN 2-digits level of the Eurostat Comext database and can serve further users as a basis for more detailed material flow studies by using more disaggregated data available from the Comext database. Excepted are data for 1990 to 1994 for the EU Accession countries in 1995, Austria, Finland and Sweden, for which the Comext reports only since 1995. The extra-EU trade of these countries has been estimated for 1990 to 1994 in order to derive the total foreign trade of EU-15 (Bringezu and Schütz 2001, Eurostat 2002). Imports and exports of the total foreign trade (extra-EU plus Intra-EU) were available from the original national databases mentioned before, respectively derived from Comext for Austria, Finland and Sweden since 1995.

Foreign trade data of ACC are presented by material categories available from international or national statistics as described in Annex 2.

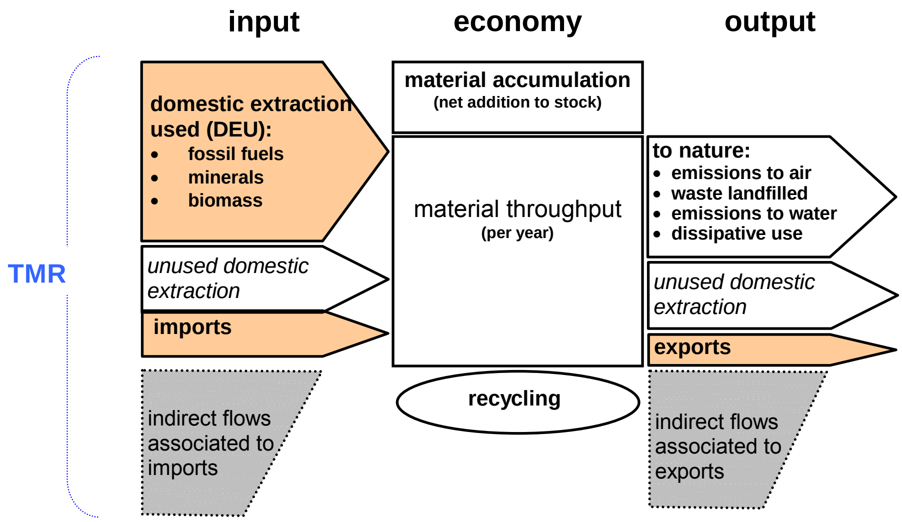
This database thus allows disaggregating the material compositions of DMI and DMC at the level of fossil fuels, ores and metals, industrial minerals, construction minerals, biomass from agricultural harvest, ancillary or additional biomass from agricultural harvest, biomass from grazing, biomass from forestry, biomass from fishery, biomass from hunting, other biomass, and other compound products.

Results derived from the database established in this study are presented in the following chapter 2.3.

2.2 Methodology: DMC in the context of aggregated indicators for resource use derivable from economy-wide material flow accounts

Economy-wide material flow accounts and balances show the amounts of physical inputs into an economy, material accumulation in the economy and outputs to other economies or back to nature (Figure 2.1). A guide published by Eurostat (2001a) serves as a methodological framework and practical guidance for establishing material flow accounts and material balances for a whole economy and to derive material flow indicators. Strength of economy-wide MFA is that it provides a comprehensive and consistent picture of the quantity and composition of the metabolism of economies (Bringezu et al. 2003).

Figure 2.1: Economy-wide material balance scheme (excluding air and water flows)



DMI = domestic extraction used + imports

DMC = domestic extraction used + imports – exports

TMC = TMR – exports – indirect flows associated to exports

Note: DMI: Direct Material Input TMR: Total Material Requiremnet
DMC: Direct Material Consumption TMC: Total Material Consumption
Source: Eurostat (2001a)

The summary indicators derived from economy-wide MFA provide a physical description of a national economy, complementing the greater detail offered by other common indicators (e.g. energy use, waste generation or air emissions). In economic terms, the summary indicators show the dependency on physical resources and the efficiency with which the resources are used by national economies. In environmental terms, material input indicators can be used as a proxy for environmental pressures associated to resource extraction, the subsequent material transformation, and the final disposal of material residuals back to the environment.

The indicators accounted for and analyzed in this study are Direct Material Input (DMI) *and in particular Direct Material Consumption (DMC)*, two out of a set of material flow indicators derivable from economy-wide material flow accounts.

The *Direct Material Input (DMI)* measures the direct input of materials for use into the economy, i.e. all primary materials which are of economic value and are used in production and consumption activities; DMI equals domestic (used) extraction plus imports (Eurostat 2001a). The DMI of a country quantifies the amount of material input used for processing in industry. DMI comprises the amount of materials that is either accumulated in infrastructure, buildings, and durable goods according to their lifetime or – after short-term use and change of composition – released to the environment domestically or exported (subsequently contributing to environmental release elsewhere) (Bringezu et al. 2003). Recycled materials are excluded from DMI. DMI is not additive across countries. For example, for EU totals of DMI the intra-EU foreign trade flows must be netted out from the DMIs of Member States.

The *Direct Material Consumption (DMC)* equals DMI minus exports. Whereas DMI quantifies the amount of materials used for domestic production (including trade), DMC quantifies the amount of materials for domestic consumption and the amount of materials subsequently being released to the environment on domestic territory (Bringezu et al. 2003).

The following accounting scheme – as derived from the Eurostat MFA Guide (Eurostat 2001a) – illustrates the relation of DMI and DMC:

+	Domestic Extraction Used (DEU)
+	Imports
=	DMI (Direct Material Input)
–	Exports
=	DMC (Direct Material Consumption)

Each element of this *direct materials account* can be disaggregated into material categories. According to the Eurostat MFA Guide (Eurostat 2001a), four main material categories are used: fossil fuels, minerals, biomass, and other composite products. Often, the minerals are further disaggregated into metals (ores), industrial minerals, and construction minerals.

While the conceptual basis and the general methodology of DMC is well established by the Eurostat guidelines (Eurostat 2001a), uncertainties due to some specific unsolved methodological problems still exist, which actually came up through practical follow-up work on compiling economy-wide material flow accounts by several national authorities and research institutes. With regards to major influences on the level and trend of DMC, these uncertainties concern mainly the accounting for (1) the domestic harvest and grazing of biomass used as fodder for ruminants (where standardization of water contents is the main problem), (2) the domestic extraction of bulk minerals for construction (where statistical data are often insufficient), and (3) the domestic extraction of metallic minerals (where gross weights of ores should be counted, but net metal contents are often only available from statistics). Besides, one has to be aware of flaws in statistical databases, inconsistencies, gaps etc. which limit the quality of the results and comparability of the accounts and derived indicators across countries. This study provides a structured analysis of major limitations and seeks for solutions to proceed towards better comparability of the results of economy-wide MFA. This is described in detail in Annex 2.

The methodology on economy-MFA was recently presented to representatives of national authorities of 18 European countries, Australia and the OECD in a training workshop in Luxembourg on 17-18 June 2004, jointly organized by Eurostat and the ETC on Waste and Material Flows (for the minutes see: http://forum.europa.eu.int/Public/irc/dsis/envirmeet/library?l=/20041108-09_material&vm=detailed&sb=Title). The methodological training was performed by Helmut Schütz and Stephan Moll from the Wuppertal Institute, being team members in this study. Major methodological issues requiring further clarification, as also adressed in Annex 2, were identified and proposed to be discussed by a task force on MFA to be organized by Eurostat.

This task force on economy-wide MFA was actually re-established by Eurostat with experts from national authorities and research institutes in the EU (including the Wuppertal Institute being a partner in this study). A first meeting was held in Luxembourg on 8-9 November 2004. The major envisaged outcome of the work of the MFA task force will be a harmonized practical guideline on how to establish economy-wide material flow accounts including standard accounting tables. This outcome should be the basis for countries' activities in establishing harmonized MFA datasets with better cross-country comparability, and should contribute to respective activities of the OECD. It is therefore recommended to let produce future official material flow accounts and derived indicators like DMC by national authorities and experts, based on these harmonized practical guidelines to be developed.

The *Total Material Requirement* (TMR) is an MFA based indicator considering all *primary materials* which are required by a national economy in order to perform its production. In addition to DMI, it includes unused domestic extraction, i.e. material which is extracted but not further processed in the production system (e.g. mining waste). TMR also includes upstream 'hidden flows" of imports (indirect flows associated to imports). The *Total Material Consumption* (TMC) considers all *primary materials* which are associated to the final demand or consumption of a national economy.

The following accounting scheme – as derived from the Eurostat MFA Guide (Eurostat 2001a) – illustrates the relation of TMR and TMC:

+	Domestic Extraction Used (DEU)
+	unused domestic extraction
+	Imports
+	indirect flows associated to imports
=	TMR (Total Material Requirement)
–	Exports
–	indirect flows associated to exports
=	TMC (Total Material Consumption)

The computation of TMR and TMC requires additional data related to unused domestic extraction and indirect flows. In contrast to DMI and DMC accounts, this additional information can not immediately be derived from official statistical sources. For unused domestic extraction, statistics on mining overburden, ancillary mass etc. can sometimes be obtained from publications by the respective mining industries or their associations. Often specific estimation procedures using coefficients e.g. from scientific literature may have to be developed. The latter particularly applies for estimating the indirect flows associated to imports. Estimation procedures and coefficients exist from mainly scientific studies mainly for raw materials and semi-manufactured products, so far, hardly for any finished product (Eurostat 2001a). For some imported raw materials specific information from statistical sources of the country of origin may be used too.

All in all, the statistical robustness of TMR and TMC accounts needs to be improved. One step towards this aim would be the establishment of a database with estimation procedures and coefficients.

TMR and TMC are not considered in this study.

2.3 Results: DMC for the EU and MS and for other European countries

This section will provide an overview on how much "new" renewable and non-renewable raw materials are used by European economies annually in the 1990s. The focus is on Domestic Material Consumption (DMC) because of best current data availability at a harmonized state and high policy relevance in the context of the Commission's proceedings towards a thematic strategy for the sustainable use of natural resources.

The DMC indicator is derived from DMI (Direct Material Input which equals domestic extraction used plus imports) minus exports. It is a physical measure for all (direct) materials consumed within the national economy in one year.

The difference between DMI and DMC, thus, depends on the relative importance of exports by a national economy in terms of direct material flows. The percentage of DMC relative to DMI indicates this. In 2000, most of the European countries studied had a relatively high DMC share of more than two thirds of DMI. The EU-15 as well as EU-25 ranged at 94%. Even higher was the share of domestic material consumption relative to direct material inputs in Cyprus (97%), Malta (96%), and Turkey (95%). Contrary, countries with a high physical relevance of the exporting industries show a low DMC share of DMI. The lowest DMC shares of 50% for Belgium/Luxembourg and 57% for the Netherlands in 2000 underline the extraordinary situation of these economies among European countries. The low DMC shares for Belgium/Luxembourg and for the Netherlands are mainly due to a relatively high proportion of direct material inputs being processed in these countries for export to other European countries and the rest of the world. The direct material flows picture for the EU-15 and EU-25 proved to be rather conservative over the 1990s, i.e. the DMC share of DMI had hardly changed.

The DMC per capita of EU-15 and EU-25 has been fairly constant, thereby relatively de-coupling from economic growth which had increased from 1992 to 2000 significantly more (Table 2.1). GDP per capita had increased in all EUROPEAN countries studied during the 1990s, with the highest rate in Ireland (plus 76%) and the lowest in Bulgaria (plus 5%). As compared with 1992, the EU-15 GDP per capita had increased by 16.4%, for EU-25 even by 17.5%. Of the 28 countries studied, 15 had also increased their DMC per capita from 1992 to 2000, though at very different rates. Thus, 13 economies had succeeded in reducing the domestic material consumption per capita over that period, in particular Romania and the Czech Republic. They had therefore achieved absolute de-coupling of (direct) material consumption from economic growth. There are only two cases where relatively more DMC had been required than the GDP had grown: *Portugal and Lithuania. These two economies must be characterized as generating economic growth by rising amounts of direct material resource consumption.*

The GDP per DMC is called resource productivity. It is a measure (indicator) expressing how much GDP is generated from one unit DMC and thereby in a way reflects the enviro-technological and economic state of the final consumption pattern of the respective national economy. Although the resource productivity is on increase in most European countries studied, there exist huge disparities in the resource productivity level across countries (Table 2.1). Broadly, resource productivity for consumption in old Member States (former EU-15) is about 4 times higher than in new Member States (former AC-10). Resource productivity of the EU-25 in total, however, is only about 10% lower than in EU-15 in 2000. Furthermore, it had increased slightly more from 1992 to 2000 (plus 15.7%) than DMC productivity for EU-15 (plus 15.2%). This is partly due to a high share of EU intra trade of the AC-10 which is excluded from DMC in the account for EU-25, and partly due to the relatively low share of AC-10 in the GDP of EU-25 which ranged only by about 20% higher in 2000 than GDP for EU-15. Only the DMC productivity of Portugal and Lithuania showed an exceptional downward trend over the 1990s, indicating an over-proportional direct resource consumption for achieving economic growth in these two countries.

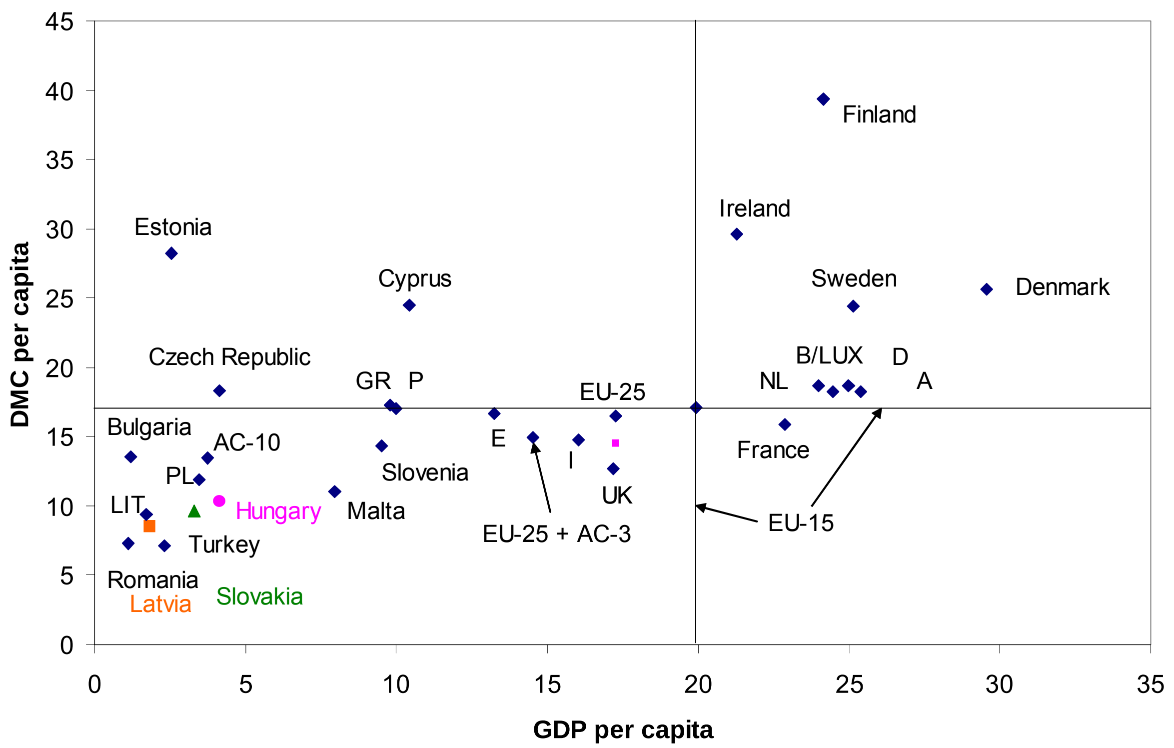
The status quo of the relation of DMC to GDP (per capita) in 2000 in the European countries studied is shown in Figure 2.1. Relative to the situation of the EU-15, especially countries of Northern and North-Western Europe are characterized by both higher GDP and DMI, with Finland on top. As for DMI versus GDP (results not shown here), there are economies with lower GDP but higher DMC than in EU-15, especially Estonia, Czech Republic, and Cyprus. And, again as for DMI, most of the Accession and Candidate countries of the EU are characterized by both lower GDP and lower DMC than EU-15.

Consequently, higher GDP per capita in the new and forthcoming EU member states should be achieved without increasing the requirement as well as the consumption of material resources and associated pressures on the global environment.

Table 2.1: DMC, GDP and related resource productivity in European economies

	GDP per capita		DMC per capita		GDP per DMC				
	2000	2000 vs. 1992	2000	2000 vs. 1992	2000	2000 vs. 1992	relative to EU-15		
	Euro 1995	%	t	%	EURO per kg	%	2000 (EU-15=1)	2000 vs. 1992 in %	factor 2000 to reach EU-15
EU-25	**17.259**	**17,5%**	**16,5**	**1,5%**	**1,05**	**15,7%**	**0,90**	**0,4%**	**1,11**
EU-15	**19.937**	**16,4%**	**17,1**	**1,0%**	**1,17**	**15,2%**	**1,00**	**0,0%**	**1,00**
Austria	25.379	16,1%	18,2	-3,2%	1,39	20,0%	1,19	4,2%	0,84
Belgium-Luxembourg	24.476	18,8%	18,3	-6,2%	1,34	26,7%	1,15	10,0%	0,87
Denmark	29.558	20,2%	25,6	10,6%	1,16	8,7%	0,99	-5,7%	1,01
Finland	24.139	30,0%	39,3	5,1%	0,61	23,8%	0,53	7,4%	1,90
France	22.867	13,5%	15,9	-0,4%	1,44	14,0%	1,23	-1,1%	0,81
Germany	24.985	10,0%	18,6	-5,0%	1,34	15,9%	1,15	0,6%	0,87
Greece	9.765	14,2%	17,3	11,7%	0,57	2,3%	0,48	-11,3%	2,07
Ireland	21.270	76,4%	29,7	9,9%	0,72	60,5%	0,61	39,3%	1,63
Italy	16.037	13,5%	14,8	-0,4%	1,08	13,9%	0,93	-1,1%	1,08
Netherlands	23.979	22,2%	18,7	-1,9%	1,28	24,6%	1,10	8,1%	0,91
Portugal	9.966	23,0%	17,1	39,2%	0,58	-11,7%	0,50	-23,3%	2,00
Spain	13.243	22,1%	16,7	13,3%	0,79	7,7%	0,68	-6,5%	1,47
Sweden	25.133	22,1%	24,4	4,8%	1,03	16,5%	0,88	1,1%	1,13
United Kingdom	17.189	24,8%	12,7	-3,9%	1,36	29,9%	1,16	12,7%	0,86
New EU countries 2004	**3.733**	**36,8%**	**13,5**	**4,2%**	**0,28**	**31,2%**	**0,24**	**13,9%**	**4,22**
Cyprus	10.422	22,8%	24,5	8,6%	0,43	13,1%	0,36	-1,8%	2,74
Czech Republic	4.118	15,7%	18,3	-8,8%	0,22	26,8%	0,19	10,0%	5,20
Estonia	2.540	34,6%	28,2	-7,4%	0,09	45,3%	0,08	26,1%	12,98
Hungary	4.148	30,0%	10,3	24,0%	0,40	4,8%	0,34	-9,0%	2,91
Latvia	1.841	21,8%	8,5	7,4%	0,22	13,4%	0,19	-1,6%	5,38
Lithuania	1.713	7,2%	9,4	8,0%	0,18	-0,7%	0,16	-13,8%	6,41
Malta	7.969	38,2%	11,0	-7,7%	0,72	49,8%	0,62	30,0%	1,61
Poland	3.451	49,0%	11,9	2,9%	0,29	44,8%	0,25	25,7%	4,03
Slovakia	3.297	42,1%	9,6	-4,3%	0,34	48,4%	0,29	28,8%	3,41
Slovenia	9.493	36,1%	14,4	21,8%	0,66	11,8%	0,57	-3,0%	1,77
AC-3 countries									
Bulgaria	1.189	5,2%	13,5	1,0%	0,09	4,1%	0,08	-9,6%	13,31
Romania	1.131	8,8%	7,3	-14,1%	0,16	26,7%	0,13	10,0%	7,53
Turkey	2.303	16,4%	7,1	13,7%	0,32	2,4%	0,28	-11,2%	3,62

Figure 2.2: GDP and DMC in European economies in 2000

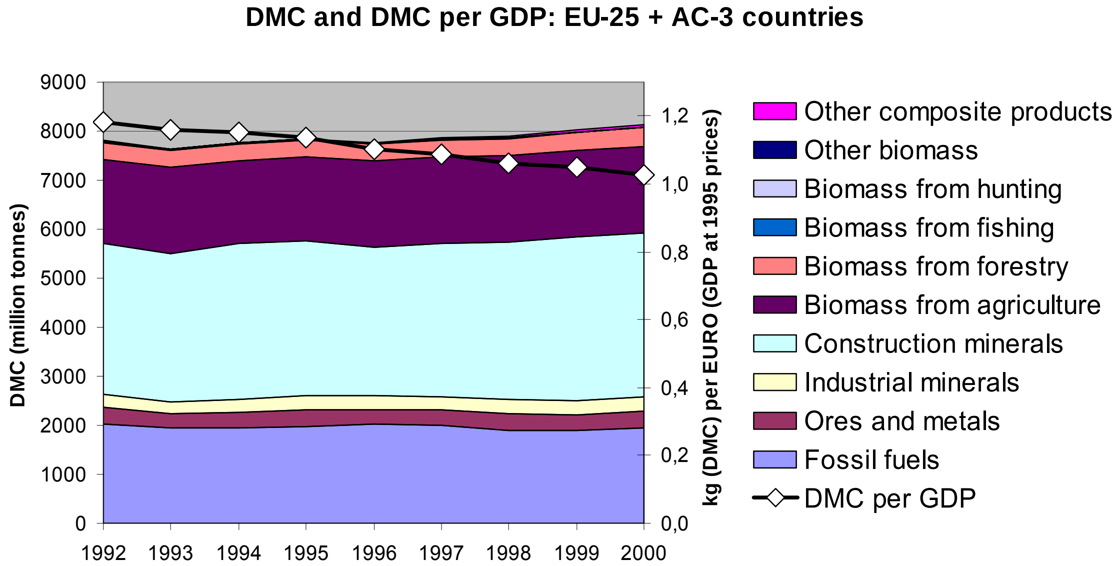


Note: DMC per capita: in metric tonnes; GDP per capita: in thousand ECU at 1995 prices

Figure 2.2 shows that the EU economy (EU-25 plus AC-3) has become more eco-efficient in terms of its direct materials consumption, i.e. increasingly less DMC has been needed to produce one EURO of GDP during the 1990s (or, vice versa, its material productivity in terms of GDP per DMC has increased). However, two important points should be considered in this context:

- the absolute amount of direct materials consumed (DMC) has not decreased but even slightly increased over the 1990s (see figure 2.3), indicating that absolute decoupling of material use from economic growth has not been achieved (but relative decoupling);
- potential shifts of the EU's resource requirements to foreign economies are not sufficiently reflected in the DMC indicator which accounts for direct materials only and neglects indirect material flows associated with imported and exported commodities. To overcome this bias, the material flow database would have to be further developed towards indicating the EU's global Total Material Consumption (TMC) which could be a matter of future studies.

Figure 2.3: DMC and DMC per GDP in EU-25 plus AC-3 countries, 1992 to 2000.



In figure 2.3, the contribution of the main material groups to the absolute level and trend of DMC can also be detected. A contribution to this process of relative decoupling came from a slight absolute reduction of the direct materials consumption of fossil fuels (obviously favoured by a substitution of low-energy coal by high-energy gas as results for the EMC in this report indicate). Contrary, the DMC of biomass had slightly increased and the DMC of construction materials had increased even more, with the overall effect of a slight increase of the total DMC (by 4% while GDP had increased by 20%). Obviously, increased domestic use of construction materials mainly prevented a development towards absolute reduction of the EU's direct material consumption.

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3 Derivation of a weighted indicator of material flows based on environmental impacts

In this chapter, a methodology is described to weigh specific material flows with information on the environmental impact related to these materials, and to use these weighting factors to compose indicators to assess the environmental impact of the materials consumption of national economies.

The first step is to obtain a notion of the environmental impacts connected to the materials. The approach taken is based on previous work by CML for the Dutch National Institute of Public Health and the Environment (RIVM), conducted within the framework of a Dutch policy on dematerialisation (Van der Voet et al., 2003). The second step is an application of the methodology to the material consumption in the EU-25 and AC-3 countries. This will make it possible to compare the environmental impacts associated with materials consumption between countries, and might offer some first handles for a policy on resources. The third step then is to use this information to set up an indicator for environmental pressure of materials. This will be discussed in Chapter 7.

In Section 3.1, the methodology is presented and the choices and difficulties within each step are discussed. In Section 3.2, the methodology is applied to the materials consumption in the EU and accession countries.

3.1 A methodology to assess the environmental impacts related to the consumption of specific resources

3.1.1 Outline of the methodology

To specify the environmental impacts of a material, a Life Cycle Impacts approach is taken. For every considered material, an estimate is made of its contribution to environmental problems throughout its life cycle. This includes not only the impacts related to the material itself, but also the impacts of auxiliary materials, energy used for its production, emissions of impurities and pollutants included in the material during use or waste treatment, etcetera. Two types of information are generated and used to determine the environmental impacts of materials:

(1) the cradle-to-grave impact per kg of the material
(2) the number of kilograms of this material being consumed.

A first issue to be discussed concerns the materials or resources that will be included in the study. This has to do with completeness on the one hand, and with the position in the economic chain on the other. Regarding completeness, the aim is to include all important materials and be as complete as possible. Restrictions are provided only by the availability of data. If we can find no data on the environmental impacts related to a material, it will not be included. The same applies to data on the use of a material. The position in the economic chain is a matter of choice: will we define our materials as resources, as close to the extraction from nature as possible, will we define them as close as possible to products, or somewhere in between? This choice will be debated and made in Section 3.1.2.

For establishing the per kg impacts, the CMLCA software (Heijungs, 2003) and an established LCA database, the ETH database (Frischknecht, 1996) are used. In the meantime, a follow-up of this database has become available: the newly published Ecoinvent database (Frischknecht, 2004). The Ecoinvent database contains more materials, enabling a wider scope, and its process descriptions are more up to date. However, changing to the Ecoinvent database has proven to be a difficult job. Although preliminary results are available based on Ecoinvent, the results presented in this report are still based on the ETH database. In Section 3.1.3, a more detailed description is given of how the per kg impacts are established.

The other main source of information, required to specify the number of kilograms of the material, are the MFA accounts presented in the Zero study (Moll et al., 2003) and refined in this project (see

Chapter 2). Additional data are used from various sources. Issues of system boundaries and problems of distilling the right information out of the databases are discussed in Section 3.1.4. These issues have proven to be the most problematic.

By combining these sources of information, the contribution of materials to a number of environmental problems or, in terms of LCA, impact categories can be specified. This is described in Section 3.1.3. To translate the information into an indicator or set of indicators requires more. The goal is to derive a weighting factor from the information on environmental impacts that can be used as a multiplier for the material flows. Such a weighting factor should be composed out of all different sorts of impacts related to the cradle-to-grave chain of the material. On the one hand, it should include mining, production, use and waste management. On the other hand, it must reflect issues of depletion, land use, waste generation and all the various forms of pollution. The cradle-to-grave information is taken care of by using the LCA database. The inclusion of all kinds of different environmental impacts requires a procedure to add them all up or integrate them into one value. This is discussed in Section 3.1.5.

3.1.2 Materials included in the study

Definition of "materials" in the cradle-to-grave chain

When determining the environmental impact of a material, it is important to be specific about the position in the cradle-to-grave chain. It should be clear that in all cases the whole chain is included when determining the environmental impacts, but in order to avoid double-counting, materials should be defined at one specific stage. Double-counting doesn't have to be a problem for some uses of the database. For example, the information on impacts related to the chain of fertilisers can be relevant next to information on impacts of the chain of agricultural crops, although the fertiliser chain is already included in the latter. However, when the information is used to derive an overall indicator for environmental pressure related to material consumption, double-counting should be excluded - in the example, the use of fertiliser should not be accounted for separately since it is already included in the chains of the agricultural crops.

Figure 3.1 illustrates the options available to us. We can define materials at the front of the chain, at the point of extraction from the environment. Materials then are equivalent to natural resources. However, a material such as sand is not used as sand only, but ends up in other materials as well, for example cement, concrete or glass. The impacts related to the production and use of these materials should then be included in the sand chain as well. Another option is to define materials at the level of finished materials, i.e. just before they are applied in products. All resources used for these finished materials then should be included in their chains. A third option is to define materials somewhere in between. The advantages and drawbacks of each option are discussed below.

Figure 3.1 Chains from natural resources to finished materials

raw materials		**materials**	**materials**	**finished materials**	**products**
water	water	water	water	water	water
ores	iron ore	iron	pig iron	steel	cars
	bauxite	aluminium	aluminium	aluminium	cans
	zinc ore	primary zinc	zinc	zinc	gutters
		secondary zinc	zinc oxide	zinc-oxide	additive, pigment
	copper ore	primairy copper	copper	copper	wiring, pipes etc.
		secondary copper	copper oxide	copper-oxide	additive, pigment
	lead ore	lead	lead	lead	sheet, isolation material
	chromium ore	chromium	chromium	chromium	
	nickel ore	nickel	nickel	nickel	
	etc.	etc.	etc.	etc.	
minerals	silica sand	glass	glass	glass	bottles
					window glass
	construction sand	construction sand	construction sand	leveling sand	height
			concrete	concrete	prefab elements
	gravel				
	clay		ceramic	ceramic	tiles, bricks
	limestone				
	salt	chlorine			
		NaOH			
	N2 gas	NH3	N-fertiliser	crops	bread
	P-rock	P-acid	P-fertiliser		meat, milk
	potash	kalium	K-fertiliser		
	sulphur				
	bentonite				
	gypsum				
	etc.				
biomass	wood		woodchips	paper	notebooks
			roundwood	board	windowframes
fossil fuels	oil	energy (heavy oil)			
		energy (light oil)			
		energy (diesel)			
		energy (petrol)			
		ethylene	PE	PE	pipes
		propylen	PP	PP	window frames
		styrene	PS	PS	bags
		vinyl acetate	PVC	PVC	
		benzene	etc.	etc.	
		phenol			
		active elements	pesticides		
		etc.			
	gas				
	coal				

extraction	production	use			
extraction	production		use		
extraction	production				use
extraction	production				

Figure 3.1 shows some examples of the gradual transformation from resources to products. The leftmost column contains some natural resources, raw materials or basic materials. The second column includes materials derived from natural resources. Some of those are applied as such. Most are transformed and refined further. This process repeats itself until we arrive at products. The most important problem related to double-counting is that some materials are partly used as starting materials for further transformation, while for another part they are used as finished materials.

A definition of materials at the level of resources provides the best connection with the MFA databases. Another advantage is that this approach, at least theoretically, is the best guarantee for completeness: it catches all major flows of an economy. At the start of the chain, double-counting is easily prevented. A drawback is the crudeness of the MFA database. Because the emphasis is on the large flows, this could mean that less attention is paid to small flows which might have a large impact, and data in that respect are incomplete. A second drawback may be that the level of natural resources might not be the most relevant, since the diversity within the chains can be large. For example, the sand chain includes not only sand but also concrete and glass, while the crude oil chain includes not only oil but all kinds of derived fuels, plastics, solvents and a long list of chemicals. It is then not clear what determines the score, and what a “sand policy” or a “crude oil policy” should look like. Moreover, derived materials such as glass, concrete or plastics are not visible with such an approach.

The second option is to select the level of finished materials, or in other words materials just one step away from being applied in a product. Wheat and cotton fibre are then materials, not bread or textile. Glass is the material, not windows or bottles, nor sand, although all of these are present in the glass chain. This, too, is consistent with excluding double-counting. An advantage is that the materials are more recognisable: in this approach, concrete and glass are not hidden in the sand chain. A disadvantage is the weaker link with the MFA databases. Another disadvantage is that, when applied consistently, some materials disappear from sight. Fertiliser for example is part of the chain of cotton fibre, but is not a separate material since its use is solely within the production chain of other materials. This option provides the opportunity to include more detail, although we must beware not to be too detailed.

As will be clear from Figure 3.1, it is practically impossible to avoid double-counting somewhere in between. For reasons mentioned above, it therefore cannot be our starting point. There could be other reasons however to go for a mixed in-between level. This enables to select for each material a specific and most relevant level. Raw materials can be included next to finished materials and materials halfway the production chain. This could contribute to a relevant list of materials. Due to the non-systematic approach, it would not be possible to compose an integrated indicator.

Summing up the arguments, we choose the second option, the finished materials, as the most relevant option still in line with the requirement of being able to exclude double-counting.

Level of detail

In the report “Dematerialisation: not just a matter of weight” (Van der Voet et al., 2003) the problem of the differences in level of detail is mentioned. In the ETH-database, a difference is made between six different types of steel, but on the other hand the total of agricultural production is just distinguished into two materials: crops and animal products. Aggregation of six types of steel is always possible. Breaking down highly aggregate categories is more difficult since it requires additional information.

From Van der Voet et al. (2003) it appears that that agricultural products, both animal and vegetable, score highly on most of the environmental impact categories. This is due to both a high impact per kg and the size of the consumption flow. For this group, a more detailed classification is therefore in order. In line with De Bruyn et al. (in prep.) the following categories are distinguished:

Table 3.1 Agricultural product groups (materials) and their applications

Product group or material	Application		
	Nutrition	Textile	Bio-materials
Starch crops for food (potatoes, grains etc.)	x		
Starch crops as raw material for bio-materials			x
Fibre crops for food (vegetables and fruit)	x		
Fibre crops for materials (cotton, hemp)		x	
Animal fibres for materials (wool, leather)		x	
Protein crops (pulses)	x		
Animal proteins (meat, eggs)	x		
Fish proteins	x		
Oil crops (rape seed, sunflower)	x		
Animal fats (milk products)	x		

In other cases, practical reasons may force us to aggregate. This will be treated further in the Results section (section 3.2).

3.1.3 Impact per kg material

For determining the environmental impacts per kg material, we will draw on work already done for the Dutch policy on materials (Van der Voet et al., 2003). The ETH and Ecoinvent databases for LCA studies contain a large number of industrial, energy generation and waste treatment processes. For the Dutch study, the database was supplemented with additional data for missing materials and some estimates of our own, especially for the use and waste management stages. Of all of these processes, the LCA database contains data on their economic (materials and products) and environmental (resources, waste and emissions) inputs and outputs. The processes of the database can be combined into process trees connected to functional units. In this case, the "functional unit" is 1 kg of a specific material. Of course, there is no real functional unit involved for this application, hence the quote marks. For the aggregate indicator, one could state that the total consumption of materials in the EU and accession countries would be the functional unit. The 1 kg of material is chosen for practical reasons. All processes involved in mining, extraction, and production of the material are called on. This not only includes the production processes themselves, but also for example the processes related to transport or electricity generation insofar these occur in the chain of these materials.

Processes connected to the use of the materials are included in a limited sense. The emissions related to the material itself are included, while the energy use of the products the material is applied in is not attributed to the material. Losses of the material itself during use through corrosion or evaporation can easily be attributed to the material itself and therefore are included in the impacts per kg material as we calculate it. However, it is difficult, if not impossible, to allocate the energy requirements of a product to the individual materials a product is composed of. Moreover, energy requirements in the use phase are in most cases not "inherent" to the material, while the production processes are. In a product policy, where specific applications are the focus of policy, the energy performance of products is an important aspect. In a resources policy, as well as in our impacts per kg factors, energy use in the consumption phase is visible as the resource group fossil fuels. Energy use in the consumption phase is thus included in the overall indicator we develop in Section 3.3. It is not allocated to other materials but appears directly in the chains of the different fossil fuels. Any significant change in the overall energy intensity of products in the use-phase will result in a change in the amounts of fossil fuels used in households and will therefore be visible in the overall indicator as well.

For the waste management stage, processes are included in the database. In most cases we used those, but for some we made additional assumptions of our own. These can be found in Van der Voet et al. (2003). The LCA databases are not quite consistent for the waste stage, for example in their treatment of recycling. For some materials, standard recycling percentages are used. For others, a difference is made between the primary and secondary material. While the quality of mining and production data can be considered adequate, the waste management data should be improved to enable a fruitful use of LCA databases for this specific purpose. An alternative would be to use the LCA database only for the cradle-to-gate impacts, the impacts of extraction, mining, refining and production. An indicator based on this information would then be limited to the production stage and indicate improvement options for this stage only. This alternative is not followed up for the moment, but will come back in the discussion around composing an indicator for resource productivity in Chapter 7.

The result of the LCA Inventory is a list of environmental interventions for the whole process tree: resource extractions, emissions, waste generation and land use. The CMLCA software translates these interventions into potential contributions to a number of impact categories.

The process data out of the ETH and Ecoinvent database are representative for "Western Europe". This implies that for some countries, especially the newly accessed and accession countries, the database may not be representative. Within the framework of this study, it is not possible to amend this. Therefore we will use the database containing the per kg impacts of materials as it is.

A further issue is the specification of the environmental impacts. By using the ETH or Ecoinvent database and the CMLCA software, the LCA impact categories of the CML methodology automatically will come out. These categories correspond for a large part with the environmental impacts mentioned in the Technical Annex, as can be seen below:

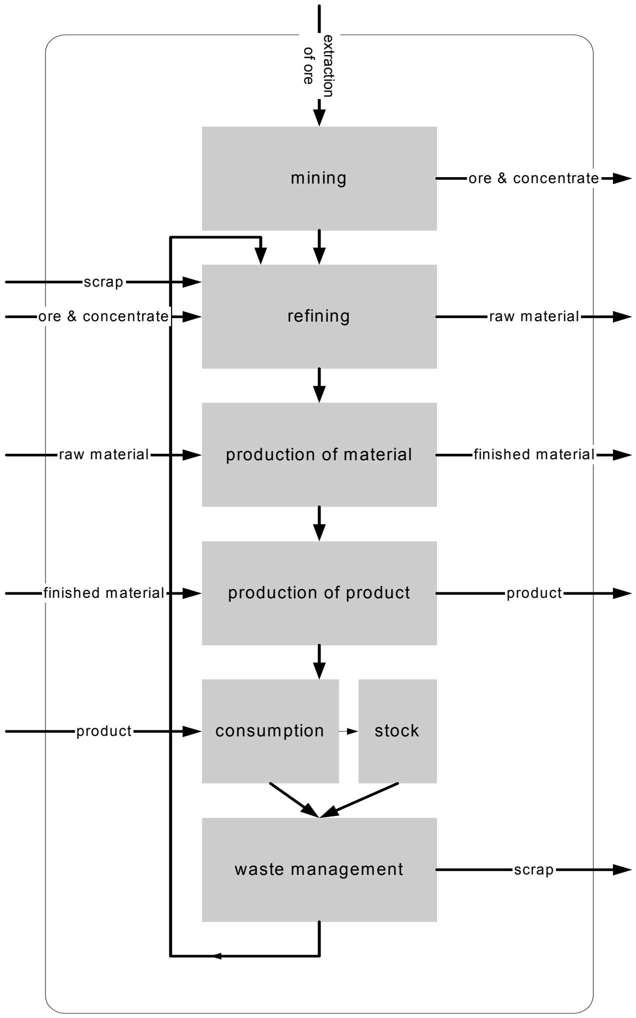
Technical Annex	LCA Impact categories
greenhouse gas effect	global warming
stratospheric ozone depletion	stratospheric ozone depletion
air acidification	acidification
water eutrophication / nutrient enrichment / BOD, COD	eutrophication
photochemical ozone / oxidant formation	photochemical ozone formation
non-renewable resource use / depletion	abiotic resource depletion
human toxicity	human toxicity
ecotoxicity / release of persistent toxic substances	aquatic ecotoxicity terrestrial ecotoxicity marine ecotoxicity
waste generation	final solid waste generation
noise, odour	-
radiation	radiation
-	land competition

One thing needs to be noted, which follows from the use of LCA impact factors: the impacts related to the cradle-to-grave chain are neither location specific nor time specific. Impacts related to the mining of the materials may occur in countries outside Europe. They will still be included. The same is true for impacts related to the management of waste exported to other countries. Mining in the past and waste management in the future are still allocated to the materials and therefore the environmental pressure related to them is included. This implies that the score on impacts must not be interpreted as real environmental impacts occurring in the same year within the country of consumption. On the one hand, this makes the measure for environmental impacts quite abstract: based on steady state, not dynamic. On the other hand, it shows the complete impacts of consumption in a country, wherever and whenever they may occur. This enables policy to avoid problem shifting to other areas of the world.

3.1.4 System boundaries: quantities of material consumed

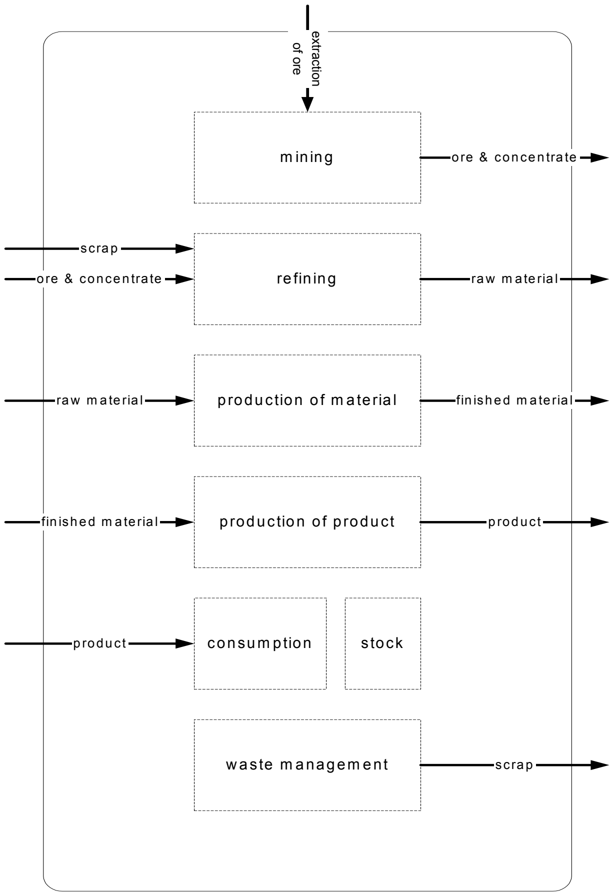
When the cradle-to-grave impacts per kg material are determined, the next step is to determine how many kilograms of each material are “counting”. This depends on the system boundaries. In line with the Technical Annex, the starting point is not the inflow (as with the DMI indicator), nor the production (as in Input Output Analysis), but the consumption of materials in each of the countries. The first problem we encounter then is that data on consumption are not available. Statistical offices do not collect them. Sometimes, specific studies are available for the consumption of specific materials in specific countries, which could be a starting point. These are incomplete and mostly do not contain time series, so they cannot be used as a source of information although some of them could be used as a check. This means consumption data have to be derived from other data which are being collected by statistics offices. Since trade statistics and production statistics generally are available, it should be possible to arrive at consumption data through drawing materials balances. Figure 3.2 shows this.

Figure 3.2 Flows of a material in, out and through a country



The consolidated MFA database of the Zero study (see Chapter 2) is our starting point for estimating consumption data. This database contains time series of imports, extractions and exports of materials and products for the EU and accession countries and is the basis for the earlier mentioned material based indicators. In accordance with the Technical Annex, the DMC indicator (Domestic Materials Consumption) is selected as the starting point. Figure 3.3 shows the DMC system boundaries. The DMC system, which is a measure for consumption, is based on transboundary flows. It is calculated as extractions + imports - exports. This implies that DMC is not equal to final consumption in the standard economic sense, calculated as the flow to the consumers + the export, since the internal flows in the system are not accounted for which can be quite large. It is also not equal to apparent consumption, since apparent consumption is calculated as import + production – export, production being different from extraction. Apparent consumption of materials moreover does not include import and export flows of products, while DMC does. The main difference for many of the materials however is related to the difference between extraction and production. Production encompasses not only primary production from raw materials, but also secondary production from waste materials. For specific materials, the secondary production or recycled flow can be very large. DMC therefore is more of a measure of consumption of “new” materials, i.e. imported materials of uncertain origin and primary produced materials within the country. An increase in recycling becomes visible only indirectly, through a reduced consumption of “new” materials.

Figure 3.3 DMC system boundaries



For an assessment of the consumption of materials, we find that there are problems in using the DMC system boundary directly, since for various reasons it is not possible to arrive at materials balances. For the method developed to prioritise materials, the most suitable choice would be to start from the apparent consumption of materials. For apparent consumption, it is possible to arrive at material balances per material based on import + production - export. This, however, does not connect to the DMC and more in general the MFA database, which was the prerequisite for this study. How to solve these problems? The first step is to obtain insight in the methodological differences between the two systems. Then, the difficulties are identified of overcoming these differences. The next step is to define criteria for a solution, and finally some options are identified and put to the test.

Methodological differences

The most important differences between the two systems are:

- The DMC is defined as a total, and can be broken down into a small number of groups of materials: biomass, fossil fuels, minerals and building materials. The methodology to prioritise materials (further referred to as: materials method) considers each material separately.
- Next to import and export data, DMC uses data on extraction, while the materials method uses data on production
- The materials method uses weighting factors, DMC adds weight-only.
- The differences in systems definition have certain practical consequences as well. For example, in the materials method it is difficult to include products, because the material composition of these products is unknown or differs greatly within one product category. For DMC, an estimate of the weight is sufficient. Another problem with the materials method is, that due to the use of production statistics we are frequently confronted with missing or undisclosed data. DMC is much more robust against that. On the other hand, the resolution is much higher in the materials method, allowing for more detail.

Combination of the two approaches

For this study, both approaches must be combined. This step of combining both methodologies creates some extra difficulties, some of them related to the differences in system boundaries:
It appears impossible to arrive at sufficiently reliable balances per material by using MFA / DMC data alone. There are different reasons for that: statistical errors, unclarities in statistical categories, and the fact that all kinds of different stages of the life cycle (ores, materials, products) are included in the DMC, which calls for a translation step.

MFA / DMC does not consider flows within the economy. Not only production, but also recycling is out of the picture. In the materials method, both production and recycling are included in estimating consumption. This implies that "consumption" according to DMC does not equal "consumption" in the materials method. DMC only includes "new" materials (which is not equal to primary materials, since imported materials can be secondary materials as well).
In the materials method, the cradle-to-grave chains of the materials are the basis for the impacts per kg. These cannot be combined with DMC directly. DMC contains materials at various life cycle stages. For sand in DMC, we cannot just use the impact factor for sand, because the sand chain also includes the materials cement, concrete and glass. Moreover, there is a risk of double counting due to the use of cradle-to-grave impact factors. Imported fertiliser is visible in DMC, but is also a part of the chain of agricultural products, which is also visible in DMC. Multiplication of both flows with a cradle-to-grave impact factor implies a double-counting of (parts of) these chains.

Conditions for a solution of problems

To combine DMC and the materials method, the abovementioned problems must be solved. We define the following conditions for the combination of DMC with impacts per kg:

- Impact of materials / resources can be calculated as: Consumption of materials (kg) * impact of materials (impact units / kg).
- Different materials should be recognizable in their contribution to the total. This means we must reach a sufficient level of detail to enable the combined DMC / materials method to be relevant. Neither the total level nor the four or five DMC categories are sufficiently detailed.
- Consumption of materials should be traceable to DMC. Therefore, we keep to the DMC system boundaries. That is to say, internal flows are out of the picture, and as a consequence, production and recycling are not included in the determination of the amount of consumption. An increase in recycling over time becomes visible only indirectly through a reduced need for new materials.
- The impact / kg measure should be based on the cradle-to-grave life cycle of each material.
- The problem of double counting needs to be solved, since double-counting is unacceptable for an integrated indicator of environmental impacts.

Options

We see three roads towards a solution:

- We translate all DMC / MFA data into finished materials
- We translate all DMC / MFA data into resources
- We limit ourselves to 5 - 10 rough categories of materials within DMC and define an average impact factor for each of these categories.

All three options are in principle possible, but have different advantages and drawbacks. In Annex 3 the ins and outs of these three options are evaluated in more detail. Considering all and weighing practical problems against theoretical considerations, we choose to follow Option 1. Option 2 is too elaborate for the present study and we have some doubts regarding its policy relevancy. Option 3 is a default option, to be used if all else fails.

When following Option 1, the system is that of (estimated) apparent consumption of "new" materials. This means that materials embedded in products are not included. For some materials this might lead to lower quality results, especially in small countries where there may be no production of the material. In general, however, the flows related to the products are small compared to the flows of (raw) materials, and therefore the mistake won't be too large.

3.1.5 Combining the per kg impacts with the material flows

In all, it has proven to be more difficult to arrive at usable flow data than to arrive at per kg impact data, however many uncertainties these might include. Once having them, the procedure to arrive at an idea of the impact of a certain material flow will be to multiply the per kg impacts with the kilograms of material consumed per country. We then have for each country the contribution of the cradle-to-grave chains of the materials to a number of impact categories, as specified in Section 3.1.3. To arrive at one indicator for environmental impacts, this information then must be aggregated somehow to one indicator. The required addition of all environmental impact categories into one measure for environmental pressure is complicated and has not only a "scientific" but also a normative aspect. Different aggregate indicators have been proposed and are used to assess whether or not de-coupling takes place. They include kilogram-based measures such as DMI, DMC or TMR, land-surface measures such as the Ecological Footprint (Wackernagel & Rees, 1996), aggregated environmental impact-measures such as the Eco-indicator (Goedkoop & Spriensma, 2000), or indicators in monetary terms such as the shadow prices (de Wit et al., 1997). Since there are quite some objections to "adding it all up", indicators also exist on a less aggregated level. An example is to use the non-aggregated contribution to specific environmental problem categories as a set of indicators, as used for example in the NAMEA accounts. All have their strong points, but also their drawbacks.

Weighing on a mass basis connects to the Factor-4 approach, as supported for example by the Wuppertal Institute (von Weiszäcker et al., 1997). The idea behind this is that mass, although indirectly, is a useful indicator for environmental problems. More mass usually means more energy use, more waste and more emissions. This approach has a certain beauty because of the simplicity of both the message and the approach. However, it is also clear that different materials vary many orders of magnitude in their per kg environmental impacts. The debate on the indicative value of these indicators for environmental impacts is by no means finalised. We will come back to it in Chapter 4.

Of special attention is here the weighting of various environmental impact categories into one environmental impact score. In order to arrive at one indicator for environmental pressure, this is a required step. However there is no generally accepted way to do this. In the RIVM study aggregation was performed as an example by weighting all impact categories equally. There are other options to weigh. A set of weighting factors used sometimes is the NOGEPA set, defined by a group of representatives of industry, government and science, based on a rough estimate of the relative importance of the environmental problems (Sas et al., 1996). In the Eco-indicator 99 (Goedkoop & Spriensma, 2000) another addition is made, based on available - be it incomplete - knowledge regarding the ultimate impacts on human health, ecosystems and economic damage. Another option is to weigh the environmental impacts with shadow prices. In some recent studies, efforts have been made to assign monetary values to the LCA outcomes (cf. BIO Intelligence and O2 France, 2002). Such shadow prices can be useful to compare changes in the CO_2 levels resulting from material use with other environmental impacts. In Section 3.3 the different options will be elaborated further.

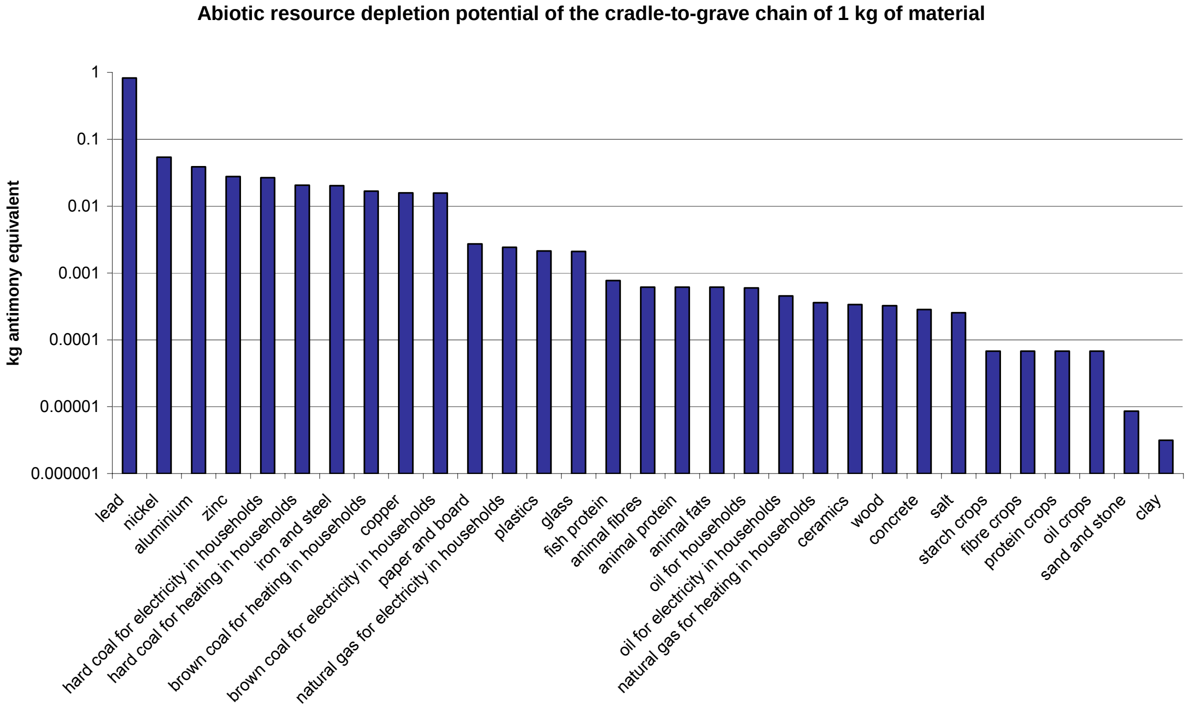
Finally, it is important to find out whether the environmental weighting of the DMC really matters. For that we investigated the correlation between mass based weighting and various other weighting schemes. The results are shown in Chapter 4. In this way, also, it can be considered whether the environmental weighting of material flows does matter from the statistical perspective, or whether an unweighted DMC can be perceived as a good proxy for the environmental impacts associated with the material flows.

3.2 *Application of the method*

3.2.1 Per kg impacts

In Annex 4, materials included in the study are presented. Annex 4 also contains the complete list of per kg impact scores. Below, some results are shown: the top-twenty materials based on their per kg impact score for depletion of resources, global warming and aquatic ecotoxicity. Similar top-twenties can be made for the other impact categories.

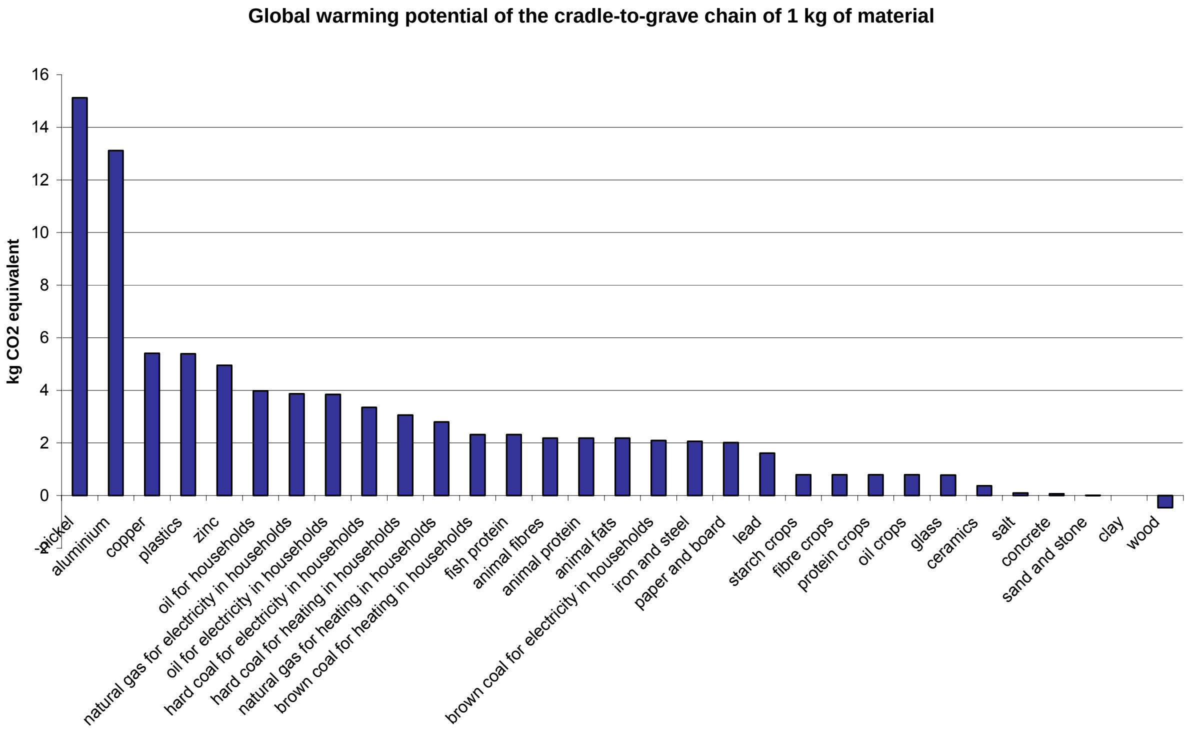
Figure 3.4 Materials, per kg contribution to depletion of abiotic resources (logarithmic y-axis, crosses at 0.000001)



The units on the y-axis represent "abiotic resource depletion potential" (ADP), expressed in kg antimony equivalents. This is a standard way of expressing impact potentials in LCA. It is best known in connection with the problem of global warming: emissions of greenhouse gases are expressed in kg CO_2-equivalents. These CO_2-equivalents are obtained by environmental models, wherein fate and impacts of greenhouse gases are calculated. Based on substance characteristics, the climate forcing potential of 1 kg of a certain greenhouse gas is calculated and compared with that of 1 kg of CO_2. Similar procedures are followed for the other impact categories. In each case, one substance - or, in the case of resource depletion, one element, is chosen as a reference, comparable to CO_2 in the global warming impact category. An ADP of 1 for lead, for example, means that the extraction of 1 kg of lead contributes equally much to the global depletion problem as 1 kg of antimony, which is the reference for this impact category. The definition of these impact categories, their reference substances and their problem causing potential are treated extensively in the updated LCA guide as composed at CML (Guinée et al., 2002).

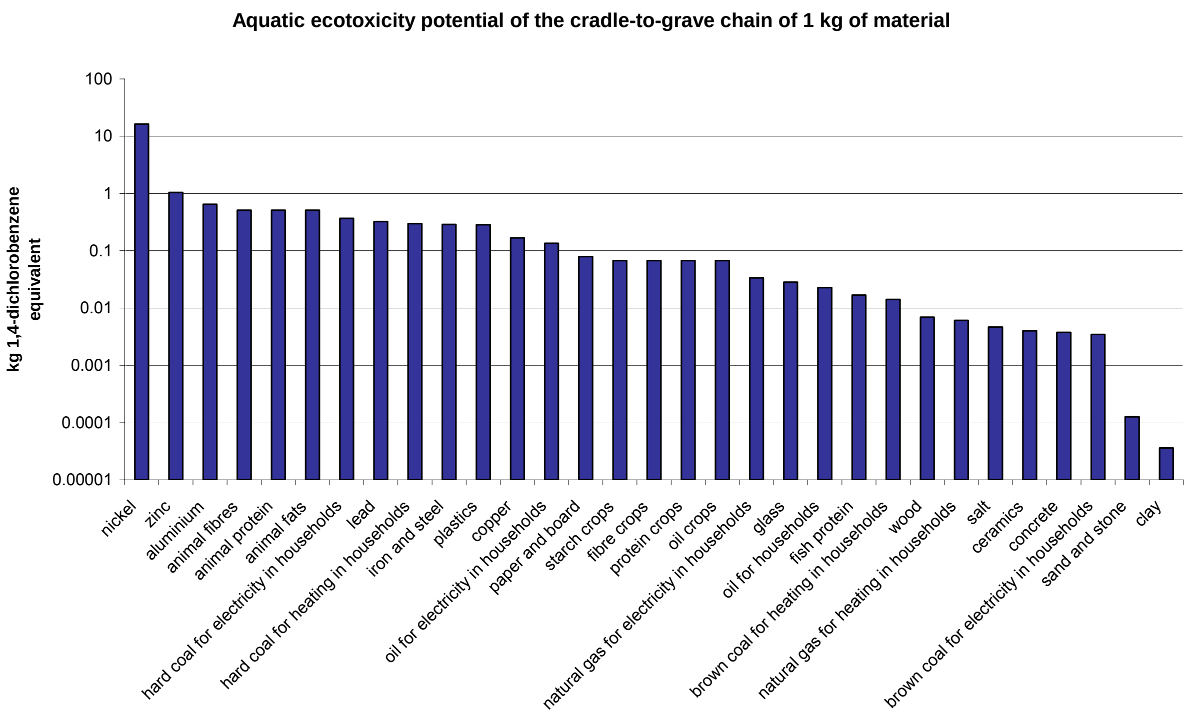
Coming back to the impact category in question, it can be seen clearly that metals, closely followed by fossil fuels, have the highest resource depletion potential per kg.

Figure 3.5 Materials, per kg contribution to global warming



The same metals also contribute most to global warming. This is due to the amount of energy needed for their mining and refining. Wood has a negative score since it fixates CO_2 rather than emitting it. Wood products are therefore CO_2 sinks, which is an important fact when considering resource use from the point of view of mitigating the problem of global warming.

Figure 3.6 Materials, per kg contribution to aquatic ecotoxicity (logarithmic y-axis, crosses at 0.00001)



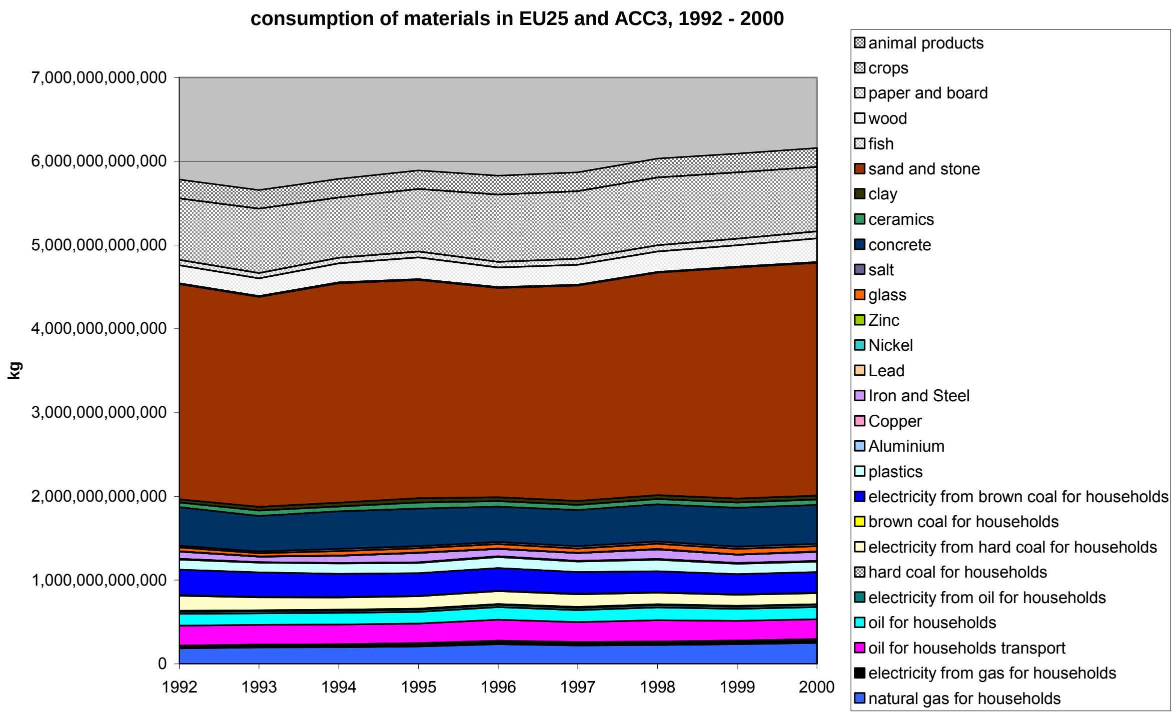
Next to metals, agricultural products contribute a lot to toxicity per kg. This is due to the fact that pesticides are used in their chains. Of the fossil fuels, coal scores highest because it contains heavy metals in small amounts.

Whether or not these materials end up as priority materials for a resource policy from an environmental point of view, depends not only on the per kg impact but also on the volume of consumption. The per kg impact in itself is still useful information, for example when substitution is considered. The information makes it possible to determine whether or not a shift to an alternative material is a good idea from an environmental point of view. It is not the only relevant information: when considering such a shift, many other aspects are relevant as well, for example cost related aspects, the function for which the materials are used, their substitutability etc. etc.

3.2.2 Volumes of materials

Figure 3.7 shows the development of the apparent consumption of "new" materials in the EU-25 and AC-3 as we calculated it from DMC. Similar pictures are available for each country, as well as for the new EU member states and accession countries.

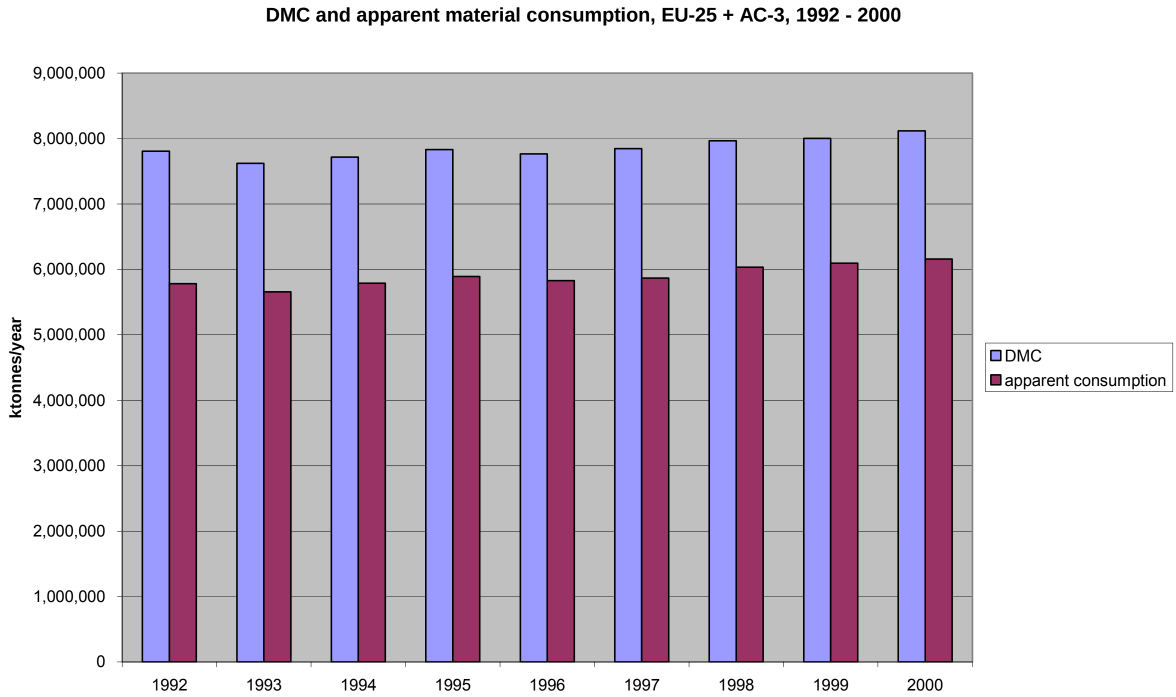
Figure 3.7 apparent consumption of materials, EU-25 + AC-3, 1990 – 2000.



Construction materials dominate the picture. Together, they account for roughly two thirds of consumption. Agricultural products contribute another 20%. Metals are invisible, with the exception of iron and steel which show up in a small lilac band. The remainder is fossil fuels. On the whole, a slight dip is visible around 1993 in many materials. A 1996 dip occurs in sand and stone. Since these dominate the score, the total also has a dip in 1996. After 1996 there is a rise in the materials consumption, again mainly caused by sand but also visible in gas consumption.

A comparison between DMC and consumption as we calculated it for the EU- and AC-countries is given in Figure 3.8.

Figure 3.8 DMC and materials consumption in the EU-25 + AC-3, 1992 – 2000.



DMC is consistently higher than the consumption as we calculated it. Breaking down DMC and consumption into the contributing categories might shed some light on the reasons. Figures 3.9 and 3.10 show this.

Figure 3.9 Contribution to consumption of different categories of materials in the EU-25 + AC-3, 1992 – 2000.

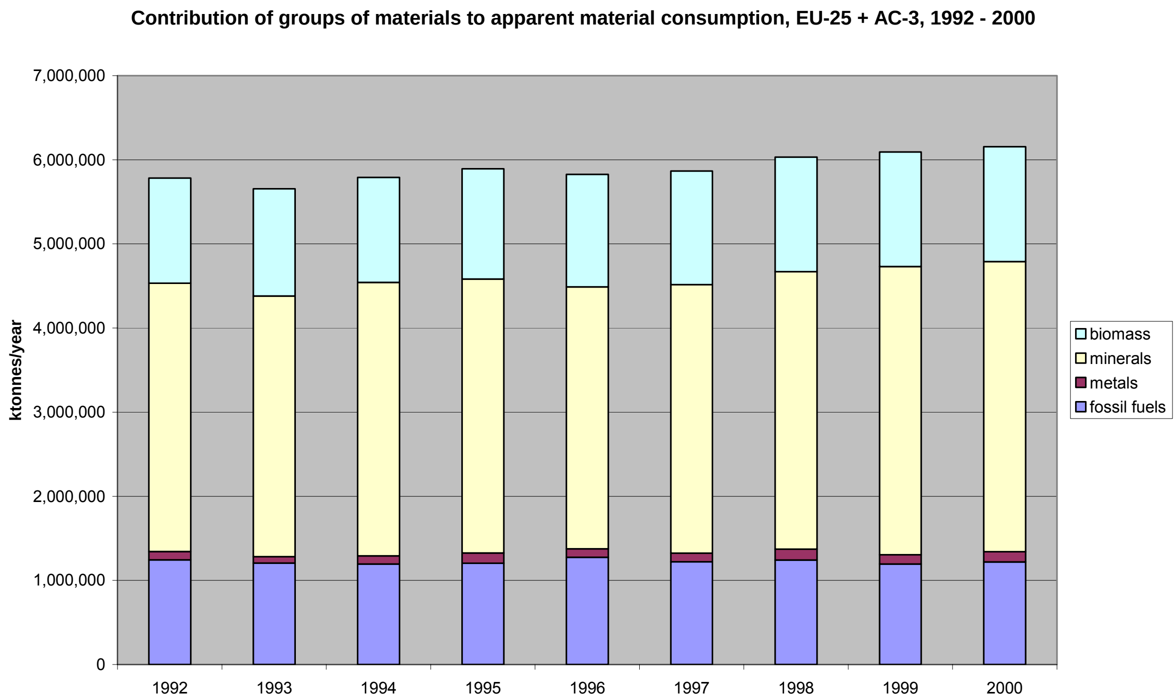
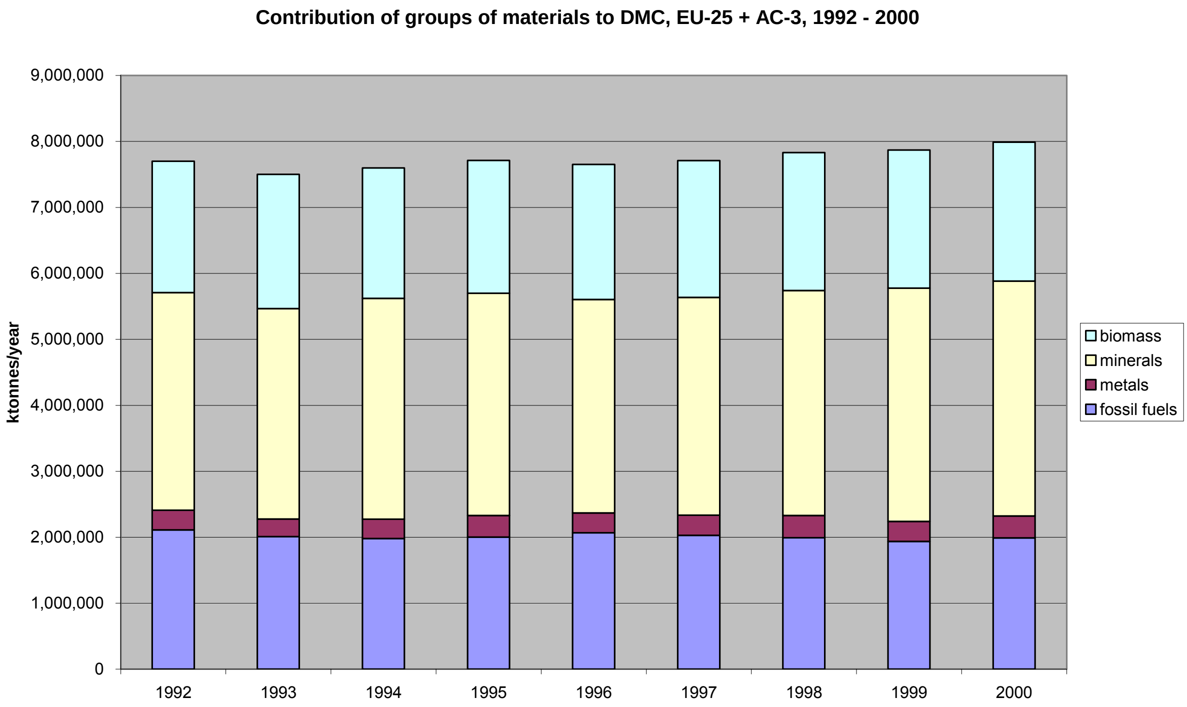


Figure 3.10 Contribution to DMC of different groups of materials in the EU-15, 1992 – 2000 (excluding products and excluding Austria).

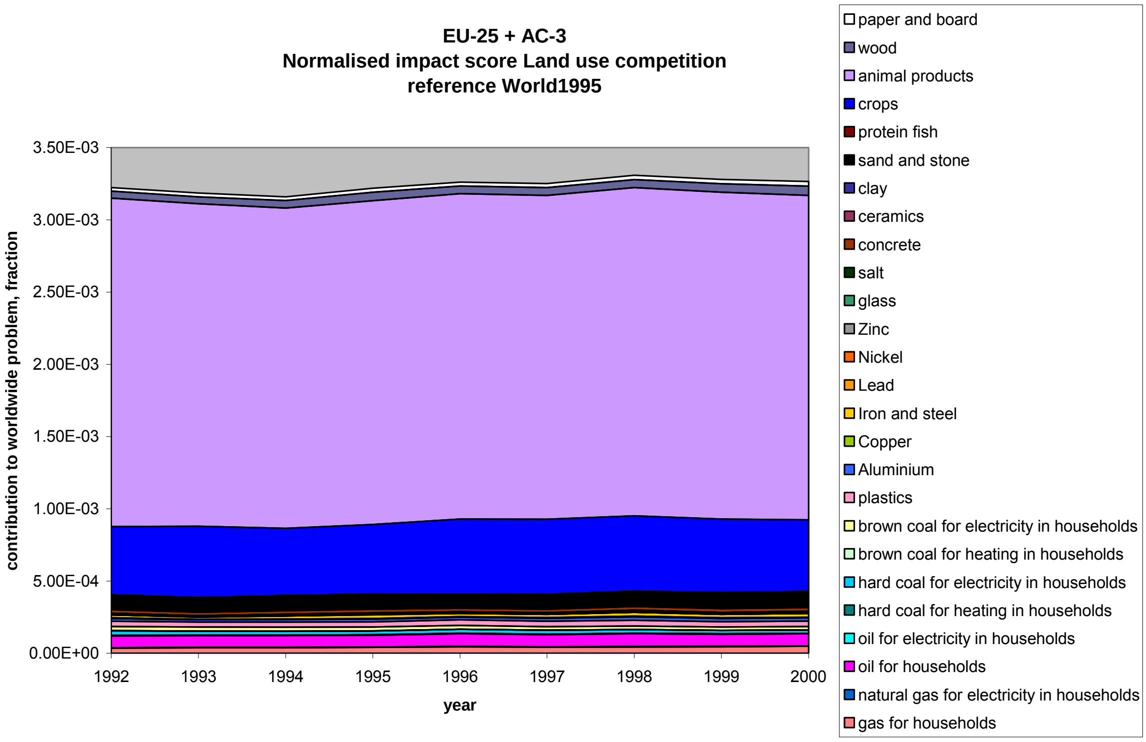


Three out of four categories are significantly smaller in the calculated consumption than in the DMC. For fossil fuels, DMC is roughly 2 times higher than consumption. This is due to the subtraction of energy used in production processes, which is assumed to be already included in the impact per kg factor of the materials. For metals, the refining process from ore to metal will account for the losses underway. For minerals, the differences are small. Construction minerals dominate the score. For biomass, a reason for the difference probably is grass and greens for animals. This is produced in large quantities, but does not appear in the consumption as we calculated it. In our approach, grass and fodder are not finished materials, but parts of the animal products chain. The kilograms therefore are not counted, but the environmental impacts related to it will appear in the impact per kg factors of animal products.

3.2.3 Combining per kg impacts with volumes

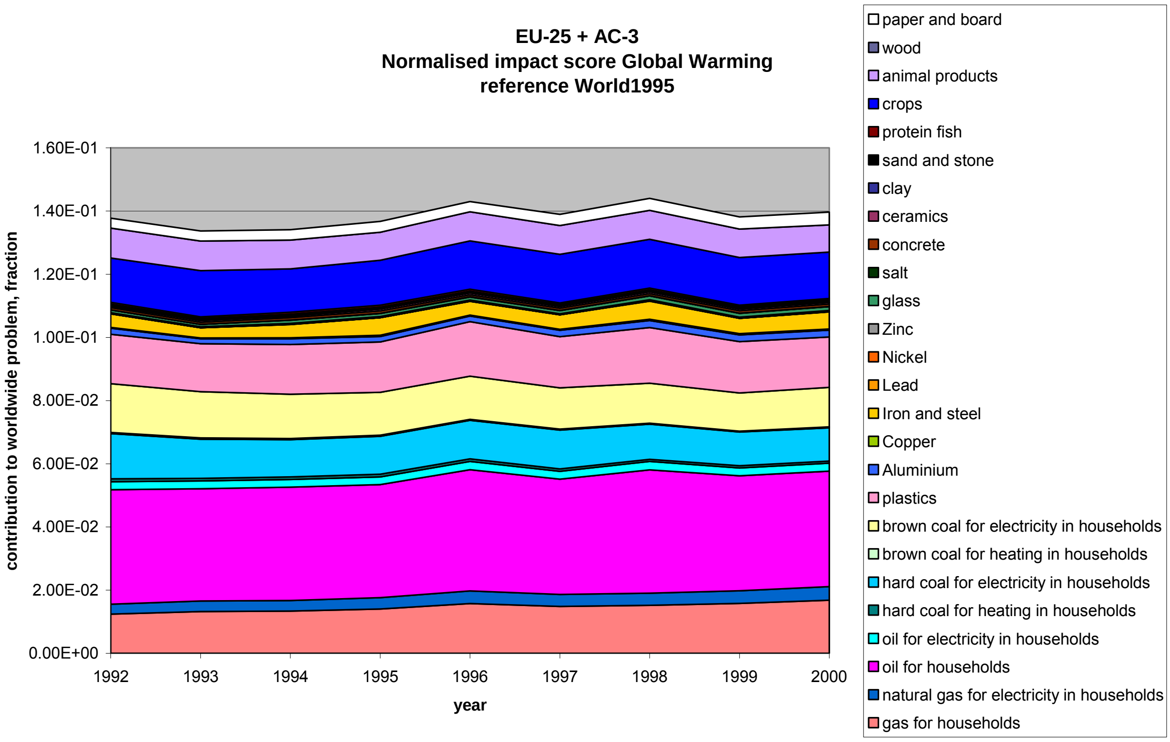
Below, the results of applying the developed methodology are shown for the 28 European countries. The figures are obtained, per impact category, by multiplying the per kg impact by the number of kilograms consumed in the EU-25 and AC-3. This score is then “normalised”, a step that is necessary when different environmental impact categories have to be added. Normalising in this case means dividing the contribution of the materials to the impact category by the global contribution to the impact category, for example dividing the GWP emissions connected to consumption in the 28 countries by the worldwide GWP emissions. The values on the y axis therefore can be interpreted as: the contribution of the EU-25 + AC-3 countries' material consumption to the worldwide problem of global warming. As an example, three impact categories are shown below in Figures 3.11 to 3.13: land use, global warming and human toxicity.

Figure 3.11 Contribution of materials consumption to Land use competition, EU-25+AC-3, 1992-2000



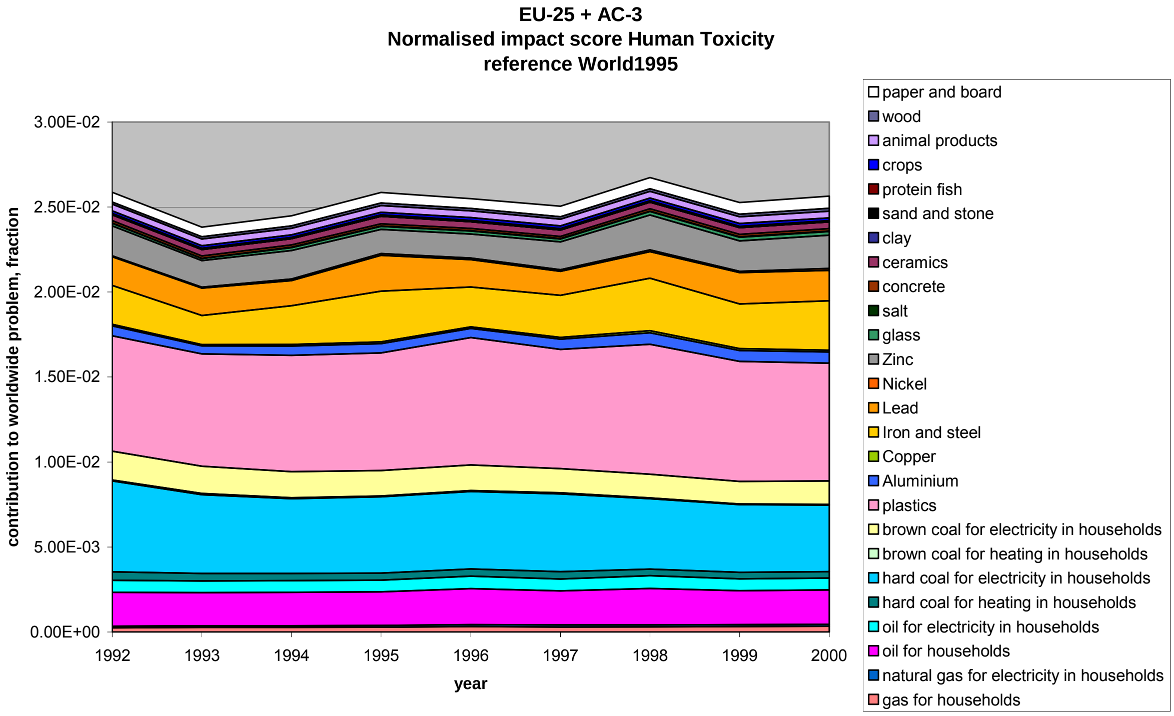
As could be expected, the agricultural materials dominate the land use score. From Figure 3.11, it can be seen clearly that animal production has a large claim on land. The majority of the crops produced are not consumed by people but by cattle. If grass is included, this amounts to 80 – 90% of crop/grass production in the EU.

Figure 3.12 Contribution of materials consumption to Global warming, EU-25 + AC-3, 1992 – 2000



Global warming, again as might be expected, is dominated by fossil fuels and derived materials (plastics). Although the per kg contribution of fossil fuels is not that high, the amount used compensates for that. Bulk-metals such as iron and steel and aluminium are also visible, as are animal products. Most materials with a significant contribution will be energy-intensive. Therefore the contribution of fossil fuels is actually much higher. The fossil fuels appearing in Figure 3.12 refer to their end-use for space heating and electricity. A shift over time is visible from coal to gas, leaving the total impacts related to fossil fuels at more or less the same level.

Figure 3.13 Contribution of materials consumption to Human toxicity, EU-25 + AC-3, 1992 – 2000



Plastics and some of the metals contribute most to the problem of human toxicity. For plastics this is due to their volume in combination with the high use of electricity. For most of the metals the volume is not so large, but the per kg impact is high, partly due to energy, partly to the refinery process and partly due to emissions during waste management.

Comparing the three pictures, it can be seen that the different materials contribute to a different degree to the selected environmental problems. While animal fats is the dominant material for land use, fossil fuels determine the score for global warming and plastics and metals score highly on human toxicity.

The general trend for the development of the three impact categories is similar – more or less level, with a slight dip around 1993 and a slight increase toward the end. This same trend is visible in the consumption data (see Figure 3.7).

A relevant question is, what the difference is in the contribution of (groups of) materials between these impact categories and the materials consumption or DMC in kilograms. Is the overall picture, if we look at the general categories of materials, similar or completely different? Figures 3.14 to 3.16 show the answer.

Figure 3.14 Contribution of categories of materials to Land use competition, EU-25 + AC-3, 1992 – 2000

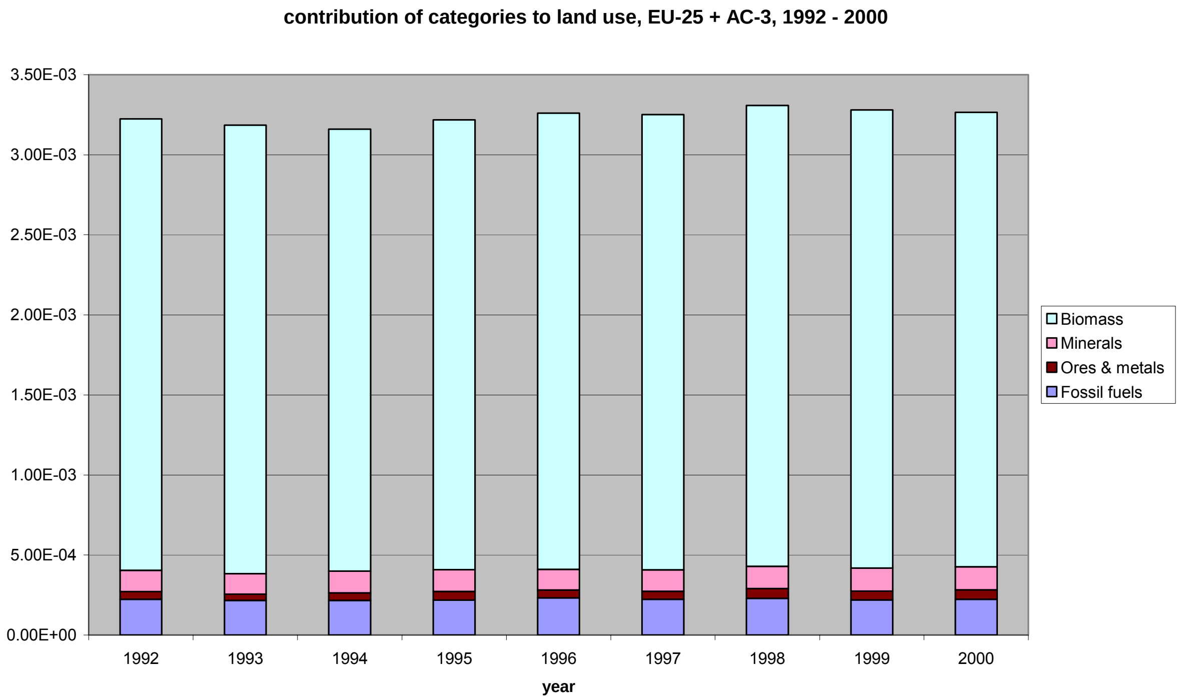


Figure 3.15 Contribution of categories of materials to Global warming, EU-25 + AC-3, 1992 – 2000

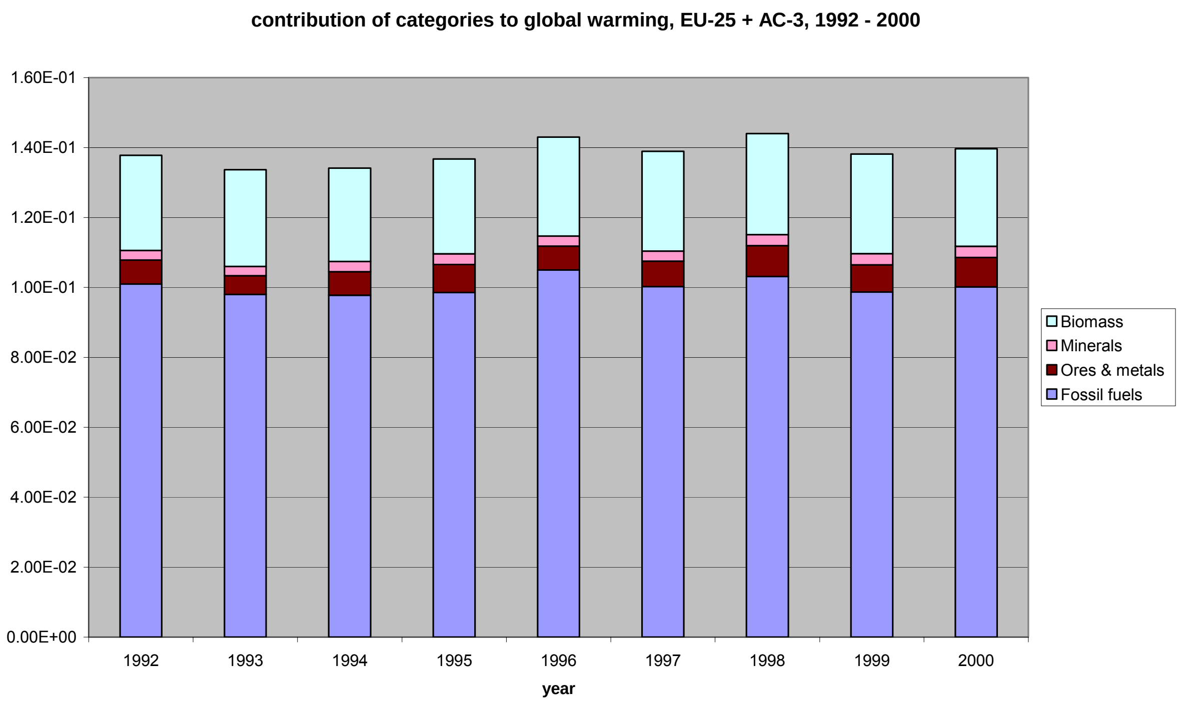
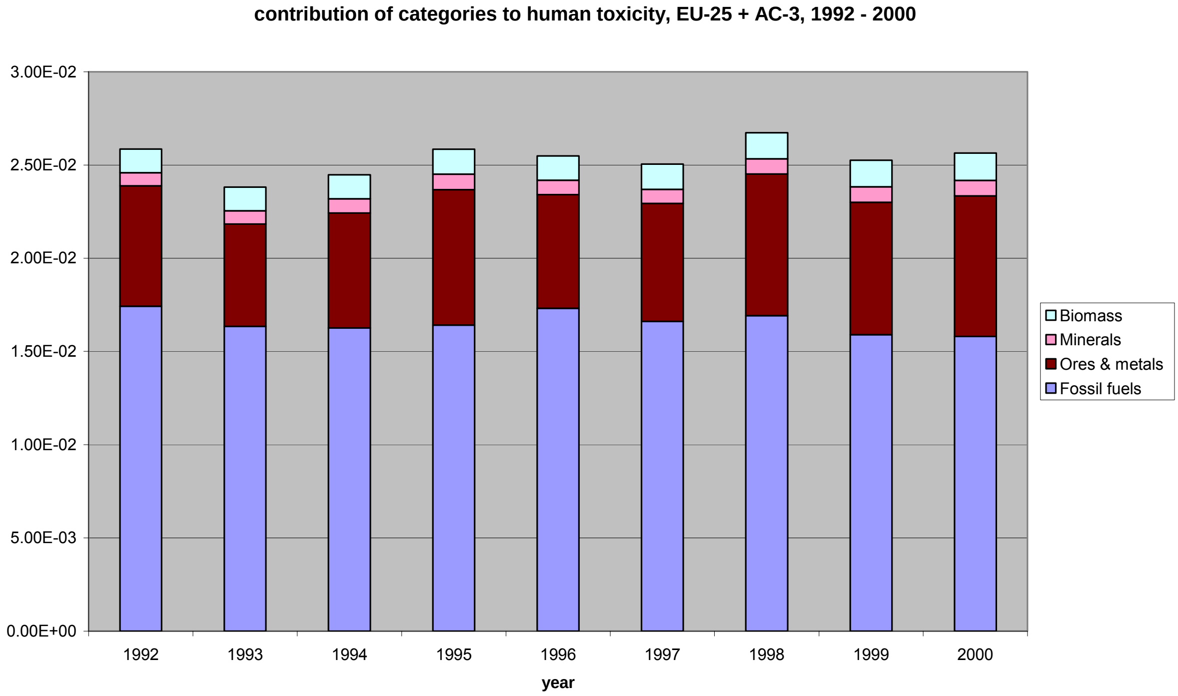


Figure 3.16 Contribution of categories of materials to Human toxicity, EU-25 + AC-3, 1992 – 2000



All three are different: land use is dominated by agricultural biomass, global warming by fossil fuels and derived materials, and toxicity by metals. Neither of these resembles consumption or DMC, where construction minerals are dominating.

3.3 Indicators: different approaches to a weighting of environmental impacts

3.3.1 Requirements of an indicator

The environmental impact indicator or indicators to be developed in this study should conform to some basic requirements:

- It should indicate the environmental impacts related to materials on a from-cradle-to-grave basis
- It should be traceable to DMC
- It should enable to make comparisons between countries
- It should enable to follow developments over time
- It should conform to general notions of (scientific) rigour such as sound system boundaries, excluding double-counting, transparency, and depending on solid data.

The first two issues are already treated in Section 3.1. The third issue is about comparability. This implies that the datasets used for the different countries should be comparable. On the side of the material flows, this is not quite true, since data quality differs considerably for the different countries and definitions of subcategories are not identical either. Still, the methodology used is the same for all countries and at least for the EU-15 countries should lead to comparable results. On the side of the impacts per kilogram, comparability is no issue since the database used does not distinguish between countries. The database is presented as a Western-European average. From a comparability point of view, this is an advantage. However it puts some doubts on its representativeness especially for Eastern European countries.

Another issue related to comparability between countries has to do with their size. Small countries with a small population naturally have a lower consumption of materials and concurrent environmental impacts. There are different options to handle the size issue, each with their own rationale:

- Recalculate to impacts per capita, most closely related to the idea of consumption

- Recalculate to impacts per €, providing a measure of eco-efficiency on the national level
- Recalculate to impacts per km^2, which is most close to an environmental pressure indicator.

We try out all three options below.

The fourth issue is about following developments over time. For the material flows, we have time series for a ten year period for EU-15 countries, and an eight year period for the AC-13 countries. The impacts per kilogram however do not change over time. The LCA database is updated every now and then but does not enable to capture general year-to-year technological progress. This implies that changes over time in the impact indicators are determined only by changes in the flows of materials. When a new version of the LCA database is forwarded, new impact factors can be calculated to replace the old ones.

3.3.2 Weighting procedures

It is of course possible to define indicators for environmental pressure at the level of the individual impact categories. We then end up with a set of indicators instead of just one. This could be acceptable, since comparisons between countries are still possible and developments over time are still visible. It is also policy relevant information, since it allows monitoring differences in progress between the different impact categories. If the aim is to have just one indicator however, the scores for the different environmental impact categories have to be added up. In order to do so, a weighting step is required: an indication of the relative importance of the environmental impact categories.

There is no generally accepted set of weights to be added. In practice, different weighting procedures are used in LCA studies which could be applied here as well. Annex 5 discusses a number of them. A first requirement for using a method is that it is more or less encompassing. A number of methods do not live up to this requirement because they focus on energy or global warming only. Some remaining options are the following:

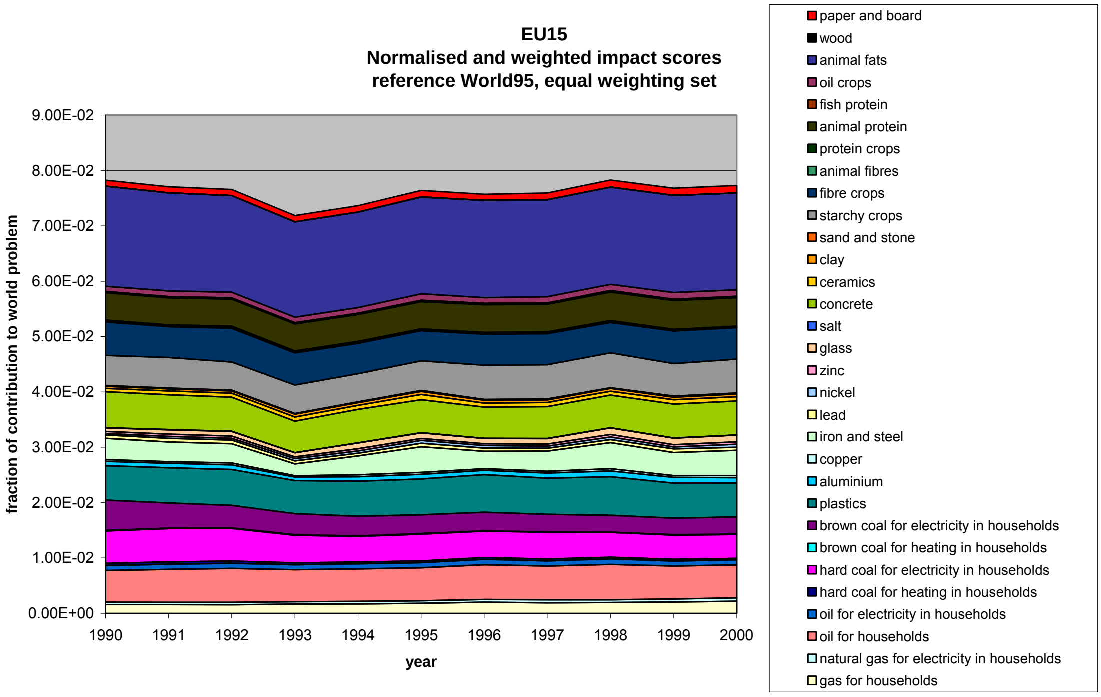
- Equal weighting: all established environmental problems are, as a default until policy has made a clear statement otherwise, considered equally important.
- NOGEPA weight factors (Sas et al., 1996; updated by Huppes et al., in prep.): this could be seen as a political set of weights, negotiated between representatives of industry, government and science for the NOGEPA covenant between the Dutch government and oil companies, but more widely used in LCA studies.
- Eco-indicator99 (Goedkoop & Spriensma, 2000): this is a method that could be regarded as expert opinion. It tries to remain “objective” as long as possible and uses model calculations to translate impact categories into impacts on human health, ecosystem damage and resource depletion.
- Shadow prices (Wit et al., 1997; updated by Davidson et al., 2002): this is an economic weighting method based on damage control costs.
- The EPS method (Environmental Priority Strategies; Steen, 1999): also an economic method based on “willingness to pay”.

Figures 3.17 to 3.21 show the results of application of these five weighting procedures, which we applied to the former EU-15 countries. It can be seen clearly that the outcomes of the different weighting procedures are quite different. Some key reasons for these differences are hidden in the details of the weighting schemes:

- NOGEPA attaches a heavy weight to global warming, with eutrophication and acidification next in line. Waste is not included, nor is land use and abiotic depletion.
- Implicitly, Ecoindicator99 attaches a lot of weight to the respiratory damage and damage to health due to global warming. Ecoindicator99 uses different impact categories due to the philosophy of modelling the environmental impact chain throughout the final impact on human health, ecosystems and depletion of resources. Waste is not included.
- In shadow prices, ozone layer depletion and eutrophication have the heaviest weight and together account for 85% of the score. Land use and depletion of resources are not included.
- In EPS, depletion of resources dominates the score. No impact categories are used, but weights are attached to individual extractions and emissions of substances. EPS is also very limited in the emissions that are included. In that respect, it is the least complete of these methods.

A comparison of the different weighting methods is performed for the former EU-15 countries. The purpose is to show the differences in outcome.

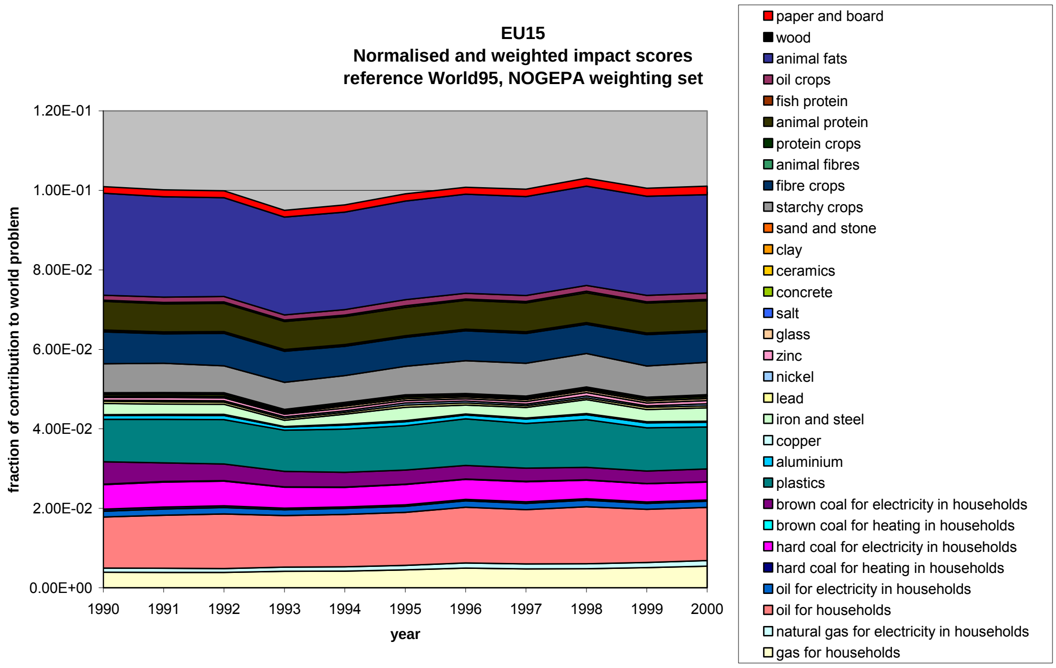
Figure 3.17 Normalised an weighted contribution of materials to environmental pressure, former EU-15, 1990 – 2000, equal weighting



The figure can be interpreted as: the contribution made by EU-15 countries to total, worldwide environmental pressure. The reference is the world in 1995, which is the most recent dataset available. According to this figure, the EU-15 countries contribute ca. 7-8% to the world total. A brief check shows that this more or less conforms to expectations: for greenhouse gas emissions, Western Europe contributes ca. 10% to the world total. A contribution of 7-8% may be regarded as in the right order of magnitude, given all uncertainties embedded in the data. Moreover, it must be kept in mind that environmental pressure as specified here is not related to the emissions on EU territory, but to the emissions related to the material chains of EU consumption. In the case of greenhouse gas emissions, for example, the emissions within Dutch territory are much larger than the emissions related to Dutch consumption. The same may be true for the EU as a whole, leading to a lower estimate than the average 10%.

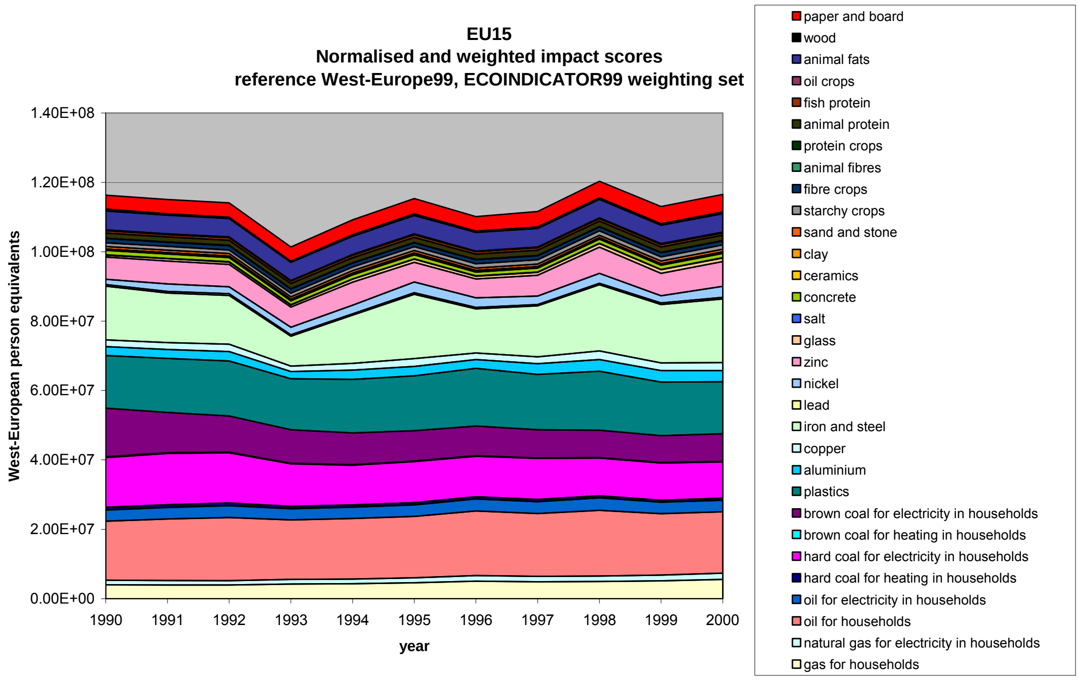
Equal weighting is quite straightforward in principle. The results depend on how many and which impact categories are included. In order not to overweigh toxicity (four categories) we calculated one average score for toxicity and used that instead. This implies that we used nine impact categories.

Figure 3.18 Normalised an weighted contribution of materials to environmental pressure, EU-15, 1990 – 2000, weighting with NOGEPA weighting set



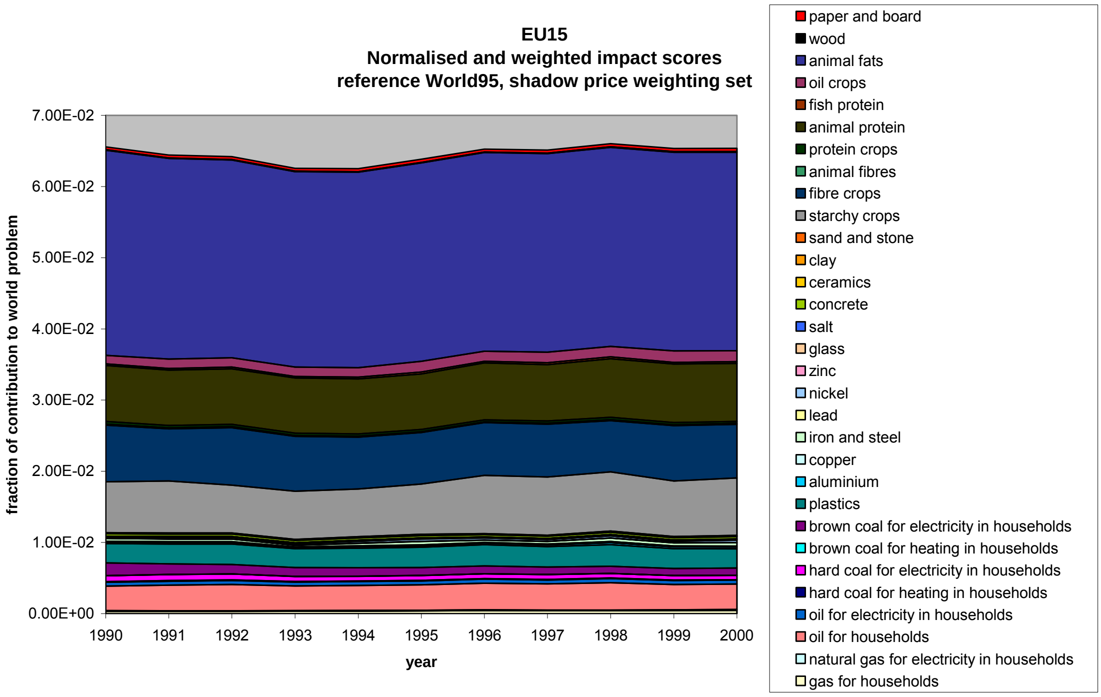
The NOGEPA weighting set excludes some impact categories: resource depletion, land use and final solid waste formation. The impact categories of waste and land use were not considered important; for depletion of resources the problem was that no generally accepted impact assessment method exists. It puts the highest weight on global warming, which is the reason that the fossil fuels and derived materials score higher than under the equal weighting. The fact that agricultural products still contribute much to the total is most likely due to the fact that eutrophication also has a relatively heavy weight in the NOGEPA set.

Figure 3.19 Normalised an weighted contribution of materials to environmental pressure, former EU-15, 1990 – 2000, weighting with Eco-indicator 99 weighting set



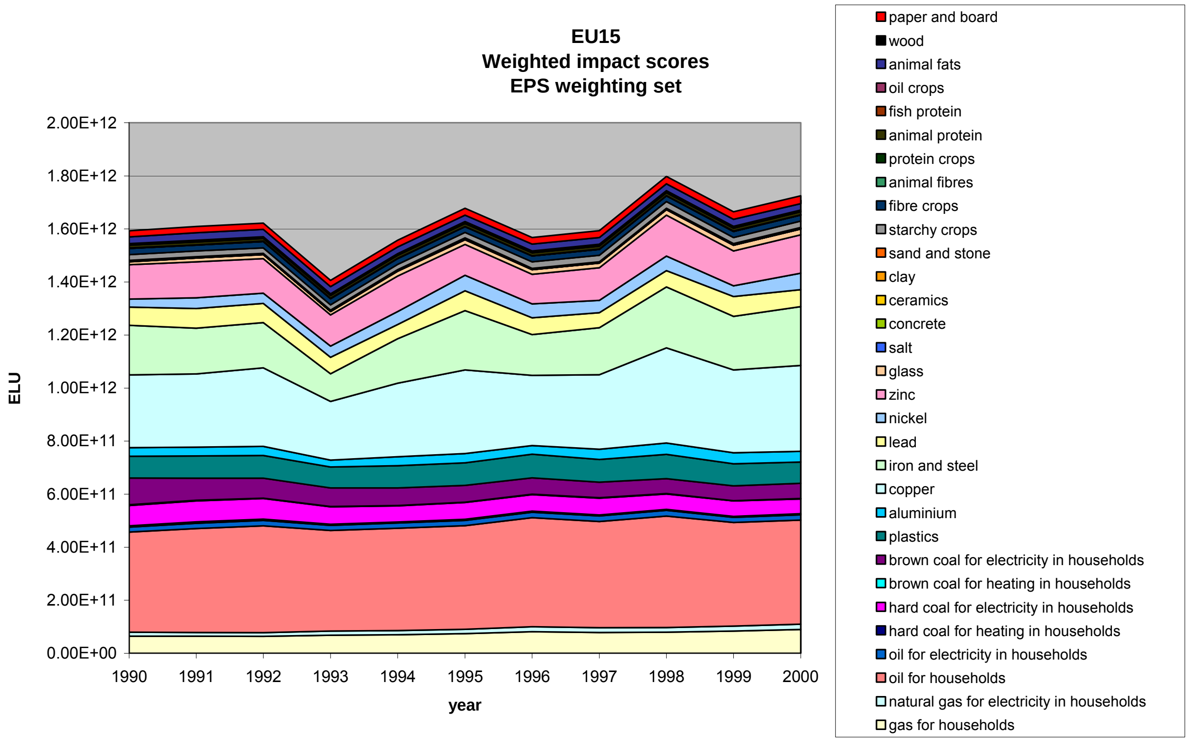
Fossil fuels come out even more in the Eco-indicator weighting procedure. This is not surprising, since depletion of resources is important in this method, as well as the impacts related to global warming. Metals contribute more than in the previous two methods due to the importance of ecotoxicity. Agricultural products do not contribute as much. This is probably due to the exclusion of land use. Land use is a part of the Eco-indicator method, but our inventory is unfortunately incompatible with the Eco-indicator method for this impact category. This implies that Figure 3.19 does not give the complete picture.

Figure 3.20 Normalised an weighted contribution of materials to environmental pressure, former EU-15, 1990 – 2000, weighting with shadow prices



Resource depletion, land use and radiation are excluded from this method. Fossil fuels do not contribute a lot when weighting with shadow prices. This is due to the fact that the weight for global warming is very low. Ozone layer depletion contributes most to the score. Eutrophication and acidification also have heavy weights in the shadow price weighting set. This is probably the reason that the agricultural products score heavily.

Figure 3.21 Normalised an weighted contribution of materials to environmental pressure, former EU-15, 1990 – 2000, EPS weighting

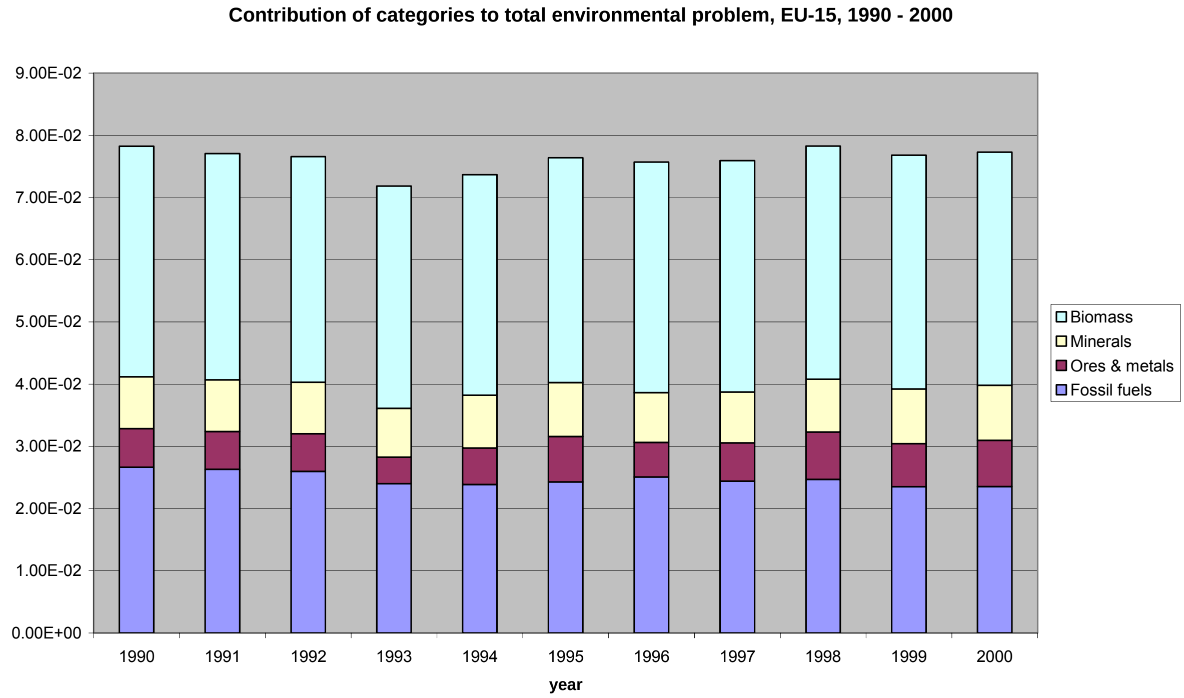


The EPS method implicitly attaches a very high weight to depletion of resources. Renewable resources, i.e. all categories of biomass, therefore do not contribute a lot to the score. Metals and fossil fuels do, however. In the score of the other materials, the use of energy in the cradle-to-grave chain is probably dominant over any emission related impacts.

The differences between the weighting methods lead to some explanations of the differences in the figures. A material like concrete, for example, comes out as a large contributor only in equal weighting. Its score there is mainly caused by final solid waste formation. In most other weighting schemes, waste is not included or has a small weighting factor, therefore concrete does not appear as a very important material. Agricultural products show especially heavy in shadow prices, due to the dominance of eutrophication. Heavy metals score excessively in EPS because of the importance of resource depletion. Fossil fuels come out on top in Ecoindicator, directly as well as indirectly in the chains of other energy-intensive materials, due to the importance of global warming and respiratory damage (esp. coal!). In NOGEPA, agricultural products (esp. animal) have a high score due to their contribution to eutrophication and global warming.

The above comparison on weighting methods shows that it is important. Therefore it should get attention, especially from politics since weighting is normative rather than objective. However, at present there is no generally accepted method for weighting. At the moment, therefore, to use any weighting scheme is by definition controversial and the results from this study could be considered to be valid only at the disaggregate level of the different impact categories. However, as stated before, to arrive at one environmental indicator some sort of aggregation is mandatory. For that reason, we will make the aggregation as and illustration. To aggregate, we will use equal weighting in this study. This expresses the wish to include all impact categories while at the same time avoiding an expression about their relative importance. By equal weighting the scores of each material on all impact categories are added to one total: the *Environmentally Weighted Material Consumption*, or *EMC*.

Figure 3.22 Contribution of groups of materials to EMC, former EU-15, 1990 - 2000



A comparison with Figure 3.9, the contribution of the same groups of materials to DMC, shows that the general development over time is similar. Compared to DMC, minerals contribute less and agricultural biomass and metals more to the EMC.

3.4 Country comparisons

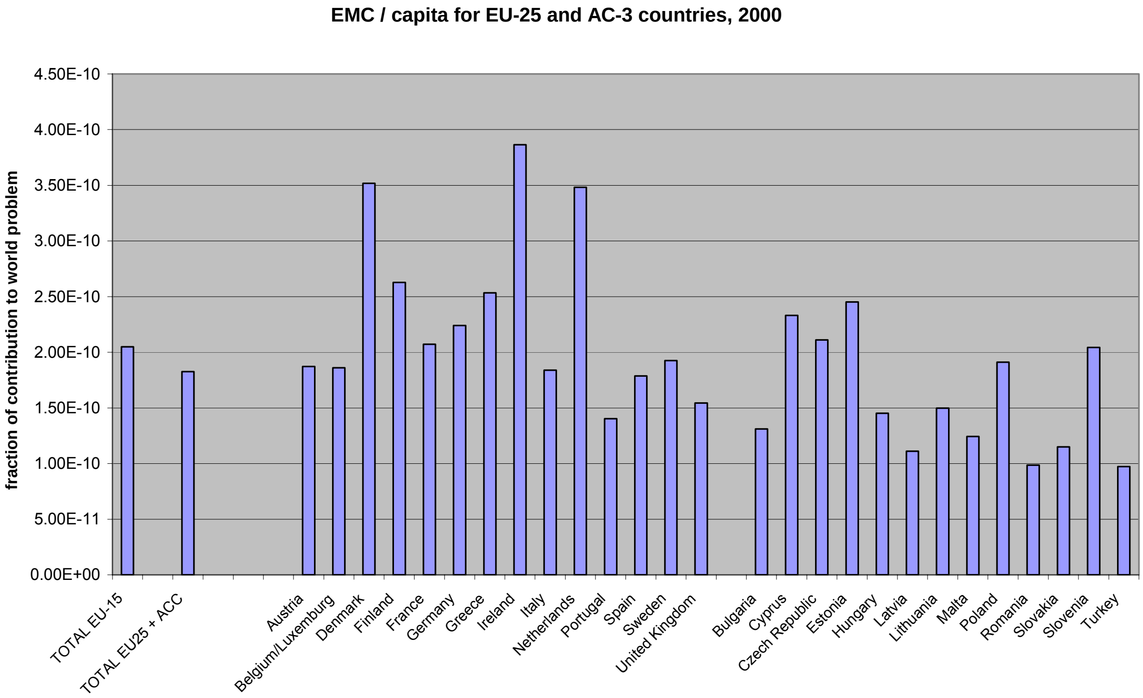
In order to compare countries, both DMC and EMC need to be translated to a measure that is indeed comparable. A comparison without further ado would just be a comparison of the size of the countries. Three options are presented in the next sections:

- EMC per capita
- EMC per €
- EMC per km^2.

3.4.1 Impacts per capita for one year

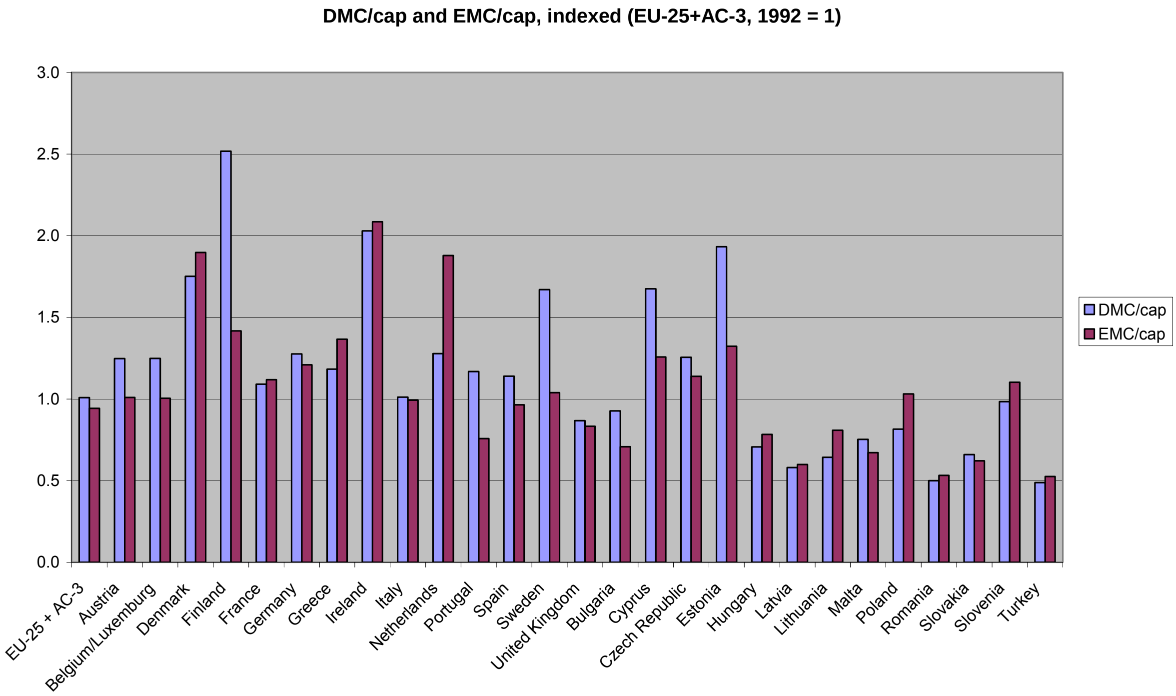
Figure 3.23 shows the impacts per capita for EU-25 and ACC-3 for the year 2000.

Figure 3.23 EMC per capita related to materials consumption, 28 countries, year 2000.



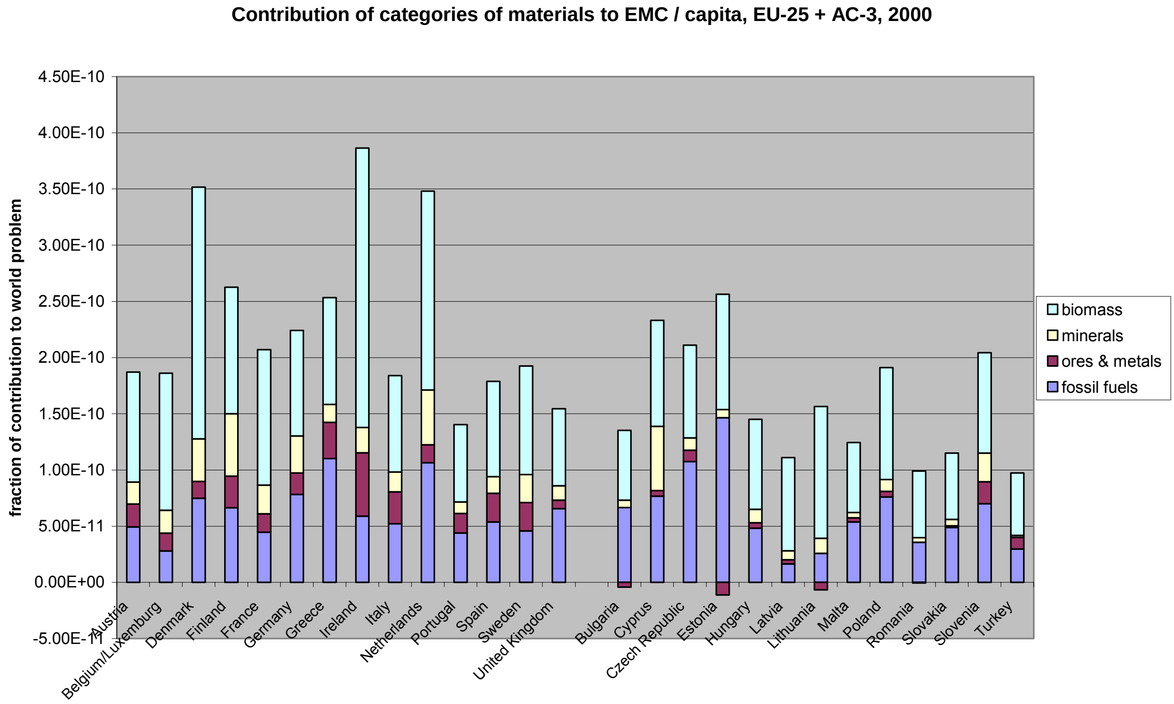
There are considerable differences between countries. The former AC-13 countries in general have a lower EMC / capita than the former EU-15 countries, but there is no clear distinction. Ireland, Denmark and Netherlands appear to have a very high EMC / capita. In all, Turkey and Romania score lowest. Of the former EU-15 countries, Portugal has the lowest EMC / capita, while of the former ACC-13 countries Estonia has a surprisingly high EMC / capita.

Figure 3.24 Differences between countries in DMC and EMC per capita



From Figure 3.24 it can be seen that a higher DMC often, but not automatically, goes hand in hand with higher impacts. Most marked exceptions are Finland, Sweden, Portugal, Cyprus and Estonia on the one hand. These countries have a higher DMC than EMC. On the other hand, the Netherlands, Greece and some of the Eastern European countries have a higher impact score than DMC. Some causes may be found one level of detail lower. The following figure shows the impact score for the 28 countries for respectively fossil fuels, metals, minerals and biomass. This may shed some light on why countries score high, or low.

Figure 3.25 EMC / capita, groups of materials, EU-25 and AC-3 countries, 2000.

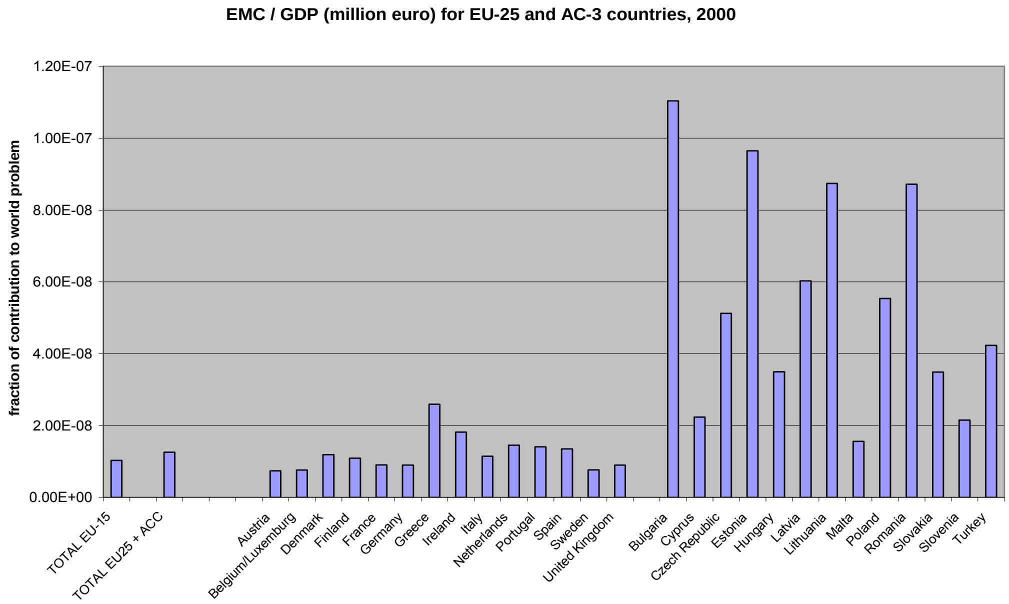


Ireland, the Netherlands and Denmark have a very high per capita impact related to biomass, probably due to their intensive agriculture and especially stock breeding sector. Greece and Estonia show a relatively very high consumption of fossil fuels. The contribution of metals in Ireland is furthermore remarkable. A relatively high score on minerals can be seen in the Netherlands, Finland, Denmark and Cyprus. No straightforward explanation comes to mind. In Chapter 4, correlation with explanatory variables may shed some light on the causes.

3.4.2 Impacts per unit of GDP for one year

In Figure 3.26, the EMC per million Euro is compared for the EU-25 and AC-3 countries, for the year 2000.

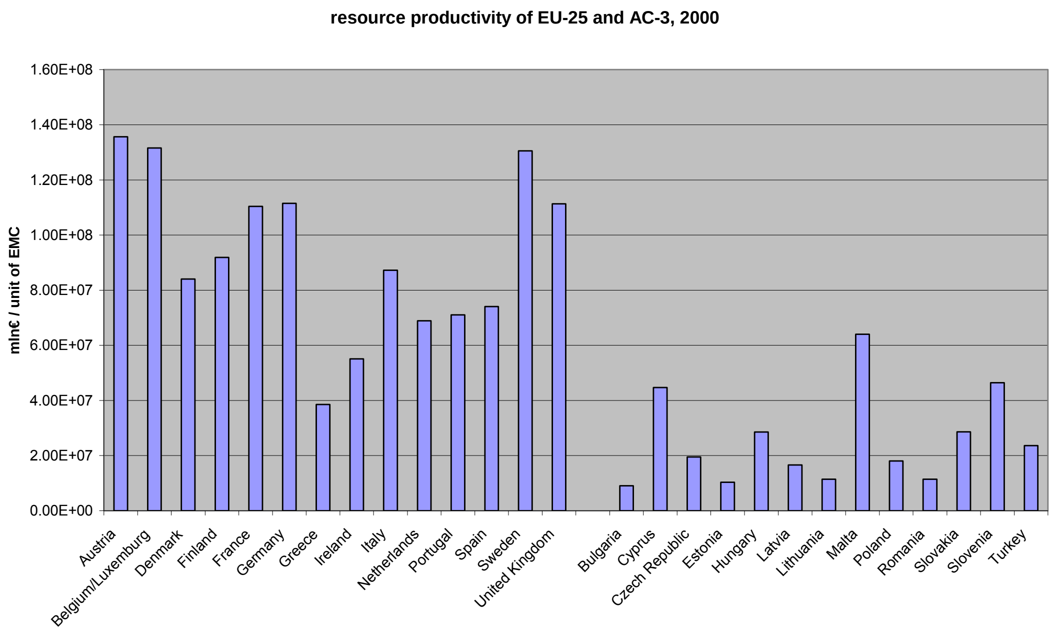
Figure 3.26 EMC / mln €, EU-25 and AC-3 countries, 2000



The differences per country are considerably larger than for the EMC per capita. Whereas the Eastern European countries generally score lower than the former EU-15 countries on the EMC per capita, their EMC per € is much higher. The difference between the lowest and highest scoring countries is a factor 10. The EMC/€ seems to be inversely related to income per capita. It can also be seen, that the difference between the average former EU-15 and the average EU-25+AC-3 is small. This implies that the contribution of (former) AC-countries to the total is not very large. In Chapter 4, more attention will be paid to this.

This indicator can be seen as a measure for impact-intensity or eco-efficiency: the amount of environmental impact potential connected with making (or spending) a million Euro. The inverse, € / EMC, can be seen as a measure for resource productivity. The interpretation is a bit more difficult than when DMC is used. The € / DMC indicator means the amount of money being made out of 1 kg or ton of materials. The € / EMC indicator then is the amount of money being made at the cost of 1 unit of environmental impacts. A higher resource productivity thus implies less damage per Euro. Figure 3.27 shows this.

Figure 3.27 million € / EMC, EU-25 + AC-3, 2000

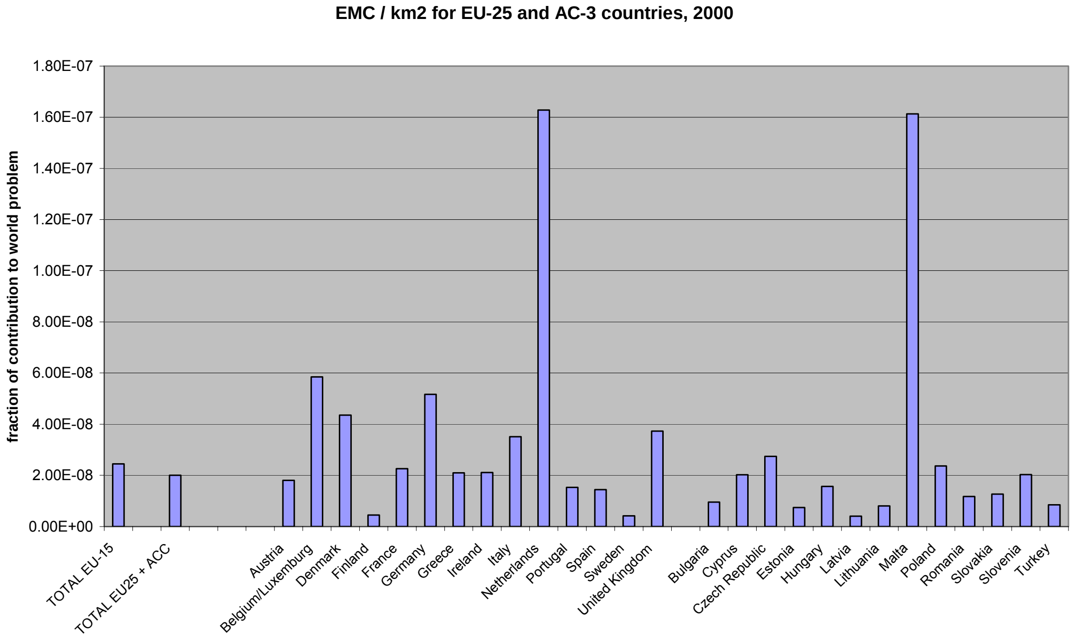


Resource productivity indeed shows the opposite pattern to the efficiency. It makes no sense to calculate the contribution of groups of materials. To provide relevant information, the contribution of these materials to GDP should be known first. This information might be obtained from national economic accounts, but is not pursued further in this project.

3.4.3 Impacts per km2 for one year

A third possibility to compare different countries is to express the EMC per unit of land surface. This is shown for the EU-25 and AC-3 countries in Figure 3.28.

Figure 3.28 EMC / km^2, EU-25 + AC-3, 2000



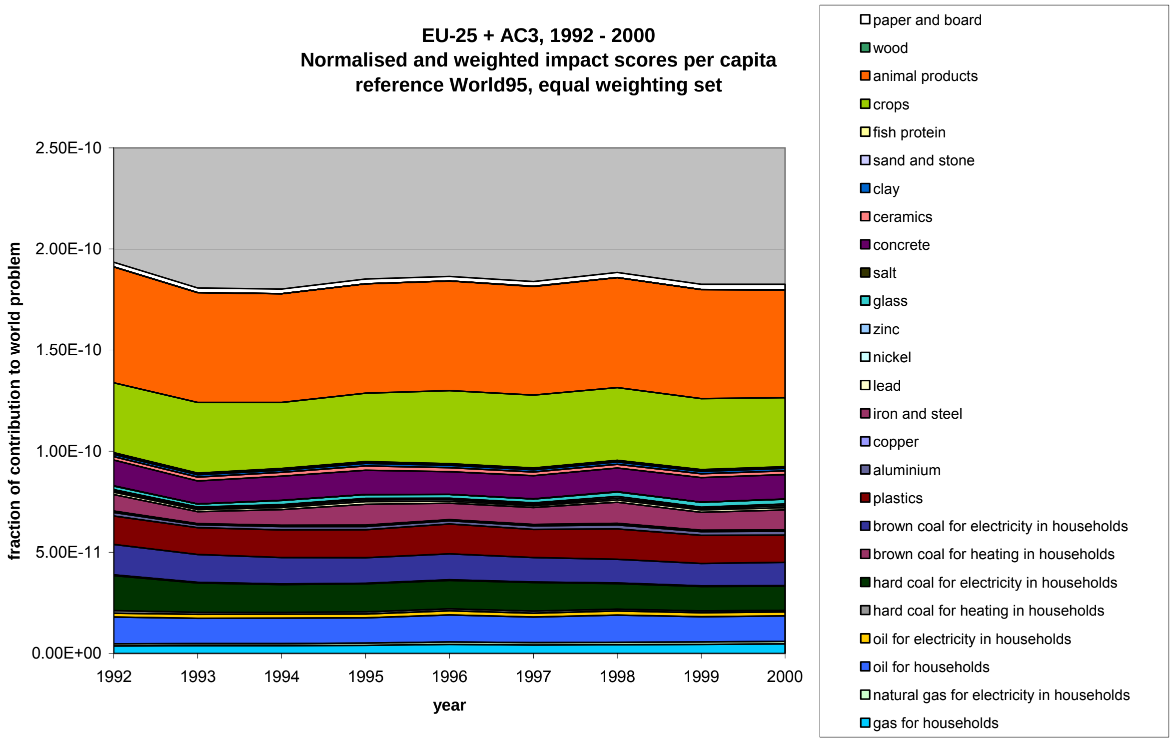
The figure shows some very high values for Netherlands and Malta We suspect this pattern is dominated completely by the number of inhabitants per km^2. While a high population density may lead to a larger environmental efficiency and therefore a lower score per capita, it will also mean a large score per km^2. We also have to keep in mind that this is not a picture of actual environmental impacts in the country. The EMC is a measure of consumption, environmental impacts connected to the chains of materials may occur elsewhere. The meaning of this indicator therefore is doubtful.

3.4.4 Developments over time

EMC per capita

Figure 3.29 shows the developments of the EMC/capita indicator for all countries included in the study.

Figure 3.29 EMC per capita for the EU-25 and AC-3 countries, 1992 - 2000.



The EMC per capita neither increases nor decreases much over time. Nevertheless it shows some trends, visible at the EU-level but also, and sometimes more clearly, in some individual countries:

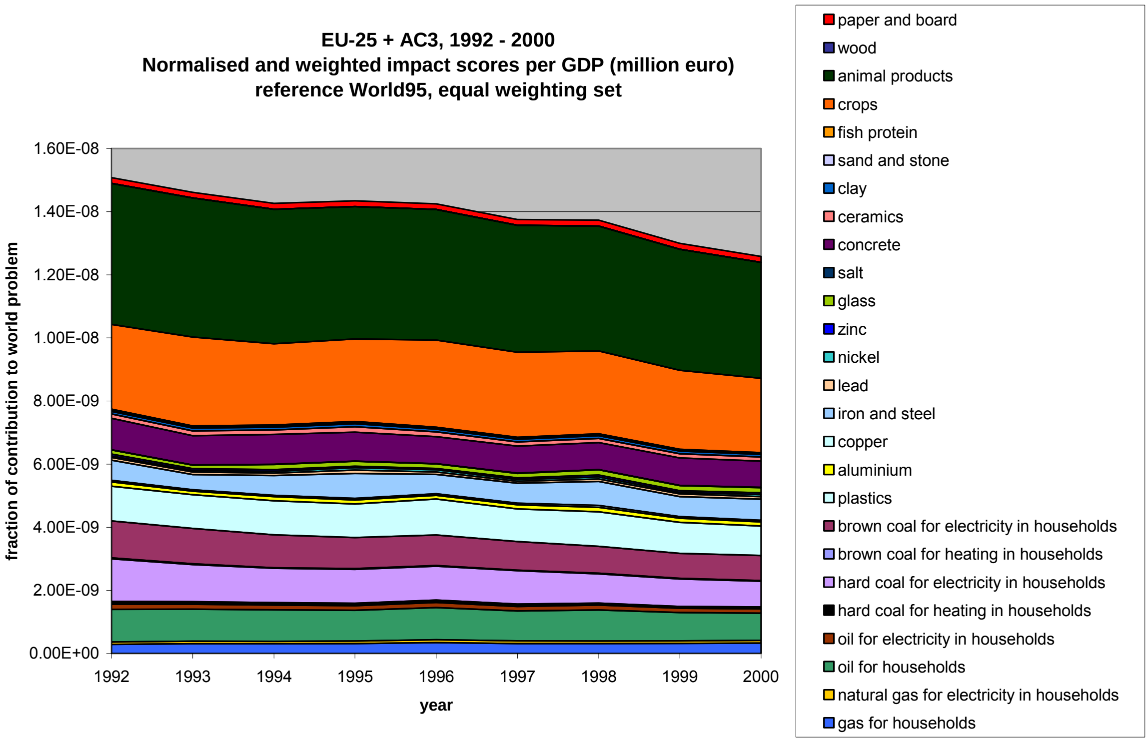
- A reduction of coal use, often replaced by increased use of gas, leads to less impacts (gas is “cleaner” than coal) related to fossil fuels in many former EU-15 countries. It is also visible in the former EU-15 as a whole. In Eastern Europe, coal use is still widespread.
- The 1993 dip is visible in all EU-15 countries. Either something happened Europe-wide, or it originates in statistics. There are some indications to the latter; it seems that around that time some statistical definitions have changed, at least concerning iron and steel.
- Some countries show a decreasing trend over time, especially Germany and the UK, and to a lesser extent Sweden. This seems to originate especially in a reduction of impacts related to fossil fuels.
- Some countries show a clear increase over time, especially Portugal, Spain and to a lesser extent Greece and Italy. This cannot be attributed to specific materials; the increase seems to be going on in all categories.
- Most other countries and the EU-15 do not show either an up-going or down-going trend but stay level or show some up and down fluctuations.
- The smoothest development of the curve can be found in countries with a high score on biomass (Ireland, France, Denmark, Belgium/Luxemburg).
- In Malta and Cyprus there is a marked dip in biomass in 2000. Might this be due to a failed harvest? Turkey and Italy also show a slight dip, so weather conditions around the Mediterranean could be the cause.
- Metals disturb many trends because they fluctuate and show negative values now and then. Sweden, but even more Bulgaria, Lithuania and Estonia are clear examples. While the indifferent data quality makes it difficult to draw conclusions for the newly accessed and accession countries, this should not be the case for Sweden, at least in general.

EMC per €

In most if not all 28 countries, EMC per € is decreasing. This implies that countries are getting more eco-efficient over time. Comparison with EMC per capita shows that the environmental gain per € is counteracted by the increase in income. Trends in DMC show a similar pattern.

Figure 3.30 shows the development of EMC per unit of GDP in the EU-28 and AC-3.

Figure 3.30 EMC per million € GDP, EU-25 + AC-3, 1992 - 2000



In this case, the breakdown to materials makes no sense, since we don't know the economic data for the individual materials. The indicator therefore should be read only as a total.

3.4.5 Discussion of the results

The data set used for the quantification is incomplete in many respects and contains a large number of uncertainties. This is true for the selection of materials, for impact data and for flow data. Naturally these uncertainties have an influence on the robustness of the results.

Uncertainties related to the use of the LCA database are the following:

- For the impact data, the implicit choices made for allocation in the ETH database may have a large influence, as well as the assumptions made in the ETH database for recycling. The assumptions we made ourselves for the use and waste management phase are also quite crude.
- The LCA database contains technical process data relevant for a certain time period. No technological progress is included. This is especially relevant when making time series in order to monitor progress by using the EMC indicator: changes over time are caused by changes in materials flows only, not by changes in impacts per kg. In the real world, technological progress occurs constantly. To include this in product studies, the LCA database is updated intermittently. It is recommended to update the EMC as soon as a newer version of the database appears.
- The LCA data are considered representative for Western Europe. This implies (1) that they may not be representative for Eastern Europe, and (2) that within Western Europe there may be differences between countries that do not come to light by using these generalised, average data.

Most of these uncertainties apply to LCA-product studies as well and are well-known. The only real exception is the use for time series to monitor progress, which is not a normal part of an LCA study. This additional uncertainty is to be considered seriously. It means that time series can only be made with one database for the period for which the database is considered more or less representative. Changing to a new database will lead to discontinuities in time series. Continuous updating would be ideal from the point of view of the use of this database for the purpose of making time series.

There are also large uncertainties in the material flow data. These are discussed in Chapter 2, insofar they relate to the consolidated MFA database. For some categories of materials, statistics are much better than for others. For some materials, data are lacking completely. For others, we have only imports and exports, not production or extraction. Additional difficulties arise from bridging the gap between (apparent) consumption of materials and DMC, as discussed in section 3.1. The exclusion of products is in some cases a large problem when estimating material flows - materials embedded in products are not visible, which sometimes even may lead to negative values. The same is true for the exclusion of recycled materials. Using the apparent consumption system boundaries without trying to conform to DMC could therefore be a more rational choice. On the other hand, other options as identified in Section 3.1 to harmonise system boundaries may be explored, for example the options of translating back to the extraction phase.

The results must, in view of the uncertainties mentioned above, be regarded as indicative only: the method has been developed and has proven to be applicable, but the results so far are highly uncertain. That does not mean that every conclusion is liable to be proven untrue in future. Generally, it can be seen that a few materials dominate the score if we look at the results per impact category. Even under the large uncertainties as specified above, it may be expected that the dominating materials will remain the same. When the differences are smaller, the uncertainties may have a large influence. This must be kept in mind when defining indicators for environmental impacts of materials. This is discussed further in Chapter 7.

3.5 References

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4 Socio-economic explanations for the difference in materials consumption between countries

4.1 Introduction

This chapter will give an analysis of the driving factors behind resource consumption and resource efficiency at the macro-economic level. First, we will summarize in paragraph 4.2 some theoretical and empirical literature on the various driving forces. Based on this, we will select 30 socio-economic variables which might influence resource consumption. The selection of these variables is arbitrary in a sense, as the major selection criterion has been data availability, but we believe that such a set might explain differences in DMC and EMC between countries and over time.

Then, in paragraph 4.3, we will present some statistical information on the relationship between the (components of) DMC and EMC in order to better understand why the DMC and EMC differ between countries. Furthermore, we will present the analysis of the relationship between the selected socio-economic variables and the two indicators of resource use. Subsequently, in paragraph 4.4, we will present some regression analysis on the effects of the driving forces on materials consumption measured as DMC and EMC. This will provide insight into the factors that influence the materials consumption between countries and over time. Paragraph 4.5, finally, contains an analysis on the determinants of resource productivity and some benchmarking between countries will be introduced here.

4.2 Selection of variables

4.2.1 Theoretical background

As there does not exist a clear theory on the driving forces behind DMC and the EMC, the question is how to select variables that influence the DMC. In principle, one could take an inductive approach and link over a 1000 variables with the DMC and EMC to figure out what variables appear to be most influential, but this most likely ends in spurious results. For example, the amount of pigs in the Netherlands was heavily correlated with the amount of cars until the 1990s, but this does not imply that pigs drive cars or that cars are fuelled by pigs. Hence, we need some loose theoretical backgrounds that guide us in the selection of the variables. One of these backgrounds could be offered by the intensity of use hypothesis formulated by Malenbaum (1978). According to Malenbaum, materials consumption M of a certain country can simply be rewritten as the product of income (Y) and the material intensity (U=M/Y) of that country, which in a certain year, t, gives:

$$M_t = Y_t \bullet U_t \quad (4.1)$$

Changes in the material consumption over time can then be explained by changes in Y (representing economic growth) and changes in U. Changes in this latter variable reflect, according to the decomposition methodology (see for example Ang, 1994) (i) changes in the composition of production and consumption, and (ii) changes in technologies and the use of materials in production and consumption. Hence we distinguished three effects (De Bruyn, 2000):

- The economic-growth effect
- The compositional effect
- The technological effect

The first effect refers to the influence of economic growth on material consumption. Of all else stays equal, economic growth results in an equiproportional increase in material consumption by virtue of (4.1). However, in reality, the *ceteris paribus* condition does not hold due to changes in the composition of economic activities and technological advancements. The composition of production and consumption, the second effect, is generally believed to be dependent on the level of income. Changes in consumer behaviour, institutional changes and changes in international competitiveness may result in changes in the composition of economic activities that take place in a country, with associated changes in environmental pressure. Such compositional changes have been labelled alternatively as “structural” or “intersectoral” changes. Developing countries with an economic structure relying on subsistence farming typically have a low level of materials and energy intensity. But when industrialisation takes off, countries specialise first in heavy industries to satisfy the material-intensive demand for consumer durables (houses, infrastructure). The consumption of materials and energy and associated pollution increase at a higher rate than income growth. The growth in pollution will level off as countries start to specialize in light consumer product industries. A subsequent shift towards service sectors may finally result in a decline in the relative demand of materials (Malenbaum, 1978; Baldwin, 1995). In other words, the relationship between the composition of production and income is believed to have an inverted-U shaped pattern. As the sample of countries under investigations in this particular study does not contain any developing countries, one may expect that only the part after the turning point is captured in this sample: the structure of consumption and production becomes less material intensive as income grows.

The third effect is the result of the changes in the technologies of production and use of products. Over time, economic agents replace their capital stock with new capital stock, which is usually more efficient, both in terms of energy and material inputs as in terms of services delivered. The vintage of technology is probably a crucial determinant of the environmental consequences of economic growth, and replaced capital stock is usually also environmentally benign. Technological innovation is the driving force behind these developments and governments can influence innovations and the market introduction of new technologies with policies, such as IPP or Ecodesign (see Chapter 5). However, the real driving force behind technological changes is in general poorly understood. According to the traditional neo-classical economic literature, technological changes depend on investments in human capital (Becker, 1964; Romer, 1990). Others (Schumpeter, 1934; Dosi and Orsenigo, 1988) have pointed out the existence of a so-called process of creative destruction which enables new innovations and which appears almost randomly over time. Innovations come, according to the latter vision, mostly in clusters. In De Bruyn (2002) evidence is presented for the existence of clusters in the consumption of steel and energy.

4.2.2 Defining a set of explanatory variables

Economic growth, compositional changes and technological changes are important drivers for the change in materials consumption over time. The primitives of these ‘functions’ (i.e. the level of income, structure of the economy and state of the technology) can hence be expected to form important determinants for the variation in materials consumption between countries.

However, regression analysis with these driving forces is hampered by, at least, two facts:
(i) There does not exist a uniform measure for the state of technology; (ii) Economic growth, the structure of the economy and the state of technology themselves are influenced by other effects, such as consumer preferences and governmental policies[1].

For these reasons we have to investigate which variables may influence the structure of production and consumption and the state of the technology. Clearly, this is a mix of policy influences, socio-economic preferences and cultural variables. We categorize the variables in the following way (in the following paragraph the dimensions of these variables are explained and in Annex 6 the sources of data are being described):

- GDP, reflecting the level of income
- Variables reflecting the structure of production;
- Variables reflecting lifestyles of consumers
- Variables influencing innovation and technological progress
- Policy variables
- Circumstance variables

These are described in more detail below, except for the GDP which is straightforwardly taken from the data.

[1] In addition, one may add that in principle the effects of economic growth, structural changes and changes in technologies form a so called singular matrix as equation (2) is an identity. This implies that the most efficient estimators of the effects cannot be computed in regression analysis.

The **structure of production** can be an important element of the material consumption of a country. The DMC is an indicator representing the consumption of new materials in an economy. As the material input in the economy becomes smaller along the chain (i.e. mining and basic industries consume much larger quantities of materials than the manufacturing and service industries), it can be expected that the structure of production may explain differences in the material consumption in a country.

For the analysis in this chapter we therefore selected indicators representing the structure of the economy by the NACE-shares of agriculture, mining, manufacturing and construction respectively. The expected sign of these indicators is positive: lower shares of material intensive sectors are correlated with lower levels of material consumption, measured as DMC or EMC. It can be expected that these shares correlate negatively with per capita GDP, as economies advance from agricultural societies via industrial societies to service-based societies (Baldwin, 1995).

Some have suggested that the decline in materials, energy consumption and associated emissions could be due to a relocation of dirty industries towards less-developed economies (Arrow et al., 1995; Stern et al., 1996). Empirical evidence for a shift of material- and energy-intensive production towards less developed economies is presented in Suri and Chapman (1998) and Schutz et al., (2004). Hence, a smaller share of the material intensive sectors should not be mistakenly interpreted as a lower final consumption.

Lifestyles are possibly an important determinant of the materials consumption in a country. Such lifestyles are often both socially and culturally determined. Of specific interest here are lifestyles that result in a burden on global resources. The question is which indicators are good representations of lifestyles. The COICOP household expenditures show too many missing values to be included in the analysis for the sample of countries. Besides, one may argue that expenditures are a poor measure for the burden, as environmental friendly production (organic farming, etc) involves higher costs for consumers. We have taken a practical route and investigated which data allowed us to investigate some effects from lifestyles and used the following variables:

- Daily animal fat intake per capita, for the suggestion that consumption of meat involves a large pressure on the environment compared to consumer crops;
- Car possessions per capita, for the suggestion that countries with a modal shift oriented towards automotive mobility will consume more resources (both materials and energy);
- Length of motorways per km2 and length of railways per km2 as an alternative to the car possession variable.
- The average household size, for the suggestions that larger households consume less resources
- New dwellings completed as this gives an indication of the demand for housing;
- Floor space per new dwelling completed, as this gives an indication of qualitative aspects in the demand for housing with consequences for material consumption.

Technological innovation may be an important element for the materials consumption of a country. As described above, most economists argue that investments in human capital are crucial for technological progress and innovations (i.e. Becker, 1964; Romer, 1990). As an indicator for the investments in human capital, we take the spending from the central government on education[2]. As a second indicator one may investigate the number of applied patents per capita, which may give a general picture of the level of technological innovations in a country.

Others (e.g. Porter, 1990) have pointed at the importance of competitiveness for technological advancements. There is a strong connection between the average level of competitiveness and the integration on the world market of an economy. This essentially works in two ways: (i) industries in open economies face more competition and tend to be more energy- and material efficient; and (ii) material- and energy efficient industries will have a better position on the world market and are

[2] It should be noted that education in some countries, especially Cyprus, Latvia, Spain and the UK, is also financed through the private sector. Although some partial data on these spendings from the COICOP surveys are available, we have not included them here as this would require quite some estimations and time-consuming recalculations. There is to our knowledge no study where such data have been combined. Hence the here presented indicator may not be representative of the total efforts in education.

therefore able to export more, which raises the integration of the economy in the world market. We therefore included a variable for the openness of the economy representing the trade integration of goods in the world market.

Governmental policies may influence the composition of consumption, as well as on the technologies of production. The government can in various ways influence the material consumption of an economy, e.g. by using economic instruments, by spatial planning procedures or by setting standards. The previous chapter indicated already the existing policy initiatives for reducing material- and energy consumption in the various countries. However, not all variables have a sufficient coverage for all the years or countries in the sample, especially for the tax-rate variables. For that reason we have included in Chapter 5 a more comprehensive analysis of environmental policy instruments in place in order to reduce the materials consumption.

Here we will focus on variables that can be included in the regression analysis, and they can be categorized as follows:
Tax and price variables
- Energy end-user price index
- Motor fuel end-use price index
- Industrial electricity price
- Tax on products

As sufficient data on the tax rates for energy products are not available, we included only end-user prices. This is justified by the observation that the main variation in energy prices comes from the tax component (excise duties, VAT and environmental taxes).[3] Chapter 5 gives information on the specific tax rates for the countries for which data were available. In addition, we included in the regression analysis a dummy variable indicating the countries where a tax policy exists for specific materials, such as sand or forest-products.

Waste treatment variables
- Share of municipal waste land filled
- Share of municipal waste recycled
- Share of municipal waste composted
- Share of municipal waste incinerated

Waste treatment may have important consequences for the material consumption in a country as incineration may reduce fossil fuel demand and recycling or composting may reduce the demand for new materials. Again, these variables merely reflect the outcome of a policy process instead of actual policies themselves. More information on waste policies will be presented in Chapter 5.

Spatial policy variables
Through spatial planning, governments may influence material consumption, for example through the amount of construction materials consumed. We take here three spatial policy variables:
- The density of motorways
- The density of railways
- The changes in forest areas

Other policy variables
The amount of renewable energy is another variable taken into account in this study, as this is heavily influenced by governmental policies in most countries.

Circumstance or state variables, finally, are variables that may influence all the above-mentioned variables but can hardly be altered actively. The variables included in this analysis are:
- Temperature
- Rainfall
- Size of a country

[3] No prices for materials have been included in this study as policies that influence the prices of materials are rare in Europe (chapter 5) and the time-series effects of the prices is probably absent as the data span is too short (only 9 years) to fully take into account effects from eventual price changes.

- Population density

Although population density may be influenced by specific policies (birth rate control, migration policies) in the long run, the variable can be interpreted as fixed in the short run at least. Hence these variables are only used for comparison between the various countries.

In addition to these state variables, one may want to include a few dummy variables in regression analysis which indicate historical facts that cannot be influenced anymore by policies or changes in lifestyles.[4] Two proposed dummy variables are:

- D1: Former communist economy
- D2: Accession country

The first dummy variable refers to the fact that the former communist economies have a legislative, cultural and economic history quite different from market economies. The transition towards market economies comparable to those in the EU is still not completed.

The second dummy variable refers to the fact that the accession countries were not exposed to the internal market of the EU and the EU-regulations and this may have had some influences on the efficiency of production in these countries.

4.2.3 Overview of all variables used in this study

Table 4.1. provides an overview of the 30 variables that are used in the empirical analysis.

Table 4.1: Overview of the data used in this study

Variable	Description	Unit of measurement	Epect.	Type	Mean	Min.	Max.	St. Dev.
Carposs	Car possession	Cars per 1000 capita	+	Slope	311.4	37.4	563.4	125.6
Dwelcap	Existing dwelling stock/capita	Dwellings per 1000 capita	+	Slope	393.6	150.0	561.0	77.6
Education	Public spendings on education	Share (%) of state budget	-	Slope	5.2%	2.3%	8.3%	1.4%
Energyprice	Energy price index	US$/toe	-	Slope	770.9	223.5	1310.6	241.7
Fat	Daily animal fat intake	Calories/Capita/Day	+	Slope	201.9	30.0	486.9	115.7
Floorspace	Floorspace of dwellings completed	m2	+	Slope	106.7	63.2	212.6	29.1
Forest	Forestation/deforestation	Av. annual change in forested area's	-/+	Const.	0.5%	-0.2%	2.9%	0.6%
GDPcap	GDP per capita	GDP (in constant 1995 US$) per capita	-/+	Slope	14611	1238	38482	11225
Househsz	Householdsize	Average capita per household	-	Const.	2.94	2.24	4.23	0.57
Indprice	Industrial electricity prices	US$/kWh	-	Slope	0.056	0.001	0.145	0.022
Motorfuel	Motorfuel price index	US$/toe	-	Slope	947.0	239.6	1531.0	311.7
Motorway	Density of motorways	Km / km^2	+	Slope	0.013	0.000	0.056	0.015
NACEAB	NACE AB, agriculture/fishery	Share (%) in total GDP	+	Slope	6.7%	1.0%	24.0%	5.6%
NACEC	NACE C, mining	Share (%) in total GDP	+	Slope	1.1%	0.1%	4.4%	0.9%
NACED	NACE D, manufacturing i	Share (%) in total GDP	+	Slope	19.6%	2.0%	40.0%	6.9%
NACEF	NACE F, construction	Share (%) in total GDP	+	Slope	5.9%	2.0%	11.5%	1.4%
NDwelcap	New dwellings completed	Dwellings completed per 1000capita	+	Slope	4.27	0.38	13.04	2.87
Openess	Openess of the economy	Average of Imports and Exports of goods as % of GDP	-	Slope	32.97	10.90	78.00	15.28
Patentcap	Patents submitted	Number of patents per 1000 cap	-	Slope	0.05	0.00	0.36	0.08

[4] The inclusion of dummy variables of course depends on the type of estimation procedure followed (see paragraph 3.4). For some types of panel data analysis, inclusion of dummy variables may not be needed as the country specific effects will capture these.

POPdens	Population density	Capita per km2	?	Slope	118.0	14.9	382.8	89.1
Precip	Average annual Precipitation	Rainfall in mm, average 1961-1990	?	Const.	742	498	1220	191
Prodtax	Tax on products (ESA95, D2)	Taxes on production and imports as % of GDP	-	Slope	13.7%	7.2%	18.4%	2.1%
Railway	Density of railways	Km / km^2	?	Slope	0.047	0.000	0.117	0.030
Renew	Renewable input in electricity production	% of production in total electricity consumption	-	Slope	14.9%	0.0%	68.2%	15.4%
Surface	Surface Area	km2	?	Const.	205932	9251	774815	200594
Temp	Average annual temperature	Degrees Celcius, average 1961-1990	?	Const.	9.29	1.70	18.40	3.87
Wcomp	Municipal waste composted	% waste composted	+	Const.	5.3%	0.0%	23.6%	6.7%
Wfill	Municpal waste landfilled	% of municipal waste landfilled	-	Const.	74.0%	10.0%	100.0%	30.0%
Wincin	Municipal waste incinerated	% of waste incinerated	+	Const.	11.7%	0.0%	52.3%	14.9%
Wrec	municipal waste recycled	% waste recycled	+	Const.	8.9%	0.0%	36.2%	11.2%

This table also lists the dimensions of the variables, mean and standard deviation.[5] The column "expect." gives the a-priori expected signs based on the discussion in the previous paragraph. The column "type" shows that in the set two type of variables are considered: constants and variable slope variables. The constant variables do not change over time in the database. They are mostly meant to correct for country specifics, such as climate or the sheer size of a country. In some cases, such as the waste variables or the annual forest cover change, the data available did not permit us to make an analysis over time as there were too many missing observations. In that case we selected the most recent year of estimates from a country and made hence a constant variable. As the household size did vary over time (but no reliable data were available), we included also a variable indicating the total dwelling stock per capita, which should be an alternative indicator for representing the household size. The slope variables change over time.

4.2.4 Selection of years and countries

The time series that have been constructed run from 1992 to 2000. For the (former) AC-countries, the DMC is only calculated from 1992 onwards, so an earlier estimate would not be possible. Data for 1990 and 1991 are available for the EU15, but these have not been included in order to create a balanced panel. This facilitates the interpretation of the results from the panel data analysis in paragraph 3.4.

For Austria and the Czech Republic, no data on the EMC had been established at the moment of writing this chapters, and these countries are therefore excluded from the analysis. For Malta, many series showed missing values. As the country is very small, we have decided to exclude it from the analysis. The figures for Luxembourg have been added to those of Belgium as many series are presented for the Belgium-Luxembourg economic union (BLEU).

Missing values for the other countries were also found in individual series. There are basically two ways to deal with them in regression analysis:

(i) to use specific methods for unbalanced panels;

(ii) to estimate the missing values, based on other data sources, or (in few cases) on past observations.

In this analysis, the second approach has been chosen. The advantage is that the estimates may be regarded as slightly more accurate for the whole sample: missing values tend to be associated with AC-countries and taking unbalanced panel estimates would be biased towards the EU15. The disadvantage is that it is much more time-consuming. Annex 6 describes the data manipulations that have been conducted.

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5 In addition to these 30 variables, three dummy variables have been included in the regression analysis (materials taxes, former centrally planned economies and accession countries). Renewable energy has also been calculated as the share of renewable energy in TPES, however, this variable performed poorly in general in the models. GDP per capita is used both in terms of nominal exchange rates (US$) and in terms of Purchasing Power Parities, see paragraph 4.4.3 for more explanation.

4.3 Relationships between socio-economic and materials consumption variables

In this paragraph we will analyse the relationship between the various variables. First we will investigate the correlation between various dependent variables (DMC, EMC and their components). Second, we will investigate the correlation between the various independent variables (the socio-economic variables) in order to understand the nature of the dataset and prevent multicollineairity in the panel data analysis. Finally, we will present a graphical overview of the influence of individual variables on materials consumption. This shows which variables are most likely to influence materials consumption.

4.3.1. Relationship between material consumption variables

The DMC and EMC are to a certain extent correlated. The following table gives information on the (linear) correlation coefficients between both variables and the various subcomponents that may be distinguished.

Table 4.2. Correlation coefficients between the variables representing materials consumption and their components.

	DMCtot	EMCtot	EMCbio	EMCbuild	EMCfoss	EMCindmi	EMCmetal	EMCminer	DMCbio	DMCbuild	DMCfoss	DMCindmi	DMCmetal	DMCminer
DMCtot	1.00													
EMCtot	0.73	1.00												
EMCbio	0.54	0.89	1.00											
EMCbuild	0.68	0.60	0.43	1.00										
EMCfoss	0.44	0.53	0.20	0.10	1.00									
EMCindmi	0.05	0.15	-0.01	0.19	0.18	1.00								
EMCmetal	0.41	0.54	0.45	0.49	-0.07	0.10	1.00							
EMCminer	0.66	0.60	0.42	0.99	0.12	0.32	0.48	1.00						
DMCbio	0.65	0.58	0.73	0.34	-0.08	-0.20	0.44	0.30	1.00					
DMCbuild	0.76	0.47	0.32	0.88	0.02	0.18	0.48	0.87	0.38	1.00				
DMCfoss	0.49	0.51	0.20	0.10	0.96	0.17	-0.06	0.12	-0.02	0.01	1.00			
DMCindmi	0.48	0.27	0.06	-0.03	0.73	-0.04	-0.27	-0.04	0.03	-0.01	0.80	1.00		
DMCmetal	0.34	0.08	0.02	0.15	-0.06	-0.11	0.36	0.13	0.35	0.19	-0.03	-0.09	1.00	
DMCminer	0.89	0.54	0.32	0.80	0.30	0.15	0.35	0.79	0.36	0.92	0.32	0.38	0.14	1.00
DMCcomp	0.20	0.01	-0.02	0.12	-0.04	-0.08	0.09	0.10	0.18	0.28	-0.15	-0.14	0.06	0.21

This table shows that various components are correlated with each other, indicated by the yellow areas. The correlation between total DMC and EMC is about 73%, which is rather high. But what exactly does this mean? It indicates that there is a certain linear relationship between the DMC and the EMC. How strong is this relationship? This cannot be determined with the correlation coefficient alone and one should run a regression analysis in order to interpret the strength of the relationship. As a rule of thumb, one may take the squares of the correlation coefficients in Table 4.2. and interpret them as the amount of variation in one variable caused by the other. So in the DMC-EMC case, one may assume, as a rule of thumb, that around 53% (= 0.73^2) of the variation in the EMC is explained by the DMC, and vice versa. Thus, one could assume that the DMC is a good predictor for the EMC in more than half of the cases. We will elaborate on this in more detail in paragraph 4.3.4

If we concentrate on the other correlation coefficients, we see that the total DMC seems to be most influenced by the DMC for minerals. As a matter of fact, the variation in the DMC for minerals is a good predictor for the variation in the total DMC in almost 80% ($=0.89^2$)of the cases. The total EMC instead is mostly influenced by the EMC for biotic materials. This is logical as the EMC identifies the biotic materials as most polluting (Chapter 3). The category “minerals” for both indicators seems to be most influenced by the indicator for building materials. As a matter of fact it seems not really necessary to distinguish a separate category of building materials as their correlations with the total minerals are close to unity. When we compare the various categories of the EMC with the corresponding categories of the DMC, we see that both indicators are strongly correlated for the fossil fuels. Hence, the DMC of fossil fuels seems to be an appropriate measure for the EMC of fossil fuels, which in a sense is logical as kilograms tend to be a measure of environmental impacts from fossil fuels.[6] The DMC and EMC diverge especially substantial for metals, for which apparently the kilogram measurement results in a different weighting than the environmental-impact measurement.

4.3.2 Relationships between explanatory variables

Table 4.3. gives information on the correlations between the socio-economic variables. Investigating this correlation is important in order to understand the nature of the variables we select and to exclude possible interactions between highly correlated variables in the regression analysis.

Overall, the correlation between the explanatory variables is not very high. The waste variables all seem to be heavily correlated. This is logical as the variables are set up as the share of the total waste stream which is –respectively- land filled, incinerated, composted or recycled, and together they add up to one. In regression analysis they cannot be included all at once, and it is best to include only one of them to reduce problems of multicollineairity.

Table 4.3. Correlation coefficients between explanatory socio-economic and circumstance variables

	Temp	Preci	Surfa	Fores	POPde	Wrec	Wcomp	Wfill	Winci	House	Opene	Carpo	GDPca	Motor	Railw	NDwel	naceD	naceA	naceC	naceF	Fat	Dwelc	Floor	Renew	Prodt	Energ	Motor	Indpr	Educa
Temp	1.00																												
Precip	0.04	1.00																											
Surfac	-0.04	-0.19	1.00																										
Forest	0.23	0.45	-0.13	1.00																									
POPde	0.19	0.35	-0.14	-0.19	1.00																								
Wrec	-0.13	0.20	0.07	-0.12	0.62	1.00																							
Wcom	0.08	0.12	0.07	-0.20	0.59	0.71	1.00																						
Wfill	0.11	-0.11	-0.09	0.19	-0.56	-0.91	-0.86	1.00																					
Wincir	-0.17	0.02	0.09	-0.21	0.40	0.76	0.75	-0.95	1.00																				
House	0.09	0.20	-0.01	0.39	-0.34	-0.53	-0.46	0.63	-0.67	1.00																			
Opene	-0.35	0.20	-0.59	0.13	0.04	0.03	-0.04	0.06	-0.13	0.30	1.00																		
Carpos	0.06	0.36	0.03	-0.05	0.40	0.62	0.52	-0.61	0.53	-0.50	-0.09	1.00																	
GDPca	-0.11	0.24	0.13	-0.07	0.44	0.80	0.64	-0.85	0.82	-0.57	-0.13	0.76	1.00																
Motorv	0.20	0.22	-0.19	-0.29	0.87	0.72	0.76	-0.71	0.54	-0.40	0.14	0.56	0.60	1.00															
Railwa	-0.13	0.34	-0.14	-0.26	0.71	0.54	0.34	-0.43	0.30	-0.35	0.14	0.31	0.29	0.55	1.00														
NDwel	0.54	0.18	0.03	0.43	0.13	0.22	0.22	-0.20	0.15	-0.06	-0.21	0.39	0.43	0.26	-0.17	1.00													
NACEI	-0.30	-0.38	0.14	-0.54	-0.14	-0.14	0.04	0.06	-0.03	-0.08	0.05	-0.12	-0.26	-0.08	0.13	-0.48	1.00												
NACE	0.04	-0.43	0.05	-0.09	-0.35	-0.56	-0.44	0.54	-0.47	0.28	-0.03	-0.73	-0.70	-0.46	-0.31	-0.45	0.29	1.00											
NACE	-0.13	0.09	-0.04	-0.05	0.23	-0.17	-0.04	0.16	-0.17	0.25	-0.04	-0.35	-0.28	-0.07	0.19	-0.30	0.04	0.29	1.00										
NACEI	0.35	-0.24	-0.14	0.03	-0.15	-0.24	-0.13	0.30	-0.36	0.27	-0.04	-0.15	-0.32	-0.06	-0.26	0.28	-0.03	0.03	0.05	1.00									
Fat	-0.29	0.15	-0.24	-0.17	0.31	0.51	0.29	-0.53	0.55	-0.39	0.24	0.29	0.43	0.35	0.67	-0.14	0.09	-0.44	-0.20	-0.32	1.00								
Dwelca	-0.06	-0.08	-0.08	-0.21	0.07	0.36	0.34	-0.45	0.48	-0.72	-0.19	0.63	0.57	0.23	0.05	0.16	-0.13	-0.33	-0.32	-0.18	0.17	1.00							
Floors	0.27	-0.19	-0.22	-0.35	0.22	0.19	0.18	-0.19	0.16	-0.07	0.08	0.05	0.19	0.46	0.08	0.17	-0.09	-0.19	-0.30	0.14	0.16	0.04	1.00						
Renew	-0.26	-0.07	0.39	-0.06	-0.40	-0.11	-0.04	0.03	0.04	-0.01	-0.21	-0.10	-0.08	-0.32	-0.37	-0.19	0.44	0.13	-0.23	-0.23	-0.19	-0.13	-0.19	1.00					
Prodta	-0.24	0.01	-0.01	-0.07	-0.29	-0.07	-0.08	-0.08	0.24	-0.03	-0.06	0.01	0.09	-0.29	0.06	-0.23	0.15	-0.13	-0.03	-0.38	0.38	0.10	-0.04	0.20	1.00				
Energy	0.19	0.41	0.19	0.21	0.50	0.58	0.49	-0.60	0.56	-0.41	-0.31	0.65	0.71	0.45	0.29	0.40	-0.37	-0.63	-0.23	-0.33	0.25	0.31	0.01	-0.05	0.07	1.00			
Motorf	0.14	0.24	0.21	0.04	0.47	0.61	0.52	-0.66	0.65	-0.50	-0.28	0.71	0.80	0.52	0.22	0.46	-0.32	-0.67	-0.31	-0.31	0.25	0.39	0.15	-0.03	0.09	0.93	1.00		
Indpric	0.54	0.17	0.22	0.26	0.27	0.19	0.24	-0.22	0.18	-0.13	-0.46	0.34	0.27	0.23	-0.01	0.41	-0.24	-0.29	-0.21	0.01	-0.10	-0.03	0.07	0.06	-0.12	0.70	0.59	1.00	
Educa	-0.55	-0.03	-0.13	-0.13	-0.27	0.16	0.15	-0.31	0.44	-0.25	0.12	0.28	0.32	-0.10	-0.09	-0.19	0.07	-0.38	-0.09	-0.14	0.40	0.36	-0.06	0.17	0.44	0.02	0.10	-0.18	1.00
Patent	-0.44	0.01	0.27	-0.19	0.16	0.58	0.35	-0.62	0.65	-0.53	-0.16	0.55	0.77	0.24	0.13	0.12	0.00	-0.45	-0.14	-0.38	0.24	0.51	-0.07	0.16	0.16	0.46	0.58	0.05	0.43

[6] It must be noted, however, that the DMC and EMC use different system boundaries with respect to consumption of fossil fuels. Hence, the correlation may simply indicate that the apparent consumption of energy, as used in the EMC, correlates with the total consumption as calculated in the DMC.

The waste variables also seem to be correlated with GDP. Clearly, the practice to incinerate municipal waste seems to exist especially in the more wealthy countries. Similarly is low income a sign that most of the waste will be landfilled. Per capita GDP is furthermore rather strongly correlated with car possessions per capita, which is quite intuitively appealing. There is also a strong correlation of GDP with the calculated price-index of motor fuels which seems also to be logical as excise taxes are higher in wealthier countries. In addition, there is a strong correlation between per capita GDP and the patents per capita. If we investigate the GDP-effect furthermore, we find some negative correlation between the share of agriculture and fishing (naceAB) and GDP. Again, this is appealing as higher-income countries tend to have a lower share of agriculture in their economies.

Furthermore, the amount of motorways per km2 is correlated with population density. This again is logical, as more densely populated areas will have more paved infrastructure. The amount of motorways seem furthermore to be correlated with the share of composted municipal waste: as there seems to be no reason why these variables correlate, this should be considered as purely accidental.

Finally, the energy price index and the motor fuel price index are heavily correlated, which is not strange as the price of motor fuels constitute the major part of the calculated energy price index. In the regression analysis, only one should of them should be included.

On average, per capita GDP has the most correlation with all the other variables in the sample. The lowest correlation is the tax rates on products as % of GDP, which is rather independent from the other explanatory variables. Also the surface area, floor space of houses, the renewable energy share and the openness of the economy seem to be poorly connected, on average, to the other explanatory variables.[7]

4.3.3 Relationships between materials consumption and explanatory variables

Finally, we are also interested in the relationship between the various categories of the DMC and EMC and the socio-economic variables. Table 4.4 gives the overview.

The green areas present the variable with the highest linear correlation with the specific component of the DMC and EMC. The blue areas indicate relationships that are also important and that are worthwhile investigating. We also investigated correlations under a logarithmic transformation of one of the variables. Purple and pink areas indicate variables between which linear relationships performed poorly but nonlinear relationships were substantially more significant.

[7] The surface area itself is rather negatively correlated with the openness of the economy, which again is intuitively appealing as smaller countries tend to trade more with other countries than larger countries.

Table 4.4. Relationship between categories of DMC and EMC and socio-economic variables.

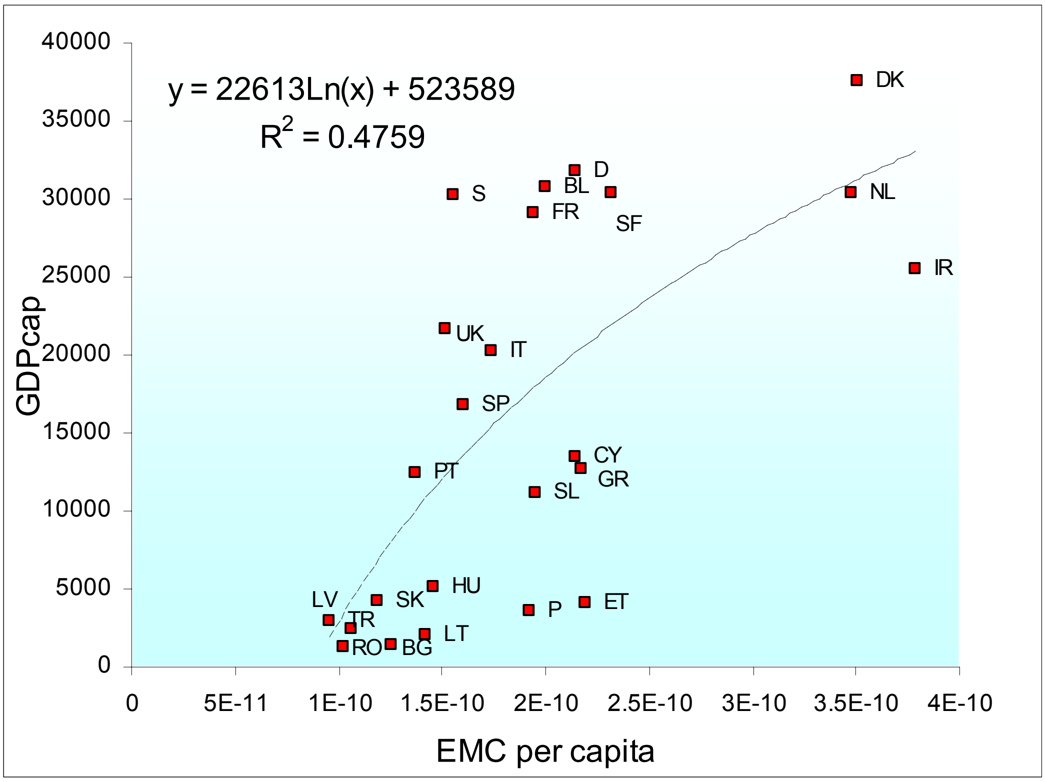
	DMCtot	EMCtot	EMCbio	EMCfoss	EMCmetal	EMCminer	DMCbio	DMCfoss	DMCmetal	DMCminer	DMCcomp
Temp	-0.24	-0.13	-0.17	-0.11	0.17	-0.06	-0.40	-0.16	-0.31	-0.01	0.19
Precip	-0.03	0.16	0.23	-0.04	0.22	-0.07	0.16	-0.03	-0.15	-0.10	-0.03
Surface	-0.13	-0.30	-0.29	-0.32	0.18	-0.09	-0.03	-0.32	0.18	-0.09	0.23
Forest	0.16	0.22	0.38	-0.09	0.33	-0.25	0.50	0.01	0.03	-0.07	0.23
POPdens	-0.12	0.28	0.14	0.24	0.27	0.25	-0.32	0.14	-0.26	0.02	-0.55
Wrec	0.31	0.48	0.37	0.18	0.46	0.41	0.18	0.12	0.20	0.32	-0.37
Wcomp	0.13	0.44	0.36	0.12	0.44	0.39	-0.02	0.03	-0.01	0.23	-0.32
Wfill	-0.32	-0.52	-0.43	-0.14	-0.47	-0.49	-0.19	-0.06	-0.15	-0.36	0.26
Wincin	0.35	0.49	0.44	0.09	0.40	0.51	0.25	0.02	0.16	0.38	-0.10
Househsz	-0.17	-0.10	0.05	-0.04	-0.19	-0.41	0.08	0.03	-0.19	-0.29	0.10
Openess	0.15	0.25	0.33	0.22	-0.19	-0.07	0.22	0.28	0.04	-0.01	-0.45
Carposs	0.43	0.32	0.15	0.08	0.45	0.51	0.11	0.06	0.11	0.57	0.00
GDPcap	0.60	0.63	0.50	0.10	0.63	0.71	0.42	0.08	0.19	0.63	0.00
Motorway	0.11	0.40	0.25	0.21	0.32	0.49	-0.20	0.12	-0.20	0.30	-0.54
Railway	-0.21	0.11	0.04	0.21	-0.03	0.00	-0.26	0.12	-0.19	-0.17	-0.48
NDwelcap	0.40	0.36	0.27	-0.05	0.60	0.46	0.26	-0.04	-0.02	0.50	0.22
NACED	-0.30	-0.41	-0.41	-0.13	-0.34	-0.15	-0.31	-0.15	-0.05	-0.20	-0.15
NACEAB	-0.45	-0.46	-0.39	-0.06	-0.43	-0.50	-0.33	-0.03	0.06	-0.51	-0.03
NACEC	-0.19	0.09	0.01	0.39	-0.17	-0.18	-0.23	0.31	-0.10	-0.29	-0.10
NACEF	-0.03	-0.05	-0.06	0.07	-0.20	0.00	-0.17	0.04	-0.32	0.09	0.08
Fat	0.09	0.27	0.36	0.03	-0.02	0.13	0.19	0.00	-0.08	0.07	-0.23
Dwelcap	0.45	0.31	0.11	0.27	0.25	0.45	0.08	0.27	0.22	0.48	0.14
Floorspace	0.11	0.19	0.14	0.08	-0.03	0.37	-0.10	0.03	-0.26	0.29	-0.22
Renew	-0.17	-0.43	-0.31	-0.54	0.03	-0.14	0.11	-0.49	0.25	-0.15	0.17
Renew2	0.11	-0.23	-0.16	-0.32	-0.01	0.02	0.30	-0.25	0.39	0.04	0.11
Prodtax	0.12	0.07	0.12	0.00	-0.01	-0.02	0.22	0.00	0.21	-0.01	0.30
Energyprice	0.23	0.31	0.26	-0.10	0.62	0.35	0.21	-0.12	0.05	0.29	0.05
Motorfuel	0.38	0.37	0.27	-0.09	0.64	0.55	0.25	-0.12	0.16	0.48	0.03
Indprice	-0.01	-0.02	-0.04	-0.24	0.38	0.14	-0.06	-0.28	-0.18	0.19	0.21
Education	0.46	0.31	0.32	0.12	-0.05	0.30	0.40	0.12	0.17	0.39	0.22
Patentcap	0.53	0.41	0.28	0.05	0.44	0.65	0.39	0.06	0.38	0.50	0.16

Below, we present some graphical analysis on the factors that seem to influence DMC and EMC the most. We take as reference year 1999, as some of the explanatory variables showed missing values for the year 2000.

Total material consumption

Total materials consumption appears to be correlated mostly with per capita GDP, both for the DMC and the EMC as shown in Figures 4.1 and 4.2. The relationship between the EMC and GDP can best be depicted as concave: rising levels in per capita GDP result in more than proportional increases in the EMC. However, this result is mainly due to the outlier position of Denmark, the Netherlands and Ireland. If these countries were to be omitted from the analysis, a different relationship would emerge.

Figure 4.1. Relationship between per capita EMC and per capita GDP (in US$1995), 1999[8]



It appears that there exists a group of countries (Sweden, France, Belgium-Luxembourg and Finland that do relatively well with respect to their expected EMC based on the per capita GDP. Ireland, Estonia and Poland typically have higher EMCs than expected.

For the DMC the relationship is more linear than in the case of the EMC (Figurer 4.2). Estonia is now a clear outlier with a much higher DMC than expected on their per capita income. Also Cyprus, Bulgaria and Finland perform rather poorly. Most Western European EU-countries perform better than expected on this relationship. Also, the similarity between the Netherlands, Belgium and Germany is striking in this case.

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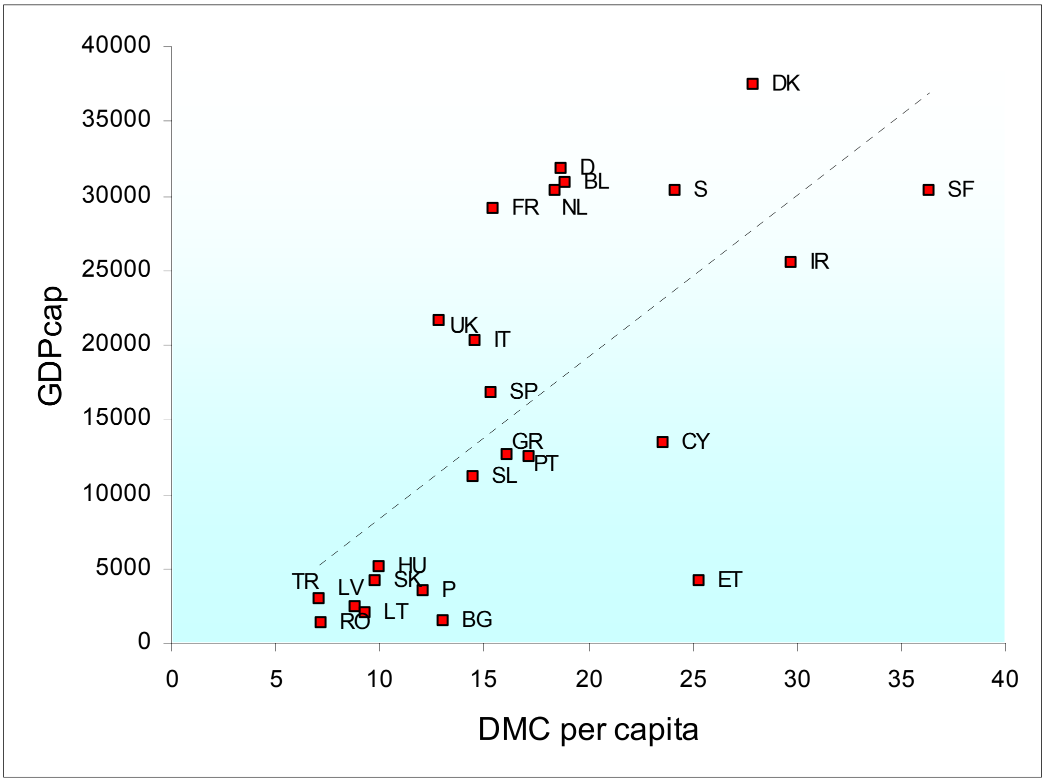
[8] The country codes are as follows:

BLEU	BL	Italy	IT	Spain	SP
Bulgaria	BG	Ireland	IR	Sweden	S
Cyprus	CY	Latvia	LV	Turkey	TR
Denmark	DK	Lithuania	LT	United Kingdom	UK
Estonia	ET	Netherlands	NL		
Finland	SF	Poland	P		
France	FR	Portugal	PT		
Germany	D	Romania	RO		
Greece	GR	Slovakia	SK		
Hungary	HU	Slovenia	SL		

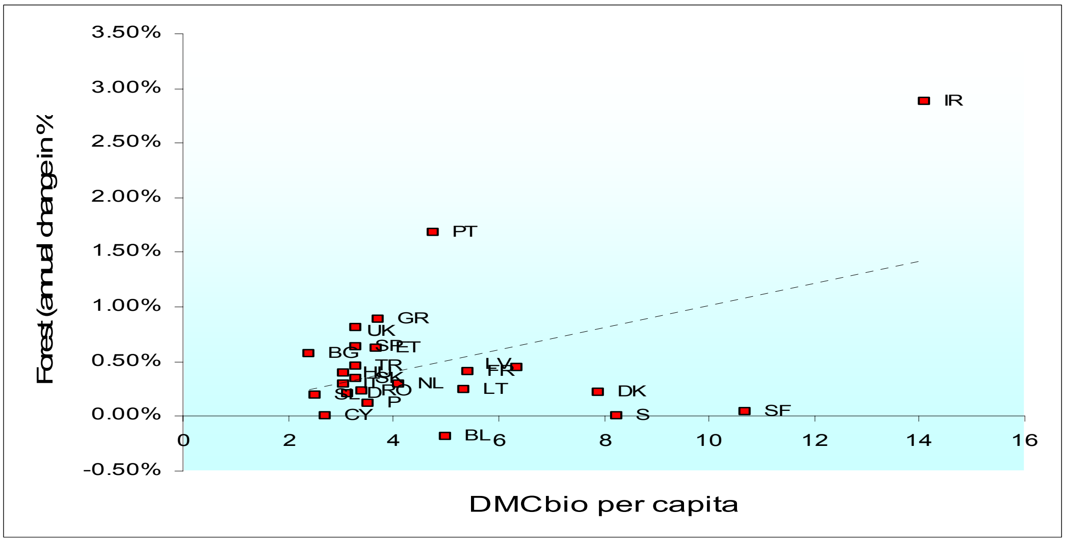
Figure 4.2. Relationship between per capita DMC and per capita GDP (in US$1995), 1999



Biotic materials

The biotic materials in the DMC are in general poorly explained by the variables in our model. The change in forest area seems to be the most significant and the results are given in Figure 4.3.

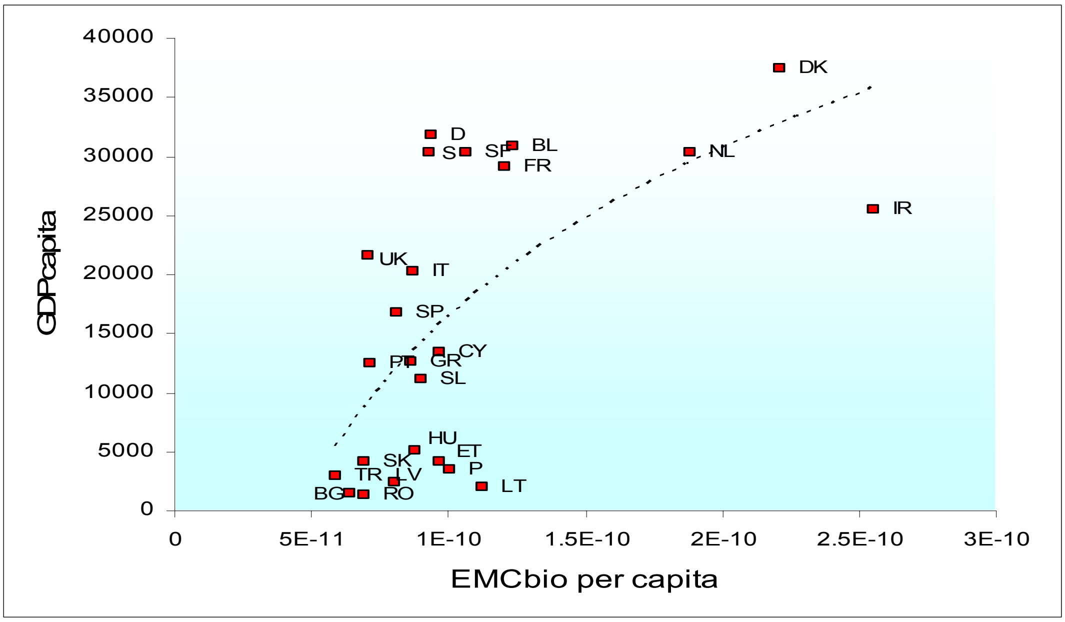
Figure 4.3. Relationship between per capita DMC for biotic materials and annual change in forested areas, 1999.



The positive relationship, however, is largely due to the outlier position of Ireland, which has a much higher per capita consumption of biotic materials than expected. The relationship is also different than expected; an increase in forested area is associated with higher consumption of biotic resources which may indicate that forest resources are used as economy input rather than for nature and wildlife. However, if one would leave out Ireland and Portugal, one may argue that the per capita consumption of biotic resources is negatively correlated with annual forest area change. This would make more sense, intuitively; a transformation of agricultural lands towards forest areas, or a reduction in logging activities, reduces the amount of biotic resources harvested.

The EMC for biotic resources is influenced mostly by per capita GDP as shown in Figure 4.4. However, the relationship is again heavily influenced by the outlier position of Denmark, the Netherlands and Ireland in this respect. If these countries were excluded, the influence of per capita GDP on the consumption of biotic resources would be much smaller.

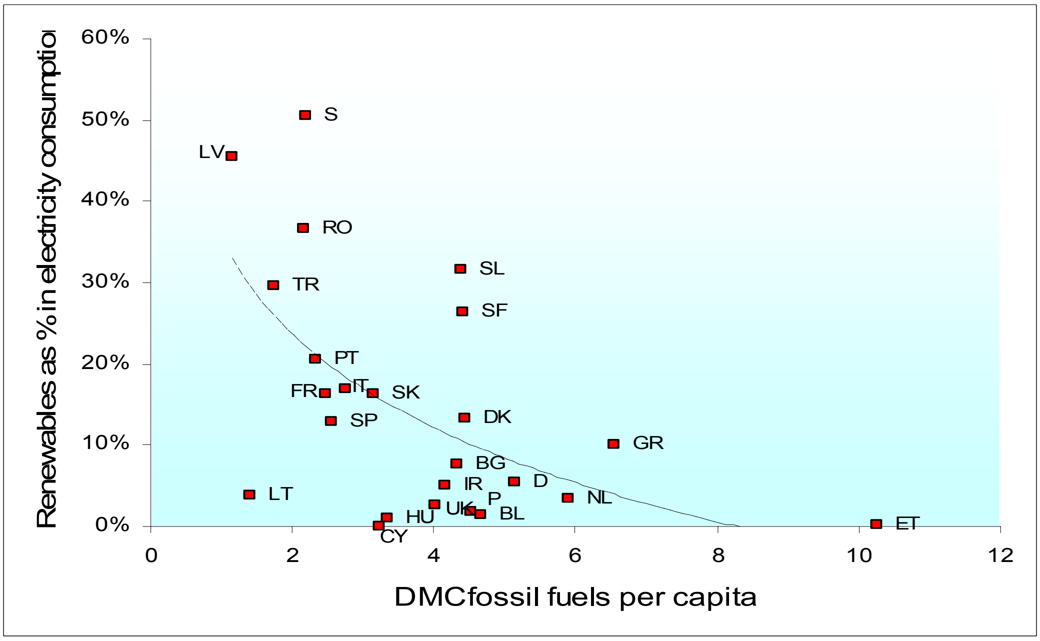
Figure 4.4. Relationship between EMC for biotic resources and per capita GDP, 1999.



Fossil fuels

The DMC for fossil fuels is mostly influenced by the share of renewables in total electricity consumption. The following figure shows that more renewables are indeed heavily correlated with less fossil fuel consumption in weight.

Figure 4.5. Relationship between DMC for fossil fuels and share of renewables in electricity consumption, 1999.



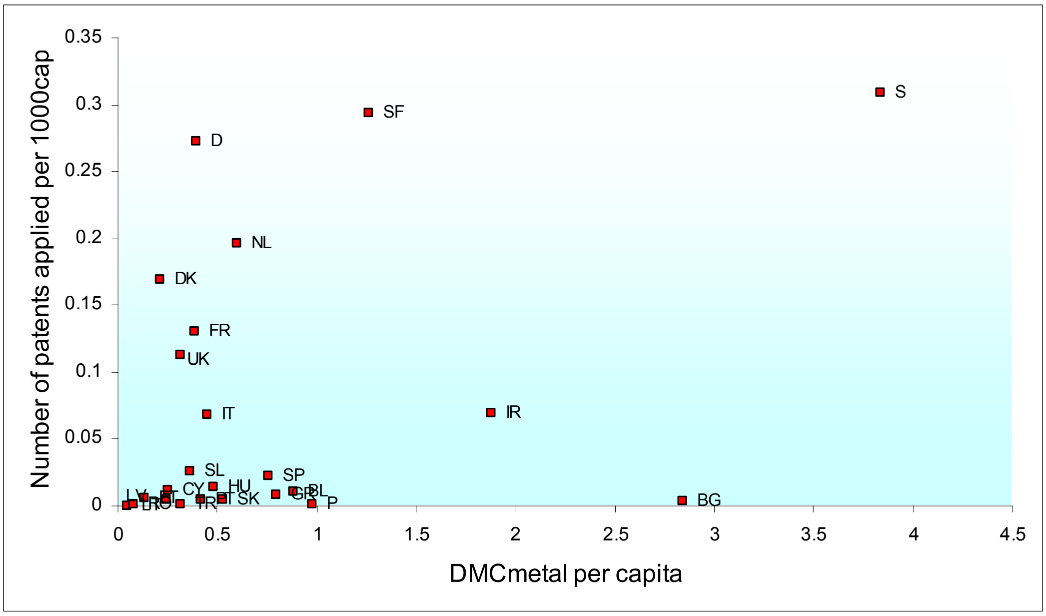
Sweden, Latvia, Romania, Slovenia, Finland and Greece typically perform better than expected on the basis of this relationship. Latvia, Hungary and Cyprus typically perform more poorly. For Cyprus, this is due to the fact that solar energy is used for heating purposes. This indicator may underestimate the contributions from the Southern European countries, in general.[9] Again, Estonia can be regarded as an outlier in this analysis.

The development of the EMC for fossil fuels is very similar to that of the DMC. This is due to the fact that the correlation coefficient between fossil fuels from the DMC and EMC is close to unity. As noted above, weight seems to be an appropriate measure to summarize all environmental effects from fossil fuels.

Metals

The correlation of the DMC for metals was insignificant with all of the variables in our model. The best explanation was provided by the per capita applications of patents, which has a correlation coefficient of only 0.38. This basically indicates no relationship at all. From Figure 4.6 we see that Sweden and Bulgaria have a remarkable high consumption of metals compared to the other countries in the sample.

Figure 4.6. Relationship between per capita DMC for metals and number of patents applied, 1999.

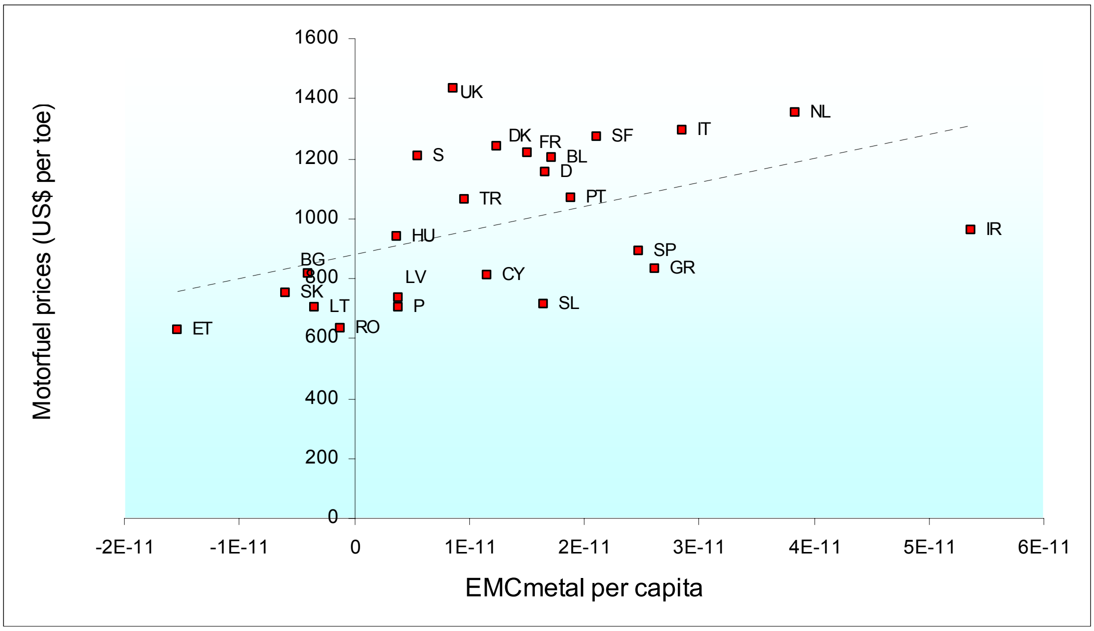


The EMC consumption of metals is explained by a wide range of factors (see Table 4.4): car possession, GDP per capita, the energy price and the motor fuel price. Car possession and motor fuel prices may show a similar trend; higher motor fuel prices may imply lower car possessions and hence lower metal consumption. Of course, other interdependencies are also possible, e.g. higher motor fuel prices tend to be a proxy for fuel prices in metal industries. Below, we show the relationship between the motor fuel price and the EMC for metals.

As we can see from this figure, Ireland and also the Netherlands tend to have a high consumption of relatively polluting metals. However, when we compare it to price level of motor fuels, we find that the consumption of the Netherlands is lower than expected based on the relationship. Some countries have a negative EMC for metals, indicating that export was larger than production and import. This might happen if a country releases some of their stocks of metals. The UK clearly has an outlier position here, with a very low EMC for metals compared to motor fuel prices.

[9] Although we tried to include an indicator indicating the share of renewables in total TPES, this indicator performed poorly in the model. This can be due to data problems in establishing this indicator.

Figure 4.7. Relationship between EMC for metals and the motor fuel price, 1999.

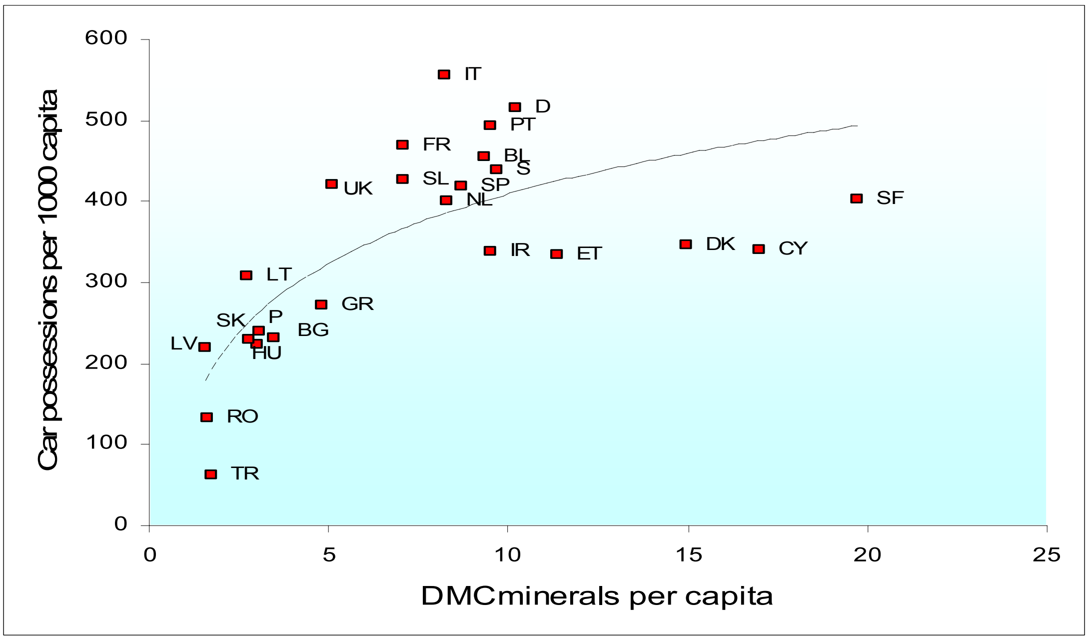


Similar relationships are found between the environmentally weighted metal use and car possession.

Minerals

The DMC for minerals seems mostly be influenced by per capita GDP. In addition, also car possession seems an influential variable. The reason for this could be that a higher car possession could be associated with a higher (political) demand for roads and parking lots which require a lot of minerals.

Figure 4.8. Relationship between car possession and the DMC for minerals, 1999.

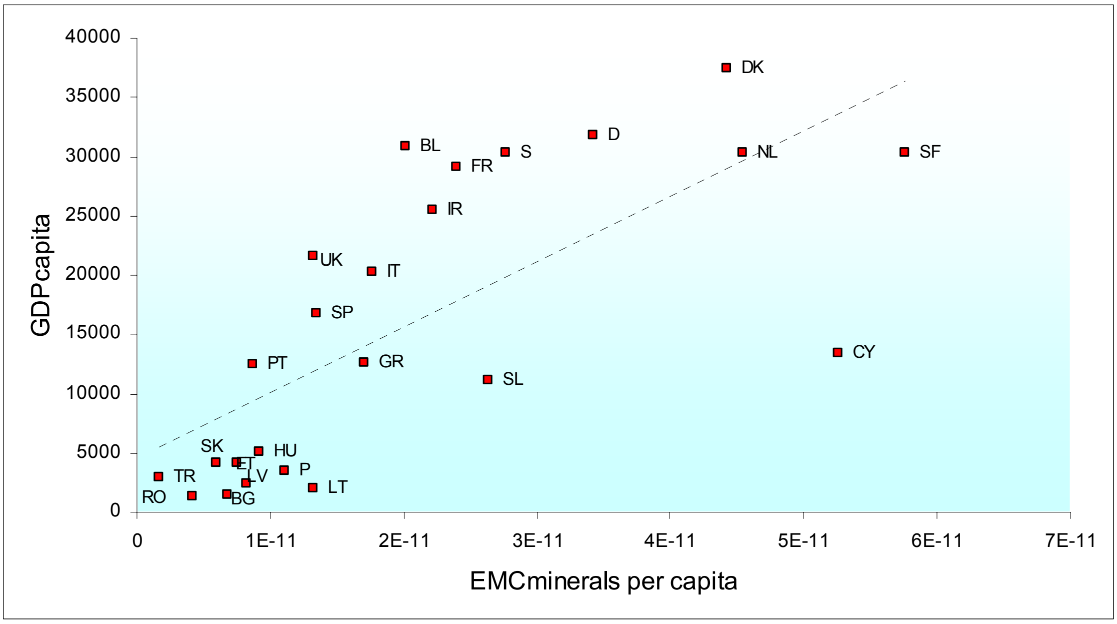


From the figure we see that Italy has the highest car possession per capita. However, the associated mineral consumption is much lower than expected. Ireland, Estonia, Denmark, Cyprus and Finland have a higher consumption of minerals than expected on the basis of their minerals consumption, which of course indicates that other factors influence mineral consumption as well.

The EMC for minerals seems mostly be influenced by per capita GDP (see Figure 4.9) and the patents per capita. The patents per capita have, however, the opposite sign as expected. More patents applied indicate a higher environmental burden from mineral consumption.

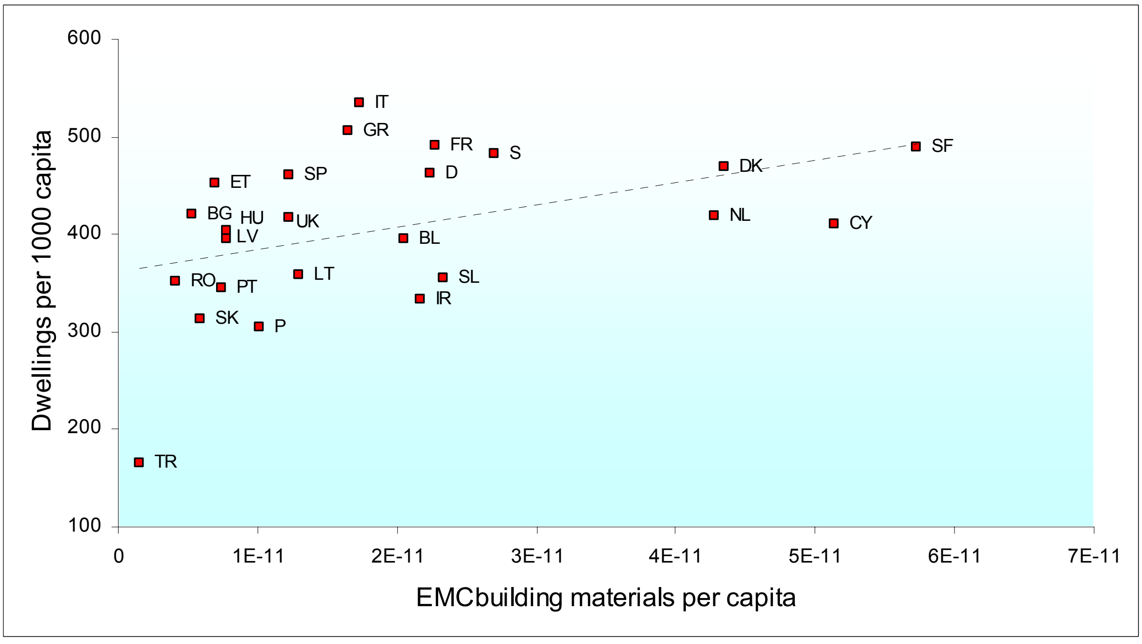
As for the GDP per capita, results are given in the figure below. Cyprus seems a clear outlier with a much lower consumption of minerals than expected from the level of the GDP. The opposite is true for Belgium and Denmark that have a higher mineral consumption than expected from their GDP-levels.

Figure 4.9. Relationship between per capita GDP (in 1995US$) and per capita EMC for minerals, 1999.



The DMC and EMC for minerals can be decomposed into the part building materials and the part industrial minerals. The EMC for building materials seems influenced most by the dwellings per capita, which is quite logical. The following figure gives the results:

Figure 4.10. Relationship between EMC for building materials and dwellings per capita, 1999.



This shows that the relationship is as expected: more dwellings indicate a higher consumption of building materials.

The DMC for building materials is influenced most by per capita GDP.

4.3.4. A note on the relationship between total DMC and EMC

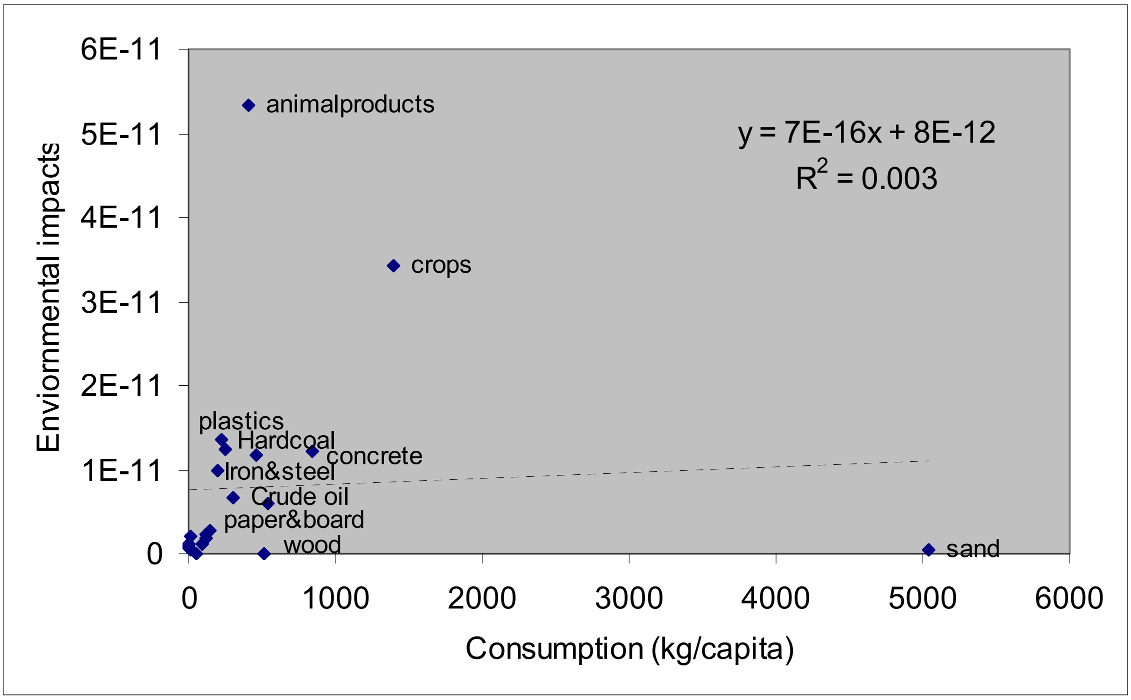
Finally, we want to return to the relationship between the DMC and EMC, as described in paragraph 4.3.2. The analysis there showed that the DMC correlates with the EMC: for about 73% of the cases, the DMC seems to be indicative for the EMC. One important question is now the following: Does this imply that the DMC is a good proxy for the environmental impacts, as calculated with the EMC?

One may answer that question on different levels:

1. Is weight a good proxy for environmental impacts of individual materials?
2. Is weight a good proxy for total environmental impacts of individual countries?
3. Is weight a good proxy for total environmental impacts over time?

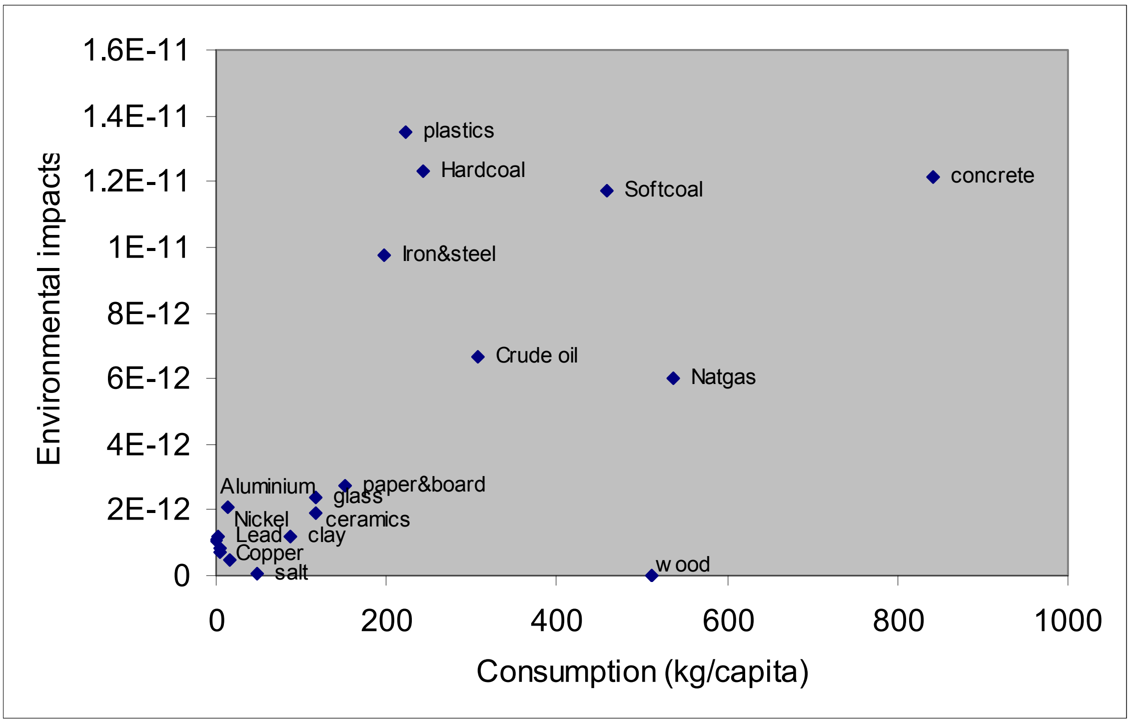
Below we will try to answer those questions.
First, if we investigate the relationship at the level of individual materials, we see a great variation between weight and environmental impacts, as indicated in Figure 4.11.

Figure 4.11. Relation between consumption and environmental impacts (consumption x LCA-impact factor as in the EMC) for 22 materials, year 2000 for the EU28.



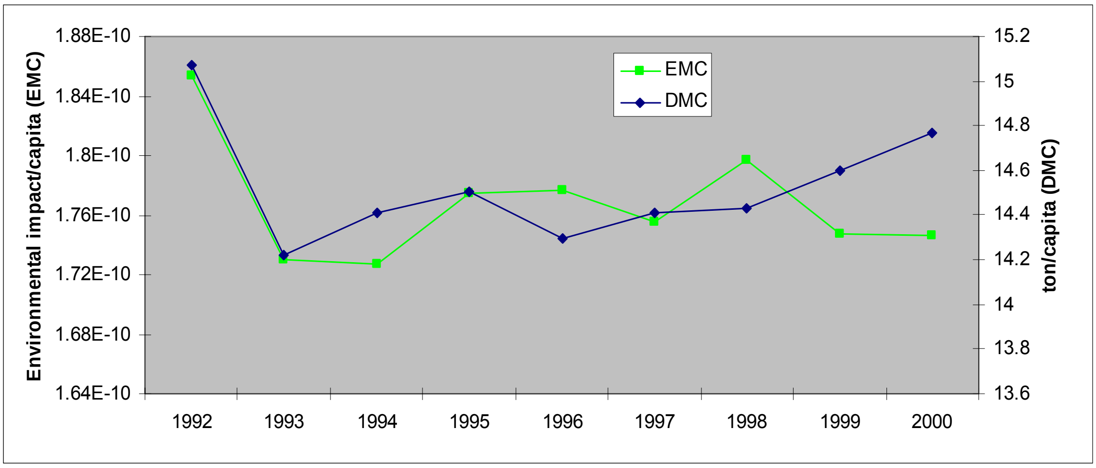
The R^2, the coefficient indicating the strength of the relationship, indicates that only in 0.3% of the cases weight is an indicator of environmental impacts for individual materials. Most of the materials are located in the lower left corner in this graph, and Figure 4.12 shows that the variation remains large if we zoom in on the materials with both a low consumption and a low environmental impact. This need not to indicate, however, that the DMC itself is a poor indicator of environmental impacts as the DMC cannot be established on the level of individual materials. Iron and Steel, for example, require iron ores, energy and auxiliary materials as inputs and taking all of these materials together may result in a DMC-equivalent of the Iron and Steel weight based indicator. This indicator must then subsequently be compared with the environmental impacts in order to assess the predictability of the DMC for environmental impacts on the level of individual materials.

Figure 4.12. Relation between consumption and environmental impacts (consumption x LCA-impact factor) for 19 materials, year 2000



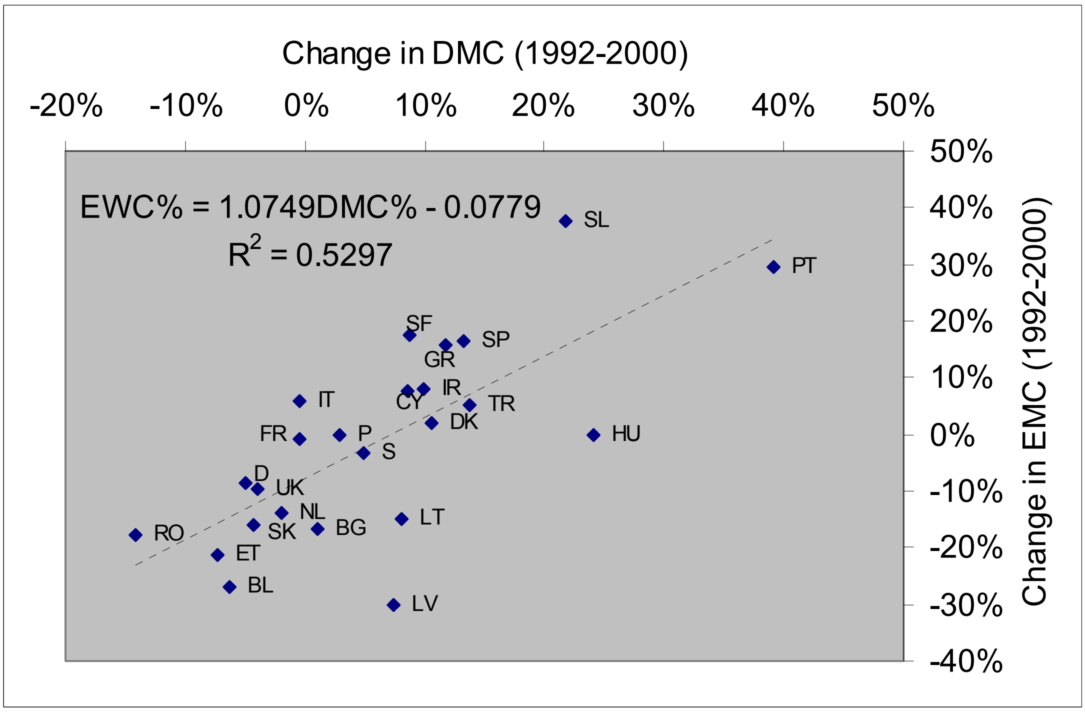
One way to investigate whether the total DMC correlates with the EMC is to investigate the relationship over time. Figure 4.13. shows the variation of the EMC and the DMC over time. We see that in most years they change in the same fashion, but for some years there are diverging developments.

Figure 4.13. Relationship between per capita EMC and per capita DMC, EU28, 1992-2000.



The correlation coefficient of the two series is 0.63 – so less strong than the relationship for all countries as presented in Table 4.2. We can also conduct this analysis for individual countries. Figure 4.14. gives the relationship between the change in the DMC and the EMC between 1992-2000 for individual countries.

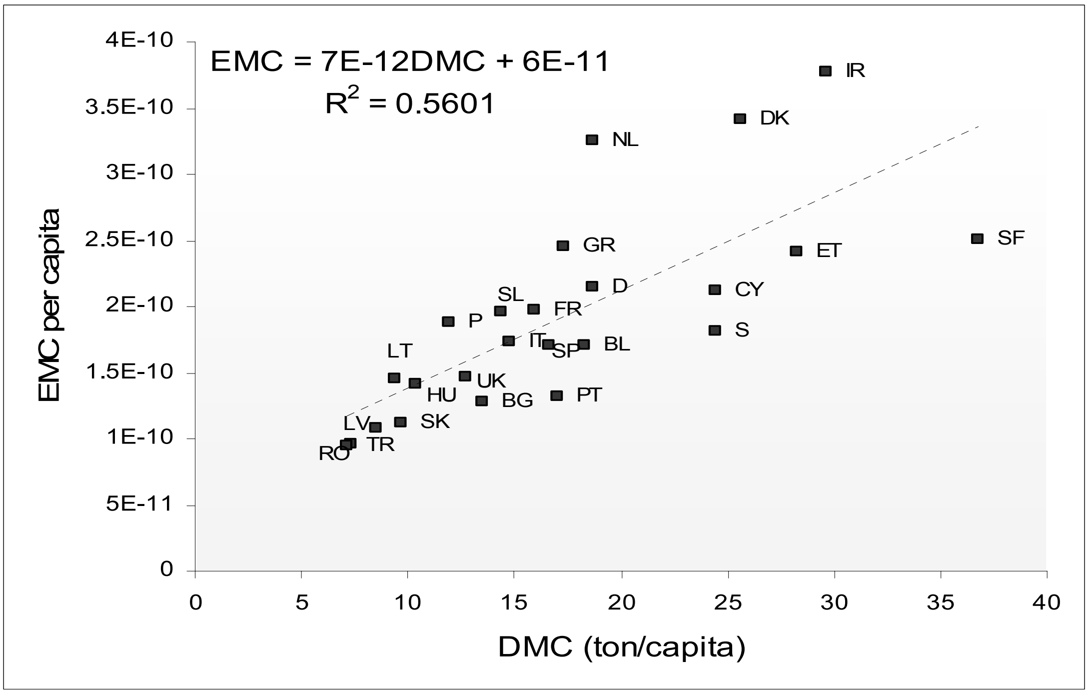
Figure 4.14: Relationship between changes in DMC and EMC, 24 countries.



We see a relationship between the DMC and EMC, indicating that countries that have reduced their DMC most likely also have reduced their EMC. The correlation coefficient is 0.72, hence similar to the 0.73 reported in Table 4.2. Outliers are on the one hand Slovenia and Finland where the EMC grew at a much faster rate than their DMC, and on the other hand Latvia, Lithuania and Hungary that reduced their EMC while their DMC was rising. The R^2, the coefficient of determination that indicates the strength of the relationship, indicates that in 53% of the cases changes in the DMC give a "good" prediction for the changes in the EMC.

A similar relationship holds if we investigate purely the levels of EMC and DMC in a given year, as presented in Figure 4.15 for the year 2000.

Figure 4.15. Relation between EMC per capita and DMC per capita, 2000.



We see a reasonable fit between the DMC and EMC per capita, and that countries with a higher DMC tend to have a higher EMC and vice versa. In 56% of the cases, the DMC gives a good estimation for the EMC. Clear outliers are on the one hand the Netherlands, Denmark, Ireland where the EMC is much higher than expected on the basis of the DMC, and on the other hand Finland, where the EMC is much lower than expected on the basis of the DMC.

Do these analysis imply that the DMC is a good proxy for environmental impacts as calculated by the EMC? This depends, amongst others, on the time-frame and the use of the indicator. The DMC and EMC over time will definitely be correlated if the composition of materials consumption does not change over time. There is some strong reason to believe that technical coefficients of production are fixed in the short-run; companies do not suddenly change their techniques of production as these are dependent on long-term investments and technological innovation, and consumers tend to have a relative stable pattern of consumption in the short-run. In other words, it can be expected that no sudden changes in the composition of materials demand occur unless external shocks (such as drastic price changes or technological breakthroughs) force companies to reconsider the material consumption of their products and consumers to reconsider their lifestyles.[10]

When the composition of materials consumption starts to diverge from the initial positions, it is more likely that the DMC and EMC will start to develop differently. However, this largely depends on the question whether the DMC for individual finished materials (i.e. including all used materials for producing the finished material) correlates with the EMC for these materials. This should be an interesting focus for further research.

As a conclusion we may state here that the DMC and EMC do correlate to a certain extent, certainly over short periods of time, as the technical coefficients of production tend to be fixed in the short-run at least. Given the fact that the scores of individual materials are so different, one can safely assert that apparently the composition of material use has not changed drastically over this time span. This may of course change if we look at longer time-period or compare economies with each other with quite different economic structures.

[10] In De Bruyn (2003) some graphical expression of the limited change in short-run periods in steel and energy consumption was presented.

4.4 Regression analysis for the DMC and EMC

The previous paragraph identified single explanations for the (various components of the) DMC and EMC. However, such single explanations may not be extremely powerful as material consumption is typically influenced by more than just one variable. In this paragraph we will analyse all variables together using regression analysis.

Regression analysis is a specific tool in the socio-economic sciences and should be used with care. While many researchers do not bother about model specifications and hypothesis testing and investigate merely the R^2, this approach will surely lead to biased results (spurious regression). Here, we will investigate the relationship between materials consumption and the chosen socio-economic variables more carefully. This implies that a lot of technical details need to be discussed before we can set up the right model specification. The following subparagraphs will only summarize the outcomes of the analysis. The technical details can be found in Annex 7 which includes a full treatment of the hypotheses that we have tested and the model specification that followed from the hypotheses testing.

4.4.1 Hypothesis testing

As described in Annex 7, we first estimated whether the 30 socio-economic variables alone would give sufficient explanatory power for explaining the differences between countries in their levels of materials consumption, either expressed as DMC or EMC. The result was negative. Our 30 selected variables were not able to explain fully the differences between countries for the DMC and EMC and there were other variables which have a profound influence on the DMC and EMC but have not been included in the analysis here.

This is not surprising, as the total factors that influence materials consumption within an economy could easily run into the thousands. Especially lifestyle and policy variables may be important and these have many dimensions. For example, we selected in our sample the amount of cars per capita as a variable influencing materials consumption. In reality, however, this variable may be too crude, as not only the amount of cars is a critical variable, but also:

- the type of cars that is being consumed (are these merely Suzuki Alto's or Mercedes Benz);
- the material composition of these cars;
- the average lifetime of a car (a longer lifetime will drastically reduce materials consumption from car possessions;
- the fuel consumption of a car (more energy-efficient cars will result in lower DMC and EMC)
- the waste regime for used cars (is it recycled or merely dumped)
- the import- and export of cars, etc.

Moreover, cars are only a small fraction of total consumption and similar variables could be set up for televisions, furnaces, balconies, DVD's, tobacco, and so forth.

Of course, one hopes that the amount of cars is also indicative of the type of cars consumed or of the amount of refrigerators consumed, and that the amount of recycled municipal waste is indicative of total waste recycling in a country, but our tests (Annex 7) indicated that the selected 30 variables were too limitative for explaining all variation between countries. This obviously happens with aggregated indicators, like DMC and EMC, as these treat the economy as a "black box" and reveal only information on what goes in and what comes out. The amount of incoming and outgoing flows can obviously not be fully revealed by relating the DMC and EMC to variables that describe what is going on "inside the black box". [11]

[11] However, one should not be too skeptical about this, as it can be expected that similar results would hold for data on emissions (CO_2, SO_2), or many economic variables. From the literature on regression analysis we know that only a few variables, like exchange rates, can be revealed fully in terms of underlying factors. This is exactly why panel data are so popular nowadays in econometrics, as they allow for countries to vary in their initial levels of the dependent variable, or in the effects of the explanatory variables on the dependent variables

4.4.2 Estimating the influences of socio-economic variables on the DMC.

Subsequently we want to investigate which variables do influence the DMC. For that, we constructed a panel data analysis with fixed effects (varying country intercepts), and with the procedure outlined in Annex 7, the following model appeared to fit the data best (Table 4.5)[12]:

The abbreviation of the variables is as in Table 4.1 and the L_ suffix indicates that a logarithmic transformation of the variable has been chosen. Included here is an AR(1) term which is used to control the data for fist-order autocorrelation (see Annex 7).[13]

First we note that the overall fit of the model seems appropriate. The DW is close to 2 and the AR(1) is not close to unity. Hence, we have some confidence that this model is specified correctly.

The most significant variables are here the car possession, the size of the construction industry (NACEF) and the time-effect. All these variables have the expected signs, indicating that more cars and more construction activities are correlated with a higher per capita DMC. The variable for car possession, for example, indicates that a 1% growth in car possession per capita is associated with an increase in the DMC of 0.27% in that particular year. However, the data form here a process over time, so that increased car consumption now will also influence the DMC in the future, as more cars result in a higher energy consumption and may imply a political demand for more roads. An approximation of the long-term equilibrium can be found by dividing the coefficients with (1-AR(1)), as explained in Enders (1995). This gives some information on the effects from changes in one variable on the DMC in the long run.[14] The fourth column gives then the information on the total effects from a change in one socio-economic variable on the other variables. This shows that a 1% increase in car possession is associated with a 0.45% increase in the materials consumption per capita in the long-run. The time variable shows that per capita DMC will reduce with 1,5% per year (ceteris paribus) due to autonomous technological improvements. Moreover, we see that an economic growth of 1% results in a higher DMC immediately of 0.24% and 0.39% in the long run. This is far less than unity, indicating some decoupling between material consumption and economic growth. The per capita GDP variable is, however, only significant at the 10% level interval and some may argue that it is therefore not significant.[15] The biggest influence on per capita DMC comes from the construction sector. A 1% increase in the share of construction in GDP results in a 3,6% increase in per capita DMC in the long-run. The importance of construction activities for DMC is also captured by the variable indicating the per capita dwelling stock in a country. A 1% increase in the dwelling stock results in 0.5% rise in per capita DMC directly, and 0.8% in the long-run. The floor space of new buildings could be another important variable, however, it is not significant in this regression analysis at the 10% confidence level.

Table 4.5. Estimated outcome of the regression on per capita DMC.

	ßi	t-stats	ßi_effect	Statistics	
Constant (avg)	-2.950	NA		R2-adj.	0.989787

[12] The model has been estimated in semi-logarithmic form, as this facilitates the interpretation of the results enormously. All variables are hence transformed to logarithms, except the variables which are given in percentages and the state variables (see paragraph 4.2.2. for a description of the variables). As the estimation of fixed effects assumes varying intercepts between countries, we cannot include several state variables which are given as constants. Hence, the effects of temperature, precipitation, surface area and household size leave out the equation. Also the waste variables are excluded now, as we could not establish reliable time-series on these data. All these variables are now included in the individual country-effects on the intercepts.

[13] The value of a given variable in year t is often best explained by the value the variable took in the last year (t-1). Hence, the best prediction for the DMC in the year 2000 for each country is the value of the DMC in 1999 for each country. Regression analysis results in spurious results, if not corrected for this. The AR(1) term corrects for this and gives information on the importance of the lagged DMC for estimating the current DMC in a given year. So the value of the DMC in 2000 is for almost 40% explained by the value in the last year.

[14] This is only an approximation, as the full convergence is dependent on initial values of DMC and on the effects of for example lagged GDP on current GDP.

[15] The probability-value for per capita GDP is 0.06 and hence nearby the confidence level of 5%. The decision which variables are significant is of course rather arbitrary in statistics. The general convention is that only variables at the 5% level are statistically significant. This criterion should be stricter for large samples or for more precisely determined variables. As the sample here is rather large and we can safely assume that per capita GDP is probably the most reliable variable in our database, there is strong evidence that the variable is not significant.

L_CARPOSS	0.273	(3.002)***	0.45%	R2-Harvey	0.294073
L_GDPCAP	0.239	(1.892)*	0.39%	R2-crosssection	0.6445
L_MOTORWAY	0.073	(1.216)		DW	2.00544
RAILWAY	5.611	(1.971)*		AIC	-159.308
NACED	0.229	(1.342)		SSR	0.373074
NACEF	2.231	(3.438)***	3.65%		
L_FAT	-0.069	(-1.58)			
L_DWELCAP	0.528	(2.027)**	0.86%		
L_FLOORSPACE	-0.095	(-1.19)			
RENEW	-0.190	(-1.78)*	-0.31%		
L_MOTORFUEL	-0.095	(-2.25)**	-0.16%		
L_EDUCATION	-0.123	(-2.30)**	-0.20%		
L_PATENTCAP	0.022	(1.783)*	0.04%		
TIME	-0.015	(-2.61)***	-0.03%		
AR(1)	0.389	(5.036)***			

Note: ***, **, * indicate significance at the 1, 5 and 10% two-sided confidence levels respectively. DW=Durbin Watson Statistic, AIC=Akaike Information Criterion.

Finally, there are a couple of policy-related variables which give a clue as to what governments might do in order to reduce the DMC. The renewable-energy share is only significant at the 10% level, but the sign indicates that a higher share of renewable energy implies a lower DMC. If renewable energy share is to increase with 1%, the DMC will be reduced by 0.3% in the long-run. As the average increase due to policy plans in the EU equals 7.3% (from 13.7 in 2000 to 21% in 2010), this implies that the per capita DMC will be reduced by 2.3 % in the long run (see Chapter 5 on policy initiatives).

Higher motor fuel taxes are correlated with lower per capita DMC, although the estimated long-term elasticity is only –0,16, so fairly low. However, studies in many OECD countries show an average short-term price elasticity of approx. - 0.05 to - 0.1. The long-term price elasticity of demand is in general 2-3 times as high. These values are hence in line with the here calculated ranges of price-elasticity. The education variable, which was constructed as the share of educational spending in GDP, can be interpreted as follows: governmental spending in education at a higher rate than the rate of economic growth are associated with lower per capita DMC levels, though the elasticity is fairly low.

The overall fit (R2-adjusted) of the model seems very high with almost 99%. Some researchers may be tempted to suggest that the variables in their model explain for 99% the variation in the DMC. However, most of the variation actually comes from the autoregressive process in the data. In other words: the best explanation for the DMC is given by the initial levels of the DMC and subsequently by the fact that the DMC in the year 2000 is best explained by the DMC in 1999. If we correct for this autoregressive process, one may come more closely to the value added of including all the 30 variables in the regression analysis above a simple model where the DMC is only explained by the initial levels and the autoregressive process. Following the procedure outlined by Harvey (cited in Maddala, 1992) we arrive at an estimation of the value added by including these variables of 29% (R2-dependent).[16] This provides the insight that the variables in our model alone explain 29% of the variation in the DMC, leaving around 70% for the autoregressive process and the initial levels of DMC.

Now, the question is what is the true explanatory power of the dependent variables in our estimation. On the one hand we calculated an R2 of almost 99%, on the other hand we have seen that around 70% of this variation can be explained by a simple autoregressive process and the initial levels of DMC. One way to arrive at a measure is to multiply the AR(1) coefficient with our R2, which would indicate that around 62% of the variation in our model is explained by the variables. Another way would be to estimate the model in a cross-section setting, hence for an individual year. This reveals that the R2 adjusted is around 65%. Hence we would confidently say that the variables in our sample explain around 60-65% of the variation between countries.

[16] This can be corrected by estimating the model with an AR(1) trend only and comparing the differences in the residual sum of squares.

4.4.3 Estimating the influences of socio-economic variables on the EMC.

The influence on the EMC was estimated from a similar procedure to that of the DMC.17 Table 4.6 gives the results.

Table 4.6: Estimated outcome of the regression on per capita EMC

	ßi	t-stats	ßi_effect	Statistics	
C(avg)	-29.859	NA		R2-adj.	0.986717
LGDPCAP	0.394	(3.698)***	0.57	R2-Harvey	0.296636
LMOTORWAY	0.155	(3.283)***	0.22	R2-crosssection	0.586
NACEAB	2.137	(3.116)***	3.09	DW	1.957321
NACEC	2.457	(1.476)	3.55	AIC	-193.988
NACEF	2.013	(3.647)***	2.91	SSR	0.328073
LDWELCAP	0.727	(3.045)***	1.05		
RENEW	-0.184	(-1.75)*	-0.27		
PRODTAX	0.842	(1.460)	1.22		
TIME	-0.018	(1.476)			
AR(1)	0.308	(3.647)***			

Note: ***, **, * indicate significance at the 1, 5 and 10% two-sided confidence levels respectively, DW=Durbin Watson Statistic, AIC=Akaike Information Criterion.

The R^2 is again fairly high, but most of the variation is explained by the AR(1) coefficient. The Harvey-corrected R^2 is 29%, similar to the estimate of the DMC and the cross-section estimate reveal a strength of 58%. In general we would say here that the EMC is for 58-66% explained by the variables in our model.[18] Furthermore, the statistics are fine: the AR(1) coefficient is not nearby unity and the DW-statistic falls within the confidence levels so that no first-order autocorrelation is present in the errors.

There are in total 5 variables that are significant at the 1% level. Per capita GDP has a profound influence on the EMC. An economic growth of 1% will result, according to this estimation, in an increase in the EMC of 0,4% directly and almost 0.6% in the long run. The effect of economic growth on the EMC is higher than estimated for the DMC indicating that economic growth fuels the consumption of relatively more polluting materials. Furthermore, the EMC is strongly determined by the size of the agricultural and construction sectors in the economy. Of these two, the agricultural sector is the most important. A 1% lower share of the agricultural sector is associated with a 3% lower EMC in the long run. The effect of an increase in the construction industry is a bit lower than the effect estimated for the DMC. Furthermore, the increase in the dwelling stock is also an important variable. An increase of 1% in the amount of dwellings in a country will result in a 1% higher EMC in the long-run. The estimated time-effect suggests an autonomous annual improvement in the EMC of 1.8% per annum, however, this variable is not significant at the 10% level. The calculated rate is, however, higher than in the case of the DMC, indicating that over time the environmental impacts from material consumption declines more than the weight of materials. .

There is also the suggestion that countries with a denser motorway network tend to have slightly higher values of the EMC. The effect of the renewable energy variable is –in the long run- a bit smaller than for the DMC.

4.5 Regression analysis for resource efficiency and benchmarking

The analysis above showed the influences of some of the socio-economic variables on resource use, either measured as DMC or EMC. However, for the policy maker, the real variable of interest may be

[17] The results from the first test round, with all the variables included are given in Annex 7.

[18] The 66% figure comes from multiplying the adjusted R^2 with the (1-AR(1)) term.

resource productivity or resource efficiency, as targets like Factor 4 are set in resource efficiency terms. For this reason, we investigate the factors that influence resource productivity in this paragraph.

4.5.1 Conceptual elements

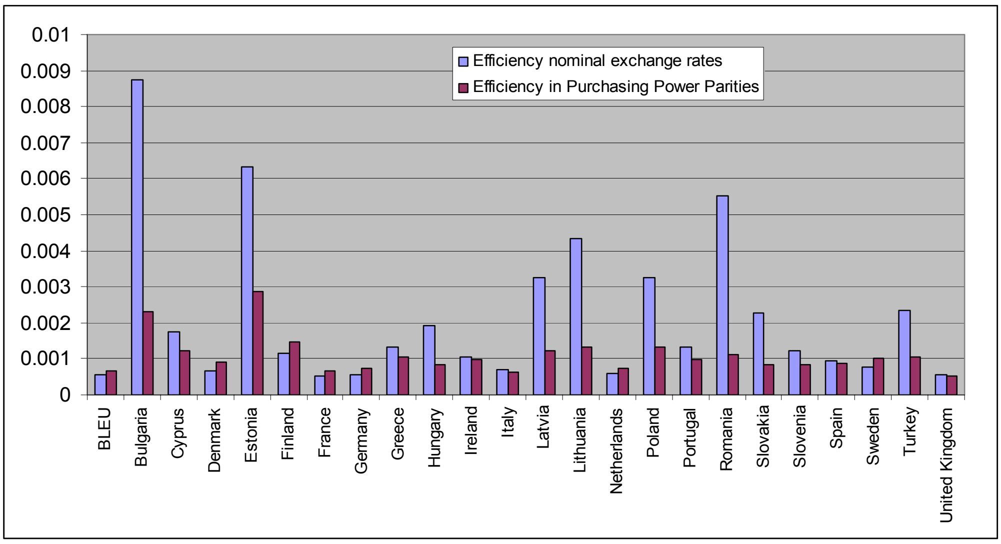
First, we should clarify some terms. Resource productivity is the reciprocal of resource efficiency. Both terms are used in the international literature. As they are simply linked results on resource efficiency tell us something about the resource productivity and vice versa. However, we should choose either one of these concepts. In this paragraph we choose to use resource intensities, as this may present a scientific more robust concept than resource productivity. The reason for this is that resource productivity implies that a certain amount of welfare, or money, can be generated with resources. However, in the economics account, welfare is only generated with the input of labour (and capital) in the production processes. The true price of resources is zero, if there were no labour required to obtain them. Labour productivity is therefore a meaningful concept, whereas resource productivity has no meaning in an economic sense. Such facts are well-known in, for example, the field of energy economics, where the target variable of study is energy efficiency, or better energy intensity. Energy productivity is almost never used.

Resource efficiency is measured as DMC/€ or EMC/€.; i.e. the intensities of resource consumption over GDP. A low resource intensity indicates that the economy is relatively resource efficient. A high resource intensity indicates a lower resource efficiency.

If we want to estimate the resource efficiency of various countries, we should, next, investigate which measure for GDP is going to be used. While so far in the report, we only used nominal GDP figures, these figures may not be entirely relevant when explaining the differences between countries. Ordinary GDP-figures use nominal exchange rates in order to calculate all GDP's of different countries to a common denominator. This is often the US$, or the €. However, the nominal exchange rates may not reflect the wealth of a country, as the nominal GDP figures essentially indicate the amount of products and resources that consumers can buy in the US, or the Eurozone. Many countries, however, have much lower price levels, for electricity, housing, etc., simply because the wages in these countries are lower. It is therefore no surprise that Bulgaria, in fact the country in our sample where the price levels are the lowest, has the lowest resource productivity, as outlined in Figure 3.27 for example.

The alternative is to use Purchasing Power Parities (PPP) which compare countries on the basis of what consumers locally can buy for their money. Figure 4.16 shows the resource efficiency of the various countries, according to both methods. In general the picture emerges that poorer countries have a much lower resource intensity when using PPP instead of nominal exchange rates.

Figure 4.16: Resource Efficiency for the DMC, 2000: in kg/US$ per capita.



Data: Worldbank.

Such corrected figures reveal that Estonia and Bulgaria are still the countries with the lowest resource efficiency, but the efficiency of countries like Romania and Latvia is now almost similar to those in Western Europe. We think that GDP in PPP gives more accurate the stress from consumption on the environment, as GDP in PPP is a better measure for the amount of consumption in general.

4.5.2 Estimating influences of socio-economic variables on resource efficiency

Next, we want to investigate the driving forces behind the differences in resource efficiency. For this, we estimated the model using a similar procedure as in the last paragraph and outlined in Annex 7. In addition, we conducted two additional tests investigating whether the per capita GDP (in PPP) and the time-related gains in resource efficiency are similar among all countries (see Hsiao 1986) . These tests indicated that the per capita GDP might be considered as similar among the countries, but the time-effects clearly not. Obviously, countries differ not only in their initial levels of resource use, but also in their success in reducing the resource use over time.

If we re-estimate the whole procedure for both the DMC and the EMC with individual time-effects for the countries, the following results appear.

Table 4.7: Estimation of resource intensities according to the EMC and the DMC, results.

	EMC			DMC		
Dependent variable:	ln(EMC/GDPppp)			ln(DMC/GDPppp)		
Explanatory	Coeff	T-stats	Sign.	Coeff	T-stats	Sign.
GDP_ppp (log)	-0.34	-3.74	***	-0.47	-4.74	***
NACE_AB	2.09	3.81	***	Excluded using AIC-procedure		
NACE_F	1.62	2.15	**	1.63	1.91	*
Time (avg)	-0.02	-2.90	**	-0.01	-1.79	*
Const (avg)	-28.78			-2.32		
R2 (adj)	0.99			0.99		
DW	2.09			2.03		

Note: ***, **, * indicate significance at the 1, 5 and 10% two-sided confidence levels respectively, DW=Durbin Watson Statistic.

First we note that economic growth results in lower resource intensities. This is not surprising as the previous paragraph already showed that the effects of 1% economic growth results in an increase in the DMC and EMC of less than 1%. Hence, some relative decoupling is obviously achieved in the process of economic growth. Next, we see that the EMC is, as above, influenced by size of the agricultural sector and the construction sector in the economy. The DMC is only influenced by the size of the construction sector. The annual autonomous improvements in resource efficiency for the EMC are 2% on average, which is about double the size of the autonomous improvements for the DMC. For this, there is no simple explanation, but we will elaborate the effects of the autonomous improvements a bit more in detail below. It is furthermore interesting that all other explanatory variables, including those of dwellings per capita, car possessions, energy prices and renewable energy input, are now insignificant and obviously well enough captured by the negative time trend for individual countries. Finally, the AR(1) coefficient could be omitted in this equation, as the estimation tended to be free from first order autocorrelation, as indicated by the DW-statistic. However, some higher-order autocorrelation is still present, so the high R2 should be interpreted with some care (see Annex 7 on these issues).[19]

If we compare the estimates for the DMC with those of the EMC, it is apparent that the annual reductions in EMC are higher, but that economic growth also result in a higher EMC than for the DMC. This indicates that over time, the more dirtier materials grow slower, but that economic growth speeds up the consumption of more polluting materials. We have not attempted here to determine the net effects altogether.

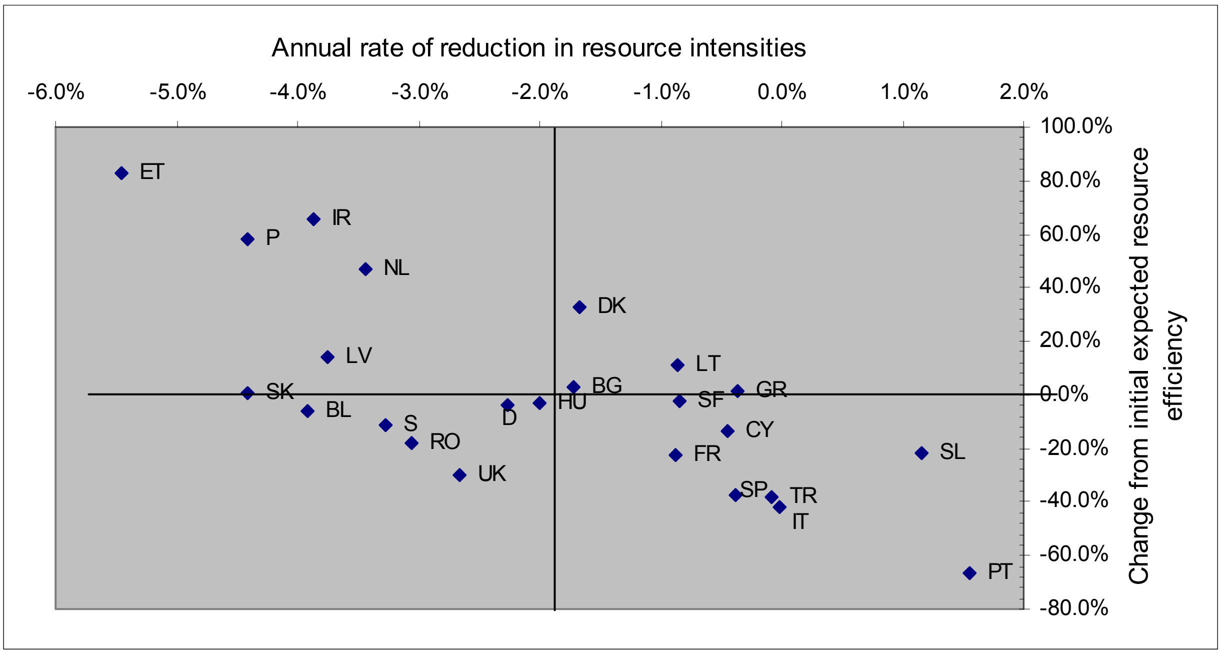
[19] The cross-section R2 was 0.47 for the EMC-estimation and 0.26 for the DMC-estimation.

4.5.3 Benchmarking

One of the advantages of the estimated model is that it allows for a kind of benchmarking: with this model we can estimate how well countries perform in reducing their resource intensities over time and compared to each other when corrected for the influence of their income levels and structure of the economy. In Figure 4.17 such a benchmark is given. Here the countries are plotted against two axes: on the y-axes stand the initial (1992) levels of resource intensities (EMC/€) of the individual countries when corrected for their levels of income and structure of the economy. We see that given this correction, Estonia has an initial level of resource intensity which is almost 80% higher than the average of all the countries together, and Portugal, on the other hand, has an initial level of resource intensity which is more than 60% lower than average. On the x-axes stand the annual rate of reduction in the resource intensities, as given by the time-variable from Table 4.7. An annual reduction in resource intensity of 2% is the average for the whole sample. Estonia has now a much higher annual rate of reduction than the average, and Portugal, together with Slovenia see their resource intensities increase over time.

The countries in the bottom-left quadrant tend to perform relatively well: both low initial levels of resource intensities when corrected for the influences of GDP and structure of the economy, and high rates of annual reductions. Among them are the United Kingdom, Romania, Sweden and Belgium-Luxembourg. The countries in the upper-right quarter perform relatively poor: high initial levels of resource intensities and low annual rates of reductions. Among them are Denmark and Lithuania.

Figure 4.17. Benchmarking for the EMC/€: and the relationship between annual rate of reduction in EMC-resource efficiency and initial levels of resource efficiency.



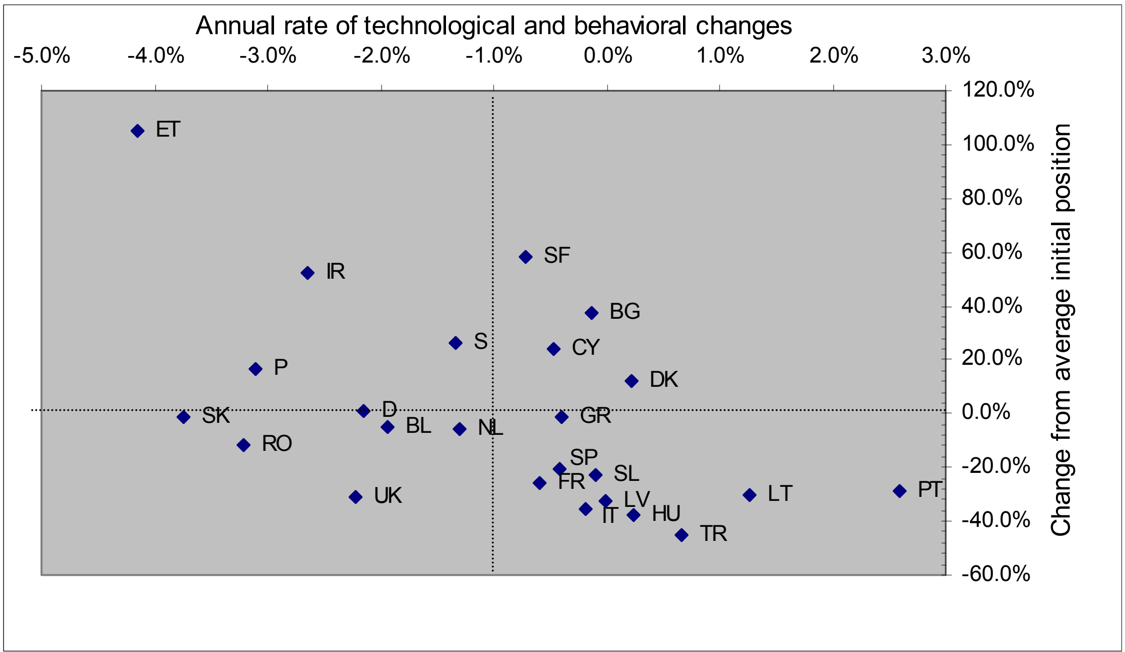
The analysis in figure show that there is a tendency to convergence. Countries that initially had higher than expected levels of resource intensities (indicating lower resource efficiency, such as Ireland, Netherlands, Estonia and Poland), tend to have higher rates of annual improvements in resource efficiency. And countries that have high initial levels of DMC/€ and EMC/€ reduce their resource intensities faster than countries that already have low levels of resource intensities.[20]

[20] The initial levels are in fact the constants in the regression equation: they show the level of DMC corrected for differences in per capita GDP and the structure of the economy. The time-related effects are calculated as the coefficient of the time-related effects multiplied by the probability that the coefficient is significantly different from zero. In formula: Effect = c*(1-p), where c is the coefficient and p the calculated probability from the regression analysis.

We also see that Bulgaria now takes the middle position, while it was identified in Figure 4.16 as the country that was the least resource efficient. The reason is that Bulgaria has the highest share of agriculture in their economy (around 24% of total GDP), and when we correct for this particularity, the resource efficiency of Bulgaria is in line with what we would expect from this model.

A similar benchmark can be made for the DMC resource efficiency and the results are given in Figure 4.18 where the dotted lines are the averages for all the countries together. We see again that Estonia and Ireland are outliers: higher initial levels of DMC-resource intensities than expected from the regression model, but also higher than average annual reductions in resource intensities indicating a movement towards a higher resource efficiency. Countries that perform relatively poorly are again found in the top right corner, indicating that Finland, Bulgaria, Cyprus and again Denmark have higher than expected initial levels of DMC/€ and lower than expected annual reductions.

Figure 4.18. Relationship between annual rate of reduction in DMC-resource efficiency and initial levels of resource efficiency.



Countries that perform better than average are found in the bottom-left corner. Especially Romania and the United Kingdom have lower than expected levels of DMC/€ and higher than average annual reductions.

The Figures 4.17 and 4.18 give information on the relative positions of individual countries with respect to their resource efficiency when corrected for differences in the structure of the economy and per capita GDP. Table 4.8 gives information about the differences between absolute resource efficiency in 1992, and the resource efficiency after correcting for differences in per capita GDP and the structure of the economy. This provides the insight that the standard deviation is reduced by more than half for both the DMC/€ and EMC/€. Hence, around half of the variation in resource efficiency can be attributed to the structure of the economy and per capita GDP-levels (measured in purchasing power parities).

Table 4.8. Differences in resource efficiency in 1992 in observed differences and in differences when corrected for GDP and the structure of the economy.

	DMC/Euro		EMC/Euro	
	1992	Corrected	1992	Corrected
BLEU	-8.7%	-5.2%	-11.4%	-6.1%
Bulgaria	169.2%	37.3%	149.0%	2.6%
Cyprus	54.6%	23.8%	9.1%	-13.4%

Denmark	10.5%	12.3%	28.9%	32.6%
Estonia	381.9%	105.4%	290.5%	82.5%
Finland	94.0%	58.5%	-1.5%	-2.2%
France	-17.7%	-25.5%	-17.6%	-22.3%
Germany	-3.1%	0.9%	-6.6%	-3.5%
Greece	24.1%	-0.9%	36.6%	1.2%
Hungary	-2.8%	-37.9%	32.7%	-2.7%
Ireland	89.2%	52.5%	97.2%	65.5%
Italy	-21.9%	-35.4%	-30.4%	-42.0%
Latvia	47.2%	-32.5%	132.7%	13.8%
Lithuania	29.2%	-30.0%	103.7%	11.0%
Netherlands	-0.5%	-5.8%	58.4%	46.8%
Poland	109.3%	16.8%	174.4%	58.3%
Portugal	-1.5%	-29.0%	-33.9%	-66.4%
Romania	58.8%	-11.4%	75.6%	-17.7%
Slovakia	31.1%	-1.4%	39.6%	0.9%
Slovenia	3.0%	-22.9%	0.3%	-21.7%
Spain	5.8%	-20.3%	-15.4%	-37.6%
Sweden	24.5%	26.2%	-19.2%	-11.3%
Turkey	18.1%	-44.8%	36.5%	-38.0%
Un. Kingdom	-23.8%	-30.9%	-24.3%	-30.2%
Standard deviation.	0.857	0.365	0.789	0.359

4.5.4 Reasons for the different successes in the countries

Although the differences between countries in resource efficiency have been reduced by correcting for the structure of the economy and per capita GDP, some differences still remain. One may be interested in two interrelated questions:
1. Is the existing variation in initial levels due to circumstance variables, such as the size of a country, population density, temperature, etc.?
2. Are the annual reductions in resource intensity somehow related to policy variables?

This may answer the question why countries do better than others, while at the same time it gives insight into the factors that cannot be influenced by policy makers which shape initial levels of resource efficiency.

For this reason, we conduct an auxiliary regression analysis on the data given in Figures 4.17 and 4.18. The result for the initial positions is given in Table 4.9. This gives information on the initial levels of EMC/€ and DMC/€ when corrected for the level of income (GDP) and the structure of the economy.

Table 4.9. Outcome of regression analysis on initial levels of EMC/€ and DMC/€ (the constants from the regression analysis from Table 4.7)

Dependent variable:	Initial level EMC/€			Initial level DMC/€		
Explanatory	Coeff	T-stats	Sign.	Coeff	T-stats	Sign.
C	0.704	0.1235		NA		
TEMP	-0.050	0.0158	**	-0.002	0.0076	***
SURFACE	-9.3E-07	0.0252	**	-2.6E-08	0.0157	**
COM	-0.367	0.0582	*	NA		
PRECIP	-0.001	0.0429	**	-2.1E-05	0.0932	*
HOUSEHSZ	0.240	0.089	*	0.010	0.0025	***
POPDENS	NA			4.0E-05	0.1561	
R2-adj.	0.243			0.39657		

This shows that the initial levels of EMC/€ and DMC/€ are indeed influenced by the so-called circumstance variables for 24% and 40%, respectively. Firstly, average temperature and precipitation tend to negatively influence the resource efficiency. Hence, dryer and warmer countries tend to have a lower resource efficiency level than expected on the basis of their GDP and structure of the economy. Secondly, we see that larger countries tend to be more resource efficient –which is difficult to explain but may relate to the lower export shares in GDP of these countries and hence merely a statistical artefact of the indicators constructed. Countries with a larger household size tend to be less resource efficient. This is remarkable, as one may expect the reverse to be true (larger household size requires less buildings, televisions, etc. per capita). This may indicate that the household size is related to another omitted variable, which has not been taken into account in the analysis.

The results for the auxiliary regression on the time-effects is given in Table 4.10.

Table 4.10. Regression on the individual time-effects per country.

Dependent variable:	Time-effects per country EMC			Time-effects per country EMC		
Explanatory	Coeff	T-stats	Sign.	Coeff	T-stats	Sign.
Initial level	-0.028	0.0019	***	-0.770	0.002	***
WREC	-0.067	0.0026	***	-0.101	0.000	***
COM	-0.019	0.0014	***	-0.022	0.000	***
M1	0.011	0.067	*			
R2-adj.	0.404			0.531		

This table gives the information that the time-effects are larger in former communist countries than in Western-European countries. Clearly, the process of capital replacements is faster in the transition phase of the former centrally planned economies allowing for more efficient and environmentally benign technologies. Secondly, the waste policies have now a profound influence on the rate of technological progress. Higher recycling rates of municipal waste are associated with economies that have a higher rate of improvement in their resource efficiency. Other policy variables, including those on renewable energies and motor fuel prices were not significant and were omitted from the equation during the procedure as outlined in Annex 7. Also the initial level is fairly significant for both the DMC and the EMC, indicating the kind of convergence already observed in the Figures 4.17 and 4.18. Countries that have higher than expected initial levels of DMC/€ and EMC/€ also have a higher rate of technological progress. The M1 dummy variable, indicating whether countries have installed a tax on materials, is not significant.

From this analysis we can draw some conclusions:

- Resource efficiency can best be estimated using GDP in Purchasing Power Parities, which reduces the variation between countries by about a half.
- The differences in resource efficiency can be attributed for a large part (around 50-60%) to differences in GDP per capita and differences in the structure of the economy;
- The remaining differences can be explained for around 25-40% by reference to the temperature and rainfall in a country and the size of a country
- Countries differ with respect to the annual reductions in resource intensities; former communist countries tend to have larger reductions as their rate of capital replacement is much higher than those in Western Europe. Moreover, recycling policies tend to result in higher annual reductions in resource efficiency.

4.6 Concluding remarks

The results from the above analyses indicate that the variables selected in this study were not able to capture all the specifics for countries. Hence, the variation between the DMC and EMC cannot solely be explained by reference to differences in income levels, structure of the economy, certain aspects of lifestyles and policy variables. The most likely reason for this is that the levels of materials consumption in a country are the result of a wide variety of influences and capturing all these influences in a single model is perhaps too ambitious. This result is in line with the literature: Auty (1985) already remarked that the various influences on materials demand are in general poorly understood and various models behaved poorly in empirical estimations.

This study added the insight that materials consumption is indeed influenced by the structure of the economy: the DMC is influenced by the levels of construction activities within countries, and the EMC is influenced by the levels of agricultural and construction activities within a country. The difference between the DMC and EMC is logical in this respect as the EMC lists biotic resources as the most polluting on a global scale.

Per capita GDP is another important variable, as earlier defined in the literature. We think that the poor results for the DMC in this case are more likely explained by reference to the nature of the data (few observations for the years) than to the underlying causal process.[21] More important is the finding that the influence of economic growth on the DMC is 0.4% and on the EMC almost 0.6%. This result suggests that economic growth results in higher increases in the environmental pressure of materials consumption than in the materials consumption itself: it is an indication that in the process of economic growth the consumption of relatively more polluting materials is higher than the relatively cleaner materials.

With respect to policy influences, the estimates for the DMC gave us more clues than the estimates for the EMC. In both cases there is some suggestion that materials consumption (measured as DMC or EMC) is reduced when renewable energy is increased[22]. The similarity between the DMC and EMC estimates in this respect is not surprising, as kilograms proved to be a rather reliable estimate of the environmental impacts from energy consumption, given by the partial correlation coefficient of (0.99) in Table 4.2. The DMC offers some other handles for policy makers than the EMC: more public investments in education are related to lower levels of DMC. Also, higher prices of motor fuels are related to lower levels of DMC.

When we investigated the resource efficiency, we saw that the differences between countries are very large. Such differences can be made smaller by around 50% if resource efficiency is estimated using GDP in Purchasing Power Parities. The remaining differences in resource efficiency can be attributed for a large part (around 50-60%) to differences in GDP per capita and differences in the structure of the economy. Other influences are related to temperature, rainfall and the size of a country. Finally, there is a substantial variation in the performance of countries in improving their resource efficiency over time. In general, former communist countries tend to have larger reductions as their rate of capital replacement is much higher than that of Western Europe. Moreover, recycling policies tend to result in higher annual reductions in resource intensity. Other policy influences, like energy prices, renewable energy input and investments in education provided no explanation for the differences in the country specific reductions in resource use per unit of GDP. One explanation would be that such policies do not matter for resource efficiency. Another explanation would be that these variables are so much correlated with GDP that their influences were already captured by the rates of economic growth.

The regression analysis in this chapter provided some insight on why the resource consumption and resource efficiency differs between countries. However, they do not provide a full picture. In essence, indicators like EMC and DMC treat the economy as a black box. Obviously, it is not possible to reveal later completely the driving forces ex-post by using regression analysis. One improvement in the future would be to repeat the analysis with more variables, but it is doubtful whether this would give more insight in the driving forces of resource consumption. One very obvious improvement, however, would be to conduct the analysis over a longer time-period, as this would drastically improve the reliability of the results and would allow a better understanding the long-run effects of the various driving forces.

[21] It might also be true that the statistical computations for the DMC include some flaws, especially for semi-finished and finished goods as trade statistics may be unreliable for this.

[22] Surprisingly we found that in both regressions, the variable representing renewable energy was best expressed as the share of renewables in electricity production, and not in the total primary energy supply. As the share of renewables in total energy supply is in principle the better variable (as it indicates the total savings on energy input), two explanations are possible: (1) the variable presenting the share of renewables in total energy consumption is flawed; (2) the variable presenting the share of renewables in electricity consumption is correlated with another, omitted variable, which influences materials demand. We think that both explanations could be true in this case, but that the first explanation is more likely (see Annex S on data collection).

One particular application of the chosen models is forecasting. The models estimated can be useful for forecasting the developments of the DMC and EMC if statistical time-constraints do not allow for a full collection of the data. As the model fit, including the AR(1) term is close to 0.99%, these estimates should be rather reliable.

4.7 References

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5 Background and EU policies

5.1 Introduction

The previous chapter showed the influence of all chosen variables on materials consumption. Some policy related variables were shown to have an influence on materials consumption, notably the renewable energy share in electricity production. This does not imply, however, that other policy initiatives are not significant in influencing materials consumption. In many cases, the effects of policy initiatives only reveal themselves after a couple of years due to slow adjustment processes in the economy.

For these reasons, a more qualitative approach towards describing the potential influences of policy initiatives for reducing materials consumption is presented in this chapter.. An inventory is made of policies both at EU and at national level for all of the Member States (MS). In some cases a distinction is made between the "old" 15 MS and the 13 ex-accession countries (ex-AC) for reasons of data availability.

In this chapter we describe the two main points of action of policies as well as existing EU policy and legislation: policies that interact on specific material use (paragraph 4.3) and policies that interact on (specific stages of) the lifecycle of products (paragraph 4.4). But first, in the next paragraph, we will present some analysis of the demarcation of the study.

5.2 Demarcation

In order to establish the possible influence of existing policies on materials consumption (DMC) and on the environmental burden due to materials consumption (EMC), an inventory of policies is made. Six relevant policy areas are included:

- Integrated product policy (IPP), ecolabeling, ecodesign, etc.
- Life-cycle policies on use of chemical substances
- Waste management
- Packaging and packaging waste
- Fiscal instruments
- Energy efficiency and renewable energy programmes

The investigation only takes government (either national or EU level) policies into account. The Natural Resources Strategy of the European Commission (communication, see next paragraph) outlines steps to be taken over the next 25 years to achieve a decoupling of resource-related environmental impacts from economic growth. It states knowledge gathering, policy assessment and policy integration as some of these steps. This report tries to contribute to those steps.

There are currently no policies in the EU or the individual Member States that act directly on the DMC or the EMC as a whole. Instead, policies act, by weight or by environmental burden, on individual raw materials, on generated waste, on import and export, etc.

In order to establish the possible influence of existing policies on materials consumption (DMC) and on the environmental burden due to materials consumption (EMC), an inventory of policies is made that

1 act directly on (raw) materials, or

2 act on specific stages of the life cycle of products.

The first type of policy aims to achieve a reduction of the use of a material through stimulation of efficiency and recycling or a reduction of environmental burden by improving significantly the environmental performance of a material. Instruments are taxes, recycling targets, renewable energy targets, efficiency policies, etc.

The second type of policy aims to achieve a reduction of – mostly – environmental burden of parts or all of the life cycle of a product, including its material content. Integrated Product Policy (IPP) is one of the guiding principles in this context, with several instruments that can be listed as part of IPP, such as labelling, ecodesign, VAT. For several product groups, policies exist that focus on the reduction and proper management of the products' waste. The waste management stage of life cycles has historically been given most attention in a policy sense. The same goes for packaging, being a part of the life cycle of many products. Therefore, next to IPP as a generic concept, waste and packaging policies deserve a separate inventory in paragraph 4.

One may distinguish three types of materials: materials used as source of energy, other abiotic materials used in products, biotic materials used as fibres, food or a source of bio-energy. This distinction is interesting from a policy point of view, as the three material flows are managed with different instruments.

In the table below, main instruments are listed for the three material flows, according to the classification described above: acting on materials or products, by weight or by environmental burden. The distinction between policies acting by weight or by environmental burden does not indicate the *effect* of the policies, but only the point of action of the mechanisms used. For example, energy-efficiency as well as renewable-energy policies will try to minimize environmental impacts, but the former achieves this by minimizing the amount of energy used and the latter by minimizing the environmental burden caused by a certain amount of energy.

Table 5.1 Classification of policies and existing instruments by points of action

Acting on :	*By:*	**Energy**	**Abiotic materials**	**Biotic materials**
Materials	*Weight*	Efficiency targets Taxes	Recycling Taxes	(Recycling)
	Environmental burden	Renewable	Recovery (other)	Stewardship
Life cycle stages	*Weight*	Ecodesign energy using products	Waste / packaging	Ecodesign
	Environmental burden	Kyoto	IPP/Ecodesign (Taxes) Kyoto REACH	IPP/Ecodesign Kyoto

In practice, the classification of policies acting on materials or on part of the life cycle is obviously not applied so strictly. Recycling, for instance, is obviously part of waste policies in almost all cases. IPP is clearly a “life cycle” instrument, but often links to instruments that act at a materials level, such as renewable energy or labels for sustainably grown wood. Also, for waste and packaging (waste) there is a development to target life-cycle environmental impacts rather than weight (see below EU policies).

5.3 Overview of EU policies

For all of the areas and instruments described in the previous paragraph, European policies exist. At a national level, many policies are implementations and extensions of this European legislation. In table 5.2, relevant directives and policy communications are listed for policy areas mentioned in table 5.1.

Table 5.2 Relevant EU directives, communications, labels

Natural Resource Strategy	COM(2003)572	Communication on strategy on sustainable use of natural resources
Ecodesign	COM(2003)453	Proposed directive for energy-using products (link to Ecolabel)
IPP	COM(2003)302	Communication from the commission
Energy labelling	1992/75/EC	Household equipment
Energy efficiency specific equipment	1992/42/EC, 1996/57/EC, 2000/55/EC	
Energy efficiency end-use energy	COM(2003)739	Proposed directive
Reduction CO2 Kyoto	COM(2003)403	So-called “Linking directive” amending 2003/87/EC
Bio-fuels	2003/30/EC	Reference target 5.75% (2010)
Renewable energy	2001/77/EC	EU target 12% (2010) of gross domestic energy
Waste electronic and electrical equipment (WEEE)	2002/96/EC	

End-of-life vehicles (ELV)	2000/53/EC	
Landfill directive	1999/31/EC	
Waste framework	1975/442/EC	
Waste from extractive industries	COM(2003)319	Proposed directive
Packaging directive	2004/12/EC	Amending 1994/62/EC
REACH	COM(2003)644	Proposed regulation Chemical Substances
Ecolabel		European environmental certificate
Energy star		International voluntary energy label

For IPP and related policy instruments (ecodesign, labeling), EU policy is very much in the development stage. The communication on IPP is as yet not considered to be a prelude to a directive or a white paper. The proposed directive on Ecodesign of Energy-using Products, however, has passed the first reading in parliament. For many specific product groups, energy-efficiency requirements, including labeling, exist and there is a voluntary label for office equipment (Energy star). The general environmental “Ecolabel” is strongly related to EU policy making. Criteria for product groups are proposed by the commission and adopted by the EU Ecolabeling Board. Ecolabel is explicitly positioned as a possible part of IPP.

A target of 1% reduction of energy use is stated in the draft directive COM(2003)739 on energy end-use efficiency. At this moment, generic energy efficiency is in the hands of the individual member states (see 5.4). National indicative targets for renewable energy, however, should add up to the global target quantitatively established in EU legislation. For fuels, national indicative minimum targets have to be set, taking into account the reference values for targets given in EU legislation.

Recycling and other waste handling is covered by many directives. Only a few that target specific product groups include recycle targets and design for recycling (WEEE, ELV, packaging). Especially for packaging, there is a tentative move toward assessing packaging by (life-cycle) environmental burden instead of by weight. An ongoing study [Ecolas & Pira 2004] evaluating the packaging directive 94/62/EC and options for improving it is addressing the possibilities of introducing a packaging environmental indicator. The generic waste directives are mostly concerned with reducing the amount and the (environmental) consequences of landfill (waste, landfill, extractive industries).

The proposed regulation concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) focuses on a life-cycle approach of the control of substances in trying to limit the consequences of the use thereof. Substances are classified by the effects of their use and presence in products at various life-cycle stages including application by the end consumer.

Although directives apply in principle to all EU Member States, instruments and measures used in their implementation may differ from MS to MS. Often directives state minimum and/or maximum standards, allowing for differences between MS. Therefore, in the following chapter, quantitative indicators will be shown for individual MS to assess the different effects of policies in each country.

5.4 Specific instruments

In this paragraph, several policy instruments are discussed and inventoried for the EU member states. Differences between countries are discussed briefly and will be addressed in chapter 3 in relation to their relevance in explaining deviations from the statistical regression models. The available data do not always allow for a comparison of all MS in exactly the same year. Where possible, the year 1998 has been used, as data were found to be most widely available for that year. In some sets, some MS will be missing altogether, mostly ex-AC countries.

5.4.1 Materials

Fiscal instruments

A large variety of taxes may influence either the DMC or EMC (or both) of a country. However, as outlined in paragraph 4.2, we will not consider taxes that influence materials consumption indirectly, for example road taxes, as virtually every tax may have some implications for materials and energy use.

One may distinguish the following direct taxes:

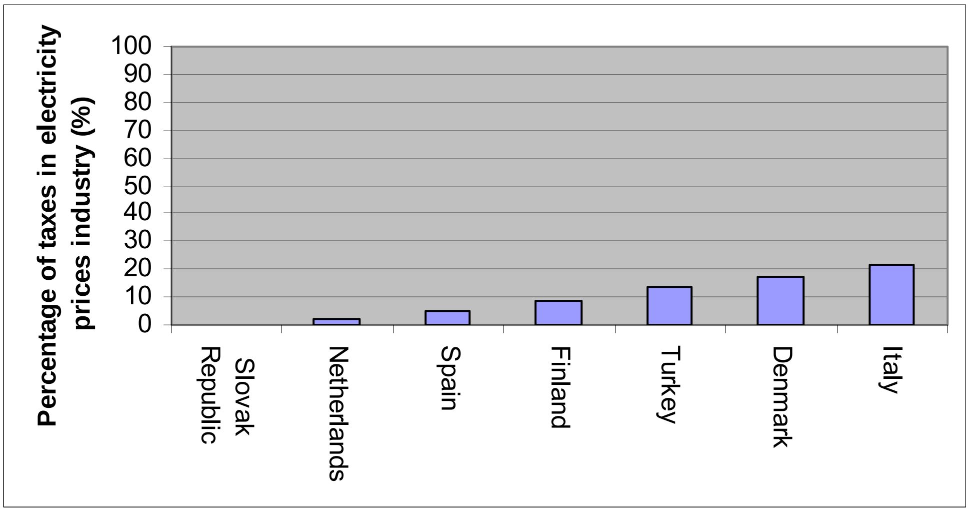
- Energy taxes
- Taxes on materials
- Product taxes (other than energy products), such as import tariffs or VAT.

Of these three categories, the latter is not related to weight or the environmental burden, but included here as it can be perceived as a general tax, potentially altering the choice between consumption of material goods and/or services.

In figures 5.1 to 5.5, the percentages of taxes in the price of several different energy carriers is shown for European countries, for industry and households. They reveal some interesting differences between countries. For electricity, both for households and industry, the differences between countries are large. However, motorfuel taxes tend to be rather similar for the various countries.

For only 7 countries data is available of the percentage of taxes in electricity prices for industry. Of these 7 countries, Italy and Denmark have a high share of taxes in the prices (17% and 21% respectively), while taxes in The Netherlands and Slovak Republic have a small share in the final price (only 1,9% and 0,3% respectively).
For taxes in electricity prices data is available for 20 countries. Of these countries Denmark and Italy (together with Sweden) have the highest share of taxes in electricity prices again, while Slovak Republic belongs to the countries with the lowest share. Interestingly, Denmark and Italy are also the only EU countries with a share of solar, wind- or geothermal power significantly higher than about 1%[23]. However, in contrast to taxes in electricity prices for industry, Denmark has a low share of taxes in the light fuel oil prices, while Italy again tops the list.

Figure 5.1 Percentage of tax in electricity prices industry



[23] Of total domestic electricity use

Figure 5.2 Percentage of taxes in electricity prices households (source: IEA 2002, data: 1998, *1997)

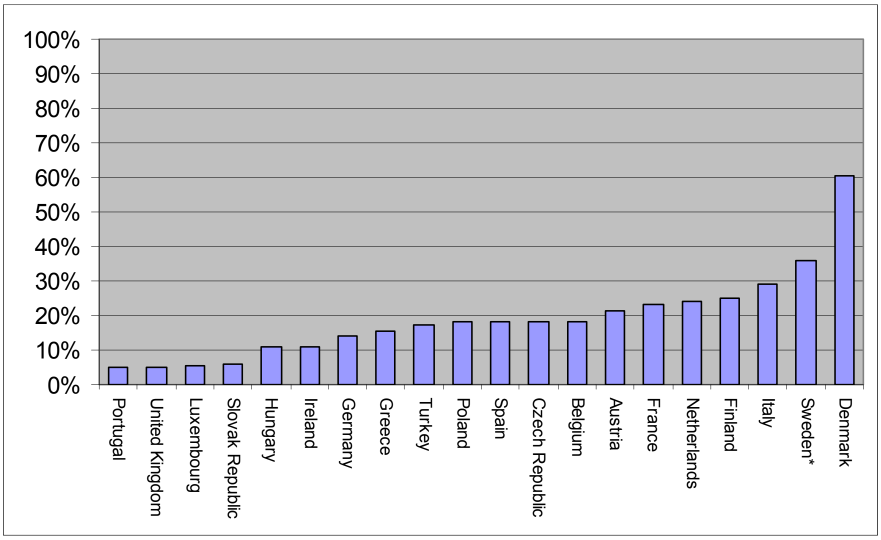
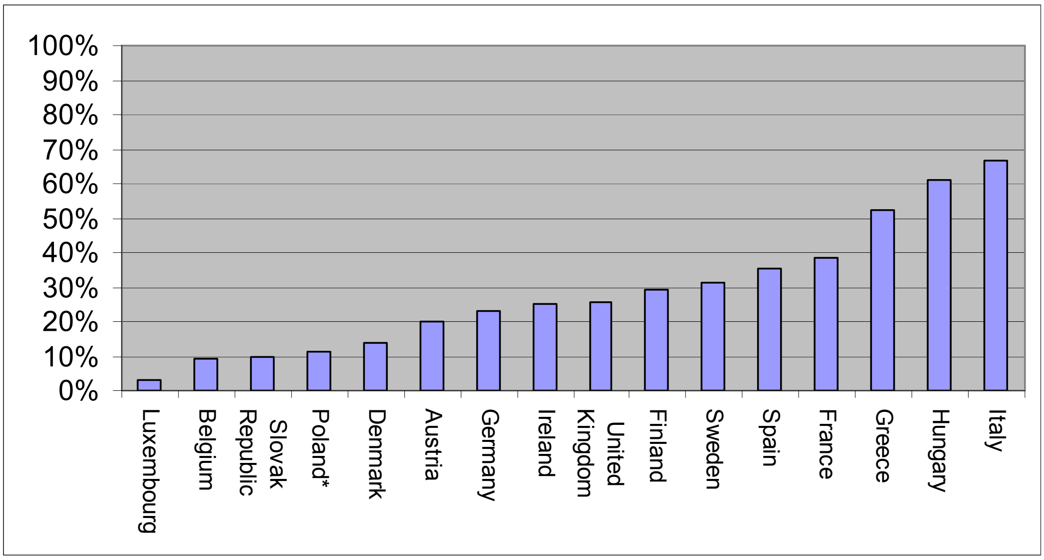


Figure 5.3 Percentage of taxes in light fuel oil industry (source : IEA, 2002, data: 1998, * 1999)



For diesel and petrol the tax percentage is fairly constant. Across Europe, about 70% of the price of these fuels is taxes. In the UK and France, the highest tax percentages apply, in Poland and the Slovak and Czech Republics the lowest. This is not so remarkable, as the general price levels are also lower for these countries.

Figure 5.4 Percentage of taxes diesel prices non commercial (Source: IEA, 2002, year data: 1998)

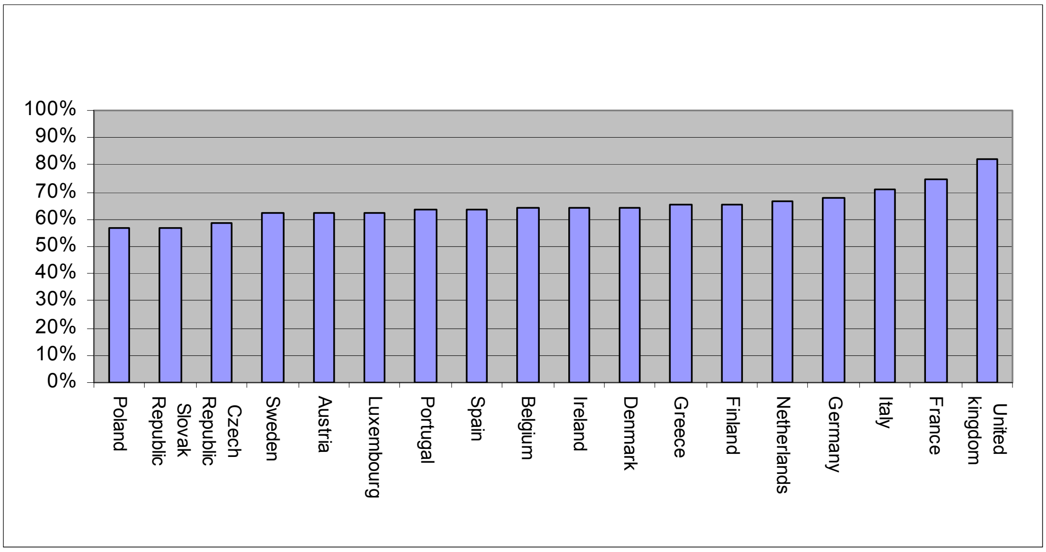
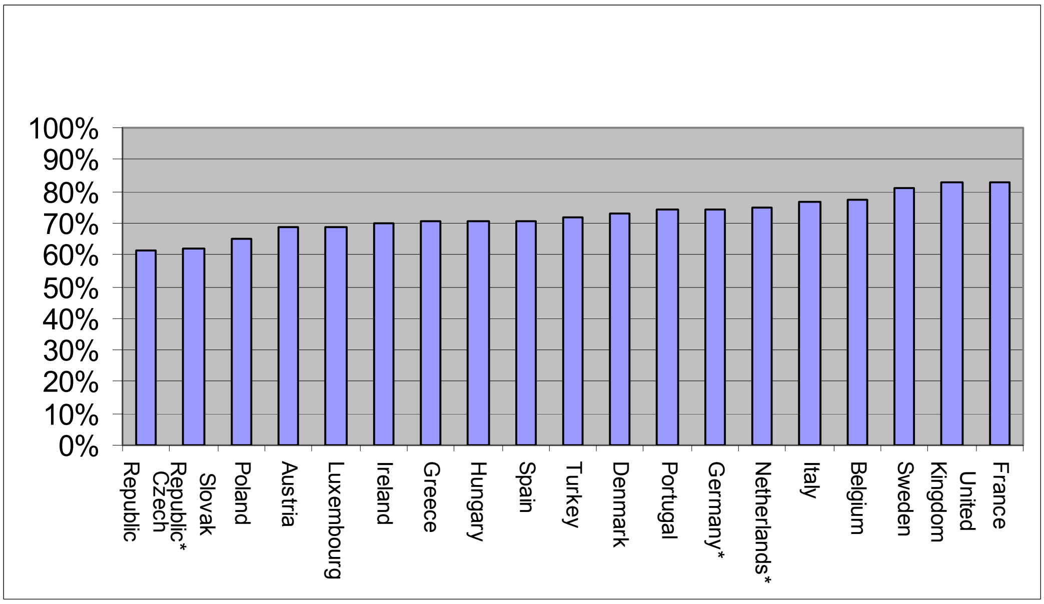


Figure 5.5 Percentage of taxes in gasoline prices (source: IEA, 2002, data: 1998, * 1996)



Taxes on *materials* are far less general than taxes on energy carriers. In the OECD database, taxes on (raw) materials can be found for ten European countries only. They are listed Table 5.3.[24]

This table shows that material taxes typically apply only in the Scandinavian countries, the United Kingdom and Baltic countries. In addition, Poland and Bulgaria target forestry with taxation. The year of introduction is not known for most material taxes in these countries. However, the levy in the United Kingdom has been introduced in the year 2002 according to the OECD database. Therefore this levy has no impact on the material consumption of the reference period in this study.

[24] Additional requests from REC did not provide new information and hence we think that this list should be fairly exhaustive.

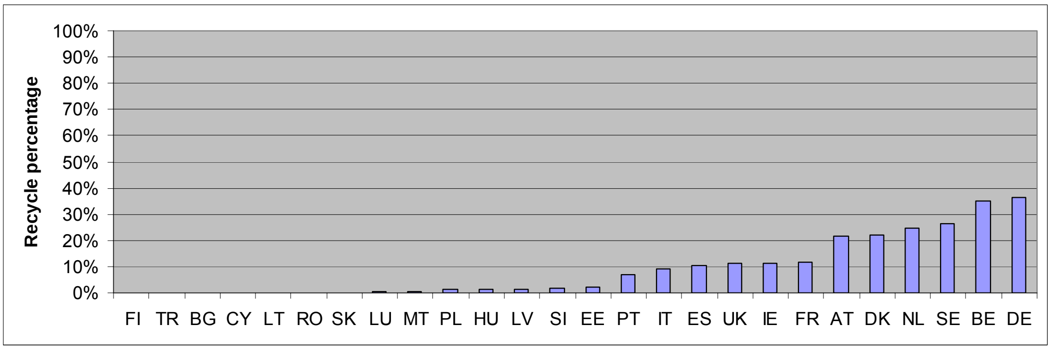
Table 5.3 Taxes applied to raw materials

Country	Tax	Specific tax-base	Tax rate	Units
United Kingdom	Aggregate levy	Aggregate production	2,58	€ per tonne.
Denmark	Duty on raw materials	Raw materials	0,67	€ per m3
		Excavation of peat		
		Material permitted for abstraction 50 000-199 999 tons		
	Excavation charge	Use of motorcycles, weighing 76 kg or more		
		The use of a lorry with a total weight of 12 tonnes or more		
Sweden		The use of a lorry with a total weight of 12 tonnes or more		
	Fee on imported aluminium cans	Imported aluminium cans	0,05	€ per can
	Licence fee for exploitation of peat	Exploitation of peat	0,76	€ per ha
	Mineral act charge	Natural gravel	0,54	€ per tonne
	Natural gravel tax	Mineral extraction		
Finland	Fee on gravel abstraction	Gravel abstraction		
France	Gerneral tax for polluting activities	Granulats		
	Tree cutting charges	Type of tree and the use of wood	0,5-51	€ per tree
Bulgaria	Mining charge	Extraction of sand and gravel	0,03-0,08	
		Extraction of clay pit and quarry	0,05-0,15	
		Construction sand	0,30	
		Technological sand	0,36	
		Construction gravel	0,46	
		Cement clay	0,15	
Estonia	Mineral extraction tax	Ceramic clay	0,09	
		Cement limestone	0,45	
		Construction limestone and dolomite	0,30	
		Decorative dolomite	0,60	€ per m3
		Low-decomposing peat	0,14	
		High-decomposing peat	0,23	
		Soil	0,36	
		Construction sand	0,09	
		Sand for glass and molding	0,36	
Latvia	Natural resources charge	Gravel	0,18	
		Clay for cement and brick	0,18	
		Clay and dolomite for ceramics	0,23	
		Decorative dolomite	0,11	
		Oil		20% of sales price
		Dolomite	0,18	
		Clay	0,10-0,27	
		Construction sand	0,09	€ per m3
		Sand and gravel mix	0,08	
		Construction soil	0,05	
		Anhydrite	0,14	
Lithanuania	Mining taxes	Limestone	0,23	
		Chalk Marl	0,17	
		Opoka	0,14	€ per tonne
		Sapropel	0,23	
		Sand used in glass industry	1,02	
		Peat (for exports)	1,44	
		Peat (for domestic use)	0,32	
		Amber		9,0-13,77 € per kg
Poland	Charge for bush and tree removals	Bush and tree removals	2,8 - 388	€ per cm of tree trunk circumference

Recycling

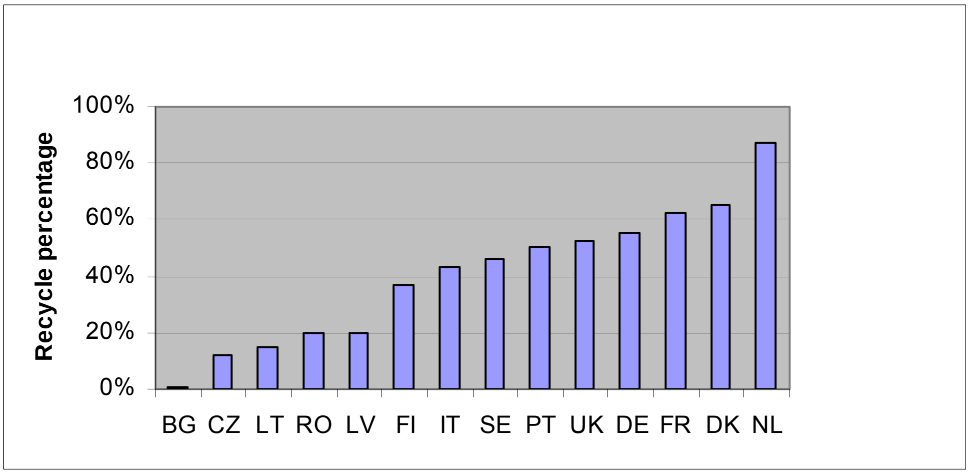
Recycling is an important means to reduce the use of raw materials, even if the total amount of materials “in the economy” at any given moment does not change. A means to reduce the environmental impact of raw materials can be recovery of waste. Recovery includes both recycling and other forms of waste upgrading, such as application of waste in construction or waste incineration with energy recovery. Recycling will have the most significant direct influence on the use of (raw) materials.

Figure 5.6 Recycle percentage municipal waste managed in countries



Regarding to municipal waste management there is a clear difference between the former accession countries, the southern European countries (together with United Kingdom and Ireland) and the northern European countries. While the recycling rates are very small to zero in the former accession countries, the recycling rates are about 10% in most southern European countries. In the northern European countries the rates are the highest which ranging from between 20% and 40%.

Figure 5.7 Recycle percentage of industrial waste managed in countries



Regarding the recycle percentage of industrial waste the northern European countries again top the list while the percentages are lowest in the former accession countries.

Energy efficiency

For fossil fuels, recycling[25] is not an option for increasing the efficiency of the use of materials. Instruments focus on direct energy efficiency. Different countries use very different instruments for increasing energy efficiency of their industries, as can be seen in the table below.

Mostly, countries have national plans that deal with energy issues. If quantitative targets are stated, they are often in terms of absolute reductions. This may be partly due to the fact that those national plans are developed in support of the Kyoto obligations. Other countries (Slovenia, Latvia) set national energy intensity targets, that is to reduce energy consumption relative to the gross domestic product. The Netherlands is the only country that uses a voluntary agreement with energy-intense industries to increase the energy efficiency at the level of production processes. In the Benchmark Covenant, participating industries have agreed to be amongst the top 10% of the world when it comes to energy efficiency. In the Long Term Agreements, participating industries set energy efficiency targets. Part of this efficiency improvement may be realized in the life cycle of the product instead of in the process installation.

[25] Exception is in some sense incineration of plastics with energy recovery

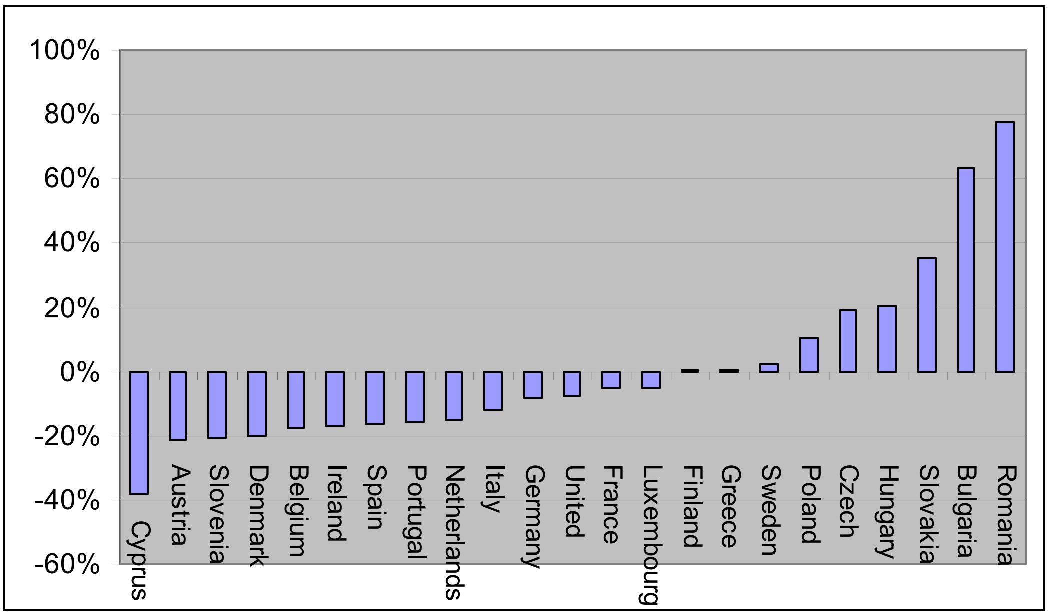
Table 5.4 Energy efficiency policy instruments in EU member states

Country	Energy efficiency policy	Objective
Belgium	National Climate Plan 2002-2012	
Bulgaria	National Energy Efficiency Program	Reduction 246 Ktoe per year
Finland	Action Plan for Energy Efficiency (2002)	4-6% reduction in the consumption of primary energy sources in 2010
France	PNLCC : National Programme against Climate Change from January 2000	
Germany	1. National commitment to reduce CO2 emissions.	
	2. Commitment of Germany under the EU burden sharing.	
	3. National Climate Protection Programme of the Federal Government	
Greece	Operational Programme for Energy (OPE)	
Hungary	Energy Saving Strategy and Action Programme	increasing energy efficiency by 3,5% per year
Ireland	National Climate Change Strategy	
Italy	1 Decree of Activity Productive Ministry of 24/April/2001 on energy efficiency	
	2 National plan for the reduction of GHG	
Latvia	National Energy Efficiency strategy	25% decrease of primary energy consumption per GDP by 2010
Lithuania	National Energy Efficiency Programme	
The Netherlands	1 Benchmark convenant	Improve energy efficiency by 1,3% per year
	2 Long term agreements	
Poland	During 2003 no programs existed	
Portugal	POE – Operational Programme for Economic Activities	
Romania	No programs existed in 2003 (there is a program under preparation)	
Slovenia	Resolution on the Strategy of Energy Use and Supply	decrease of energy intensity by 2% a year
	Strategy of Efficient Energy Use and Supply (supporting material)	
Sweden	Technology Procurement Programme (TP), Information dissemination, R&D	
Turkey	No programs existed in 2003 (there is a program under preparation)	

Latvia has the furthest-reaching target by aiming for a reduction of the national energy intensity of 25% by 2010.

An important driver for energy efficiency may be the Kyoto-protocol. Although not explicitly oriented on energy use, we list here shortly the policy implications from the protocol.

Figure 5.8 Kyoto targets per country related to the year 2000



In Figure 5.8, the Kyoto targets for the different countries are shown, which are calculated based upon the reduction in relation to the emission level in 2000. While Cyprus, Denmark and Austria have to reduce their emissions, in Eastern European countries like Romania and Bulgaria emissions may increase with more than 60%.

Renewable energy

Improving the environmental performance of “energy use” is achieved by increasing the percentage of renewable energy in the total mix. The most prominent sources of renewable energy are wind, solar power, hydro power and the incineration of biomass and waste. The last category is subject to discussion for a variety of reasons. Following a verdict by the European Court of Justice, waste incineration is no longer a form of recovery, but still included in the targets of the new packaging directive (see 2.3.3). The use of special energy crops for energy from biomass, instead of e.g. waste timber, is less controversial. The data do not allow separating the sources of biomass, however, so in figure 5.10 “biomass and waste” is shown as one class.

The share of renewables is defined as the ratio between the electricity produced from sustainable energy sources and the gross national electricity consumption in 1998.

Figure 5.9 Share of renewable energy (Source Eurostat, New Cronos)

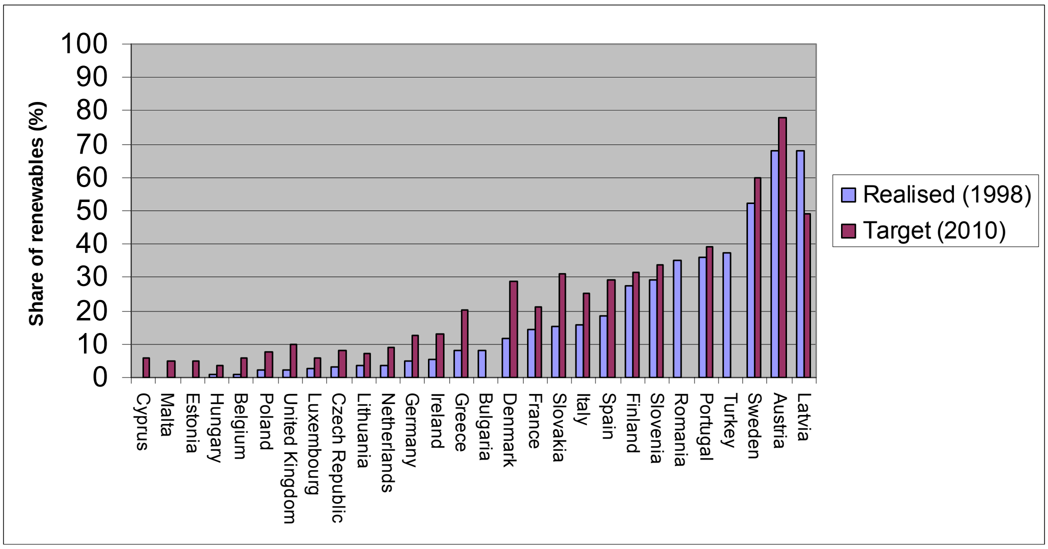
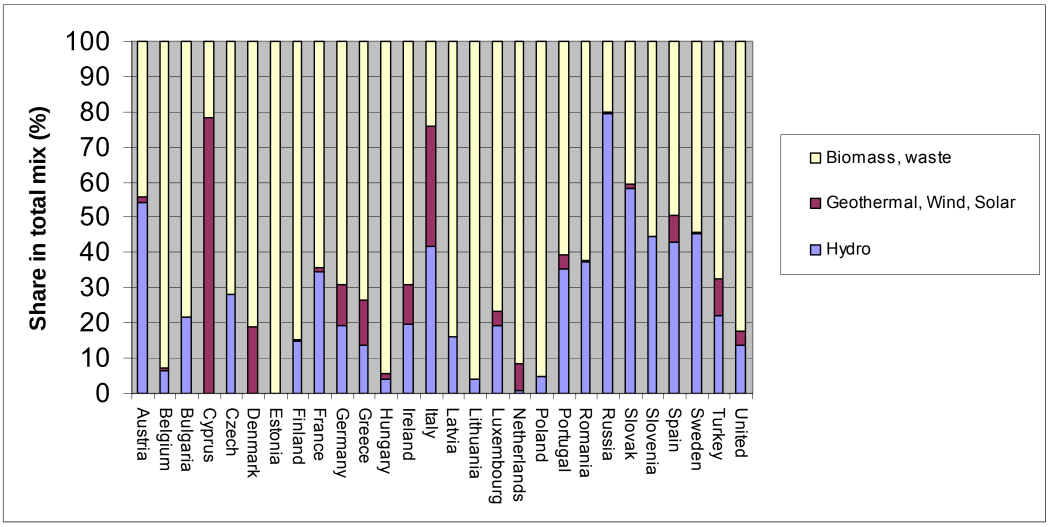


Figure 5.10 Distribution of types of renewable energy (source: IEA)



In Sweden, Austria and Latvia, more than half of all electricity is generated from sustainable sources. Even in Sweden, however, most of the renewable energy is from incineration of biomass and/or waste. Italy and Denmark are the only countries with a considerable share of solar, wind or geothermal power in the total mix (about 5% and 3% of total energy supply, respectively).

Table 5.5 Instruments employed in renewable energy policies

Country	Feed-in tarrifs	Qouta obligations/green certificates	Bidding systems	Environmental funds	Fiscal measures	Investment subsidies*
Austria	X	X			X	X
Belgium	X	X			X	X
Denmark	X				X	X
Finland	X					X
France	X		X			X
Germany	X					X
Greece	X					X
Ireland			X		X	
Italy	X	X				X
Luxemburg	X				X	X
The Netherlands	X				X	X
Portugal	X				X	X
Spain	X					X
Sweden		X			X	X
UK		X			X	X
Bulgaria				X	X	
Cyprus					X	
Czech Republic	X			X	X	
Estonia	X			X	X	
Hungary	X			X	X	
Latvia	X		X	X	X	
Lithuania				X	X	
Malta					X	
Poland		X		X	X	
Romania					X	
Slovenia	X			X	X	
Slovakia				X	X	
Turkey					X	

* The source of the EU-15 countries is (De Vries et al, 2003) while the information of the ex-AC-13 countries originates from (Reiche et al, 2003). In (Reiche et al,2003) investment subsidies are not categorised and could be integrated in the category environmental funds.

In Table 5.5 per country is shown which type of policy instruments are used.
These instruments are:

Feed-in tarrifs: this tarrif is used both for for a regulatory, minimum garanteed price per unit to be paid to the producer, as well as for a premium in addition to market electricity prices.

Quota obligations: The obligations are used to impose a minimum production or consumption of electricity from renewable energy sources. The government sets the framework within which the market has to produce, sell, or distribute a certain amount of energy from renewable sources. The obligation is imposed on consumption (often through distribution companies) or production

Bidding procedures: these procedures can be used to select beneficiaries for investment support or production support (such as through feed-in-tariffs), or for other limited rights- such as sites for wind energy. Potential investors or producers have to compete through competitive bidding system

Environmental funds: In some countries environmental funds exist which also support projects in the field of renewable energy. The revenues from these funds come mainly from fees and fines.

Fiscal instruments: Some EU countries support renewable electricity by means of the fiscal system. These schemes may take different forms, which range from rebates on general energy taxes, rebates from special emission taxes, proposals for lower VAT rates, tax exemption for green funds, to fiscal attractive depreciation schemes.

Investment subsidies: these subsidies can help to overcome a barrier of a high initial investment. This type of subsidy is commonly used to stimulate investments in less economical renewable energy technologies. Investment are usually 20-50% of eligible investment costs.

Table 5.5 shows that in most of the countries 3 different types these policy instruments are used. Austria and Latvia top the list with 4 different types of policy instruments used while Turkey, Cyprus and Malta have only 1 type of policy instrument.

Biotic materials

For biotic materials – sources of food, fibres, building material, energy – no specific policies exist to regulate their consumption, by quantity nor by environmental burden. There are two non-governmental initiatives, however, that regulate the environmental burden of wood and fish, respectively. NGO's and industry work together to increase the market share of products that are certified "sustainable". Such certification exists for e.g. wood and fish. As these are not governmental policies, however, they do not form part of this analysis.

5.4.2 Products and life-cycle stages

Next to policies acting on (certain types of) materials, there are policies that act on (certain types of) products or on only a specific stage in the life cycle of a material flow or product. These are partly the result of historical attention, such as waste management and packaging, and partly an attempt to integrate and complement existing instruments into a more consistent policy, such as IPP.

IPP and product instruments

Integrated Product Policy is an umbrella term used to describe collectively all instruments that aim at reducing the environmental pressure of products over their entire life cycle. The governing idea is that, by optimizing life-cycle environmental performance for all (end-user) products, the environmental pressure of the economy over the entire life cycle, including stages that take place abroad, is minimized.

This governing idea has several different interpretations in practice, however. This makes the concept somewhat opaque and may slow developments. Some interpret IPP as a way to integrate existing policies and make them more consistent. Others take the name product policy very literal, meaning a new policy that acts on products but integrates the entire life cycle and all environmental issues.

This is the reason why the Centre for Sustainable Design[26] distinguishes between IPP, as an EC initiative to harmonize existing policies, and EPP (environmental product policy) as national policies and specific instruments. Quoting them: "IPP is a European Commission initiative aimed at a common product-oriented environmental policy formulation at the EU level. EPP is a more general term that refers to product-oriented environmental policies inside and outside Europe. The EU Packaging Directive, the EU End-of-Life Vehicals (ELV) Directive, the proposed EU Waste from Electrical and Electronic Equipment (WEEE) Directive, the EU eco-labelling scheme, and the funding schemes under the EU 5th Action Framework programme (e.g., "Competitive and Sustainable Growth" scheme) can be regarded as examples of the vertical elements of an IPP at the EU level."

According to this classification, IPP stands only for the former interpretation mentioned before, EPP for the latter interpretation. This is not (yet) common practice, however.

The former interpretation underlies a study commissioned by Novem[27] (2004). The development of IPP was measured by analysing national policies for instruments used, industrial sectors covered by policies and life-cycle stages (manufacturing, use, disposal, etc) covered by policies. The results are

[26] http://www.cfsd.org.uk/ipp-epd/index.html

[27] Netherlands Agency for Energy and Environment, 2004, "Quick Scan IPP" for 16 European countries, Japan and USA (carried out by Cap Gemini Ernst & Young)

summarized in the table below. The instruments, sectors and life-cycle stages are not necessarily covered by one integrated policy and so do not reflect the presence of a true “IPP” in the countries.

Table 5.6: Indication of the level of ambition of IPP in the EU-15

IPP Quick Scan	types of instruments (max 9)	industrial sectors (max 7)	life-cycle stages (max 6)	remarks
Austria	5	3	4	
Belgium	5	4	1	only disposal
Denmark	9	5	5	
Italy	5	2	3	
Ireland	2	1	3	
Finland	6	5	3	
France	5	3	5	
Germany	6	6	3	
Greece	3	1	2	
Luxembourg	2	2	1	
Netherlands	9	7	5	Long Term Agreement
Portugal	5	3	2	disposal not covered
Spain	4	2	1	
Sweden	7	3	5	
Switzerland	5	1	3	
United Kingdom	5	3	4	

In this table, Denmark and the Netherlands top the list in terms of the wide coverage of policies in the three areas listed.

The same is found by the Centre for Sustainable Design[28]. They list as leading countries, in terms of development of EPP frameworks (the second interpretation of IPP mentioned above): the Netherlands, Denmark, Sweden, Austria and Germany. Other countries, such as France, Luxembourg, Spain, Portugal, Greece and Ireland are considered to be lagging behind.

In the other interpretation of IPP – new instruments that act on (end-user) products – several instruments are commonly considered to be part of IPP:

- Labelling
- Ecodesign
- Product panels
- Product-oriented management systems (POEMS)

At EU level a communication has been issued by the Commission. IPP is positioned as a part of the EU’s Sustainable Development Strategy. It should contribute to environmental issues identified in that Strategy and supplement existing product-related policies. It is also explicitly stated that IPP should strengthen coherence between instruments. This communication therefore supports both interpretations of IPP mentioned before.

As for individual countries, the Scandinavian countries and the Netherlands have some explicit IPP policy instruments. The “Nordic Swan” is the official Scandinavian ecolabel, the Netherlands uses “Milieukeur”, Germany the ‘Grune Punkt’. Some other IPP related activities are:

- Denmark works with product panels, multistakeholder dialogues for each product (group)
- Finland is preparing a national programme for sustainable production and consumption, that aims at eco-efficiency of materials
- The Netherlands ran a POEMS programme for stimulating product-oriented environmental management in industry. Besides, one of the energy-efficiency covenants (see paragraph @@) includes targets for energy-efficiency in the life cycle of products
- Sweden has a national IPP position paper

[28] http://www.cfsd.org.uk/ipp-epd/index.html

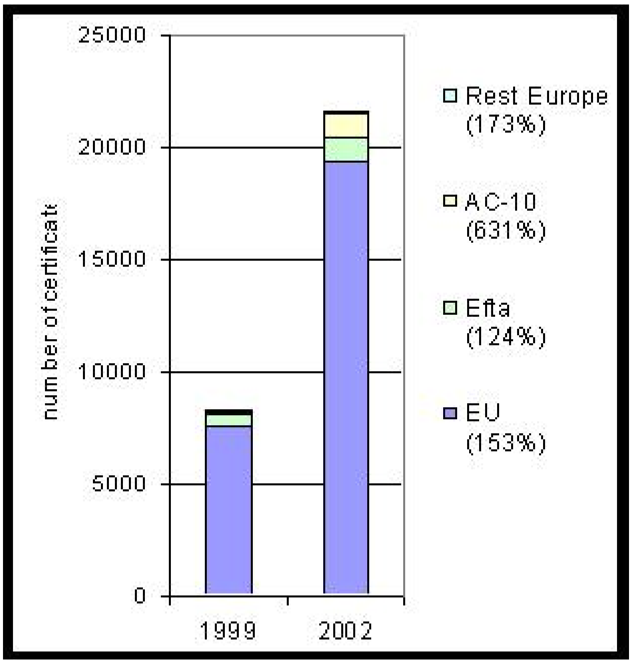
- France has a “Strategie Nationale de Developpement Durable” that focuses on ecodesign, POEMS, labelling and market demand
- UK focuses on green procurement and consumer information

The PPI[29] study makes an inventory of policies and targets for natural resources and waste in EU MS. Next to taxes and subsidies, IPP related instruments are investigated as well[30]. These are grouped as:
- producer responsibility, including implementations of ELV, WEEE and packaging directives
- voluntary agreements, such as the Danish car tyre initiative
- EMAS
- ecolabels

EMAS stands for Eco-Management and Audit System. A European regulation (number 761/2001) allows for voluntary participation in a general European EMAS.

The number of Environmental Management Systems in Europe grew with 160% between 1999 and 2002 (source: EEA 2003). There are two main systems: the worldwide adopted ISO14001 standards and EMAS. Remarkable is the spectacular growth in ISO14001 certificates in the former Accession countries – a sixfold increase since 1999. The main reason for installing ISO14001 or EMAS in companies is to achieve better contacts with regulators and clients (source: EEA 2003).

Figure 5.11 Application of EMS involve both ISO14001 and EMAS



Source: EEA 2003.

Note: 1999 refers to the number of certificates in June 1999. 2002 refers to the certificates in January 2002. The figures in brackets next to the keys give the growth in the number of certificates between 1999 and 2002. Data from Gergely Tóth, Hungarian Association of Environmentally Aware Businesses (KÖVET-INEM Hungária), and the EMAS Helpdesk, Brussel.

Taxes on products

In addition to the material and energy taxes, consumption of products is also taxed. Specific taxes for products are VAT and import tariffs. Figure 5.11 gives the total product taxes as % of the total state budget. They give an indication about the fiscal structure of countries. We see here that the product taxes are the highest in Denmark and Sweden. Cyprus and Spain, but also Germany, levy less taxes on products relative to the state budget.

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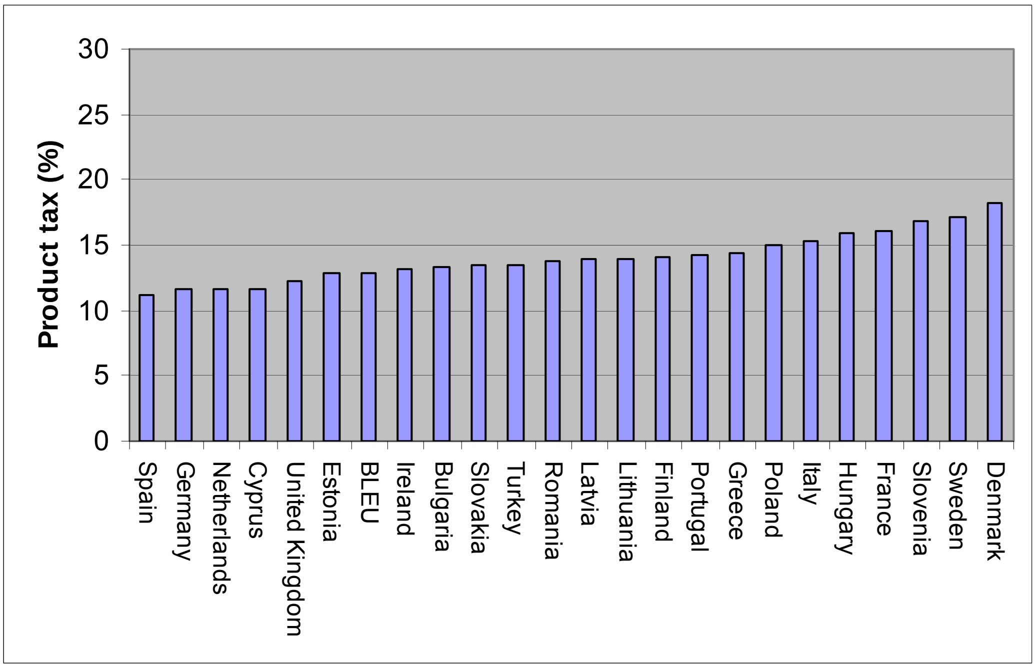
[29] Public Private Interface, Study 1 report, 2004

[30] The PPI study does not provide any final conclusions on the effectiveness of these instruments. Producer responsibility can prove very successful, voluntary agreements can be effective but in some cases are also unsuccessful.

Figure 5.12 Product taxes in European countries (source: Eurostat, data: 1998)



Use of chemical substances

The proposed European regulation concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) uses a life-cycle approach to the control of substances. Substances are classified by the effects of their use and presence in products at various life-cycle stages including application (by consumer). This regulation is still in the phase of consultation and discussion, especially concerning the potential economic impacts. Its effects on materials consumption and/or associated environmental impacts is not taken into account in this study.

Waste

Waste treatment methods are generally ranked from “best” to “worst” :

- Prevention
- Re-use, recycling, recovery (composting, incineration)
- Landfill

The two underlying goals are to reduce the amount of waste (by weight) and the environmental pressures related to it. Actual policy instruments still act by weight, however, and environmental indicators are still subject to discussion.

Figure 5.13 Management of municipal waste (source: Eurostat, 2003)

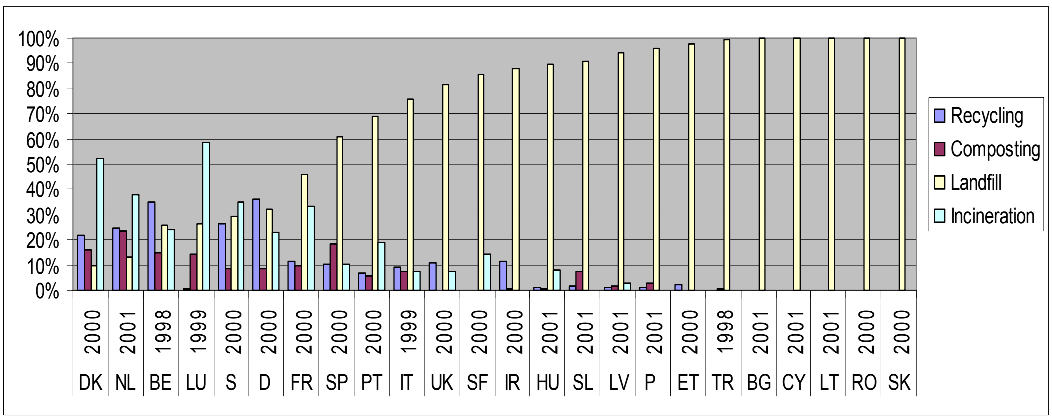
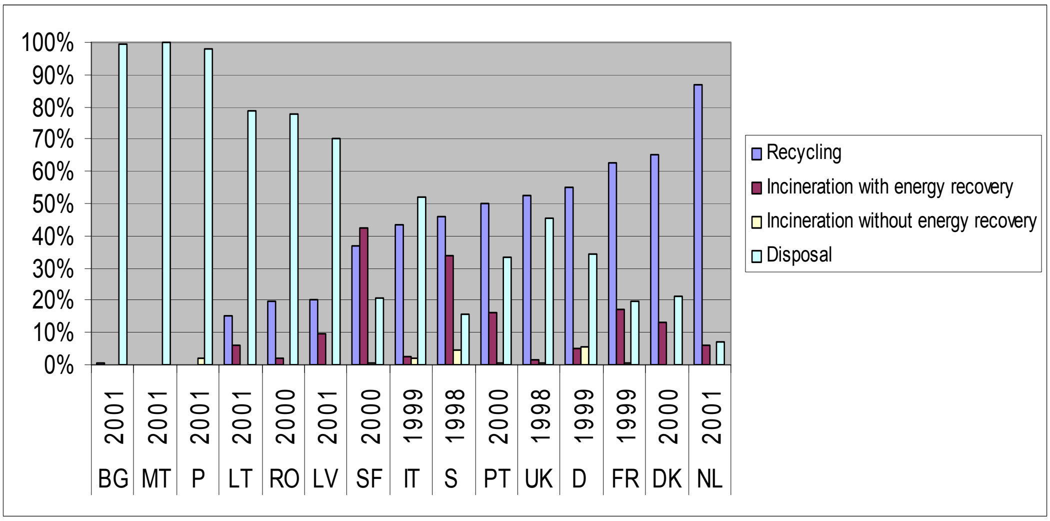


Figure 5.13 shows that land filling is the dominant way of waste management in all the former AC and many of the other EU countries. In contrast, incineration is hardly practiced in former AC. In only some countries of the former EU15, incineration has a considerable share. Particularly in Denmark and Luxemburg, where it represents respectively 52% and 59% of total municipal waste disposal. The share is also important, though to a much lesser extent, in France, Sweden and the Netherlands.

In figure 5.14, the shares of different treatment methods is shown for industrial waste. The recycling rate is high in the Netherlands, Denmark, France, Germany and the UK. The land fill rate is almost 100% in Bulgaria, Portugal and MT

Figure 5.14 Management of industrial waste (source: Eurostat 2003)



Most countries work with duties on landfill and/or incineration and collection. Household waste is covered both by information to consumers and prevention programmes for or voluntary agreements with industry, such as for packaging. The latter role of industry, through e.g. ecodesign or producer responsibility, is covered by France, Austria, the Netherlands, UK, Sweden. (Source ETC-WMF, former EU15). In some countries (UK, Luxembourg) policies exist or are proposed to judge municipalities on the total amount of waste (land filled) and adjust their subsidies accordingly.

Packaging

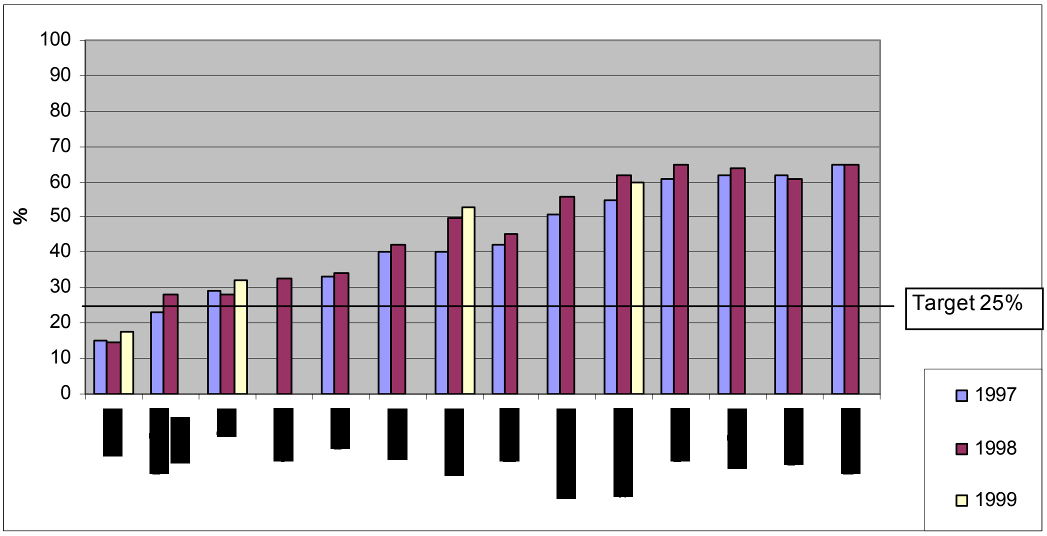
Packaging has historically received a lot of attention in both waste prevention and waste treatment policies. Being an important part of the life cycle of the majority of products, packaging has always been considered an important point of action for waste reduction. The EU packaging directive (2004/12/EC, amending 1994/62/EC) states targets for recycling and "recovery plus waste incineration with energy recovery" that Member States have to achieve by 2008. These targets are given in Table 5.7.

Table 5.7 Recycling and recovery targets in EU packaging directive

		Old directive (2001)	New directive (2008)
Recovery (including recycling)	Min	50%	60%
	Max	65%	None
Recycling	Min	25%	55%
	Max	45%	80%
Recycling per material	Glass	15%	60%
	Paper/board	15%	60%
	Plastics	15%	22,5%
	Metals	15%	50%
	Wood	15%	15%

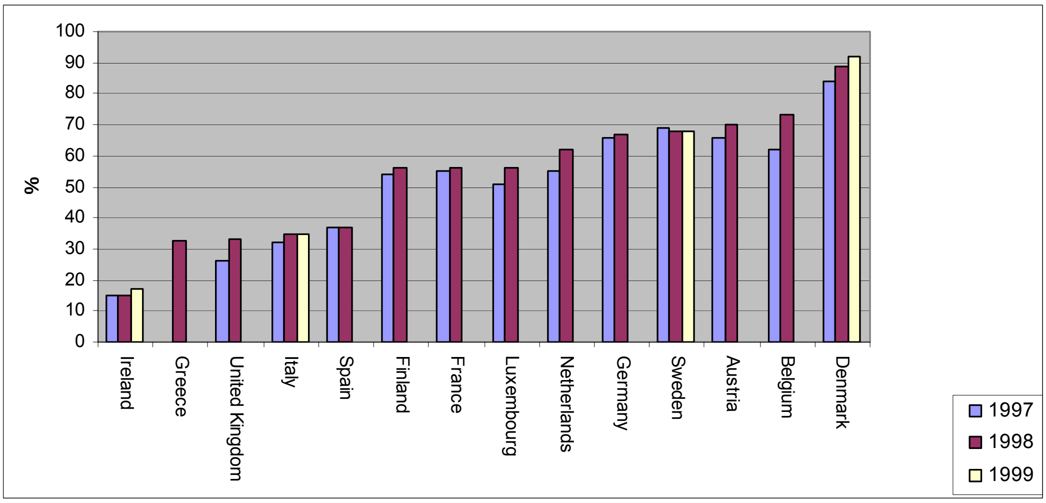
The actual achieved recycling and recovery percentages are shown in the figures below. Germany, Sweden, Belgium, Austria and the Netherlands all have average recycling rates of 60% or higher. This means they already match the 2008 targets of the directive. For recovery, Denmark tops the list with 90%. Germany, Sweden, Belgium, Austria and the Netherlands again achieve 60% or higher. Denmark is the only country where the recovery rate is significantly higher than the recycling rate.

figure 5.15 Recycling percentages across EU14 or 1997,1998 and 1999 (source: EEA)



The UK and Ireland have not, or only just, achieved the 2001 target for recycling. For recovery, also some southern European countries are still below the target in 1999.

Figure 5.16 Recovery percentages across EU14 for 1997,1998 and 1999. (Source EEA)



5.5 *Conclusions*

A general conclusion that can be drawn from the policy analysis, is that currently policies for materials or products still mostly act by weight. Only some of the instruments under IPP explicitly act by environmental impact, by stimulating the use of renewable energy or certified wood. There is a tendency, however, to move toward policies acting by environmental impacts, for instance in the area of packaging. Next to this, sectoral policies of course address emissions and environmental impacts more directly, but those are mostly tied to locations.

As to the performance of individual countries some remarks can be made. In general, a clear distinction is seen between the older MS and the newest MS. To a lesser extent, there is a distinction between northern Europe and southern Europe. In some cases, however, the UK (and Ireland) clearly differs from the rest of northern Europe, such as in the area of energy policies (tax, efficiency and renewables). This also holds for Luxembourg in some policy areas.

Interestingly, Denmark, and also Sweden, is almost always at the top of the list. This is more striking as the indicator of the EMC indicated that Denmark is also the country with one of the largest environmental burdens from resource consumption. Portugal and Greece are often at the bottom of the list (not taking into account the new MS).

The differentiation in east-west and north-south is also seen in the ratio between EWC and DMC (Chapter 4). There is no clear policy explanation for the outliers identified in that chapter, however. The economic structure appears to be more influential than policy measures, as was also concluded in the previous chapter.

5.6 References

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6 Identification of the land use intensity in the EU-15 and AC-13 (task 6)

Land use is linked with material flows and represents another type of resource use due to economic activities. In principle, land use intensity can be seen as a complementary resource use indicator to material intensity. The Technical Annex to the Call for Tender to this study hence concludes that in addition to materials "a benchmark on land use intensity (area land use/GDP) is needed, since land is considered to be a key resource. Therefore land and materials use need to be considered together to obtain a full picture of resource productivity."

The Technical Annex specifies objective (2.3): to identify the land use intensity. Related to this objective, the Technical Annex calls the contractor to conduct the following task (6): "Relate the use of land to the generation of GDP in the EU-15 and AC-13 over the last 20 years. This task should begin by collecting relevant data on various types of land use that contribute to the generation of national GDP, including a time series (1980-2000). From this a 'domestic land use' parameter similar to 'domestic material consumption' should be developed. Any difficulties in developing such an indicator should be described and potential solutions to overcome them should be presented."

In its tender, the project team has divided task 6 into two sub-tasks (6a and 6b) and has related a number of outcomes (6.1 to 6.6) to these sub-tasks:

- Sub-task 6a: land use in environmental accounting and related conceptual issues:
    - outcome 6.1: An overview on the state of the art on land use in the framework of Environmental Accounting and related conceptual issues
    - outcome 6.2 : Conceptual conclusions for the further development of land use intensity indicators
- Sub-task 6b: data on land use and definition of possible land use intensity indicators inter alia comparable to DMC:
    - outcome 6.3: Data sets on land use that can be related to the generation of GDP in EU-15 and AC-13 in time series.
    - outcome 6.4: Data sets of land use indicators comparable with DMC of EU-15 and AC-13 in time series.
    - outcome 6.5: Description of difficulties in developing these data sets and of potential solutions to overcome them.
    - outcome 6.6: Derivation and discussion of indicators for resource use in terms of land use intensity.

6.1 Conceptual issues on land use (task 6.a)

So far, 'land use intensity' is not a commonly defined concept. Relating land use to GDP or its components (e.g. gross value added of economic branches) is not a straightforward issue. Therefore, the objective of task 6a is to explore conceptual approaches as point of departure for the development of one or more land use intensity indicators.

A number of conceptual and accounting-methodological questions arise immediately when reflecting on 'land use intensity'.

- *What are the specific characteristics of land as a natural resource? What means "sustainable management" in the case of land?*
  Obviously, land is a unique natural resource with different characteristics than (renewable and non-renewable) material resources. Particular resource management aspects evolve from the multi-functionality of land.

- *Which land (uses) should be considered in a "land use intensity" indicator?*
  Land – in terms of area – is a fixed, non-changing resource asset. The territory of a country does not increase nor decrease significantly over time. What changes is the form land is used – e.g. from agricultural use towards built-up area – and each land use category has different environmental implications. In addition, a country can use land indirectly in foreign territories, i.e. through the import of agricultural products.

Multi-functionality of land
Land, as natural resource in the wider sense, provides a wide range of functions. This has been referred to as the "multi-functionality" of land. Broadly, the multi-functions of land can be distinguished into natural and cultural functions.

The natural functions of land comprise, *inter alia*:
- hosting ecosystems, habitats and biotopes,
- hosting biodiversity (flora and fauna),
- hosting and regulating "material cycles" (i.e. bio-geo-chemical cycles crucial for ecosystem functioning e.g. nutrient cycle, carbon cycle, water cycle etc.; terrestrial surface constitutes starting and end point of many material flows, and carrier of material stocks)
- hosting production of biomass and energy (net primary production, utilising solar energy and transforming it)
- hosting fertile top-soil

From an anthropocentric view, land provides also a wide range of cultural functions, *inter alia*:
- productive agricultural land constitutes main source for providing food
- productive forestry land providing materials for manufacturing (and partly for energy needs)
- hosting settlements and infrastructures, providing prerequisites for economic activities
- hosting landscape providing aesthetic values to humans

Sustainable land use
Europe is a highly densely populated area and arguably its land is most intensively used. A wide range of competing and diverse uses for land are subject to different types and levels of environmental pressures and impacts on land (EEA 2002).

The EEA has repeatedly reported on the land degradation in Europe (e.g. EEA/UNEP 2000, EEA 2002, EEA 2003). According to these reports most important threats to European land are:
- Soil sealing;
- Soil erosion;
- Land take due to urban development (urban sprawl);
- Fragmentation and partitioning of habitats;
- Contamination.

In contrast to many other natural resources there is no generally accepted definition of a sustainable land-use. The determination of the sustainability of a land-use also depends on the perspective.
- from an eco-system view: protecting land's function for biodiversity by defining certain nature protection targets
- from an eco-system view: limiting growth of built-up areas in order to "save" productive land (agriculture) and keeping "reserves" for protected land; de-coupling land use of built-up area (urban sprawl) from economic growth
- from an economic view (production factor): sustainable intensity levels for land use in agriculture and forestry which are maintainable in the long term
- from an aesthetic view: maintaining integrity of landscape

Derived from the Brundtland definition of sustainable development one can attempt a broad definition of sustainable land-use (Schepelmann 2004): "Sustainable land use is a use of land which satisfies the need of current generation without compromising the need of future generations. Future potentials of land are protected by maintaining the multi-functionality, which usually depends on the fertility of the soil and the functional integrity of ecosystems."

Different types of land use (agriculture, forestry, built-up, nature conservation etc.) serve to provide certain functions, e.g. supply with food, feed, fibres, space for living, working and recreation etc. Some of these functions are exclusive, e.g. additional roads serve extended mobility but this will be at the expense of other types of land use (e.g. forestry) and thus other service functions (e.g. timber production, recreation, climate protection).

Each land-use category has its own specific environmental implications. With regard to level of environmental disturbance there is a tentative gradient from protected nature conservation area, over forestry and agricultural land use to built-up area; however, there is no clear cut threshold which can be defined in terms of a sustainable pattern of land use which could be applied to all countries ("sustainable land use mix"). However, based on various considerations and normative decisions, a society can set some targets, e.g. as happened in the case of NATURA 2000, or in the case of the German objective to reduce growth of built-up area.

Within the broad land-use categories, there are some criteria applicable which enable a kind of sustainability assessment.

Agricultural land-use: Certainly, different cultivation practises are also having different environmental implications, e.g. disturbance of the resilience of soils. Intensification versus extensification is an issue here (however, terminology seems diffuse). A very brief categorisation into two classes could be thinkable: agricultural land-use under certified organic-farming as opposed to conventional farming. Another approach has been tested by the Federal Statistical Office Germany, i.e. classifying crops according to their environmental implications and applying weightings.

Forestry land-use: Again, a minimum solution would be to distinguish forestry land-use into sustainably managed and not sustainably managed areas.

Built-up area: What can be said is that an endless growth of built-up area would end up at a 100% sealing of total land which seems non-sustainable. Limiting growth of built-up area and stop it at a reasonable threshold may be regarded as something sustainable. Further, a distinction could be made between sealed and non-sealed areas due to their different impact levels e.g. on the water cycle. Also, a distinction for ecological sensitive areas concerned, including legal aspects, may be considered (Ebersbach 1985). At a first step, and under the provision that the proportion of sealed surface is similar in different countries the share of built-up area in the whole territory of a country may provide a first benchmark indicator with regard to the extension of the most intensive form of land degradation.

General reflections on the denominator and nominator to be used for a land use intensity ratio
In general, an intensity ratio expresses how much of a factor input is needed to generate one unit of GDP or gross value added respectively. For instance, labour intensity can be defined as hours worked per Euro GDP or gross value added. In an environmental context for instance, energy intensity has been expressed as kJ Primary Energy Supply per Euro GDP. In general resource intensity is defined as resource use per unit "welfare"/"benefit" (EEA 1999). Accordingly, land use intensity can be defined as land use per unit GDP.

However, the question arises which land use corresponds to the generation of GDP or gross value added respectively? Relating the total area of a national economy (i.e. the territory of a country) to its GDP bears some problems. This kind of land use intensity ratio would only change as much as the GDP (denominator) changes since the territory (nominator) is fixed over time.

The amounts and quality of "benefits" (e.g. gross value added) derived from a given hectare of land vary and are dependent on *how* the respective hectare is utilised by humans. Arable land provides certainly different "benefits" (e.g. gross value added) than a motor highway. Hence, one may conclude that land use intensity should consider the different forms of land use, e.g.:

- agricultural land
- land for other biomass production
- land for buildings and infrastructures hosting settlement and economic activities
- land for tourism and leisure (incl. inland water bodies)
- land for nature conservation (e.g. providing aesthetic values)

Formalising the above would lead to the following general expression of a land use intensity indicator:

$$land\_use\_intensity = \sum \left(\frac{land_i}{GrossValueAdded} \right) \qquad [1]$$

whereby i : indicates the different types of land use.

The ongoing discussion on a Thematic Strategy on sustainable use of natural resources (e.g. CEC 2003) reveals that not only the pure use of natural resource (and the derived "benefits" per unit resource) is focussed on but also the environmental impacts associated. Therefore, in addition to the above, one may consider the environmental impacts associated to a certain land use and its “benefits” derived.

Different types of land use will certainly also reveal different environmental impacts. For instance, a sealed infrastructure area (e.g. motor highway) may be associated with a different vector of impacts than a sustainably managed piece of forest. Formally, this may be expressed like the following:

$$total\_impacts\_from\_land\_use = \sum \left(\frac{impact_k}{land_j} \right) \qquad [2]$$

whereby *j* : indicates the different types of land use,
k : indicates the different environmental impacts.

Again, one land use type may reveal more than one impact, i.e. a vector of impacts.

Here, the scientific challenge is to operationalise the environmental impacts associated to the different forms of land use. Ideally, one would aim to develop an inventory giving the different impact vectors of main land use categories. Unfortunately, such an inventory has not been set up yet.

So far, we can conclude that the vector of environmental impacts related to a certain (anthropogenic) land use type may have something to do with the distance to a natural reference status (sustainable reference system). Basically, one can distinguish natural land (i.e. land in its virgin natural form) in contrast to cultivated land; the latter being somehow used by humans (i.e. cultivated). However, the “impact-issue” is still in the area of basic research.

6.2 Overview on the state of the art on land use in the framework of Environmental Accounting and related conceptual issues (outcome 6.1)

The following sections will present some applied research on land use and as it is treated within the framework of integrated environmental and economic accounting.

6.2.1 Land use accounting in the SEEA

Land use accounting derives from the System of Integrated Environmental and Economic Accounting (SEEA)[31]. The SEEA provides a common framework for economic and environmental information, permitting a consistent analysis of the contribution of the environment to the economy and of the impact of the economy on the environment. It is intended to meet the needs of policy makers by providing indicators and descriptive statistics to monitor the interaction between the economy and the environment as well as serving as a tool for strategic planning and policy analysis to identify more sustainable development paths (UN 2003).
The SEEA is compatible with the System of National Accounts (SNA) the latter being the internationally agreed accounting system for monetary flows in the economy which has been widely used in most countries of the world for many years to derive comparable figures such as gross domestic product (GDP) and national income.
The SEEA constitutes an extension of the SNA by showing how natural resources and ecosystem inputs are drawn into the economy, and products and residuals are generated.

Broadly, the SEEA distinguished between flows and assets. Flow accounts focus on aspects of product and residual generation and how they can be combined. Material Flow Accounting (MFA), for instance, is part of the SEEA’s flow accounts. Asset accounts look at natural resources and ecosystem inputs in order to assess whether the stocks of these assets are being persistently depleted or degraded. An asset account links the opening stock level and closing stock level in a given accounting period.

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[31] The revision of the United Nations Handbook of National Accounting - Integrated Environmental and Economic Accounting (commonly referred to as SEEA) has been undertaken under the joint responsibility of five organizations: United Nations, European Commission, International Monetary Fund, OECD, and World Bank. Much of the work was done by the London Group on Environmental and Natural Resources Accounting, through a review process that started in 1998.

One environmental asset treated in the SEEA is land. The full SEEA asset classification is given in .

Table 6.1 SEEA Asset Classification

EA.1 Natural Resources
EA.11 Mineral and energy resources (cubic metres, tonnes, tonnes of oil equivalents, joules)
EA.12 Soil resources (cubic metres, tonnes)
EA.13 Water resources (cubic metres)
EA.14 Biological resources
EA.141 Timber resources (cubic metres)
EA.142 Crop and plant resources, other than timber (cubic metres, tonnes, number)
EA.143 Aquatic resources (tonnes, number)
EA.144 Animal resources, other than aquatic (number)
EA.2 Land and surface water (hectares)
EA.21 Land underlying buildings and structures
EA.22 Agricultural land and associated surface water
EA.23 Wooded land and associated surface water
EA.24 Major water bodies
EA.25 Other land
EA.3 Ecosystems
EA.31 Terrestrial ecosystems
EA.32 Aquatic ecosystems
EA.33 Atmospheric systems
Memorandum items – Intangible assets related to environmental issues (extended SNA codes)
AN.1121 Mineral exploration
AN.2221 Transferable licenses and concessions for the exploitation of natural resources
AN.2222 Tradable permits allowing the emission of residuals
AN.2223 Other intangible non-produced environmental assets

Source: UN et al. 2003

"Land and surface water assets [EA.2] are defined as the areas within the national territory that provide direct or indirect use benefits (or that may provide such benefits one day) through the provision of space for economic and non-economic (for example recreational) human activities. Land and surface water assets are sub-divided into five categories: land underlying buildings and structures; agricultural land and associated surface water; wooded land and associated surface water; major water bodies; and other land." (UN et al. 2003, para. 7.61).

"… Land is an asset which is unlike any other natural resource in that it may change in quality due to human intervention but effectively cannot be either created or destroyed by man (ignoring the activities of reclaiming land from the sea and the impact of possible rising sea levels due to global warming). Nor can land be imported or exported. There are, however, implications for the use of land due to the patterns of exports where other countries demand products either embedded in the land (minerals say) or biological products dependent on the land." (UN et al. 2003, para. 8.19)

A basic distinction in land and ecosystem accounting is that between land *cover* and land *use*. Land cover reflects the biophysical dimension of the earth's surface and corresponds in some regard to the notion of ecosystems. Land use, on the other hand, is based on functional dimensions of land for different human purposes or economic activities. Land use is a more complex issue since one single land unit can provide different functions, e.g. a forest can provide timber etc. and recreational functions.

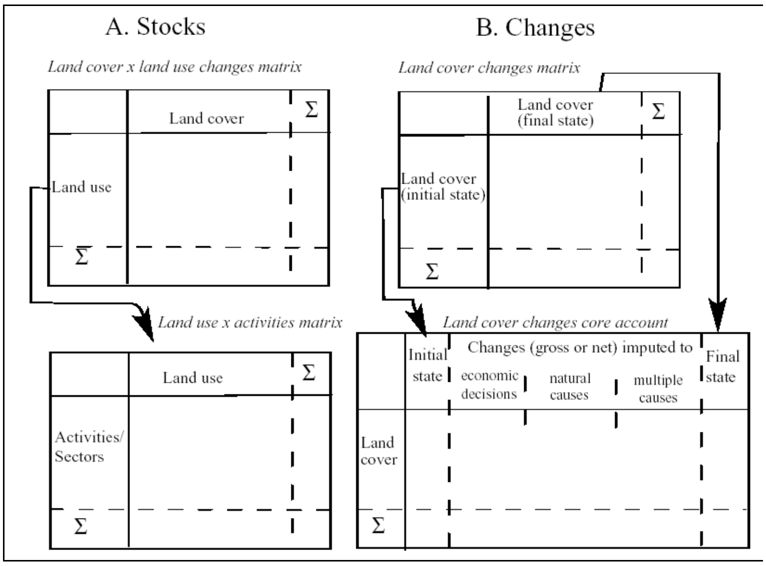
The distinction between land *use* and land *cover* may be basic from an analytical point of view. However, practical statistical work is characterised by more or less mixed classifications of land *use* and land *cover*, which also holds for the SEEA classification given in . Whereas land *cover* data tend to derive from aerial photographs, field surveys, or geo-referenced satellite data, land *use* data are mainly derived from land registers sources (e.g. cadastre). The land *use* and *cover* classifications differ considerably across countries.

In the SEEA, the view of land as providing economic benefits is only one view. Another is to consider qualitative changes of land, e.g. long-term processes of deterioration due to certain economic practices. Therefore, land use accounts can be upset in two ways: use of land by economic activity, and land from an ecological view by characterising the quality.

For land use, the SEEA recommends using the more detailed ECE Standard Statistical Classification for Land Use (see Annex 9), though it is not entirely satisfactory and several international agencies are at work towards an improved land use classification.

For land and ecosystem accounting the SEEA recommends to establish a set of basic accounts comprising 4 tables (see following figure):
1. The first one is a land-use/land-cover matrix showing the relation and overlaps between both entities.
2. The second basic table links land use to economic activities, it is a land use by industries and households matrix. Such a land use by industries table allows, for example, indicators for land productivity (value added per unit of land used) to be derived.
3. The third basic table cross-tabulates land cover at two different points in time: a land-cover change matrix.
4. Finally, the fourth basic table is another land-cover change matrix, this time showing the categories of changes.

Figure 6.1: Structure of the basic set of land cover/land use accounts



Source: UN et al. 2003, based on Conference of European Statisticians, 1995; p.6.

In addition to the basic accounts, the SEEA recommends to establish supplementary accounts. The supplementary accounts can be divided into two groups.
1. The first group specifies the second basic table (land-use by economic activities) with regards to problems of naturalness and intensity of land use. Phenomena such as sealing or fragmentation are incorporated and closer links are established to the economic activities. Some examples for such land-use oriented supplementary accounts are presented below for Germany.
2. The second group of supplementary accounts focuses on land-cover aspects such as the state of the natural environment or biotope accounting including aspects of biodiversity. Some case studies have been conducted in the UK (Stott & Haines-Young 1998). In general, the SEEA reveals a hesitative notion with regards to integration of quality aspects in both land-use and land-cover accounts. Given the current state of the art, there seems to be no scientific sound quality classification system, which covers all kind of qualitative aspects, and without including normative standards. Hence, the SEEA concludes that the only practical solution is to follow pragmatic approaches. Some approaches to extend land use by qualitative aspects are presented below.

6.2.2 Illustrative land use accounting activities by the German Federal Statistical Office

The German Environmental and Economic Accounts (GEEA)[32] have been working since the early 1990ies on issues related to land use accounts (e.g. Radermacher 1998, Schäfer et al. 2002, Schoer et al. 2003). So far, the GEEA focuses on two types of accounts: first on the land use of built up area and secondly on the intensity of pressures on agricultural ecosystem as part of ecosystem accounts (Schoer et al. 2003).

Focus on built-up area: establishing land use accounts by economic activities and deriving efficiency indicators

In Germany, the growth of land use of built up areas (settlement and traffic)[33] is an issue of high policy relevance. This is beside others due to the fact that Germany is a European country with a relative high population density and land constitutes a non-increasable resource. The use of built up area is a rather intensive type of land use requiring special attention. Use of built up area can lead to negative consequences for the water supply, for species diversity, soil functions and microclimate.

A regression analysis relating economic growth to the growth settlement and traffic areas shows a stable linear correlation of those two developments within a period of 33 years (1960-1993) in the former Federal Republic of Germany. The two growth rates are not identical, but in times of high economic growth the growth of settlement and traffic areas is also higher. This underlines the coupling of construction activities and urban sprawl with economic growth in the past. In order to obtain a first idea about the time horizon in which such a trend could lead to substantially higher built up areas, one can extrapolate the regression analysis: A 'business as usual' scenario shows that the limit of available space in the former territory of the Federal Republic of Germany would have been reached in 81 years[34] (Radermacher 1998).

The German Sustainability Strategy has identified the growth of built-up area to be a priority issue. Therein, the target has been formulated to reduce the current growth rate of built up area from about 130 ha per day to 30 ha per day until the year 2020 (German Government 2002). Therefore the GEEA has embedded this headline indicator (average daily increase of built up area) into its comprehensive accounting framework allowing integrated analyses. For instance, the recent drop of average increase from 131 ha per day in 2000 to 117 ha per day in 2001 and even 105 ha per day in 2002 can be interpreted as a result of current economic decrease. The GDP growth rate revealed a significant slow down (0,8% in 2001 and 0.2% in 2002) and even more closely related is the slow down of capital formation from about 250 billion Euro to 217 billion Euro (Schoer 2003).

Based on four-annual land use surveys supplemented by refined annual estimations for built up area, the GEEA has established the regular compilation of *land-use by economic activity matrices* distinguishing some 60 economic sectors (compatible with monetary input-output tables). Those matrices form the core of the GEEA work on built-up area (see).

- the land-use by economic activity matrices constitute a supplement to other branch related reporting activities (in particular material and energy flow account, i.e. NAMEA);
- they further allow the derivation and analysis of land use productivities of economic branches by relating the respective gross value added to the respective land use of built up area;
- in combining such matrices with monetary input-output models, one can calculate indirect land uses induced by final demand;

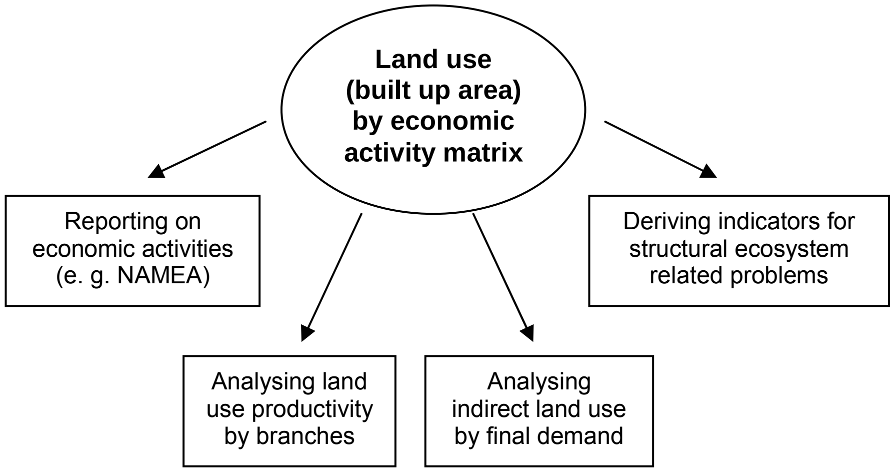
[32] The GEEA has been set up as a unit within the Federal Statistical Office Germany in the early 1990ies as a follow up of an initiative by the Federal Environment Minister Klaus Töpfer.

[33] Here, the term 'built-up area' is used as the aggregate of settlement area and transport area (following the UNECE classification). Whereas, in its English summary, Schäfer et al. (2002) use the term 'built-up area' only for buildings, industrial sites etc. and the term 'traffic area' for roads, railways etc. For the aggregate, they use the term 'total built-up and traffic area' or 'residential and transport land'.

[34] assuming an annual economic growth rate of 3% and applying the empirically found regression coefficient of 0.82 ha per million DM GDP

* based on these matrices, several extensions by ecosystem oriented indicators (weightings) can be applied.

Figure 6.2: Further applications of a land-use by economic activity matrix



Area productivity indicators (and what they express)
The GEEA is using the land-use by economic activity matrices to derive several productivity indicators. In general, productivity indicators relate outputs (nominator) to inputs (denominator). In the context of resource productivities, a natural factor input (such as raw materials, energy, land etc.) is related to an economic output. In the case of built-up area, the GEEA derives an area productivity indicator for the total economy (macro level) and branch specific area productivities (meso level) for each economic sector.

On the macro level, the area productivity of the total economy is defined as real gross domestic product per hectare of built-up area. As data for Germany reveal, the area productivity of the total economy has been steadily increasing since the 1960ies. However, the absolute amount of built-up area has been increasing too, tough at somewhat lower growth rates compared to the GDP (relative de-coupling).

It has to be noted that this macro-level area productivity indicator for the total economy only takes into account the built-up area, but, it relates this subset to the total economic output of the national economy. Hence, the input indicator (denominator) is of somewhat partial character, whereas the output indicator (nominator) is of total nature. One could argue, that the entire territory relates to the output of the national economy. However, this would not make much sense since the entire national territory is more or less fixed. Further, one could argue that at least also agricultural and forestry area is also used to derive economic output (i.e. gross value added). Schäfer et al. argue that it would not make sense to include agricultural and forestry area because this would mix up agricultural productivities (hectare yields) and environmental related productivities (use of natural factors for economic production activities). This line of argumentation seems not finally convincing, particularly when it comes to the meso-level productivity indicators.

On the meso level, specific area productivity indicators are derived for each economic branch by relating the gross value added of the respective branch to its direct land use of built-up area. The branch specific area productivities vary considerably across the branches. In general, service sectors reveal high area productivities whereas primary and basic sectors have low area productivities.
The branch specific area productivity indicators have been used by the GEEA as a basis to conduct more detailed analyses and derive better interpretation of trends underlying total economy picture (Schoer et al. 2003). The direct land use of built-up area by economic branches has been re-attributed to the final demand of goods with the help of input-output techniques. This method enables e.g. the calculation of indirect built-up area uses needed to produce export goods. It further enables the possibility which final demanded goods are requiring most of the built-up area indirectly. Structural decomposition analyses have been conducted to identify the changes of area productivities by three determining factors (area intensity, economic structural change, economic growth).

It has to be noted, that not all built-up area is attributable to economic branches. A considerable amount of built-up area has to be attributed to private households (about 54%). For the latter, no area productivity indicator can be calculated since private households generate no value added.

Focus on agricultural land-use: qualitative differentiation reflecting intensity of land use

The allocation of agricultural land to the respective economic activity is a straightforward exercise. The gross value added in the agricultural sector (or any other suitable output indicator, such as e.g. monetary or physical gross output) can be set into relation to the agricultural land use to derive a productivity measure. In order to widen the validity of this productivity or efficiency measure the GEEA aims at a more qualitative differentiation reflecting the intensity of agricultural land use and thereby the (potential) environmental implications.

Two general approaches have been investigated by the GEEA with regards to the differentiation of agricultural land use intensities (Schäfer et al. 2002):
differentiation based on crops,
differentiating by type of farming (organic farming versus conventional farming).

<u>Differentiation based on crops (intensity of cultivation):</u>
Agriculture production and land use statistics are very detailed with regards to crops. This, in general, enables the differentiation of agricultural land use intensities by crops. Based on a general proposal by Eurostat, the GEEA conducted an expert survey asking for the classification of crops and cultivation according to their intensities considering the following criteria:
how much mineral/farmyard fertiliser was used (inputs)?
how often plant protection products were used?
how high is the risk of soil compaction?
how high is the risk of soil erosion?
Three classes of intensities have been considered: high, medium, and low. In addition, some types of crops and cultivation could not be allocated (intensity not assignable). The following box shows those crops and cultivations which were assigned to the class of high-intensity.

High-intensity agricultural use (by type of cultivation/crop)				
Winter wheat	Grain maize	Sugarbeet	Hops	Silage maize
Summer wheat	Corn cob mix	Turnips	Tobacco	Orchards
Triticale	Potatoes	Winter rape	Grass-growing	Vineyards

Source: Schäfer et al. 2002

This classification scheme has been used by the GEEA to investigate trends in the intensity of agricultural land use. The result is a clear trend towards higher intensity of agricultural land use due to the changes in types of crops grown in Germany during the 1990ies.

<u>Differentiating by type of farming:</u>
Information on the intensity of agricultural land use can be derived by exploring and comparing data on organic farming with conventional farming. Thereby, a basic implication is made by assuming that organic farming is in general environmentally sounder than conventional farming. The best data basis on agricultural land use by organic farming constitutes the EU Regulation on organic farming (Regulation EEC No. 2092/91). In Germany, the area under organic farming increased from 2400 km^2 in 1993 to 3900 km^2 in 1997. This equals to 1.4% and 2.2% respectively of the total area for agricultural land use.

The GEEA, however, is aware of that differentiating only between two types of farming is only a first step towards the assessment of sustainable use of agricultural land. It ignores e.g. the fact that other means of farming (e.g. extensive use or integrated farming methods) may be comparable with organic farming as regards impacts on the environment. More detailed information by farming type are required; e.g. area-specific nitrogen surplus and use of pesticides.

Further approaches describing the environmental impacts of land-use

Radermacher (1998) reports on further approaches evaluated in some earlier pilot studies, where the GEEA tried to operationalise the environmental impacts of land use.

Partitioning of land:
The traffic network in Germany is very dense and impact of traffic on the environment is manifold. One effect is to divide habitats, creating small islands in which species are isolated. This effect was described by calculating a disparity index for the potential effects of partitioning by the traffic network. This was done by comparing two size distributions (before and after a specific traffic network). …The index measures the disparity between the two distributions. The methodological backgrounds of the approach are the Lorenz curve and the Gini Index, both of which are well known in economic statistics as a measure of relative concentration (disparities).

Soil sealing, vegetation index:
With the growth of built-up and traffic areas in recent decades the size of sealed surfaces (isolation of the soil from the atmosphere, hydrosphere and biosphere by human impact) has also increased. The isolation of the soil inactivates its natural functions as a filter and buffer and has negative effects on the water balance, local climate and flora and fauna. The climatic effects of soil sealing are higher average temperatures, a decrease of air humidity and a decreased exchange of air in the cities. …To describe the issue of soil sealing a vegetation index was derived from the satellite images… Analysis of the data showed that the index was useful for describing characteristics of the typical patterns of urban land use. The index was, however, too variable to describe temporal changes (seasonal changes between satellite images).

6.3 Conceptual conclusions for the further development of land use intensity indicators (outcome 6.2)

Land is a natural resource with certain characteristics different from e.g. material natural resources such as fossil energy carriers, minerals, biomass etc. Most important, land is a fixed natural asset, i.e. neither increasable nor decreaseable. Further, land provides a wide range of natural and cultural functions (“multi-functionality”). With regards to sustainable management of natural resources, the integrity of land to provide these multi functions is at stake. The diverse types of land use (i.e. agriculture, forestry, settlement & infrastructures, nature protection) have different impacts on the “multi functionality” of land.

1. Therefore, a land use indicator should consider different types of land use in principle.

2. Hence, aggregating all types of land use to one indicator is limited in its expression. In addition, it is not the total land area which changes, but the land-use-mix of a country.

Although some attempts exist to qualify the different types of land use with regards to their environmental implications, there is no commonly accepted approach available which could be applied, for instance, to develop a weighting scheme for aggregating the diverse types of land use.

The question of which land is attributable to GDP or gross value added respectively leads to two further questions, implying different reasoning and/or perspectives:

a) On which particular land is the generation of gross value added of a given economic activity actually taking place?

   Following this reasoning, one would look where a certain economic activity is taking place and would attribute this area to the value added generated directly by this activity. For instance, gross value added in agriculture and forestry (about 2-3% of total GVA) would be attributed to agricultural and forestry land (some 80% of the total territory). Gross value added generated in industry would be attributed to that part of built-up area which is used for industrial plants. Gross value added generated by the service sector would be attributed to the land used for office buildings and similar.

   The Statistical Office Germany has applied this approach (“Land-use NAMEA”). As a consequence of this approach, some 50% of the total territory cannot be attributed to any economic activity which is generating GVA, e.g. housings related to private households, or protected area. In the case of forestry, the question arises whether the total forestry area is used for GVA generation or only those parcels which have been actually logged.

b) Which land – as an aggregate – is appropriated to generate gross domestic product of a national economy?

In principle, this would be the total territory of a given national economy, since in Europe all land is more or less cultivated (i.e. influenced by humans and not in a natural state).

In addition, “hidden land-use” of imported goods have to be considered, since imported goods are required by the national production system to generate GDP. Further, it could be considered to deduct the “hidden land-use” of exported goods, in order to derive at an equivalent to MFA based consumption indicators (e.g. TMC or DMC). This leads to the following equation:

land use related to GDP = domestic land use + imported “hidden land” – exported “hidden land”

6.4 Data on land use and definition of possible land use intensity indicators inter alia comparable to DMC (task 6.b)

6.4.1 Introduction

Sub-task 6b relates to the empirical aspects of land use. Two main questions and related requirements with regard to data arise:

(1) Which land-use categories are the adequate ones to be considered in order to derive land-use equivalents to GDP and/or DMC respectively?
In principle, all land use categories which are used by humans to generate GDP and/or DMC respectively;
These are:

- agricultural land with its sub-categories (FAO classes)
    - arable land
    - permanent crops
    - permanent pastures
- forest and woodland (FAO class)
- those parts of built-up area land uses which are related to the generation of gross value added (UNECE class 3 - for details see Annex 9)

Note: from a material flow perspective, all built up area could be perceived as an equivalent to the use of construction minerals

(2) Which accounting elements are needed?

- Domestic land use
- Imports – indirect land uses associated to imported goods
- Exports – indirect land uses associated to exported goods

Table 6.2 Data matrix

	domestic	imports	exports
agricultural land (FAO classes) *- arable land* *- land under permanent crops*	*available from FAO data base*	*can be calculated: yields per hectare (country-specific) from FAO data base multiplied with import/export volumes from COMEXT foreign trade statistics;*	
- land under permanent pasture	*available from FAO data base*	*not available specifically, but in principle included due to use of land-use coefficients from process chain analyses of imported/exported animal products (German production)*	
forest and woodland (FAO class)	*available from FAO data base*	*not available; would require process chain analyses of imported/exported forestry products, wood, paper etc.*	
those parts of built-up area land uses related to the generation of GVA (UNECE classes): *- industrial areas (3.2)* *- land for quarries, pits and mines, etc. (3.3)* *- land for trade (3.4)* *- land for public services (3.5)* *- land for transportation and communication (3.7)* *- land for technical infrastructures (3.8)*	*aggregate of built-up area available for some countries from Eurostat NewCronos data base;* *for some countries also available for sub-categories*	*not available; would require process chain analyses of imported/exported goods;* *from LCA databases, some land-use coefficients are available; those relate to all kind of land-uses (the LCA coefficients database would have to be further developed in order to distinguish between agricultural land, forestry land and build up area), and LCA coefficients are not linkable to Eurostat COMEXT foreign trade statistics classes of goods;*	

From the data matrix above, it becomes obvious that for the time being a full-fledged land-use account (domestic + imports – exports) is only feasible for the grey shaded rows (i.e. agricultural land). Land under permanent pastures is included, however, based on requirements derived from the German agricultural animal production system (e.g. cow milk, pig meat, hen eggs). This may rather cause a tendency to underestimate land use associated with imported or exported animal products in case that the relatively high yields from German pastures deviate significantly from respective yields in countries producing animal products for international trade. The respective data for land use associated with imports and exports of animal products may therefore rather represent a lower estimate. This uncertainty could be overcome by results obtained from specific land use requirements studies for each country involved in foreign trade of animal products in and outside Europe. Such a country specific study needs to be based on detailed data for feedstuff requirements of domestic livestock, differentiated by domestic and foreign origin, and data for domestic production of animal products. Such data are available for Germany in the agricultural statistics of the Ministry of Agriculture. Still, considerable efforts in time are required to derive the land-use coefficients for animal products. This is beyond the scope of this study. It could be part of future activities towards a European database for material and land use accounting.

6.4.2 Data availability for domestic land use for EU-15 and ACC-13

(although, meanwhile 10 New member States joined the EU, the old term "ACC-13" is used here)

The following table shows the data availability for domestic land use taken from the EEA land use data set, which is based on FAO land use database. The land use categories distinguished in this database are relatively broad. It allows deriving time series for agricultural land and forest- and woodland for the EU-15 and Member States for 1961 to 2000 in general. For ACC-13 in total, respective time series are available for 1993 to 2000. The data set only contains a residual land use category "all other land" which may comprise built-up area but which also may comprise natural and/or semi-natural areas.

Table 6.3 Domestic land use, EEA/FAOSTAT

Item: Domestic land use
Data source: EEA based on FAOSTAT

Land use categories	Time series		Remarks on land use categories
	EU-15 and MS	ACC-13	
Agricultural Area	1961-2000	1993-2000	related to domestic harvest of renewable raw materials
Arable Land	1961-2000	1993-2000	
Permanent Crops	1961-2000	1993-2000	
Permanent Pasture	1961-2000	1993-2000	
Forest and Woodland	1961-2000	1993-2000	related to domestic harvest of renewable raw materials
All Other Land	1961-2000	1993-2000	may comprise built-up and natural/semi-natural areas
Land Area	1961-2000	1993-2000	
Total Area	1961-2000	1993-2000	total minus land area assumed to equal water area

General remarks:
data for EU-15 and MS largely complete for entire time series.
1961-2000 time series for ACC-13: Bulgaria, Cyprus, Hungary, Malta, Poland, Romania, Turkey.
For Estonia, Latvia, Lithuania, Slovenia only for 1992-2000, for Czech Republic and Slovakia only for 1993-2000.

Since the EEA/FAO data set does not distinguish built-up land in detail, the Eurostat NewCronos database[35] has been approached. In principle, the Eurostat NewCronos land use data are following the ECE standard classification (see Annex 9), however, data are widely incomplete across countries and land use categories. Data for built-up area have the following sub-categories, of which land for quarries, pits and mines etc. stands in general for direct land use associated with domestic extraction of non-renewable raw materials:

Table 6.4 Domestic land use, Eurostat New Cronos

Item: Domestic land use
Data source: Eurostat NEW CRONOS

Land use categories
LA_3 Built-up and related area
LA_3_1 Residential areas
LA_3_2 Industrial areas
LA_3_3 Land for quarries, pits and mines etc.
LA_3_4 Land for trade
LA_3_5 Land for public services except transport, communication and technical infrastructure
LA_3_6 Land for mixed use
LA_3_7 Land for transport and communication
LA_3_8 Land for technical infrastructure
LA_3_9 Recreational and other open areas

Data availability for built-up area, in particular for land for quarries, pits and mines etc., is shown for the EU-15 and Member States in the following table. The table provides at first sight the result that a comprehensive land use account for built-up land and land associated with domestic extraction of non-renewable raw materials for the entire EU-15 is not possible on this basis.

- Ireland and Italy did not report any data, and Greece and the UK did not report totals for built-up and related land. In these cases (and in other cases of incomplete time series), national authorities were contacted with the result shown in the following.
- Data for Germany exclude the former GDR before 1991 and would have to be supplemented by national data for 1990 and preceding years.
- Data for land for quarries, pits and mines etc. is, in addition to gaps for total built-up land, not reported for Finland and Spain, and data available are quite rare posing an additional problem to the derivation of aggregated data for the EU and for time series. The data problem related to land for quarries, pits and mines etc. may, however, be overcome by multiplying land use coefficients in terms of ha per t non-renewable materials extracted, derived from the reported data, with the amounts of respective extraction in t, to obtain estimates for land use associated

[35] This land use data are based on the bi-annual joint OECD/Eurostat questionnaire.

with the domestic extraction of non-renewable raw materials in all EU countries. This will be described later.

Table 6.5 Built-up and related land in the EU-15

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	LA_3 Built-up and related area							Remarks	
	1950	1970	1980	1985	1990	1995	2000	sub-categories	other
EU-15									
Austria					X	X		all for 1990; 3_3, 3_9: 1995; 3_7: 1995, 2000	
Belgium			X	X	X	X	X	all available	
Luxembourg					X			3_5, 3_6, 3_8, 3_9: n.a.	
Denmark					X	X	X	3_2: n.a.; others only 1990 to 2000	
Finland								none available	
France						X	X	3_1 to 3_9: only 1995 and 2000	
Germany				X	X	X	X	3_1, 3_2, 3_4, 3_5, 3_6, 3_8: n.a.; 3_3: 85-00; 3_7, 3_9: 80-00;	incl. Former GDR only since 1995
Greece								only 3_1, 3_6 available: 1970, 1985	totals for 3 not available
Ireland									no data at all available
Italy									no data at all available
Netherlands			X	X	X	X	X	3_4: n.a.; 3_1, 3_2, 3_3, 3_5, 3_6: only 1980 to 2000	
Portugal							X	only 3_1, 3_2, 3_3 available: for 2000	
Spain								only 3_1 available: for 1995	
Sweden			X		X	X		all except 3_6: 1980, 1990, 2000; 1970: none	
UK				x	x		x	only 3_1, 3_3, 3_7 available: 1985, 1990, 2000	totals for 3 not available
Data for 3_3 land for quarries etc. available:	X								
Data for 3_3 land for quarries etc. available, but no totals for 3:	x								

Starting from this available database for built-up and related land in the EU-15 and MS, we contacted national authorities in all EU Member States for which additional data were needed, asking for the status and projected developments of a national database for built-up and related land. The results of this inquiry are described in detail in Annex 9. Unfortunately, no further improvement of the NEW CRONOS EU-15 database for built-up land could be achieved by this inquiry for EU-15 countries.

Data availability for built-up and related land, in particular for land for quarries, pits and mines etc. is shown for the ACC-13 in the following table. In general, the data situation is even more critical as for the EU-15 and Member States. As described before, two principle approaches can be followed in order to overcome these data problems. First, data search at national statistical offices, and this will be described in the following. Second, application of known coefficients to derive estimates for land use associated with the domestic extraction of non-renewable raw materials in all ACC countries.

Table 6.6 Built-up and related land, ACC-13

	LA_3 Built-up and related area							Remarks	
	1950	1970	1980	1985	1990	1995	2000	sub-categories	other
ACC-13									
Bulgaria									no data at all available
Cyprus								none available	
Czech Republic								only 3_6, 3_7 for all years available	
Estonia									no data at all available
Hungary								3_1: 1980; 3_4: 1990; 3_6, 3_7: 1980-1995; 3_9: 1985	totals for 3 not available
Latvia								3_1, 3_7: 1970, 1985, 1990	
Lithuania								none available	
Malta							X	3_1, 3_2, 3_3, 3_7 for 2000	
Poland	X	X	X	X	X	X	X	3_1, 3_3, 3_7: complete; 3_2, 3_5, 3_9: 2000	
Romania								none available	
Slovakia								none available	
Slovenia							X	3_3, 3_8, 3_9: 2000; 3_7: 1995, 2000	
Turkey									no data at all available
Data for 3_3 land for quarries etc. available:	X								
Data for 3_3 land for quarries etc. available, but no totals for 3:	x								

Other sources than Eurostat New Cronos:
Malta: Environment Statistics 2002, NSO Malta
Romania: Statistical Yearbook Romania 2002: land for construction and roads and railway for 1990 to 2001

Starting from this available database for built-up and related land in the ACC-13, we contacted national authorities in all respective countries for which additional data were needed, asking for the status and projected developments of a national database for built-up and related land. The results of this inquiry are described in detail in Annex 9. However, only slight improvements as compared with NEW CRONOS could be achieved by this inquiry, in particular for Malta and Romania. However, the overall scattered data situation for built-up land in ACC-13 could not be improved.

6.4.3 Approaches to estimate missing data

Built-up land and land for quarries, pits and mines

Because of the limitations in the Eurostat NEW CRONOS database for built-up land, we tested two approaches to estimate data for built-up land (1) and land for land for quarries, pits and mines etc.(2).

The approach to estimate built-up and related land in total (1) is based on the assumption that this land category may be derived from the total other land area (which is total land area minus agricultural land and forest- and woodland) by using reference values for the share of built-up and related land in total other land. For every country, the total other land area can in principle be derived as a residual from total land area minus agricultural land and forest- and woodland (e.g. from FAOSTAT data). The reference values were derived from the datasets reporting on built-up and related land as described before. They are shown in the following table, along with changes of these ratios over the reporting periods.

Table 6.7 Built-up and related land as a % of other land area

Built-up and related land
% of other land area
DOMESTIC

	1990	Average change over period		1990	Average change over period
EU-15			Bulgaria		
Austria	20%		Cyprus		
Belgium-Luxembourg	48%		Czech Republic		
Denmark	57%	2%	Estonia		
Finland	16%	4%	Hungary		
France	37%	0%	Latvia		
Germany	49%	1%	Lithuania		
Greece			Malta		
Ireland			Poland	67%	-0%
Italy			Romania	64%	-1%
Netherlands	51%	2%	Slovakia		
Portugal	68%		Slovenia		
Spain	53%	0%	Turkey		
Sweden	12%	0%	ACC-13		
UK					

The result, however, was that shares of built-up land in total other land showed a high degree of variability, e.g. from 12% in Sweden to 68% in Portugal. Furthermore, these shares were found to vary differently over time, e.g. to be declining by 1% in Romania and to be increasing by 4% in Finland. We conclude, that in view of these high variations the envisaged estimation procedure for built-up land appears to be not suitable.

The approach to estimate land for land for quarries, pits and mines etc.(2) is based on the assumption that known coefficients in terms of domestic extraction of minerals and fossils per unit land area for quarries, pits and mines etc. could be used to derive estimates for this kind of land use associated with the domestic extraction of non-renewable raw materials. For every country, the domestic extraction of non-renewable raw materials (DEU) is known from the MFA database established in this study (task 1). The reference values (in thousand tonnes DEU per km^2) were derived from the datasets reporting on land for land for quarries, pits and mines etc. as described before. They are shown in the following table.

Table 6.8 Land for quarrying and mining

Land for quarrying and mining
intensity as '000 t DEU (fossils and minerals) per km2
DOMESTIC

	1990	1995	2000		1995	2000
EU-15				Bulgaria		
Austria	890	1.181		Cyprus		
Belgium-Luxembourg	1.525			Czech Republic		
Denmark	1.964	3.481	4.598	Estonia		
Finland				Hungary		
France		652	678	Latvia		
Germany		599	573	Lithuania		
Greece				Malta		781
Ireland				Poland	836	899
Italy				Romania		
Netherlands	2.728	2.683	3.465	Slovakia		
Portugal			436	Slovenia		1.068
Spain				Turkey		
Sweden	445	437		ACC-13		
UK	1.153		1.031			

The table clearly shows that a high variability of these reference values was found in EU-15 and ACC-13 countries, e.g. from 436 kt per km^2 in Portugal in 2000 to 4.598 kt per km^2 in Denmark in 2000. In addition, changes over time might be considerable. As for example in Denmark between 1990 and 2000. The interpretation of these derived coefficients, however, seems critical. The UNECE definition of “land used for quarries, pits, mines and related facilities” is: “Land which is used in connection with mining and quarrying activities (ISIC/ Rev. 3 division 10- 14), including abandoned mines and quarries not put to a different use”. A much more detailed “survey of land for mineral workings in England” (2000) presents information about the land-use extent of all surface and underground mineral workings and areas for the surface disposal of mineral working deposits which have valid planning permissions. From this it follows that the interpretation of different time series is critical without more detailed analysis, because e.g. in the case of England it is so that each survey that has been undertaken since 1974 is thought to be a more accurate reflection of the real extent of mineral workings. Furthermore, there is a basic difference between “permitted area”, and “worked area”. The “worked area” is what might be identified as a mineral working as it is visible as a hole in the ground. The “permitted area” will include some parcels of land which have a permit to operate, but which may never be worked. Also, the area of underground mineral workings is magnitudes larger that its surface “footprint”. This raises severe doubts about the cross-country and the over-time comparability of land use data for land for quarries, pits and mines etc. after the Eurostat NEW CRONOS database, and may explain some of the striking variations over time found in this study.

Thus, there is no way than to take data for built-up land and land for quarries, pits and mines etc. from original statistical data sources, being still aware that absolute comparability of time series for different economies may not be guaranteed. We will present and discuss the available respective data for EU-15 and ACC-13 in the following.

Land use associated with imports and exports

Land use associated with imports and exports of agricultural commodities was estimated by dividing quantities in tonnes by respective yields in tonnes per ha. The latter were taken from FAOSTAT, respectively from the database of the Wuppertal Institute. The latter refer to German and EU-15 imports and exports of agricultural raw materials respectively to the German production of plant products and animal products, and were applied to the other countries with the following exceptions:
Land use related to imports and exports of agricultural raw materials of the EU-15 in total was taken from a specific EU-study of the Wuppertal Institute (Schütz et al. 2003a),
Land use accounting for exports of agricultural raw materials in terms of field crops (cereals, vegetables, fruits, plant fibres) was based on country-specific yields in the individual countries of EU-15 and ACC-13.

For the EU-15 and Member States, respective data for imports and exports in metric tonnes had been acquired by work for task 1. For ACC-13, disaggregated data for imports and exports of agricultural commodities were acquired and sorted from the database of FAOSTAT. These data were available in great detail but diverting for imports and exports and among countries. As regards time series, these data were available for ACC-13 for 1992 to 1999, except for Czech Republic and Slovakia, which were for 1993 to 1999. Further development of the database for ACC-13 was therefore on aggregation of the diverse commodities structures to a comparable data format as applied for EU-15, i.e. the 2-digits level of the Eurostat Comext foreign trade nomenclature (HS-CN), as well as on the derivation of land use coefficients applicable to the import and export categories for commodities of ACC-13.

6.4.4 Domestic land use data

Available data for domestic built-up land and land for the extraction of non-renewables in EU-15 and ACC-13

In every country of EU-15 reporting on built-up land in time series, an increase can be observed (see following table). This increase was on the average as low as 0.1% per year in Spain and as high as 4% per year in Denmark. Data for Germany (re-united Germany only for 1995 and 2000) differed considerably between NEW CRONOS data and data published by the Federal Statistical Office Germany (FSOG). The reason for this is unknown, but we prefer to use the FSOG data being part of the environmental and economic accounting database of FSOG.

Table 6.9 Estimated built-up and related land, EU-15

Built-up and related land km^2 Source: Eurostat NEW CRONOS and national data sources

DOMESTIC

	1950	1970	1980	1985	1990	1995	2000	Change over period	Average change over period
EU-15									
Austria	:	:	:	:	3.112	3.410	3.817	23%	2,3%
Belgium-Luxembourg					5.200				
Denmark	:	:	4.071	5.079	5.887	6.664	7.291	79%	4,0%
Finland	:	4.580	7.730	:	7.520	7.595	:	66%	2,2%
France	:	:	:	32.448	35.148	39.159	42.104	30%	2,0%
Germany	18.274	25.226	30.004	31.906	33.720	42.183	45.735	8%	1,7%
Greece	:	:	:	:	:	:	:		
Ireland	:	:	:	:	:	:	:		
Italy	:	:	:	:	:	:	:		
Netherlands	2.857	3.288	5.144	5.396	5.386	5.608	5.754	101%	2,0%
Portugal	:	:	:	:	14.140	:	16.367	16%	1,6%
Spain	:	18.768	18.518	19.128	19.292	:	:	3%	0,1%
Sweden	:	11.000	10.890	:	11.720	:	:	7%	0,3%
UK	:	:	:	:	:	:	:		
Belgium	:	:	4.344	4.645	4.980	5.336	5.640	30%	1,5%
Luxembourg	:	:	:	:	220	:	:		
Germany from FSOG						41.179	43.447	6%	1,1%

As observed for EU-15 countries, built-up land increased as well for ACC-13 countries reporting these data. The following table shows only one exception, i.e. Romania with a slight decline of built-up land, even from 1995 to 2000. In contrast, Slovenia had increased its built-up land by 32% from 1995 to 2000, i.e. by 6.3% per year.

Table 6.10 Estimated built-up and related land, ACC-13

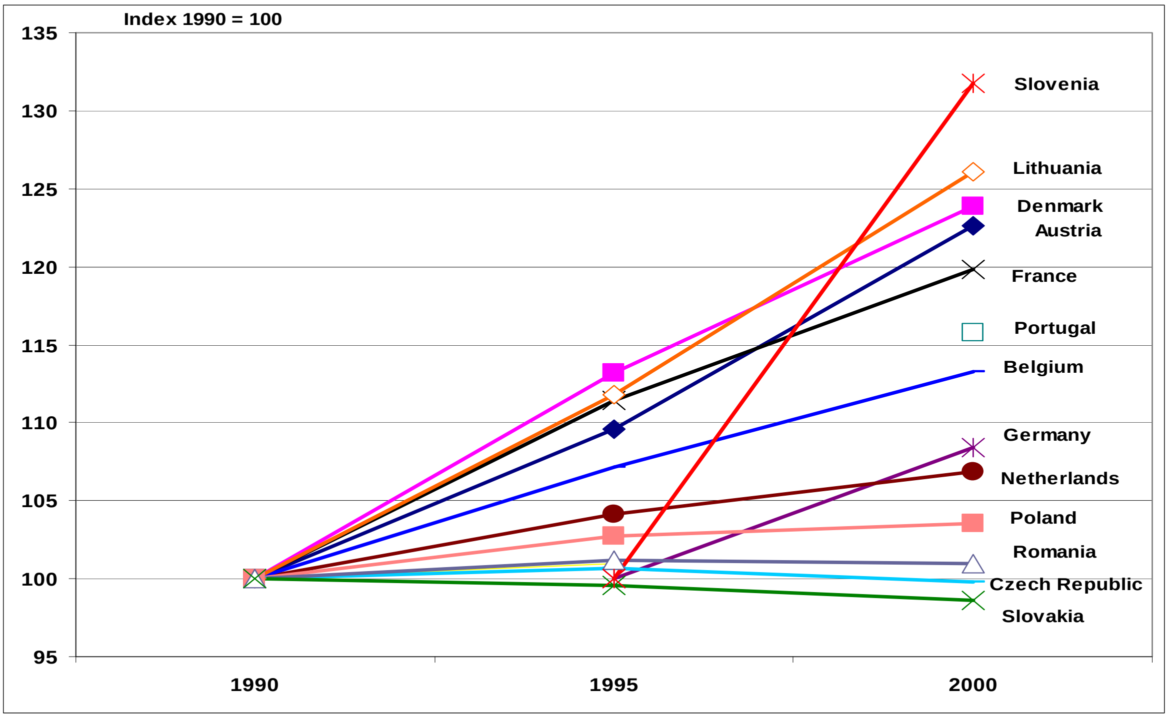
Built-up and related land km² Source: Eurostat NEW CRONOS and national data sources

DOMESTIC

	1950	1970	1980	1985	1990	1995	2000	Change over period	Average change over period
Bulgaria	:	:	:	:	:	:	:		
Cyprus	:	:	:	:	:	:	205		
Czech Republic	3.711	6.805	7.399	7.795	8.119	8.176	8.100	118%	2,4%
Estonia	:	:	:	:	:	:	:		
Hungary	:	:	:	:	:	:	:		
Latvia	1.741	2.213	2.749	2.648	2.632	:	:	51%	1,3%
Lithuania	:	1.056	1.338	1.421	1.574	1.760	1.984	88%	2,9%
Malta	:	:	:	:	:	:	73		
Poland	11.948	16.080	18.353	19.221	19.830	20.368	20.531	72%	1,4%
Romania	:	:	10.297	9.452	10.112	10.234	10.210	-1%	-0,0%
Slovakia	2.631	3.396	3.832	3.851	3.737	3.720	3.684	40%	0,8%
Slovenia	:	:	:	:	:	604	795	32%	6,3%
Turkey	:	:	:	:	:	:	:		
ACC-13									

The following figure illustrates recent trends of built-up areas in EU-15 and ACC-13 countries reporting these data.

Figure 6.3 Trends in built-up land, EU-25 + AC-3, 1990 - 2000



An important indicator for the loss of natural and reproductive land in an economy is the temporal trend of built-up land which by definition can occur only at the cost of agricultural land, land for forests and wood, and/or natural and semi-natural areas. This is documented in the following table for EU-15. In 2000, built-up land required from 4.6% of the total area in Austria to as much as 18.5% in Belgium and 18.3% in Portugal. Naturally, these shares had increased to the same extent as reported before for the absolute extension of built-up land, i.e. from 0.1% on the average per year in Spain to 4% per year in Denmark.

Table 6.11 Built-up and related land as % of total area, EU-15, 1950 - 2000

Built-up and related land %of total area *DOMESTIC*	1950	1970	1980	1985	1990	1995	2000	Change over period	Average change over period
EU-15									
Austria					3,7%	4,1%	4,6%	23%	2,3%
Belgium-Luxembourg					15,7%				
Denmark			9,4%	11,8%	13,7%	15,5%	16,9%	79%	4,0%
Finland		1,4%	2,3%		2,2%	2,2%		66%	2,2%
France				5,9%	6,4%	7,1%	7,7%	30%	2,0%
Germany	7,4%	10,2%	12,1%	12,8%	13,6%	11,8%	12,8%	8%	1,7%
Greece									
Ireland									
Italy									
Netherlands	8,4%	9,0%	13,8%	14,5%	13,5%	13,7%	13,9%	64%	1,3%
Portugal					15,4%		18,3%	19%	1,9%
Spain		3,7%	3,7%	3,8%	3,8%			3%	0,1%
Sweden		2,4%	2,4%		2,6%			7%	0,3%
UK									
Belgium			14,2%	15,2%	16,3%	17,5%	18,5%	30%	1,5%
Luxembourg									
Germany from FSOG						11,5%	12,2%	5%	1,1%

The range of built-up land as a share of total area was even higher in ACC-13 countries than in EU-15. the following table shows only 2.2% for Cyprus in 2000, and as much as 23.3% for Malta in 2000. As reported for absolute values, these shares of built-up land of the total area had slightly decreased only for Romania, but they did increase in all other ACC countries reporting on built-up land, in particular in Slovenia by 6.3% per year on the average from 1995 to 2000.

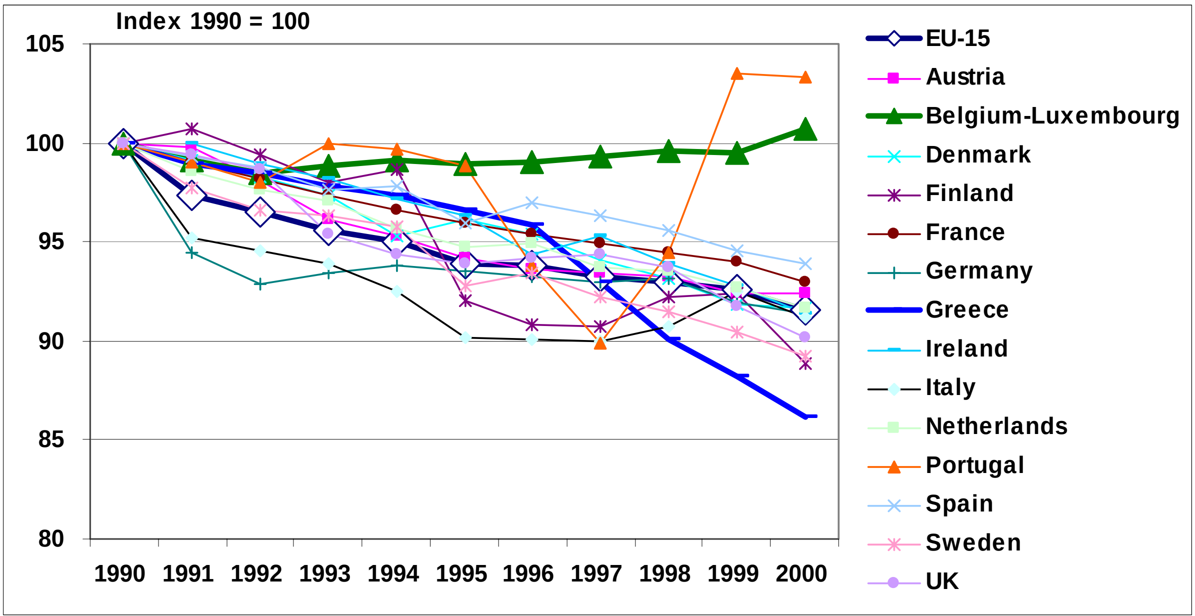
Table 6.12 Built-up and related land as % of total area, ACC-13, 1950 - 2000

Built-up and related land %of total area *DOMESTIC*	1950	1970	1980	1985	1990	1995	2000	Change over period	Average change over period
Bulgaria									
Cyprus							2,2%		
Czech Republic	4,7%	8,6%	9,4%	9,9%	10,3%	10,4%	10,3%	118%	2,4%
Estonia									
Hungary									
Latvia	2,7%	3,4%	4,3%	4,1%	4,1%			51%	1,3%
Lithuania		1,6%	2,0%	2,2%	2,4%	2,7%	3,0%	88%	2,9%
Malta							23,2%		
Poland	3,8%	5,1%	5,9%	6,1%	6,3%	6,5%	6,6%	71%	1,4%
Romania			4,3%	4,0%	4,2%	4,3%	4,3%	-1%	-0,0%
Slovakia	5,4%	6,9%	7,8%	7,9%	7,6%	7,6%	7,5%	40%	0,8%
Slovenia						3,0%	3,9%	32%	6,3%
Turkey									
ACC-13									

Domestic land use changes with focus on agricultural area

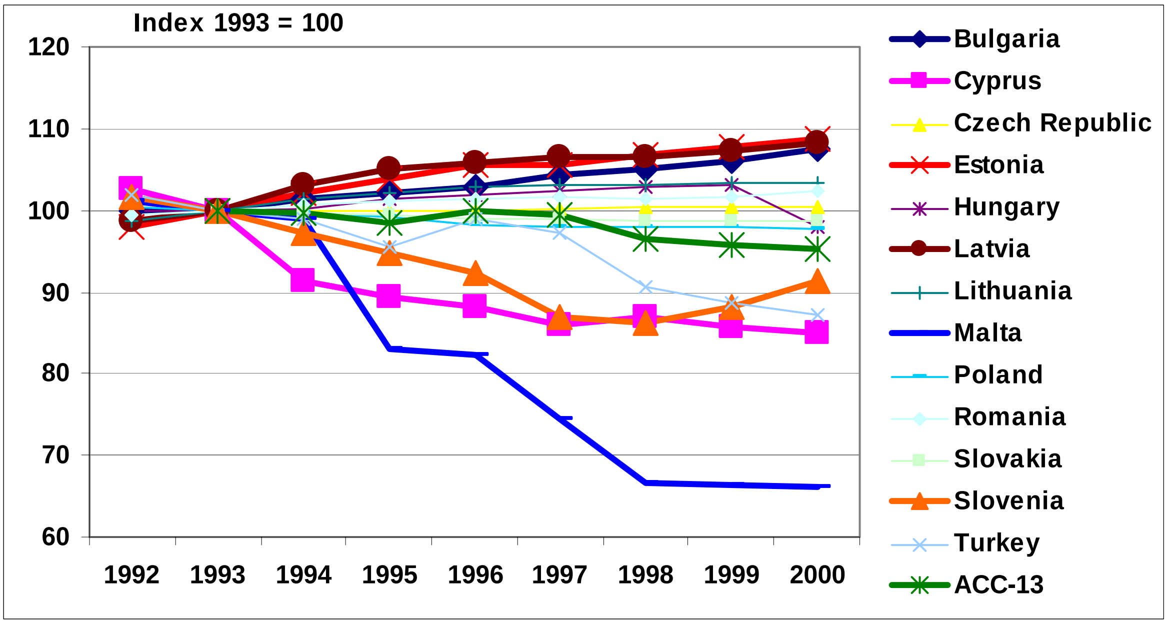
Whereas built-up areas show an increasing tendency in most European countries studied, empirical evidence suggest that in particular agricultural areas are diminished as a consequence of this increase. This is illustrated in the following figure for EU-15 and its Member States. It shows that domestic agricultural land has in fact decreased from 1990 to 2000 in most EU-15 countries and in the EU-15 in total as well. The only two exceptions are Belgium and Luxembourg with even a slight increase over the period, and Portugal with a “strange” fluctuation of its agricultural land use data (the reason for which could not be found out yet, also not by search for original data at Statistics Portugal).

Figure 6.4 Trends in domestic agricultural land use, EU-15, 1990 - 2000



The trend of agricultural areas in ACC-13 countries is more diverse than in EU-15. The following figure shows that some countries exhibit strong decreases, especially Malta and Cyprus, some less expressed increases, like Bulgaria, Estonia, Latvia, and some only slight changes over the period 1992 to 2000. The overall trend for ACC-13 was a slight decrease by 5% from 1993 to 2000.

Figure 6.5 Trends in domestic agricultural land use, ACC-13, 1990 - 2000



The above indicated shift of domestic land use from mainly agricultural areas to built-up areas in many European countries is of course only one aspect in this context. A comprehensive picture is obtained from consistent domestic land use accounts indicating specific land use changes for sub-categories. Two examples for such accounts are presented in the following: Germany (Schütz 2003) and Slovakia (Office of Geodesy,Cartography and Cataster of the SR).

The biggest individual share of land use in Germany is for agricultural area at about 53.5% of the total land area in 2001 (Table 6.13). However, the agricultural area was also the only land use which

significantly decreased between 1993 and 2001 by 4084 km², i.e. by about 2% as compared with 1993. This decrease was mainly due to the expansion of the total area for settlements and traffic (or built-up area) that increased by 3634 km² or 9% over this period, in particular the area for buildings and open space (2348 km²), the traffic area (677 km²) and the recreation area (404 km²).
This increase of the area for settlements and traffic equalled 129 hectares per day or 15 square meters every second on the average for the period 1997 to 2001, and for 2000, and the rate of increase was even accelerating from 1997 to 2000 (Table 6.14). The goal of the German government within its strategy for sustainable development is to reduce this increase to 30 ha per day by 2020 which means a reduction by about 77% or by a factor of about 4.3.
An increase of the German forest area and the decrease of agricultural land had resulted in an overall decrease of the total area for re-growing resources from 1993 to 2001 by 3306 km² or by about 1% (Table 6.13). In Germany in 2001, about 83% of the total land was used for re-growing resources. This indicates that the domestic land is already used to a high extent for regenerative resources and a further increase of the renewable share of materials use will require an increase in material efficiency. The direct extraction area for non-re-growing resources is small at 33 km² in 1997 however, interpretation of this number should take into account the limitations associated with it as discussed in Schütz (2003).

Table 6.13: Land use in Germany 1993 to 2001.

	km2			%			1993=100			km2		
	1993	1997	2001	1993	1997	2001	1993	1997	2001	1993-1997	1997-2001	1993-2001
Total land	**356.970**	**357.030**	**357.031**	**100%**	**100%**	**100%**	**100**	**100**	**100**	**60**	**1**	**61**
Area for buildings and free spaces	20.733	21.937	23.081	5,8%	6,1%	6,5%	100	106	111	1.204	1.144	2.348
Commercial areas	2.427	2.514	2.528	0,7%	0,7%	0,7%	100	104	104	87	14	101
Commercial area excl. Land for resource extraction	550	620	732	0,2%	0,2%	0,2%	100	113	133	70	112	182
Land for resource extraction	1.878	1.894	1.796	0,5%	0,5%	0,5%	100	101	96	16	-98	-82
Recreation area	2.255	2.374	2.659	0,6%	0,7%	0,7%	100	105	118	119	285	404
Traffic area	16.441	16.786	17.118	4,6%	4,7%	4,8%	100	102	104	345	332	677
Roads	14.815	15.201	15.264	4,2%	4,3%	4,3%	100	103	103	386	63	449
Other traffic area	1.626	1.579	1.854	0,5%	0,4%	0,5%	100	97	114	-47	275	228
Agricultural area	195.112	193.075	191.028	54,7%	54,1%	53,5%	100	99	98	-2.037	-2.047	-4.084
Forest area	104.536	104.908	105.314	29,3%	29,4%	29,5%	100	100	101	372	406	778
Water area	7.837	7.940	8.085	2,2%	2,2%	2,3%	100	101	103	103	145	248
Areas for other uses	7.630	7.497	7.219	2,1%	2,1%	2,0%	100	98	95	-133	-278	-411
Cemetary	327	335	350	0,1%	0,1%	0,1%	100	102	107	8	15	23
Areas for other uses excl. Cementary	7.302	7.091	6.869	2,0%	2,0%	1,9%	100	97	94	-211	-222	-433
Aggregate: settlement- and traffic-area (shaded categories)	40.305	42.052	43.939	11,3%	11,8%	12,3%	100	104	109	1.747	1.887	3.634
Other categories:												
Area for re-growing resources	299.648	297.983	296.342	83,9%	83,5%	83,0%	100	99	99	-1.665	-1.641	-3.306
Area for non-re-growing resources (extraction area)	34	33		0,01%	0,01%		100	96		-1		

Source: Deggau 2002 and Schäfer et al. 2002 except area for non-re-growing resources

Area for non-re-growing resources 1997: Langer, Landesamt für Bodenforschung Niedersachsen, Hannover, personal communication on 28.11.2001; 1993 own estimate based upon that.

Table 6.14: Increase of settlement- and traffic- area in Germany.

Increase of settlement- and traffic- area		
	ha per day	m2 per second
from 1993 to 1997	120	14
from 1997 to 1998	121	14
from 1997 to 2001	129	15
in 1997	120	14
in 1998	124	14
in 1999	130	15
in 2000 (preliminary data)	129	15
Target for 2020	30	3

Source for single years and target: http://www.umweltbundesamt.de/dux/bo-inf.htm

Note: it is assumed that about 50% of this area is sealed:

http://www-public.tu-bs.de:8080/~schroete/Bodenverbrauch/Aktueller_Stand.htm:

Our second example, Slovakia, provides direct information on qualitative and quantitative agricultural land use changes (Table 6.15). Gross decreases and increases of agricultural land are each indicated by the (main) types of land use concerned, which seems to be forestland in this case. Unfortunately, however, a big share of the total decrease and even the biggest share of the total increase of agricultural land is not directly allocated to causes. But in principle, such kind of information, extended by comprehensive data on specific land use changes between single categories in form of a matrix, and maybe extended by more details on e.g. quality of agricultural land, could be considered as a good example for future monitoring of domestic land use in the EU.

Table 6.15: Agricultural land use changes 1995 to 2000 in Slovakia.

	Changes from 1995 to 2000 000 ha
Decrease of agricultural land – total	8,38
of which due to:	
Civil and housing construction	1,05
Industrial construction	0,20
Construction of water works	0,14
Other investment purposes	0,89
Mining	0,05
Afforestation	4,26
Total increase in agricultural land	4,02
of which: Due to deforestation	1,03
Net decrease of agricultural area	4,35

Source: Office of Geodesy,Cartography and Cataster of the SR

Productivities of built-up areas

We have discussed in the beginning of this chapter that built-up land is one important component of land use to be taken as the equivalent for GDP. In fact, the Federal Statistical Office Germany derives an area productivity indicator based on built-up land for the total economy (macro level) and branch specific area productivities (meso level) for each economic sector. This approach can be transferred to EU-15 and ACC-13 to derive comparable values for the absolute productivity of the GDP per unit built-up land and respective changes over the reporting periods. This approach, however, was not further followed in this study. For those interested in the comparison between data published for Germany and data derived in this study for other EU-15 countries and ACC-13 the results are shown in Annex 9.

Land for the domestic extraction of minerals and fossil fuels

Land for the domestic extraction of minerals and fossil fuels, being part of the total of built-up land, requires rather small parts of the total areas of EU-15 countries reporting these data. In other words, it represents a rather small fraction of built-up and related land. Respective results for EU-15 and ACC-13 are shown in Annex 9. Land for quarries, pits and mines etc. constitutes by definition a part of the total land use attributable to DMC and GDP. The data situation, however, constitutes a clear limitation to its use for deriving respective economy-wide land use indicators for the EU-15 and ACC-13. Furthermore, the wide range of land use intensities found for reporting EU and ACC countries as described before, puts another limit to the derivation of these data through estimates. Consequently, there is no other way than to establish this kind of data collection at national authorities in order to make them available on an internationally comparable and regular basis. The same holds for the total of built-up land as discussed before.

6.4.5 Results: Global Agricultural Land Use Indicator (GALU)

In the following, indicators related to agricultural land use on the global scale are presented. In analogy with material flow indicators, land use indicators may be defined by major accounting elements, also on a general level:

+ Domestic (Agricultural) Land Use:	D(A)LU
+ Land Use related to (Agricultural) Imports	LU(A)I
= Global (Agricultural) Land Requirement	G(A)LR
- Land Use related to (Agricultural) Exports	LU(A)E
= Global (Agricultural) Land Use	G(A)LU

Of these, Global (Agricultural) Land Use (G(A)LU) may be considered a headline indicator[36] – in analogy to DMC and EMC (whereas Global (Agricultural) Land Requirement - G(A)LR – is related to DMI).

Global agricultural land requirement and land use of EU-15 and Member States

In 2000, the agricultural area (consisting of arable land, permanent crops, and permanent pastures) of the EU-15 was about 141 million hectares, equivalent to about 0.37 ha per capita. It was mainly located in France, Spain, Germany, the UK and Italy. On a per capita basis, however, especially Ireland, Greece, and Spain ranged clearly above the EU average availability, whereas in particular The Netherlands and Belgium/Luxembourg had much lower per capita agricultural land than the EU average.

From 1990 to 2000, the agricultural area in the EU-15 had decreased by about 5%, on a per capita basis even by about 8%[37]. The same decreasing trend was found for all Member States except Belgium/Luxembourg and Portugal with slight increases of the domestic land use for agriculture. For all 15 Member States, however, it was found that per capita availability of agricultural land had developed less favourable than the absolute extent. In other words, for each citizen of the EU-15 countries, increasingly less domestic agricultural land became available during the 1990s. This decrease was most expressed for Ireland at minus 22% reduction in absolute terms and minus 28% reduction per capita, but most of this decrease took place from 1990 to 1991 and concerned permanent pastures mainly. It might therefore be that a statistical break in FAOSTAT data for permanent pastures in Ireland from 1990 to 1991 had occurred. To check this, we compared respective Eurostat NEW CRONOS data for permanent pastures areas in EU-15. The general disadvantage of NEW CRONOS data as compared with FAOSTAT data is mainly that they are for two countries (Greece, Sweden) not available for every year of the period studied (1990 to 2000). Furthermore, NEW CRONOS data show diverting differences among EU countries over time as compared with FAOSTAT. For example, the time series for permanent pastures area in Germany is almost identical in NEW CRONOS and FAOSTAT. But for Denmark, the comparability between these two data sources is given only for 1990 to 1993, from 1994 to 2000, however, the NEW CRONOS data are by 40% to 50% lower than FAOSTAT data. The overall effect for EU-15 is that permanent pastures area after NEW CRONOS is by 8% to 20% lower than data taken from FAOSTAT. Finally, NEW CRONOS does not provide consistent and complete data for the main sub-categories of agricultural land which are arable land, permanent crops and permanent pastures, whereas FAOSTAT does and was therefore preferred in this study. For our critical case of Ireland, NEW CRONOS reports by 18% lower values for permanent pastures areas in 1990 than FAOSTAT, but by 8% higher ones in 1991, by 6% higher ones in 1992, by 2% higher ones in 1993 and 1994, and almost identical numbers with FAOSTAT from 1995 to 2000. It could not yet be found out which database actually provides the more reliable time series in this case. A respective inquiry at Statistics Ireland did not result in a clear identification of the reasons for the statistical data break for permanent pastures area in Ireland from 1990 to 1991, but it revealed that methodological changes certainly contributed to it (Carol Finlay,

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[36] G(A)LU is defined – in analogy to DMC – as the extent of global (agricultural) land use related to the annual consumption of "new" (agricultural) materials by a national economy. In terms of eco-efficiency, this would mean to achieve more welfare from less global land use (G(A)LU per € GDP). Another relevant variant is G(A)LU per capita.

[37] For an illustrative presentation of the trends of domestic agricultural land use in EU-15 and MS, as well as in ACC-13, see figures in chapter before.

Agriculture Data, Central Statistics Office, Cork: personal communication on 2nd September 2004). The data problem itself, however, could not be solved in the end. Accordingly, numbers for agricultural land use in EU-15 and Member States presented in this report might change once consistent datasets have become available. It may be assumed, however, that these changes are relatively minor with respect to general conclusions that can be drawn from the current results. Furthermore, it will have only a minor influence on results for EU-15 in total because the agricultural area in Ireland constitutes only about 3% of the agricultural area in the EU.

The opposite was observed for agricultural land related to imports of agricultural commodities (raw materials, plant products, and animal products) of the EU-15 and Member States. With the exception of Germany, all other Member States of the EU and the EU-15 in total had increased their agricultural land requirement associated with imports from 1990 to 2000, and most obvious increases were found for Greece and Finland. Germany had slightly decreased its agricultural land requirement due to imports by 2%. The EU-15 increase was relatively moderate at about 7%.

Similarly, the EU-15 as well as all Member States had provided increasingly more land due to exports of agricultural commodities to the rest of the world. For the EU-15, this increase was higher (plus 17%) than for related imports (plus 7%), however, at a significantly lower absolute level (ca. 49 million ha agricultural land use by imports versus ca. 18 million ha associated with exports).

As a result, the *Global Agricultural Land Requirement (GALR)* had increased as well for most of the EU Member States (whereas domestic land use had decreased) except for Germany, Ireland, the UK and the EU-15 in total. For the EU-15 in total it had decreased slightly by 2% from 1990 to 2000, on a per capita basis by 6%.

The result for *Global Agricultural Land Use (GALU)* is more diverse among EU countries. The EU-15 in total, as well as Austria, France, Germany, Ireland, Italy, Sweden, and the UK had decreased their total agricultural land use in absolute terms from 1990 to 2000 on the global scale. On a per capita basis, this was further true for Finland and The Netherlands. Per capita, only Belgium/Luxembourg, Denmark, Greece, Portugal, and Spain had “occupied” increasing agricultural land areas globally from 1990 to 2000.

In comparison with agricultural land available for the world population in 2000, equal to 0.82 ha per capita, the EU-15 used significantly less at 0.46 ha per capita. If, however, the global availability of arable land and permanent crops is taken as a reference, the EU-15 ranges clearly above the global average of 0.25 ha per capita in 2000. This finding leads to a critical discussion of the relevant reference for agricultural land use on the global scale. Agricultural land for domestic consumption (DMC) in the EU includes domestic permanent pastures which are obviously intensively cultivated in the EU countries. Land use of the EU related to imports and exports implicitly also includes permanent pastures because the land use coefficients applied (in ha per t animal products by type) refer to the German agricultural animal production which largely depends on intensive use of domestic permanent pastures as far as production associated with ruminants is concerned (e.g. beef meat, cow milk, dairy products). This means that land use associated with imports of these animal products is most probably underestimated because productivity on permanent pastures in Non-EU countries, and in particular in countries of the South, is probably lower than in Germany. Thus, land use abroad of EU-15, which by definition concerns land use in Non-EU countries only, is probably underestimated by this account. This uncertainty, however, cannot be solved by simple corrections for lower productivities abroad. A specific account for land use related to domestic animal production in a country requires the availability of a range of detailed statistical data on specific feedstuff requirements of domestic livestock by type and related production data for e.g. meat, milk, dairy products etc. Based on such data, a production chain analysis can be performed leading to specific land use requirements per animal product. Such an analysis requires considerable time and is beyond the possibilities of this study. The results of this study should therefore be considered as a low estimate for global agricultural land use abroad by the EU.

Furthermore, permanent pastures in Non-EU countries, and in particular in countries of the South, may be rather considered as ecologically sensitive areas (e.g. semi-natural grasslands) with rather low productivities, and their conversion to arable land with (at first) higher productivities is empirically not desirable because soils were often found to be unsuitable for a continuing production of field crops. An example for this is Kazakhstan where the conversion of pasture land to arable land (mainly for producing wheat) during the former USSR times had led to significant losses of productivities over time resulting in a failure of this land use conversion. Subsequent secondary plant land cover, however, could not re-establish the original productivity of pastureland for domestic livestock.

These arguments lead to the conclusion that the global agricultural land use of the EU should rather be oriented towards the global per capita availability of arable land and permanent crops (0.25 ha per capita in 2000) than towards total agricultural area (0.82 ha per capita in 2000).

Another observation speaks also for this conclusion. From 1990 to 2000, the global availability of agricultural land per capita has decreased by 11%, for arable land and permanent crops by 12%. This decrease was even higher than for domestic agricultural land in the EU (minus 8%) and global agricultural land requirement of the EU (minus 7%). Based on population projections of the UN the global availability of arable land can be expected to decline to about 0.17 ha per capita in 2025[38]. The FAO projects that in the next 30 years developing countries will need an additional 120 million ha for crops (FAO 2002). This equals about 4 times the area that the EU requires currently by net imports of agricultural goods. Considering that there are limits to the further increase of hectare productivity, this would mean that the EU would have to reduce its global land use for consumption of agricultural goods (GALU) significantly within the next 20 to 30 years in order to leave other countries enough space for their own consumption of food and feed. As a result, the seeming excess of agricultural land in the EU and Europe has to be put into perspective. The analysis reveals that global land use of the EU is still on average with global availability with regard to food supply. Growing additional requirements for land use, however, e.g. for biofuels, renewable materials, built-up and conservation area will lead to increasing conflicts. Trade-offs between renewable resource supply and land use should be further studied on the basis of comprehensive material and land use accounts, especially with regard to the further development in the ACC. The economy of Eastern European countries is still based to a significant extent on agricultural production. Whereas a short-term adoption of current EU-15 practices would probably lead to a sharp decline of agricultural land use, however, mid-term to long-term requirements of sustainable resource management in Europe may require a continued use of this area, e.g. for sustainable supply with renewables (food and non-food), last but not least also for the world population. Further studies are necessary which consider global land use for the consumption of agricultural commodities in an extended EU, and analyze projections of future land use and resource supply in view of transition of the economies in Eastern Europe and global development trends.

Future studies should further deal with environmental impacts associated with agricultural land use. It is quite obvious that relatively high yields resulting in relatively low land use in economies are due to mostly intensive agricultural farming systems leading empirically to higher environmental pressures than on less intensively cultivated land or on land under controlled organic cultivation which in turn are characterized by relatively high land use. Thus, the mere extent of agricultural land use is certainly not sufficient as an indicator for natural resource use. It should rather be developed towards an indicator expressing the environmental burden associated with agricultural land use, e.g. in terms of mineral fertilizer and pesticides use, soil erosion, soil compression, groundwater pollution, negative effects on biodiversity, or quality of agricultural products (see also sections 4.1 and 4.2 on task 6a). Taking these aspects into account, the agricultural land use of the EU on the global scale may get a significantly higher weight than the mere numbers for land use in hectares tell.

Such a possible differentiation of agricultural land use in general by modes of farming (as discussed in section 4.2) is presented in the following based on results for domestic land use in Germany (Schütz 2003). The information on total land used for re-growing resources in Germany is insufficient as regards information on sustainable use types. In this context specific information is required as provided for example in a study of the UGR (Environmental Economic Accounting Division of Statistics Germany) that differentiated agricultural land use by management forms and by intensities of use (Schäfer et al. 2002). The agricultural area in Germany in 1997 was used by 98% on the basis of conventional farming and thus only to a low extent by ecological farming (TABLE D). The area of eco-farming had increased from 1993 to 1997 by 62% to 2% of the total agricultural area, at the end of

[38] Based on the medium population projection of the UN (8 billion people in 2025; UN 2002) and assuming no further net expansion in arable land (even an expected increase of agricultural land by 120 million ha over the next 30 years would just be equal to an increase of 2.41%, while the world population would increase over the same period by about 25-30% – Steger 2004). A decline of arable land per capita is also projected by the UN (2002).

2001 it had increased to 3.7% (634998 hectares), and the goal of the German government is to reach a share of 20% in the next 10 years (from 2002; www.bmvel.de).
About one third (36%) of the agricultural land in Germany in 1997 was managed at a high intensity of use[39] and another 47% were farmed at a medium intensity level. The four criteria for these intensity levels were developed by the Federal Statistical Office (Schäfer et al. 2002) in cooperation with experts: (1) the amount of fertilizers applied, (2) the frequency of applying pesticides, (3) the risk of soil compaction, and (4) the risk of erosion. After these criteria, only about 11% of the agricultural land in Germany 1997 could be classified to be of low-intensity, even less than in 1993 at 14% of the total agricultural land. It appears that despite progress made in extending the still small area of ecological farming, the overall intensity of the use of agricultural land in Germany has even increased significantly from 1993 to 1997 indicating that effective policy measures are required to reduce the overall intensity of use of agricultural land in order to promote more sustainable agricultural modes of production. Increasing the share of ecological farming may significantly contribute to this end.

Table 6.16: Agricultural land use in Germany 1993 and 1997.

	km2		%		1993=100		km2
	1993	1997	1993	1997	1993	1997	1993-1997
Total	**195.112**	**193.136**	**100%**	**100%**	**100**	**99**	**-1.976**
Conventional farming	192.712	189.239	99%	98%	100	98	-3.473
Ecological farming	2.400	3.897	1%	2%	100	162	1.497
High intensity of use	64.403	69.257	33%	36%	100	108	4.854
Medium intensity of use	86.522	89.884	44%	47%	100	104	3.362
Low intensity of use	26.526	22.072	14%	11%	100	83	-4.454
Intensity of use not determinable	17.660	11.922	9%	6%	100	68	-5.738

Source: Schäfer et al. 2002

Among the EU-15 Member States, Ireland, Greece and Spain even range above the global availability of total agricultural land per capita (0.82 ha in 2000) at about 1.3, 1.0 and 0.84 ha per capita respectively. For Greece and Spain, this is mostly due to a relatively high specific domestic land requirement for total agricultural production at about 0.25 ha per t in 2000, or vice versa, due to relatively low average productivities of the agricultural land in Greece and Spain. For comparison, the average specific domestic land requirement for total agricultural production in the EU-15 was about 0.11 ha per t, less than half of that for Greece and Spain. In the case of Ireland, however, the specific agricultural land requirement in 2000 was at 0.09 ha per t even lower than in the EU-15 on average. In Ireland, the high land use per capita for the domestic consumption of agricultural goods (1.34 ha per capita in 2000) is rather due to the high per capita availability of domestic agricultural land (1,15 ha per capita in 2000) which is mainly permanent pastures. This finding underlines the methodologically based uncertainties in the land use account performed here using average specific land use requirements derived from the German agricultural system, and in particular the animal production system. In case Ireland would require significantly more agricultural land to produce the same amounts of animal products like meat, milk etc than Germany, this would lead to higher absolute agricultural land requirements for agricultural exports of Ireland and, thus, reduce the absolute amount of agricultural land required for the domestic consumption of related goods in Ireland. As discussed before, this methodologically based uncertainty could only be overcome by specific accounts for the comprehensive agricultural production system in Ireland (and any other country studied) which is beyond the scope of this study. We therefore recommend including such specific accounts in national economy-wide material and land use accounts at e.g. the level of national statistical offices or similar institutions related to issues of sustainable development.

[39] This refers to the crops: winter wheat, summer wheat, triticale, corn maize, corn-cob-mix, potatoes, sugar beets, fodder beets, winter rape, hops, tobacco, grass on arable land, maize for silage, fruit plantations, vineyards.

Table 6.17: Agricultural land use account for EU-15 and Member States: absolute amounts and relative changes from 1990 to 2000.

	Domestic 2000		Imports 2000		Exports 2000		GALR 2000		GALU 2000	
	000 ha	Change from 1990 in %	000 ha	Change from 1990 in %	000 ha	Change from 1990 in %	000 ha	Change from 1990 in %	000 ha	Change from 1990 in %
EU-15	140.965	-5%	48.831	7%	17.521	17%	189.796	-2%	172.275	-4%
Austria	3.390	-1%	1.770	35%	1.587	67%	5.160	9%	3.573	-6%
Belgium-Luxembourg	1.543	4%	11.334	48%	7.115	58%	12.877	41%	5.762	24%
Denmark	2.647	-5%	2.858	39%	2.595	20%	5.505	14%	2.910	9%
Finland	2.212	-8%	772	92%	440	65%	2.984	7%	2.545	0%
France	29.706	-3%	11.724	23%	15.196	12%	41.430	3%	26.234	-1%
Germany	17.068	-5%	14.441	-2%	13.724	33%	31.509	-4%	17.785	-21%
Greece	8.529	-8%	2.959	187%	892	23%	11.488	12%	10.596	11%
Ireland	4.402	-22%	1.881	33%	1.185	21%	6.283	-11%	5.099	-16%
Italy	15.579	-7%	11.790	22%	5.191	78%	27.369	3%	22.178	-6%
Netherlands	1.956	-2%	17.949	23%	11.179	39%	19.905	20%	8.726	1%
Portugal	4.142	5%	3.083	29%	600	134%	7.225	14%	6.625	9%
Spain	29.671	-3%	9.291	71%	4.815	50%	38.962	8%	34.147	4%
Sweden	3.156	-8%	1.534	28%	990	59%	4.690	2%	3.701	-7%
UK	16.964	-7%	10.349	10%	4.146	18%	27.313	-1%	23.167	-4%

Austria: changes are for 2000 vs. 1995

Ireland: change of domestic land took place from 1990 to 1991 mainly and concerns permanent pastures mainly.

Table 6.18: Agricultural land use account for EU-15 and Member States: per capita and relative changes from 1990 to 2000.

	Domestic 2000		Imports 2000		Exports 2000		GALR 2000		GALU 2000	
	ha per capita	Change from 1990 in %	ha per capita	Change from 1990 in %	ha per capita	Change from 1990 in %	ha per capita	Change from 1990 in %	ha per capita	Change from 1990 in %
EU-15	0,37	-8%	0,13	3%	0,05	13%	0,50	-6%	0,46	-7%
Austria	0,42	-2%	0,22	34%	0,20	66%	0,64	8%	0,44	-7%
Belgium-Luxembourg	0,14	1%	1,06	43%	0,67	53%	1,20	36%	0,54	20%
Denmark	0,50	-8%	0,54	35%	0,49	16%	1,03	10%	0,55	5%
Finland	0,43	-11%	0,15	85%	0,08	59%	0,58	3%	0,49	-3%
France	0,50	-7%	0,20	18%	0,26	7%	0,70	-1%	0,44	-5%
Germany	0,21	-9%	0,18	-6%	0,17	28%	0,38	-7%	0,22	-24%
Greece	0,78	-14%	0,27	167%	0,08	15%	1,05	4%	0,97	4%
Ireland	1,15	-28%	0,49	23%	0,31	12%	1,65	-18%	1,34	-23%
Italy	0,27	-9%	0,20	20%	0,09	75%	0,48	2%	0,39	-7%
Netherlands	0,12	-8%	1,13	15%	0,70	31%	1,25	12%	0,55	-5%
Portugal	0,41	3%	0,31	27%	0,06	132%	0,72	12%	0,66	7%
Spain	0,73	-6%	0,23	65%	0,12	44%	0,96	5%	0,84	1%
Sweden	0,36	-11%	0,17	23%	0,11	54%	0,53	-2%	0,42	-11%
UK	0,29	-10%	0,18	7%	0,07	14%	0,46	-4%	0,39	-7%
World agricultural land									0,82	-11%
World arable and permanent crops land									0,25	-12%

Austria: changes are for 2000 vs. 1995

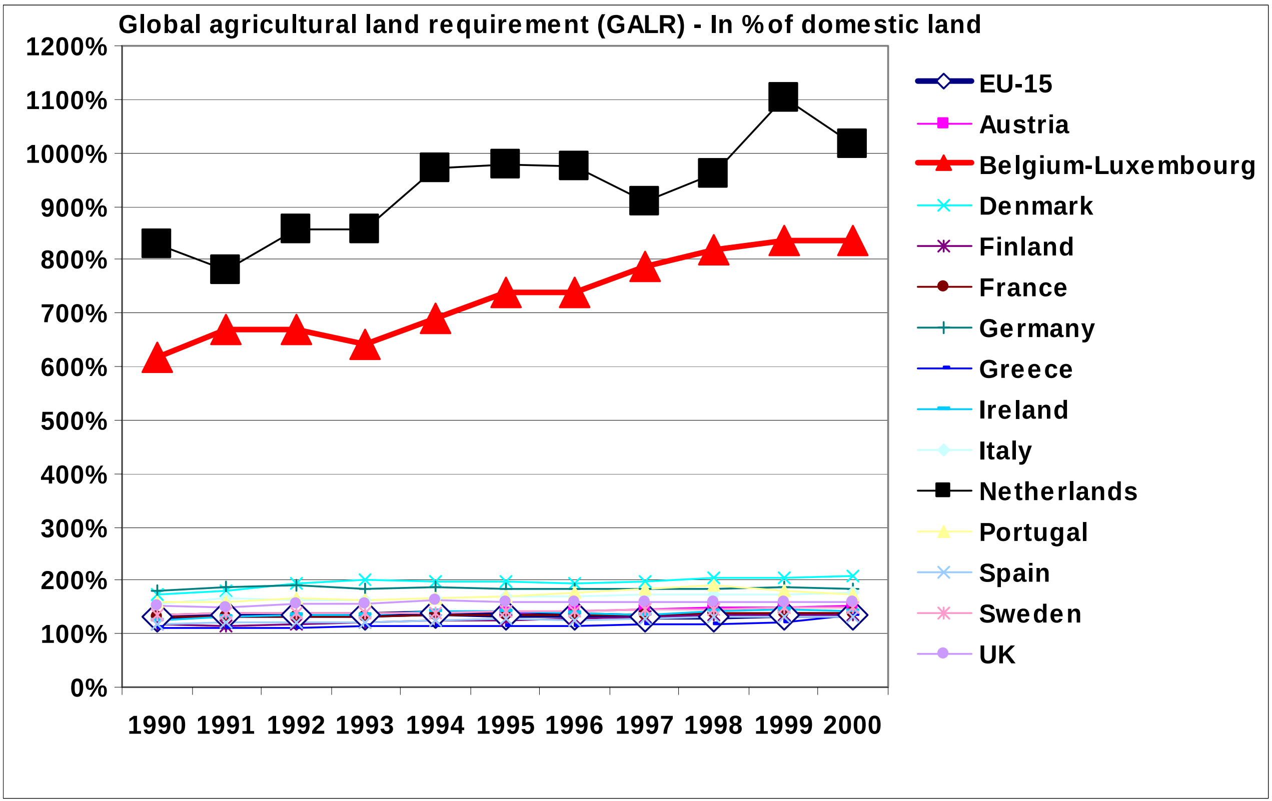
Ireland: change of domestic land took place from 1990 to 1991 mainly and concerns permanent pastures mainly.

World: changes related to 2000 vs. 1991

Setting the results for agricultural land use components into relation, it turns out that the EU-15 was requiring globally about 35% more agricultural land for domestic requirement (GALR) in 2000 than was available within the EU territory. Most of this requirement was due to domestic consumption in the EU-15 (91% in 2000) and resulted in about 22% higher agricultural land use for domestic consumption (GALU) on the global scale than the domestic agricultural land provided. The latter ratio, however, had remained rather constant from 1990 to 2000. The use of the relation of specific domestic agricultural land requirement for total agricultural production (in ha per t, 4th column of Table 6.18) has been described before.

Most of the EU countries had required additional agricultural land abroad in 2000 at a relatively similar ratio than the EU-15 in total (GALR). The most obvious exceptions from this are Belgium/Luxembourg and The Netherlands which had required about 8 times respectively 10 times more agricultural land abroad than domestically available. For The Netherlands, a similar finding was published by Milieudefensie (Friends of the Earth Netherlands). This is further illustrated in the following figure, Figure 6.10.

Figure 6.6 Global agricultural land requirement, EU-15, 1990 - 2000



This means that these three EU countries can be characterized by a domestic production system which is extremely depending on agricultural land availability outside their borders. This is supported by the finding that global agricultural land use for domestic consumption (GALU) in Belgium/Luxembourg and The Netherlands equalled only about 45% respectively 44% of the land required for agricultural material inputs into the production system (GALR). Still, domestic consumption of agricultural goods in Belgium/Luxembourg and The Netherlands is largely depending on agricultural land abroad exceeding the domestic agricultural areas by 273% respectively 346%. This is due to relatively low per capita availabilities of domestic agricultural land in these economies, whereas the total global agricultural land use per capita for domestic consumption (0.54 ha per capita for B/LUX, 0.55 ha per capita for NL in 2000) is not much higher than for the EU-15 average (0.46 ha per capita). This is further due to the highest productivities on domestic agricultural land among all EU Member States at only about 0.04 ha land required to produce one ton of agricultural raw material in Belgium/Luxembourg and The Netherlands, which is almost 3 times less than for the EU average of about 0.11 ha per t.

The only EU country that used less agricultural land for its domestic consumption of agricultural goods than was available on its own territory is France. In 2000, the agricultural land required for the domestic consumption of agricultural goods (GALU) in France accounted for only 88% of the domestic agricultural land area. From 1990 to 2000, France had continuously provided net agricultural land by exports to the rest of the world.

Table 6.19: Agricultural land use account for EU-15 and Member States: relations among components and relative changes from 1990 to 2000.

	GALR vs. Domestic 2000		GALU vs. GALR 2000		GALU vs. Domestic 2000		Domestic requirement 2000	
	%	Change from 1990 in %	%	Change from 1990 in %	%	Change from 1990 in %	ha per t	Change from 1990 in %
EU-15	135%	3%	91%	-2%	122%	1%	0,11	-7%
Austria	152%	10%	69%	-13%	105%	-5%	0,14	7%
Belgium-Luxembourg	835%	35%	45%	-12%	373%	19%	0,04	-12%
Denmark	208%	20%	53%	-5%	110%	14%	0,07	11%
Finland	135%	16%	85%	-6%	115%	9%	0,17	-5%
France	139%	6%	63%	-4%	88%	2%	0,10	-16%
Germany	185%	1%	56%	-18%	104%	-16%	0,07	1%
Greece	135%	21%	92%	-1%	124%	20%	0,25	-12%
Ireland	143%	14%	81%	-6%	116%	8%	0,09	-19%
Italy	176%	12%	81%	-9%	142%	2%	0,11	-10%
Netherlands	1018%	23%	44%	-15%	446%	4%	0,04	4%
Portugal	174%	9%	92%	-4%	160%	4%	0,12	2%
Spain	131%	11%	88%	-4%	115%	7%	0,25	-2%
Sweden	149%	10%	79%	-9%	117%	0%	0,12	-6%
UK	161%	6%	85%	-3%	137%	3%	0,11	-9%

Austria: changes are for 2000 vs. 1995

Ireland: change of domestic land took place from 1990 to 1991 mainly and concerns permanent pastures mainly.

Global agricultural land requirement and land use of ACC-13

In 1999, the domestic agricultural area (consisting of arable land, permanent crops, and permanent pastures) of the ACC-13 was about 99.5 million hectares or about 71% of the agricultural area of EU-15. In ACC-13 the agricultural area was equivalent to about 0.58 ha per capita, considerably more than in EU-15 at 0.37 ha per capita. It was mainly located in Turkey, Poland, Romania, Bulgaria and Hungary. On a per capita basis, however, especially the Baltic States Estonia, Latvia and Lithuania ranged clearly above the ACC average availability, whereas in particular Malta, Cyprus and Slovenia had much lower per capita agricultural land than the ACC average.

From 1993 to 1999, the domestic agricultural area in the ACC-13 had decreased by about 1%, on a per capita basis even by about 4%. This development was in general the same as in EU-15 though at a lower degree. The decreasing trend was especially due to the declining agricultural area in Turkey, and it was also observed in most of the other ACC-13 countries except Bulgaria, Czech Republic and Hungary with slight increases of the domestic land use for agriculture. Unlike in EU-15, where per capita availability of agricultural land had everywhere developed less favourable than the absolute extent, this was not the case for all ACC-13 countries. Bulgaria, Estonia, Latvia, Lithuania and Romania rather showed relatively higher changes in absolute agricultural area than per capita. And Bulgaria, Czech Republic, Estonia, Hungary, Latvia, Lithuania and Romania had even developed towards increasing per capita availability of agricultural land from 1993 to 1999. Thus, there was much more dynamics over the 1990s in the development of domestic agricultural land and population in transforming economies of Eastern Europe than in the EU-15.

This dynamic also refers to agricultural land use of ACC-13 countries associated with imported agricultural commodities. Unlike in the EU and its 15 Member States, where (with the only exception of Germany), all other Member States of the EU and the EU-15 in total had increased their agricultural land requirement associated with imports from 1990 to 2000, the situation was more diverse in ACC-13. ACC-13 in total had even decreased foreign agricultural land use by 2% from 1993 to 1999, per capita even by 5%. This development had been strongly influenced by Poland and Turkey constituting about 53% of the total foreign land use of ACC-13 due to imports of agricultural commodities. Whereas land use for these imports had increased for Turkey by 8% over this period, it had decreased for Poland by 16% in absolute terms. Even higher decreases were observed for Romania at minus 61% and Bulgaria at minus 34%. On the other hand, foreign agricultural land use had increased dramatically for Estonia at plus 320% and for Latvia at plus 211%. Obviously, ACC countries took a quite different development path in this respect in the course of economic development and integration into the world market during the 1990s. Some followed rather the general development of increasing foreign land use requirements as in EU-15, but the overall trend for ACC-13 was clearly different from that and points towards stable or even slightly declining foreign land use for imports of agricultural commodities. This development should be further monitored in order to evaluate whether the EU-15 path might be followed by ACC-13 during further economic development. In this context, the development is most likely to be significantly influenced by the extended EU-25 which should be investigated in future studies.

Similar to the development in the EU-15, and in contrast to imports, ACC-13 had provided increasingly more land due to exports of agricultural commodities to the rest of the world. For the ACC-13 in total, this increase was at plus 30% from 1993 to 1999 even higher than in the EU-15 (plus 17% from 1990 to 2000). Furthermore, and again unlike in EU-15, the absolute level of land use for exports of agricultural commodities (ca. 10.5 million ha) was higher than that for imports (ca. 7.5 million ha). This shows that ACC-13 countries, and in particular Hungary, Poland and Romania, had increasingly based their exports on commodities requiring (mainly domestic) agricultural land use. In how far this trend was associated with increasing trade of agricultural commodities with EU-15 in particular could be investigated in future studies.

As a result, *global agricultural land requirement (GALR)* had decreased slightly (minus 1% from 1993 to 1999) for ACC-13, on a per capita basis by minus 4%. This overall trend was mainly influenced by Turkey, Poland and Romania. An interesting exception is Estonia where global agricultural land requirements for agricultural goods had increased by 26% per capita from 1993 to 1999. The comparative increase rate for DMC is similar at plus 22%. Therefore, it seems that the Estonian population (and a similar situation is found in Latvia) had changed its consumption of food towards a significantly more land use intensive lifestyle. This is very likely in view of presumably increasing consumption of processed food and in particular animal products. It will be interesting to monitor whether also other ACC countries, and in particular the 10 new EU members, will take a similar path in the future, and which consequences this has on the overall agricultural land use of EU-25 on the global scale.

Taking the 1993 to 1999 period into consideration, *global agricultural land use (GALU)* associated with the domestic consumption of food and feed in ACC-13 had, however, taken a different development as found for the exceptional cases of Estonia and Latvia. It had actually declined by 4%, per capita even by 7%. This was found for most of the ACC-13 countries except for Bulgaria, the three Baltic States, and Malta. The reasons for this development remain unknown. It may be partly due to increasing area productivities for domestic agricultural land, or changes in the structure of the domestic agricultural system (e.g. declining populations of livestock as observed in many ACC countries), eventually counterbalancing increasing land use requirements for private consumption. This would require further investigation.

In comparison with agricultural land available for the world population in 2000, equal to 0.83 ha per capita, the ACC-13 required significantly less at 0.56 ha per capita, but more than EU-15 at 0.46 ha per capita. If, however, the global availability of arable land and permanent crops is taken as a reference, the ACC-13, like EU-15, range clearly above the global average of 0.25 ha per capita in 1999. This finding leads to a critical discussion of the relevant reference for agricultural land use on the global scale as outlined before under the interpretation of respective results for EU-15.

If the conclusion found for EU-15, i.e. that the global agricultural land use (GALU) of the EU should rather be oriented towards the global per capita availability of arable land and permanent crops (0.25 ha per capita) than towards total agricultural area (0.83 ha per capita), also applies to ACC-13, then, per capita requirements of ACC-13 range clearly above the global average availability of agricultural land.

From 1993 to 1999, the global availability of agricultural land per capita has decreased by 8%, for arable land and permanent crops as well by 8%. This decrease was even higher than for domestic agricultural land in the ACC (minus 4%) and global agricultural land use (GALU) of the ACC (minus 7%). A similar finding as for EU-15 in total. As outlined before, the global availability of arable land is expected to decline to 0.17 ha per capita in 2025, and the FAO projects that in the next 30 years developing countries will need an additional 120 million ha for crops. In this context, however, the situation in ACC-13 is basically different from that in EU-15. In EU-15, the agricultural area related to net-imports of agricultural goods equals about 4 times the projected area of 120 million ha additionally needed to sustain life in developing countries in the future. In other words, the EU-15 draws increasingly on foreign agriculture land which will be required by people in developing countries in the future. This is not the case for ACC-13. It is rather the case that ACC-13 countries in total are a net provider of agricultural land to the rest of the world, e.g. at about 3 million ha in 1999. However, this seems to be a rather small amount in view of the 120 million ha required additionally in developing countries. Furthermore, it would have to be figured out how much of the surplus is actually provided to the EU-15 and does not contribute to increase global agricultural land availability outside Europe. Consequently, the accounting and interpretation for global agricultural land use should be continued for the extended EU-25 and beyond in the future. This approach should be supplemented with prospective analysis taking e.g. future additional requirements for land use into account e.g. for biofuels or other renewable materials. Trade-offs between renewable resource supply and land use should be further studied on the basis of comprehensive material and land use accounts, especially with regard to the further development in the ACC. The economy of Eastern European countries is still based to a significant extent on agricultural production. Whereas a short-term adoption of current EU-15 practices would probably lead to a sharp decline of agricultural land use, however, mid-term to long-term requirements of sustainable resource management in Europe may require a continued use of this area, e.g. for sustainable supply with renewables (food and non-food), last but not least also for the world population. Further studies are necessary which consider global land use for the consumption of agricultural commodities in an extended EU, and analyze projections of future land use and resource supply in view of transition of the economies in Eastern Europe and global development trends.

Future studies should also consider environmental impacts associated with agricultural land use as described before. A key question will be to determine the optimal productivity of biomass per hectare, i.e. maximizing biomass production while minimizing environmental impacts or keeping them below critical levels.

Among the ACC countries, the three Baltic States Estonia, Latvia and Lithuania even range above the global availability of total agricultural land per capita (0.83 ha in 1999) at about 1.2, 1.1 and 0.96 ha per capita respectively. This cannot be explained by a relatively high specific domestic land requirement for total agricultural production which range clearly above the ACC-13 average of about 0.2 ha per t in 1999, or vice versa, it is not due to relatively low average productivities of the agricultural land in the Baltic States. The high land use per capita for the domestic consumption of agricultural goods in the three Baltic States is rather due to the high per capita availability of domestic agricultural land which is mainly arable land. Further studies might show which factors related to final domestic demand actually determine this relatively high per capita use of agricultural land in Estonia, Latvia and Lithuania.

Table 6.20: Agricultural land use account for ACC-13: absolute amounts and relative changes from 1993 to 1999.

	Domestic		Imports		Exports		GALR		GALU	
	1999		1999		1999		1999		1999	
	000 ha	Change from 1993 in %	000 ha	Change from 1993 in %	000 ha	Change from 1993 in %	000 ha	Change from 1993 in %	000 ha	Change from 1993 in %
Bulgaria	6.203	1%	218	-34%	778	4%	6.421	-0%	5.642	-1%
Cyprus	147	-8%	225	14%	82	5%	372	5%	290	4%
Czech Republic	4.282	0%	703	25%	970	111%	4.985	3%	4.015	-8%
Estonia	1.434	-1%	328	320%	158	63%	1.762	15%	1.604	12%
Hungary	6.186	1%	405	5%	1.935	34%	6.591	1%	4.656	-8%
Latvia	2.486	-1%	184	211%	45	-62%	2.670	4%	2.625	7%
Lithuania	3.496	-0%	217	34%	325	87%	3.713	1%	3.388	-3%
Malta	9	-31%	93	20%	2	-29%	102	13%	100	14%
Poland	18.435	-1%	1.620	-16%	1.505	34%	20.055	-3%	18.549	-5%
Romania	14.781	-0%	371	-61%	1.622	66%	15.152	-4%	13.531	-8%
Slovakia	2.443	-0%	300	-3%	369	25%	2.743	-0%	2.374	-3%
Slovenia	500	-11%	460	13%	462	39%	960	-1%	498	-21%
Turkey	39.050	-2%	2.327	8%	2.226	-0%	41.377	-2%	39.151	-2%
ACC-13	99.452	-1%	7.450	-2%	10.478	30%	106.902	-1%	96.424	-4%

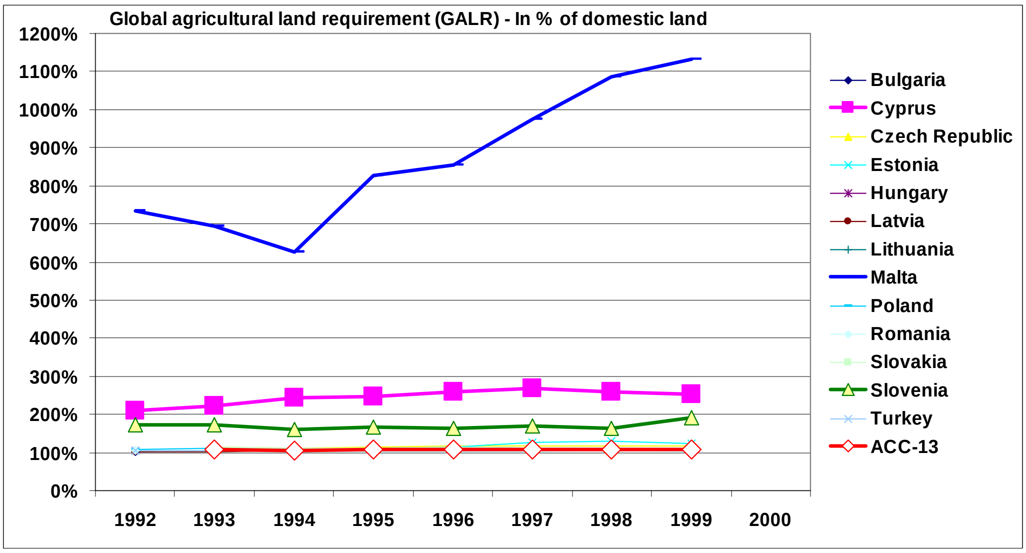
Table 6.21: Agricultural land use account for ACC-13: per capita and relative changes from 1993 to 1999.

	Domestic 1999 ha per capita	Domestic Change from 1993 in %	Imports 1999 ha per capita	Imports Change from 1993 in %	Exports 1999 ha per capita	Exports Change from 1993 in %	GALR 1999 ha per capita	GALR Change from 1993 in %	GALU 1999 ha per capita	GALU Change from 1993 in %
Bulgaria	0,76	6%	0,03	-31%	0,10	9%	0,79	4%	0,69	3%
Cyprus	0,19	-14%	0,29	6%	0,11	-2%	0,48	-3%	0,37	-3%
Czech Republic	0,42	0%	0,07	26%	0,09	112%	0,48	3%	0,39	-8%
Estonia	1,04	8%	0,24	359%	0,11	78%	1,28	26%	1,16	22%
Hungary	0,62	3%	0,04	7%	0,19	37%	0,66	3%	0,46	-6%
Latvia	1,04	7%	0,08	237%	0,02	-59%	1,12	13%	1,10	16%
Lithuania	1,00	3%	0,06	40%	0,09	94%	1,06	5%	0,96	1%
Malta	0,02	-34%	0,24	15%	0,00	-32%	0,26	8%	0,26	9%
Poland	0,48	-2%	0,04	-17%	0,04	34%	0,52	-3%	0,48	-6%
Romania	0,66	2%	0,02	-60%	0,07	70%	0,67	-2%	0,60	-7%
Slovakia	0,45	-1%	0,06	-4%	0,07	24%	0,51	-2%	0,44	-5%
Slovenia	0,25	-12%	0,23	12%	0,23	37%	0,48	-2%	0,25	-22%
Turkey	0,58	-11%	0,03	-3%	0,03	-9%	0,62	-11%	0,58	-11%
ACC-13	0,58	-4%	0,04	-5%	0,06	26%	0,62	-4%	0,56	-7%
World agricultural land									0,83	-8%
World arable and permanent crops land									0,25	-8%

Setting the results for agricultural land use components into relation, it turns out that the ACC-13 were requiring globally about 7% more agricultural land for domestic input of agricultural goods (GALR) in 1999 than was available within the ACC territory, much less than EU-15 in 2000 at plus 35%. Like in EU-15, most of this requirement was due to domestic consumption in the ACC-13 (90% in 1999). But unlike in EU-15, agricultural land use for domestic consumption (GALU) in ACC-13 on the global scale accounted only for 97% of the agricultural land available domestically (122% for EU-15 in 2000). The latter ratio had declined slightly from 1993 to 1999 (minus 3%). The use of the relation of specific domestic agricultural land requirement for total agricultural production (in ha per t, 4th column of Table 6.18) has been described before.

Most of the ACC countries had required additional agricultural land abroad in 1999 at a relatively similar ratio than the ACC-13 in total (GALR). The most obvious exceptions from this are Malta, Cyprus and Slovenia. Malta had required about 11 times more agricultural land abroad than domestically available, Cyprus about 2.5 times more and Slovenia about 1.9 times more (see figure below). This is obviously due a relatively low per capita availability on the domestic territory, in particular in Malta. Agricultural land required for domestic per capita consumption of agricultural goods (GALU) in Malta, Cyprus and Slovenia ranges rather at the lower end of values in ACC-13.

Figure 6.7 Global agricultural land requirement, ACC-13, 1992 - 2000



In total, the ACC-13 had used less agricultural land for domestic consumption of agricultural goods (GALU) than was available on its own territory. In 1999, the agricultural land required for the domestic consumption of agricultural goods in ACC-13 accounted for only 97% of the domestic agricultural land area. The same holds for Bulgaria, Czech Republic, Hungary, Lithuania, Romania and Slovakia. These economies had provided net agricultural land by exports to the rest of the world.

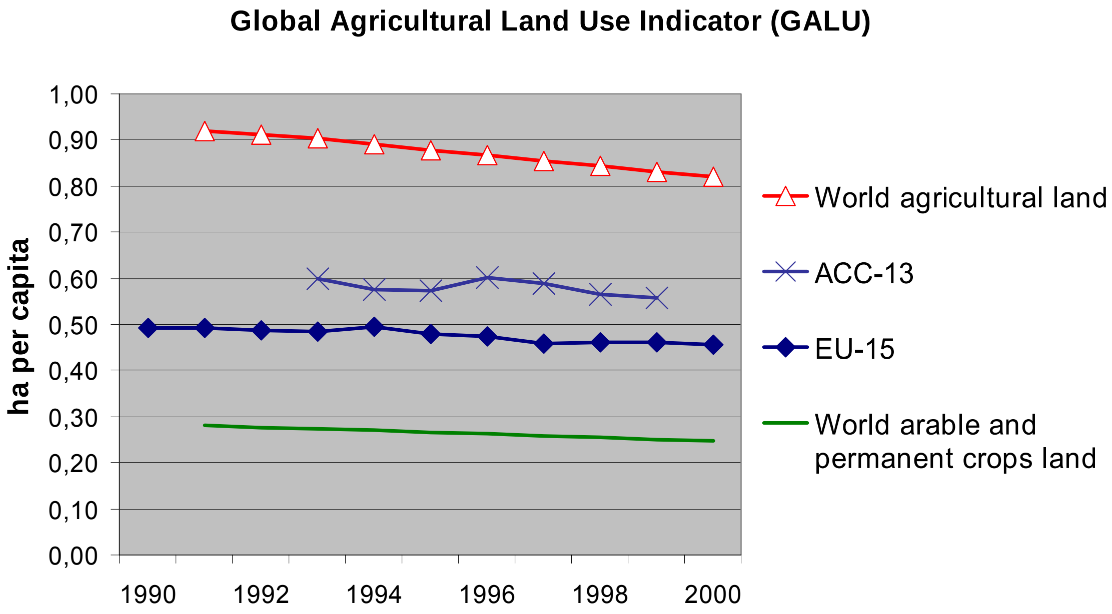
Table 6.22: Agricultural land use account for ACC-13: relations among components and relative changes from 1993 to 1999.

	GALR vs. Domestic 1999		GALU vs. GALR 1999		GALU vs. Domestic 1999		Domestic requirement 1999	
	%	Change from 1993 in %	%	Change from 1993 in %	%	Change from 1993 in %	ha per t	Change from 1993 in %
Bulgaria	10405%	4%	88%	-1%	91%	-2%	0,36	9%
Cyprus	9694%	-3%	78%	-0%	197%	13%	0,12	8%
Czech Republic	10336%	3%	81%	-11%	94%	-8%	0,18	22%
Estonia	12558%	26%	91%	-3%	112%	13%	0,36	24%
Hungary	10333%	3%	71%	-9%	75%	-9%	0,21	-16%
Latvia	11265%	13%	98%	3%	106%	8%	0,35	26%
Lithuania	10493%	5%	91%	-4%	97%	-3%	0,23	11%
Malta	10798%	8%	98%	1%	1111%	64%	0,06	-41%
Poland	9656%	-3%	92%	-2%	101%	-4%	0,16	19%
Romania	9807%	-2%	89%	-5%	92%	-8%	0,22	-3%
Slovakia	9845%	-2%	87%	-3%	97%	-3%	0,17	16%
Slovenia	9800%	-2%	52%	-21%	100%	-12%	0,12	-25%
Turkey	8907%	-11%	95%	-0%	100%	0%	0,20	-7%
ACC-13	9580%	-4%	90%	-3%	97%	-3%	0,20	3%

Summary

The figure below shows the GALU for EU-15 and ACC-13 in comparison with the world's availability of agricultural land in total and arable land plus permanent crops land in particular. From this picture, it seems that the global agricultural land use of the EU and ACC is in line with agricultural land available for each human being in the world. However, several arguments (as discussed before) speak rather for an orientation towards the global availability of arable land and permanent crops land instead of total agricultural area. With this reference, the EU's and ACC's GALUs would rather exceed global limits on a per capita basis. Furthermore, the global per capita availability of both, agricultural land and arable land and permanent crops land, is declining more rapidly than the GALUs of EU and ACC. Also, the agricultural land use intensity (in terms of fertilizer and pesticides use etc.) should be taken into consideration as well. This may put the EU's global agricultural land use into a different perspective than the mere hectares per capita show.

Figure 6.8 Global Agricultural land Use Indicator, ACC-13 and EU-15, 1990 - 2000



Underlying to this figure, an interesting difference between EU-15 and ACC-13 was observed. Whereas the EU-15 had always required a net surplus of agricultural land abroad, the ACC-13 have rather been net providers of agricultural land for the rest of the world (and most probably in particular for the EU-15). Future studies may show the status and development of agricultural land use of the extended EU-25 and beyond on the global scale, aiming at integrating qualitative aspects of land use as well.

6.4.6 Conclusions

Due to missing basic data for built-up and related land, it will not be possible at the moment to derive a comprehensive database for EU-15 and ACC-13 in total, from which complementary aggregates to DMC and GDP can be derived. This the more because potential estimation procedures for missing data were found to be not applicable. There is no way than to provide these land use data through official statistics which should be a priority task for national authorities in the future.

A "DMC-like" and “GDP-related” land use indicator should comprise the following accounting elements:

+	domestic land use	(*p*)
+	imported “hidden land”	(*i*)
–	exported “hidden land”	(*e*)
=	land use related to GDP	

For the various land use categories, data availability is as follows:

- arable land + permanent crops: *i*, *p* and *e* available
- permanent pastures: *p* available, *i* and *e* calculated based on German data, could give interpretation problems
- forest and woodlands: *p* available, no reliable estimates for i and e possible
- built-up area: only *p* for some countries.

The land use indicator could be derived for agricultural land (comprising arable land, permanent crops and permanent pastures) for EU-15 and MS, as well as for ACC-13, in time series and compared with average global availability of agricultural land on a per capita basis. This provides valuable information on the relevance of agricultural land use for domestic consumption of agricultural goods as compared with current and prospected agricultural land availability for the provision of food and renewable materials for the world population. Future development should aim at integrating qualitative aspects of land use as well.

LCA data on land use may provide some more relevant information. However, the use of LCA land use data seems at present not feasible, a plausibility check showed a factor 6 difference between total area for agriculture, this has to be further investigated.

Further, the Corinair database on land cover, and the LUCAS survey on land cover and land use (Eurostat 2003), might provide useful information and should be considered in future studies.

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7 Indicators for Mass flows and Land use

A separate task of this study is to identify a limited set of mass flow and land use indicators, and assess whether one or more of those indicators could be used for benchmarking. From the previous sections, a number of indicators can be distilled. In this chapter, these indicators will be assessed on their suitability to use for benchmarking by a set of criteria.

The indicators that have been discussed in the previous chapters are the following:

variants of Domestic Material Consumption, DMC
- DMC, DMC/capita, DMC/€, DMC/km2
- DMC broken down into categories of materials, idem per capita, per € or per km2

variants of Environmentally Weighted Material Consumption, EMC
- EMC, EMC/capita, EMC/€, EMC/km2
- EMC broken down into categories of materials, idem per capita, per € or per km2
- EMC per individual material
- EMC per impact category

variants of Global Land Use, GL
- GL, GL/capita, GL/€, GL/km2 (not available at this moment)
- GL broken down into categories of land use. At this moment, only agricultural land use can be specified sufficiently.

These indicators are judged by the following criteria:
- indicative value: is the meaning of the indicator clear and is it relevant?
- scientific soundness of methodology and data
- clarity and easiness to understand
- simplicity and transparency of calculation
- country comparability
- feasibility to disaggregate and applicability by sectors
- acceptability issues

7.1 Indicative value

To assess the indicators on this criterion, we attempted to define the meaning of the indicators. If the definition is easy and clear-cut, the meaning of the indicator can be assumed to be clear. The next question is then, whether the indicator is relevant: are we interested in its message?

7.1.1 DMC variants

The DMC can be defined as: "the annual consumption of "new" materials within a national economy". The meaning therefore is clear. The indicative value, however, is indirect. Not the consumption itself, but several implications are indicated by DMC:
- DMC is a measure of the physical basis of national economies
- DMC is a measure for net additions to stock and generated waste and emissions
- DMC is a proxy for present and future waste and emissions

It can be very useful to have an account of the physical basis of national economies. This allows for all kinds of relevant analyses, for example related to linking physical with monetary information, or to translate economic development into physical / environmental aspects. However the indicative value of such a total is again indirect. Not the physical basis or the stocks themselves are the issue, but the potential environmental pressure related to them. The use of DMC as a proxy for environmental pressure requires further elaboration. In view of the ongoing debate with regard to the sense and nonsense of counting the kilograms, a clear insight is needed in whether or not a measure of consumption in kilograms correlates with environmental pressure. From the analysis in Chapter 4, it appears that for individual materials there is no relation between weight and environmental impacts. However, the total aggregated indicator DMC is correlated with the EMC, both over time and between countries. Over relative short periods of time the technical coefficients of production do not change as these are dependent on investments in capital and technological innovations. Hence, if the DMC declines it is likely that the EMC also declines, especially for shorter periods of time. Comparing between countries, there can be the suggestion that the composition of materials consumption is not so much different for individual countries. Also, countries appear to follow the same technology path as they are interlinked through trade flows and capital transfers. More research is required to investigate the relation between the DMC and environmental impacts in longer periods of time.

Our suggestion would be that on an aggregate level, therefore, DMC can indeed be used as a proxy for future waste and emissions, or, in other words, for environmental pressure, especially for shorter periods of time in individual countries. Although no absolute target or desired level can be defined, the meaning of the indicator is clear in a relative sense: less is better. For individual materials or specific sectors, no relationship can be found between the material consumption in weight and environmental impacts and the DMC would have been added with sector-specific indicators. For comparison between countries (benchmarking), the use of DMC is questionable, but could result in reliable results if the composition of materials consumption does not differ a lot between countries. In those cases, it can be wise to correct the DMC for differences in the structure of production, as these tend to form the largest share of differences in DMC (and also in EMC) between countries.

Both the DMC/capita and the DMC/km^2 roughly have the same meaning, but are options to make the DMC indicator comparable between countries. The DMC itself, without further elaboration, cannot be used to compare countries, since the differences in size would be determining the difference in DMC. The DMC/capita is then more relevant and could be regarded as a measure for environmental pressure of consumption. The DMC/km^2 is also a good option. It is a little closer to indicating environmental pressure as such, since density is important. Countries with a dense population score higher on such an indicator. Such countries often can be more eco-efficient (see below) and even might have a lower DMC per capita, but nevertheless the environmental pressure can be high.

The DMC per € of GDP is another option to ensure comparability between countries. This can be regarded as a measure of materials intensity or eco-efficiency: the amount of materials related to the making of (or spending of) one Euro. Again, less is better, because more eco-efficient and less material-intensive.

The DMC can be broken down into a small number of categories of resources. As an account, the more detailed it is the better, since more possibilities of analysis are available. However, the relation with environmental pressure on this level is less clear. Bulk-materials for construction, for example, are very important in weight but not in environmental pressure. For metals, it is the other way round. As a proxy for environmental pressure, the DMC can therefore best be used on the aggregate level. This is true for all DMC variants, and especially for the DMC/€. On an aggregate level, the DMC/€ makes sense, but disaggregated the relation with income is meaningless. The contribution of each material to the GDP is different per kg of material. It would make sense if the GDP could be attributed to the different (groups of) materials. This can be an interesting task for the future.

7.1.2 EMC variants

The EMC can be defined as: "the global environmental impact potential of cradle-to-grave chains of "new" materials annually consumed in a national economy". It adds an environmental dimension to the DMC and therefore is a much more direct indicator of environmental pressure. It also adds a cradle-to-grave aspect to the DMC and therefore includes the impact potential of those parts of the chain that are located outside the national borders, as is done with the TMC. The environmental impact potential of consumption thus is a global impact potential. In some aspects this measure is reminiscent of the Ecological Footprint, which also takes the consumption as the starting point and specifies cradle-to-grave chains related to this consumption. The EMC needs no further interpretation or correlation. Like DMC, it is a relative indicator (less is better). Its expression is not in kg but in contribution to the worldwide environmental impact potential. Its absolute value therefore also has some meaning as well, although still in a relative sense.

The EMC per capita means the same but is a measure that is comparable between countries, unlike the EMC itself. A translation into EMC per km^2 is meaningless when the land surface of the country is used, and trivial when the land surface associated with the cradle-to-grave chains is used, if such data would have been available. Therefore the EMC/km^2 is cast aside on grounds of doubtful indicative value.

The EMC per € of GDP can be regarded as an eco-efficiency indicator, comparable to DMC/€. This indicator is a measure for the impact intensity of a Euro made, or spent. Less is better again seems to be applicable.

The total EMC is built up out of the EMCs per environmental impact category, which in turn are built up out of the EMCs per material for this impact category. The EMC therefore is also available at a more detailed level, both for materials as for economic sectors. The interpretation is easier, or at least more comfortable, at the level of the individual impact categories: the contribution of the chains of materials to, for example, global warming or human toxicity. This is less vague and ambiguous than the "total environmental pressure". At this disaggregated level, the indicator has its largest indicative power. Environmental impact categories which are doubtful, either because of lack of data or because the impact category is not yet well-established in the LCA framework, can just be ignored or left out. EMCs per material within the impact categories are equally well interpretable, but suffer from uncertainty problems in the basic data (see 7.2). EMCs per group of materials, comparable to the categories of materials in DMC, could be a better option.

The breaking down of the EMC/€ into (groups of) materials leads to nonsensical results. The reasoning is comparable to that in Section 7.1.1, where similar conclusions are drawn for the breaking down of DMC/€.

7.1.3 Global land use (GLU)

The global land use indicator, as developed in this study, can be defined as: "Global land use related to the annual consumption of "new" materials by a national economy". The concept of land use related to consumption has some similarities to the Ecological Footprint. This, too, is a measure for land use related to consumption on the national level. The GLU is more clear cut in that sense that it does not contain any "virtual" land use, but only "real" land use. It is therefore not an overall indicator of environmental pressure, only insofar related to land use. It can be used in a relative sense, less is better, but can also be related to an absolute value, i.e. the amount of land available on Earth. However, the spare land use in km2 does not consider differences in environmental pressures deriving from different forms of land-use (e.g. from built-up area different pressures evolve than from agricultural land-use). In practice there are large problems with data availability (see 7.2).

The GLU per capita means the same, only enables country comparisons. The GLU per km2 is meaningless when divided by itself. When divided by the surface of the country, it is an indicator for the net self sufficiency of a country. Densely populated countries will probably have higher values. The question is what the relevance of this indicator is. If self-sufficiency is a policy aim, it might be relevant. If not, it is again meaningless.

The GL per € again can be regarded as an eco-efficiency measure: the amount of land required to make a Euro, or related to spending a Euro.

The proposal in this study is, to break down the GLU in different types of land use, esp. built-up area, agricultural land, and forest. Agricultural land has been the only category we were able to specify. Apart from that, it is difficult to relate these categories to the categories of materials used in the DMC and EMC. Biomass seems to be the only material category for which this is possible. The built-up area can be related to the other categories, since they will be mostly used there. However, land required to produce these materials is difficult to include. The GLU is therefore not completely comparable to DMC and EMC.

7.2 Scientific soundness of methodology and data

7.2.1 DMC variants

The DMC is based on a standardised methodology of Material Flow Accounting (MFA). This methodology is published by Eurostat. MFA accounts exist for a large and increasing number of countries. OECD attempts to persuade all member states to engage in MFA accounts.

While the methodology is standardised to a large extent and easy to understand, the practice is not so straightforward due to data issues. MFA relies heavily on statistics. The quality and quantity of statistics varies a great deal between countries, even the definition of statistical categories is different in different countries. Even within the EU, where statistics are harmonised to a high degree, such problems occur. This leads to uncertainties in the data which differ per category and per country.

7.2.2 EMC variants

The EMC is obtained by combining MFA data with impact potential data from an LCA database. The methodology in principle is straightforward: multiply flow data with an impact factor expressing its environmental weight. Both underlying methodologies are standardised to some extent. For MFA, this is described above in Section 7.2.1. For LCA, there are some Handbooks, there are ISO 14000 guidelines and in the UNEP Life Cycle Initiative experts are engaged in formulating a Best Available Practice, with respect to both methodological issues and LCA databases.

In practice, however, there are some obstacles. The uncertainties of basic MFA data also apply for the EMC. Moreover, MFA data have been translated into "apparent consumption of new materials" data for a number of materials. Additional data with additional uncertainties were used for this. Still additional uncertainties and restrictions arise from the use of LCA data. The LCA process data are averages for Western Europe, implying that on the one hand differences between countries are not expressed, while on the other hand efficiency improvements over time cannot be seen. The LCA database is updated once a decade rather than once a year. Basic assumptions in the LCA database with regard to recycling and allocation are difficult to detect and may be open for improvement. Regarding the LCA impact assessment data, there are large differences in quality between the different impact categories. While global warming potentials are based on internationally agreed studies, large uncertainties exist in the impact categories related to toxicity. The LCA Impact Assessment methodology is not well developed for land use and waste generation. Depletion of resources of a biotic nature, f.e. wood and fish, is not included at all; at this moment there is no consensus on how to derive impact factors. Despite these omissions and uncertainties, the addition of LCA data in our view is a relevant step, bringing the MFA based indicator a step further in the direction of potential impacts. Both for MFA and LCA databases, improvements should and probably will be made over time, allowing for more reliable indicators. Both research and development areas are alive and many experts are working on it, which ensures a highly dynamic development field for both fields.

To calculate the EMC at its highest level of aggregation, a normative step is required: aggregation over all environmental impact categories. There is no scientific approach to this, since it is based on values - which impact category do we, as a society, consider most important? Different ways have been proposed to deal with this, but so far none are generally accepted. This, again, may lead to a recommendation to use the EMC at the disaggregate level of the individual impact categories. In the debate over sense and nonsense of weighting, a very powerful argument pro weighting is that if this isn't done according to a certain procedure, it will be done implicitly, making the outcomes unreliable and not at all reproducible. If it has to be done, it had better be done following a, for the moment agreed on, explicit procedure. In the absence of agreement, we chose to apply equal weighting for illustrative purposes. When the EMC is to be used in a policy context, this issue needs to be resolved at least for the moment.

In addition, the combination of MFA and LCA has led to some problems with conflicting system boundaries. Although we have solved these problems in a, in our view, satisfactory manner, the fact remains. In our view, it would be more appropriate to use the EMC indicator for a system of apparent consumption, which is slightly different from the DMC system since it includes recycled materials as well. The use of production statistics is then advisable.

7.2.3 GLU variants

Data availability is the largest problem for the Global Land Use indicator. Data availability allows only for a partial indicator: Global Agricultural Land Use (GALU). Even for this indicator, approximations had to be made based on German data. For other types of land use, statistics are incomplete or not harmonised, even within the EU. Outside the EU there are even more problems. On grounds of data availability problems, the GLU is rejected at this moment as a suitable indicator. The GALU can be used, but only on a disaggregate level, related to agricultural biomass. Other problems are related to the nature of land as a resource. Intensity of use and multi-functionality are important aspects that are not at present covered in the proposed GLU or GALU.

7.3 Transparency and simplicity of calculation

7.3.1 DMC variants

The calculation of the DMC is quite straightforward: import + extraction - export, in kg/year. All inflows, outflows and extractions count. In some cases, translations have to be made but in principle the transparency of DMC is high.

7.3.2 EMC variants

In principle, the calculation of EMC is simple: ∑ material flow * impact/kg material. The material flow data are based on DMC but require a step where double-counting is eliminated and the fate of raw materials is determined (i.e. 'estimation of apparent consumption'). The impacts per kg are obtained in a straightforward way from LCA database and software, however, the transparency is not very high. The calculations are not complicated but are numerous. While it is possible to determine the origins of a certain impact / kg, it requires insight in LCA methodology and the use of LCA databases and software to do so. Weighting between impact categories further complicates the picture and adds a political / normative dimension.

7.4 Feasibility to disaggregate

7.4.1 DMC variants

As a proxy for environmental pressure, DMC can best be used at an aggregate level. Breaking it down into categories of materials is possible, but the indicative value loses power. The potential for use of the MFA database, however, increases with its level of detail. Although the DMC is not built up according to a sectoral structure, it is possible to relate the groups of materials roughly to certain sectors (e.g. in the form of NAMEA tables).

7.4.2 EMC variants

The EMC can be disaggregated to various levels of detail and along different axes. In fact, it is built up out of disaggregate information. As stated before, the indicative power increases at the level of the separate impact categories. The breaking down to the level of individual materials requires caution. The comparison between materials is a tricky issue, data and database uncertainties make it impossible to do so with good faith. At the level of groups of materials the results are more trustworthy. Differences between the groups are so large that the results can be considered sufficiently robust. Although the EMC is not built up according to a sectoral structure, it is possible to relate the groups of materials roughly to certain sectors, and in addition to do analysis with NAMEA-type of accounts.

Another application of the EMC is in the field of recycled materials. While the DMC accounts recycled materials used as input in the economy as reduced consumption, the EMC is in principle able to estimate the environmental gains achieved from using recycling materials.

7.5 Comparability between countries

Comparability between countries can be reached by using the indicators per capita, per € or per km2. As mentioned above, not all combinations make sense. The per capita indicators seem most robust against becoming meaningless. The per € indicators are powerful measures of eco-efficiency, but only at an aggregate level. The per km2 indicators are doubtful in their meanings, only for DMC these seem to make sense as a proxy for environmental pressure.

7.6 Overview

Useful indicators are, presently:

- DMC/capita and DMC/km^2, as descriptions of the physical economy and as proxy for emissions and waste, at the aggregate level.
- EMC/capita, as an approximation of the impact potential of consumption
- GALU/capita, only for biomass production
- DMC/€ and EMC/€, as eco-efficiency indicators
- EMC/capita and EMC/€ broken down into separate impact categories, as contribution of consumption to those impact categories and enabling to relate with environmental problems oriented policy
- EMC/capita broken down into categories of materials, to enable relating to sectors

The choice for which indicator is to be used is dependent on the political demand for natural resources policies and the way these policies will be designed and implemented. If the main aim is to arrive at a “signal” –indicator in which the development is estimated in small periods of time, one may stick with the DMC as the calculation is already established in many countries. However, when evaluating goals for resource efficiency set in longer time-frames, one runs the risk that the paths of environmental pressure and materials consumption in weight diverge due to material substitution.

The DMC adequately measures dematerialisation. If the material composition of an economy remains unaltered, the DMC is a good proxy for reduction of environmental pressure due to the use of materials. However, if material substitution is present, the DMC over time may diverge from the environmental impacts. We also note that if material substitution is the main aim of the resources policy, the EMC provides a better indicator as the environmental gains from material substation can be estimated better with the EMC than the DMC.

Finally, one may want to conduct additional study in the effects of using the DMC in longer periods of time. As the composition of materials consumption may be altered in a time-frame of 20-25 years, this would indicate that the use of DMC to represent a Factor 4 in 20 years does not represent a reduction of environmental pressure with a Factor 4. More research should be devoted to the long-term effects of materials consumption in order to elaborate the use of DMC for goals set in a far distance.

8 Conclusions, discussion, recommendations

Development of MFA and DMC

For the EU, MFA accounts including DMC are currently estimated and up-dated by Eurostat based on standardised methods. Eurostat is encouraging Member States to establish MFA accounting in their statistical programmes and so is the OECD. Further efforts will have to be put into the methodological harmonisation of MFA accounts so as to improve the statistical cross-country comparability. The largest uncertainties appear to be in the largest flows of sand and gravel. To enhance the potential of use of the MFA databases, it could be recommended not to limit the accounts to the transboundary flows. Including recycled flows and production would increase the usefulness for all kinds of analyses.

Development of EMC

One of the major challenges of this study was the development of the environmental weighed material consumption indicator, the EMC. It's main advantage is that it gives information on the environmental impact, from cradle to grave, of resource consumption which is useful to analyse (i) upstream effects of resource consumption that do not occur in the consuming country; (ii) analyze the environmental impacts from material substitution and recycling. However, this indicator has some drawbacks as well and they relate to the more ore less arbitrary steps in setting up the EMC. Although many uncertainties, data gaps, methodological problems etc. have been encountered, we have been able to define and apply EMC. The next step is to assess whether the EMC indicator is ready for use.

On the positive side, the basic idea is simple - just adding an environmental weight to the material flow data - and the methodology builds on established tools and databases. An additional advantage of using LCA data is that this facilitates the link with a product policy. There are also some aspects that limit its potential at the moment. One important problem is that of the weighting between environmental impact categories. So far, every aggregate measure of environmental pressure or impact has suffered from this problem with regard to its acceptance. It may be kept in mind that the most influential measure for economic performance, GDP, also suffers from this problem: it is made up of different sub-indicators, which are aggregated arbitrarily. Nevertheless it is accepted as an indicator for welfare and is used for monitoring and even targeting. Many people have worked many years on its development. The same will probably be true for an indicator of overall environmental performance, to which we hopefully have made a contribution.

Other aspects limiting its potential for use refer to the mentioned uncertainties, data gaps and methodological issues. To develop the EMC further, the following activities are recommended:

- The LCA database used in this study has in the meantime been updated. It is recommended to derive new impact potentials with the help of this updated database
- In order to have a representative state of the art of technologies in the EU, a regular update of the LCA database is actually required. This is a major task for the LCA community.
- Not all relevant materials are included in the LCA databases. It is recommended to expand the database with materials related to agriculture, and with a number of secondary materials esp. metals.
- The LCA methodology does not allow assessing the problem of depletion of renewable resources. If LCA is unable to deal with it, it is recommended that a separate indicator is developed for that, comparable to the effort undertaken in this study to define a land use indicator. In such an indicator, the renewability of the resource should be accounted for as well as the depletion potential.
- There are large differences between countries which are not visible from a general LCA database. For a sensible application of the methodology in the different countries, country-specific studies are required. Per country it can be determined whether the average LCA data are valid or new country-specific processes have to be defined. This will especially be relevant for industries with little transboundary flows, such as for example the construction industry.
- Using the DMC system boundaries for the EMC has proven to be difficult and even awkward. The system boundaries of apparent consumption seem to be more convenient and meaningful. It is recommended to develop the EMC further using the boundaries of apparent consumption. Additional data have to be collected from production statistics. With the help of

these data, it may be possible to draft sufficiently reliable material balances for a more complete set of materials.

- The use of the EMC for policy purposes should be carefully considered. Its use for monitoring developments puts different requirements to an indicator than the use for targeting, or even for identifying options for policies. The EMC in its present state could be used for monitoring, especially with the improvements as indicated above.
- The EMC broken down into the different impact categories is more robust, because the tricky problem of weighting is avoided. Also, it is possible to make a distinction between more and less reliable impact categories. For the more reliable categories, general targeting (Factor Four, or suchlike) could in principle be possible. The underlying information for the individual materials could be used, as one of many necessary pieces of information, for more specific policies. It should not be allowed to live a life of its own.
- The link between a resources and a product angle should be made explicit. One of the repeatedly recurring issues refers to energy in the use phase of the life-cycle. In the EMC, energy in the use phase is represented in the chain of fossil fuels. It is therefore not invisible, but it is not attributed to the other materials. In our view, energy in the use phase can be attributed to a product, not to the materials the product is made from. From a product or service perspective, such as used in IPP, this is a very important aspect. A resource and a product perspective in our view should be additional, not mutually exclusive.

Development of Global Land Use Indicator

The other new indicator investigated in this study, the Global Land use indicator, is presently not applicable. Too many data are lacking and too little harmonisation in statistical categories exist at the moment. The LCA land use data, although they would be ideally suited to the indicator's purpose, appear to be insufficiently reliable. For the moment, only the Global Agricultural Land Use is specified. Further development of this indicator is recommended, also with attention for presently qualitative aspects such as multifunctionality and intensity of different types of land use.

Results

When actually applied, large differences between countries appear in all indicators: EMC/cap, EMC/€, DMC/cap, DMC/€ and GALU/cap. Differences in DMC/€ and EMC/€ tend to become smaller if GDP is used in Purchasing Power Parities. Moreover, the remaining differences tend to become smaller when corrected for the levels of income and the structure of the economy. Overall, these variables explain around 60% of the variation in resource efficiency between countries.

Over time, DMC/€ and EMC/€ decrease while DMC/cap and EMC/cap are fairly constant. This is EU average, again large differences between countries can be found. These differences can partly be attributed (for 50-60%) to differences in GDP and the structure of the economy. When correcting for these, one may judge the relative position of countries, for example in their success in reducing the resource consumption independent of their developments in the structure of the economy and the level of GDP.

Relation between DMC and EMC

In this study, we have investigated the relation between DMC and EMC at different levels. At the most detailed level, the level of individual materials, there seems to be no relation whatsoever between a material's consumption and its impacts. For specific resources, therefore, weight and impact have to be regarded separately. When plotting the EMC-DMC relation for the different EU and AC countries, however, there appears to be a correlation between the two, which is significant. This probably implies that the composition of material consumption does not differ that much between countries which are to a certain extent comparable in terms of their market structure and have extensive trade flows with each other. There are some outliers, however, which seem to be related especially to the economic structure and presumably to the influence of cattle stock breeding in these countries.

Over time, the correlation is also visible. The way a national economy uses materials, in terms of its technical coefficients, changes only slowly as the result of capital replacements and technological innovation or technological breakthroughs. This implies that given a certain materials input and a certain economical structure, the output in terms of waste and emissions is more or less fixed. Structural changes and really significant improvements in efficiency only happen over a longer period of time. For shorter periods of ca. 10 years, the output seems to be determined by the input and therefore the DMC can be a valid approximation of environmental pressure, at the aggregate level and within national economies. On the long run, however, changes occur and the relation may no longer be valid.

What does this mean for the expendability between EMC and DMC? If they indicate the same thing, using just one of them seems sufficient. It could be argued that, since environmental impacts are what we are interested in, the EMC as the indicator that measures this should be used. On the other hand, DMC is easier to calculate and surrounded with less uncertainty, therefore an argument could be made to use DMC. To take this argument one step further, both DMC and EMC correlate with GDP/capita. By the same reasoning, we could use GDP/capita as a proxy for environmental pressure. Yet, since we are interested in measuring the decoupling between economic growth and environmental pressure, GDP/capita cannot be used in this way. In the same line, it may also be interesting to see whether a decoupling between materials use and environmental impact potential might occur. For that reason, it still makes sense to measure both.

The application of the EMC and DMC may also differ. The DMC may be used as a “headline” indicator in a given time-period for the environmental pressure from materials consumption for individual countries or for comparing countries with a largely similar economic structure. However, if actual policies are put in place for reducing the environmental impacts from resource consumption, DMC is not appropriate as there is no linkage between environmental impacts and the underlying consumption in terms of kilograms. Also if the natural resource strategy is to contain long-term goals, such as a Factor 4 in 25 years, one may question whether on such a long time-frame the changes in impacts will still correlate with the mass flows.

Explanatory variables

As both the DMC and EMC are heavily influenced by the structure of the economy, one may arrive at better policy recommendations if the influences of the structure of the economy are deducted from the total figures. Otherwise, one of the policy recommendations of the Natural Resource Strategy would be that the Netherlands, Ireland and Denmark have to reduce their cattle stock and Bulgaria their construction activities. However, when we link the reductions in resource efficiency to actual policy variables, we find that only the recycling of waste is somehow correlated with improvements in resource efficiency. Other policy variables, like energy prices, renewable energy inputs, materials taxes and education and R&D efforts are not significant, or are already captured by state and dummy variables in the model we estimated. On the one hand we think that this might be coincidental. On the other hand, one may want to further elaborate on the effects of existing policy initiatives for the resource efficiency. This is more pressing as the analysis in Chapter 4 identified Denmark as a country with a relatively poor performance on both the EMC/capita as the EMC/€. However, the policy review in Chapter 5 identified Denmark as one of the forerunners in installing materials based policies.

There is an epistemological advantage in using resource efficiency over resource productivity as resources themselves do not generate value added if no labour were put into the extraction and refining of resources. While this is recognized in the field of energy economics (energy efficiency is the target variable instead of energy productivity), the field of resource economics sometimes sticks to the concept of resource productivity.

The most important driving forces for differences in resource efficiency relate to the level of GDP and the structure of the economy. While indirectly one may hope that a natural resource strategy may result in changes in the economic structure, there will be no environmental gains if such changes are not accompanied by equivalent changes in the structure of consumption (lifestyles). For that reason, it might be wise to periodically correct the resource efficiency for changes in the structure of production and to identify countries that have performed well over time in improving their resource efficiency.

It proved to be difficult to exactly trace back the reasons for improved resource efficiency over time. We found especially that they related poorly to policy variables that we have chosen in this study, except for the recycling of municipal waste. More efforts should be devoted towards revealing strategies that can help in reducing resource consumption over time and identifying successful policies that help to achieve the goal of decoupling environmental impacts of resource use from economic growth.

Use of the indicators

The DMC and EMC indicators developed and applied in this study are highly aggregated indicators,. which may serve the purpose to provide an overview on the development at the macro level (national or EU) with regard to material consumption and related environmental impacts. In the past, other attempts have been made to define comprehensive indicators for environmental pressure. They are often criticised severely, because they suffer from generalisations, abstractions, normative choices and simplifications which makes their meaning doubtful and their relation with any real environmental impact hazy. The criticism is rightful and indeed applies for both DMC and EMC, be it for different reasons. For EMC, the use at the disaggregate level of the individual impact categories is much more robust. Nevertheless there is a clear demand for such aggregated indicators. How to measure de-coupling without a general environmental indicator? The GDP, its counterpart as the all-encompassing economic indicator, has the same problems. Nevertheless GDP is generally used. Therefore it seems to be not just a matter of scientific soundness but also of political acceptance.

One aspect to consider is the purpose for which the indicators are used. A distinction can be made between monitoring and benchmarking on the one hand, and targeting or preparation of policy measures on the other. Past developments at the aggregate level can be monitored by such indicators, and if there is agreement on the desired direction of the indicator (less is better), benchmarking at the aggregate level - although more controversial – is also possible. Even there aspects of scale are playing a role: a temporary increase need not be problematic when it is caused by some activity that will reduce environmental pressure on the longer term. Benchmarking at the aggregate level is more controversial. For instance, benchmarking is possible for aggregate DMC and EMC with regard to eco-efficiency (Factor X improvement over a period of Y years) at the level of countries or the EU as a whole. The indicator then can be used to see whether or not the target is reached, again for monitoring. Whereas DMC can be used, by strength of its correlation with EMC, as an indicator for monitoring environmental pressure, its use for targeting or benchmarking is debateable. In future, the correlation may not hold. In fact, we can already observe somewhat different developments between DMC and EMC despite the correlation: EMC is growing a little faster than DMC especially in countries with a fast growing GDP. A possible policy aim could be the de-coupling between resource use and environmental problems by shifting resource use in a more sustainable direction.

For more specific policy purposes it is probably better to define more specific indicators, for example on the level of sectors. For a policy on the level of individual materials more detailed studies must be done regarding the flows of these materials and the applications for which they are used. The EMC can do no more than to focus the initial attention by identifying (groups of) materials contributing significantly to environmental impacts.

In that view, it is also recommended to do a careful check on the indicative value. Is "less" indeed "better" in all cases, or can we imagine instances where this may not be true? Again, there may be a difference between DMC and EMC due to the fact that they indicate different things. And again, there may be a difference depending on the scale level of observation. For individual materials, less might indeed be better. When substitution is involved and we have to look at more materials at the same time, this is not automatically true. This is the same at the EU and national level: since substitution may occur, less is not automatically better. On the other hand, the correlation between DMC and EMC indicates that it could be concluded that over the past ten years, "less" materials consumption might indeed be translated into "better" for the environment. Nevertheless, a check as recommended above could be very useful to obtain more insight in this matter.