ANNEXES

Annex 1 Minutes of the expert meeting

The draft final report of this study has been discussed with a number of experts at DG Environment, 29 October 2004. Present at the expert meeting were: Theo Geerken (Vito, Belgium), Ellen Riise (SCA, Sweden), Aphrodite Kourou (DTI, UK), Peter Hill (DTI, UK), Rocky Harris (DEFRA, UK), Caroline Raes (DG Enterprise), Annemarth Idenburg (RIVM, the Netherlands), Ernst Worrel (Ecofys, the Netherlands), Frans Vollenbroek (DG Environment), Stefan Bringezu (Wuppertal Institut, Germany), Sander de Bruyn (CE-Delft, the Netherlands), Lauran van Oers (CML, the Netherlands) and Ester van der Voet (CML, the Netherlands).

The expert meeting started by a presentation of the draft final report by Ester van der Voet. After that, experts were invited to comment on the report, the approach taken and the potential use of the results. The comments are listed below, some with a response of the team of authors:

In the report it should be unambiguously stated which aspects of the use and waste phase are included and which not.

The use of the headline indicators in the sense of "less is better" is questioned: a temporary increase of materials use and/or impacts can be acceptable if on the long run this creates a further decrease. For example, a heavy investment in windmills during some years will first lead to more resource use (construction materials) and later on to lower resource use (less fossils). Some comments about interpreting the indicators on a temporal scale should be included in the report. The authors want to emphasize, however, that this problem also exists in the concept of economic growth. Investments now lower consumption and hence economic growth in the short run, but in the long-run such investments will enhance consumption in the future.

It should be emphasised that although there is an ISO standard for LCA, there is no standard LCA methodology. There are different methods conforming to the ISO standard, each having their own type of LCI and LCIA. The same is true for the database used. There are other databases, no doubt leading to different results. Weighting is not standard and is under ISO restricted: it cannot be used for all purposes, especially for comparative assertions. The authors should be careful not to damage the slowly growing acceptance of the LCA method in industrial circles.

The high level of aggregation causes a lot of discussion. Many of the experts feel that too highly aggregated indicators loose their meaning, as has been proven in the case of energy. On a disaggregate level indicators can be used succesfully for benchmarking, for example related to specific resources, specific environmental problems, or related to the performance of specific sectors. Some state a preference for a basket or family of indicators rather than just one. On the other hand, there is a clear need for an aggregate indicator as well, comparable to GDP for economic performance. A family of indicators can be defined on various scale levels; it would be an advantage if these were related to each other.

What is actually measured by the indicators? The results of the research into explanatory variables indicate that the structure of the economy together with the level of GDP are the main explanatory variables. Is this relevant? On the one hand, no: the structure of the economy is not the target of a policy, and moreover, a change for the better in one country could imply a change to the worse in another. On the other hand, yes: if environmental impacts are really caused by it then it is by definition relevant. Nevertheless we should be wary of the use of the indicators. There is a study (Moffat-study) providing criteria to test the indicators on wrong messages. This could be applied to the indicators developed here. Therefore it should be clear for what purpose the indicators will be used. One purpose is to inform the European parliament about the progress of the EU on the road of decoupling. This requires a monitoring indicator. Benchmarking is something different. Some of the participants feel that these highly aggregate indicators cannot be used for benchmarking. The use should then be restricted to monitoring. Identifying improvement options, another potential use of the information, is sensitive. At the level of sectors or (groups of) materials this could be done, but substitution options between materials is another matter. This information cannot be obtained from the EMC indicator, because it is related to the specific use of the materials in products, nor can it be obtained from the DMC. More information is needed at the level of the materials and their applications. This calls for a clarification of the relation between the Resource Strategy and IPP.

The correlation between material consumption and impact potentials on the aggregate level and the absence of such a correlation on the level of individual materials leads to a discussion about the consistency of both findings. Only at the aggregate level, DMC might be used as a proxy for monitoring environmental pressure, since the correlation with EMC is significant at least for the recent decade. DMC cannot be used to identify priority materials. With regard to extrapolations to the future, such as targeting and benchmarking, different opinions were raised. Some participants were of the opinion that DMC can not be used as a targeting or benchmarking indicator for environmental pressure, since in future the link between materials use and impacts could be less significant. This is actually indicated by the results of the study: economic growth fuels the EMC a bit more than than DMC, indicating that economic growth is associated with a faster growth of the consumption of more polluting materials. This corresponds to the fact that transnational material flows are not included in the DMC, and future monitoring of DMC should be supplemented by information about the transnational flows. As a target, one may actually want a decoupling between domestic materials or resource use and global environmental impacts. A reference is made again to the "less is better" discussion: while for EMC less is indeed better, this is not per se true for DMC. In view of the established correlation between DMC and EMC, however, at least for some participants the idea that less resource use is also better for the environment is supported.

A suggestion is made to compare EMC with DMO rather than with DMC. There may be a closer relationship, since DMO is also about waste and emissions.

The system boundary issue is really complicated and sometimes confusing for the EMC. Perhaps this may be solved in future by choosing apparent consumption over the DMC system boundaries, although apparent consumption is no final consumption either and therefore not much closer to "real" consumption than DMC. The advantage of apparent consumption is that secondary materials can be included, and the effects of recycling on the environment can be made visible. This would be a solution for a number of comments by the stakeholders as well.

Some feel that the use of aggregate, average European data is too crude an approach. There are differences between countries, in the structure of the economy, in the industrial processes and in the environmental situation. Local aspects are not included but are important for estimating any impacts. While this is undoubtedly true, it is also understandable that location specific aspects cannot be included in a Europe-wide, aggregate indicator. They are not even included in LCA since it is often not possible to specify the location of each and every process in the process tree. A certain abstraction is unavoidable; the EMC is therefore expressed in impact potentials rather than impacts. It is therefore also, as remarked by one of the participants, a virtual measure rather than a "real" one. Downscaling to a certain extent should be possible, but to the national rather than the local level.

In the report, many data gaps and uncertainties are identified. It would be useful to obtain an idea about the extent to which such data gaps influence the outcomes.

Annex 2 Critical review of the MFA database and DMC

In the following, we will describe how 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.

In this context, we will also describe 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.

2.1 Analysis of the main limits to the derivation of consistent and comparable data sets for material flows and resource use indicators and solutions suitable to overcome data problems

In the following, the major data problems encountered during work for the derivation of consolidated material flow databases for DMI and DMC of the EU-15 and ACC-13 are described along with solutions chosen to overcome these problems.

2.1.1 Basic statistical data for material flows

Statistical data may be simply wrong.
This problem was clearly encountered when using international databases (see also *use of international statistics*). A quite frequently encountered mistake was the use of wrong units in mineral statistics of the United States Geological Survey (USGS). In general, this mistake is due to the indication of a general unit (like metric tons) given in the heading of data tables, but specific units (like thousand tons or thousand cubic meters) indicated for some materials in the respective data rows. But this indication was found to be wrong in a couple of cases leading to mistakes of three orders of magnitude if not corrected. An example for such a mistake are USGS numbers for clay for bricks in Estonia in earlier publications which were revised in the most recent series but without providing revised data for the complete time series published before. This data problem was solved by contacting a national expert in Estonia (Matti Viisimaa, KKM Info- ja Tehnokeskus - Estonian Environment Information Centre, personal communication on 3 March 2002) who provided reliable and updated data on the domestic extraction of minerals in Estonia. However, as USGS statistics currently constitute the most comprehensive database on the domestic extraction of minerals with regards to global coverage by countries, coverage by materials, and availability of time series, they are absolutely required for material flow accounts which cannot be based on specific national databases due to budget or capacity restrictions. Therefore, USGS statistics have to be used with a specific critical view on obvious data mistakes, which was done by comparison

with other data sources, especially UN industrial commodities statistics or minerals statistics of the British Geological Survey (BGS), and in combination with plausibility checks for the most critical materials data as described later. Other obvious mistakes were found occasionally in USGS statistics, but also in the Eurostat Comext foreign trade database, due to most probably typing errors resulting in numbers which were typically by one decimal place too low or too high as compared with other numbers in a time series, being presumably unrealistic.

Statistical data may be misleading.
This problem was clearly encountered for imports by The Netherlands (NL) reported in the Eurostat Comext foreign trade database. Comparison with data of the Central Bureau of Statistics (CBS) of NL used in the national MFA study (Matthews et al. 2000) showed that the Eurostat data obviously included direct transit flows of commodities through The Netherlands to other European countries (e.g. iron ores shipped to Germany). However, this inclusion was not even “consistent” over the entire time period and data for particular years rather indicated the import quantities referring to the direct material use in NL as derived from CBS data. The latter refers to what is required in order to account for an internationally comparable DMI indicator for NL in line with the Eurostat methodological guide (Eurostat 2001a). So, using national statistical data instead of Eurostat data could principally solve this data problem. However, these national data were comprehensively available only until 1996 from the database of CML. Data for imports in metric tons by NL from 1996 to 2000 were available from the database of CBS (Statline) only on the HS-CN 6-digits level of commodities. On this rather disaggregated level, however, many data are restricted and it was therefore not possible to derive comprehensive numbers for the total of imports (and exports as well) of NL for 1997 to 2000 (1996 was still available from the CML database). The CBS even does not anymore report these total numbers (CBS: Franssen, infoservice, communication by e-mail on 3 and 6 February 2004). So, as regards imports (and exports) data for NL 1997 to 2000 we were faced with the problems of misleading data reported by Eurostat and correct but incomplete data reported by CBS. The solution we chose was as follows: (1) we corrected the Eurostat data for 1990 to 1996 by comparison with the comprehensive CBS data at CML what required to aggregate the 2-digits HS-CN commodity groups of Comext to the 1-digit commodity groups of the SITC rev.3 used by CML; (2) we aggregated the HS-CN 6-digits data of CBS 1996 to 2000 to 2-digits level and estimated the missing amounts 1997 to 2000 by multiplication with factors derived for 1996 by dividing the corrected Comext data by the incomplete CBS data at 2-digits level. This is of course a very rough approach and, therefore, the most critical data in terms of weight, i.e. mineral fuels, were cross-checked with original data of the International Energy Agency (IEA) which resulted in satisfactory comparability.

It cannot be ruled out that the same problem of misleading data for imports due to inclusion of direct transit flows in the Eurostat Comext database concerns the imports of Belgium as well, being the second important entry point of transit commodities to other European countries. However, it was impossible to investigate this with respect to the limits given in this study.

The problem of transit flows in imports has no influence on the results for the EU-15 as an entire economy because imports (and exports) of the EU-15 refer to extra-EU trade only whereas foreign trade of the Member States comprises both intra-EU and extra-EU trade.

Furthermore, misleading data were found in the Eurostat Comext foreign trade database with concerned the 2-digits class 00, i.e. TOTAL FOR COUNTRIES WHOSE DATA ARE CONFIDENTIAL, BROKEN DOWN BY ORIGIN AND/OR DESTINATION. The problem with these secret data was that the numbers were considerably high for 1990 to 1992 especially for imports of Denmark, Germany, and Italy, and for exports of Denmark as well. This had much influence on the allocation of 2-digits values to the major material groups. The problem was solved by comparative analysis of Comext data and respective data from the original national databases mentioned before, which allowed distribution of the Comext numbers for 00 to the specified Comext 2-digits classes 01 to 99. For imports by Germany, this correction could be done in a detailed way, but the largest share of 00 was actually found to be missing in mineral fuels (27), and in particular in natural gas imports. Also for imports by Denmark and Italy, data for 00 were found to be missing in 27 mainly and were completely allocated to mineral fuels imports. Missing 00 data for exports by Denmark were found to be mainly missing in 27, but the difference between national data (Statistics Denmark) and Comext data for exports of mineral fuels still did not account for the total missing allocation of 00 to specific 2-digits groups 01 to 99. The remaining difference, however, was found to be rather small and remaining numbers were left in the 00-commodity class. Another problem of this kind was encountered for imports by Italy 1993 to 2000 where Comext data for the 2-digits group 99, i.e. OTHER PRODUCTS, were found to be obviously missing in the mineral fuels group 27.

In addition, the Eurostat Comext reports imports and exports for the 4-digits group 2716, electrical energy, in metric tons, which simply makes no sense. These data had to be erased in order to derive correct totals for the 2-digits group 27.

Also, significant amounts of mineral fuels were sometimes declared as confidential trade whereas resulting gaps in the time series for natural gas clearly indicated that these amounts should be rather allocated there. This is a serious limitation to in detail studies for e.g. specific environmental impacts associated with traded commodities.

The conclusion from these observations is that the Eurostat Comext database is a rather critical source for imports and exports of mineral fuels and requires considerable efforts for corrections in order to derive consistent and realistic data. In this respect, data for imports and exports of mineral fuels should be rather derived from national energy statistics or maybe from international statistics of the OECD International Energy Agency (IEA).

Statistical data may be incomplete and/or inconsistent

One example is the before mentioned problem of disaggregated foreign trade data of NL leading to incomplete figures for the total trade, a problem that will prevail in the future and obviously cannot be solved completely. Other problems of incomplete data concern mainly the domestic extraction of minerals (in particular bulk minerals for construction), and the domestic harvest of biomass on agricultural land (in particular fodder biomass taken up by grazing of livestock) as described in the following.

Minerals statistics often report on industrial minerals only (like special clays, salts, etc.) but not or only incompletely on bulk minerals for constructions like sand and gravel, limestone, other natural stones like crushed rock aggregates, and clays for the manufacturing of bricks and tiles. In case data are not reported at all, this will at least become obvious. But in case data are incomplete, it may not be obvious at first sight. For example, official statistics may provide incomplete data due to limits of reporting, e.g. by leaving out small-scale business. This may have a more significant effect on materials than on economic parameters (an example is sand and gravel extraction in Germany, which is by about 50% due to small-scale business, contributing a significant portion to DMI and DMC). In some countries, data may be underrepresented also due to illegal construction activities, if this is the case for EU-15 and ACC-13 cannot be evaluated here. Solutions to overcome these limits of official statistical data are (1) to use other data sources accounting for the total materials (e.g. reports of the Industry Associations like the German sand and gravel industry in our example), and (2) to perform plausibility checks in order to provide a basis for estimating obviously missing material amounts. The first approach, using specific data sources providing more comprehensive figures, is usually undertaken in national studies, like the ones listed before, and these data can be taken as reasonable as regards coverage of construction minerals. For the other countries, general data sources of USGS, UN and BGS had to be used, and the reasonability of these data was evaluated by plausibility checks taking well documented figures for comparison and as reference values. Three plausibility checks were performed: (1) the amount of construction materials per capita, (2) the amount of construction materials per gross value added (GVA) in the construction sector, and (3) the amount of construction materials per number of residences completed in one year (with basic data for GVA and numbers of residences derived from the Eurostat NEW CRONOS database, however, data for the number of residences completed in one year are scarce especially for ACC, but provide similar results as for 1 and 2 for EU-15 and MS). The result of these plausibility checks for construction minerals was that especially the data for Turkey were found to be certainly underestimated by the data available from USGS and BGS. Another evidence for this assumption could be taken from USGS where the number for limestone production in Turkey was characterised as being incomplete with respect to a number of other uses than the specific ones considered, and in particular the uses for construction were apparently missing. So, we estimated additional limestone production in Turkey by the reported figures for the production of lime and cement and using coefficients of the amounts of limestone required to produce one ton of lime or cement from other consistent national data sources. Bringing this result back to the plausibility checks 1 and 2 still resulted in values at the lower range of reference values but not completely out of that range.

In this context, another specific data problem pops up with regards to international comparability of material flow data, which concerns the differentiation between construction minerals and industrial minerals. Limestone is an example for that. Limestone may be used at varying ratios across countries for either industrial purposes (like fertiliser production) or construction purposes (for lime or cement production). Similarly, clays may be used for constructions (manufacturing of bricks) or for industrial uses (special clays like kaolin). Industrial uses may be considered to be quantitatively less important for sand and gravel or crushed rock, but special sands or special stones for industrial uses may be included in totals and may not be identifiable in some databases. This is not so often the case in USGS statistics where specific uses are often described for the individual minerals, but it is the case in BGS statistics for some countries as found out by comparison with well documented national minerals databases. Certainly, the differentiation problem between industrial and construction minerals cannot be solved precisely for some data sets based on international sources only, but the plausibility checks indicated whether reasonable numbers for the usually dominating amounts of construction minerals had been obtained.

The domestic harvest of fodder plants, including the amounts taken up by grazing of livestock, may be reported incompletely and/or inconsistently. Incomplete data can be identified by comparative analysis of land use and agricultural harvest of crops for fodder and silage as described in the Eurostat guide on economy-wide MFA (Eurostat 2001a). It was further investigated in this study whether net-imports of fodder plants may play a role in this context, and results for the EU-15 and MS showed very clearly that this is not the case. Data for net-imports of fodder plants were not available for ACC-13 but it may be assumed that the relevance for domestic supply is similarly negligible as for EU countries.

More serious appears to be the problem of inconsistent data with regards to reporting on fresh weight or hay weight of green fodder plants including grazing. Data in hay weight (at 15% water content) are required for internationally comparable data sets. For this, two plausibility checks were performed in this study: (1) the total amount of green fodder (from harvest on agricultural land, grazing of livestock on pastures, and additional biomass commonly used for animals feed, i.e. sugar and fodder beet leaves for silage and straw) was referred to the total population of ruminants expressed as cattle equivalents, and (2) the total amount of green fodder was vice versa estimated by multiplying the total population of ruminants expressed as cattle equivalents with a specific amount of green fodder consumed and the result was compared with the result obtained via the material flow account for green fodder standardised by check 1. The second check is therefore in principle the same as applied by Eurostat-IFF (2002) to estimate the total amount of green fodder instead of using primary data on harvest and estimates for grazing. For these two plausibility checks, the total population of ruminants was derived from FAO statistics and converted to cattle equivalents by dividing the individual livestock heads by specific requirements for green feed per animal type (which is by definition 1 for cattle). With a few exceptions, like Greece where the sheep population is about 15 times higher than the cattle population, the total ruminant population was clearly dominated by cattle. Specific green fodder requirements in hay weight were taken from German feedstuff statistics of the Ministry of Agriculture reporting annually in a consistent manner on feedstuff consumption by type and per livestock type. They were found to be close to the values used by Eurostat-IFF for their estimates mentioned above.

The total amount of green fodder for this population of ruminants for plausibility check 1 was at first derived from the reported data on harvest and estimated data for grazing and additional green fodder, and divided by the numbers for cattle equivalents, resulting in values for average green fodder consumption per head and year. These initial results from plausibility check 1 were compared with reference values derived from German feedstuff statistics mentioned before and specific feedstuff requirements reported for German livestock (Malik 1998, Wuppertal Institute, unpublished study: for dairy cows, male and female calves, heifers and bulls) and livestock in Finland (Mäenpää and Vanhala 2002: for dairy cows and bulls). They were on the average for the total cattle population similar to the value used in the Eurostat-IFF study. But they allowed in addition to identify specific differences within the composition of the cattle population which has significant influence on the average consumption of green fodder. These differences occur because dairy cows consume considerably more green feed per head than bulls or other types of cattle, as the specific studies for Germany as well as for Finland showed. Consequently, a cattle livestock with a high share of dairy cows is likely to have a higher average consumption of green feed than a cattle livestock where other cattle types are dominant. Now, in cases where the average consumption of green fodder was clearly above the reference values, it was assumed that the data for agricultural production respectively estimated grazing were in fresh weight and these were then corrected for hay weights (assuming 80% water in fresh weight and 15% water in hay weight). The corrected values were then re-submitted to plausibility check 1. Final results for the EU and MS were in a reasonable range with regards to the reference values, with data for countries with a relatively high share of dairy cows (and high milk production per dairy cow) ranging tentatively higher than the EU average, and vice versa.

The results of plausibility check 2 largely confirmed the results obtained by the material flow account and check 1 as far as green fodder consumption in the EU-15 in total is concerned, and deviations were at most ± 6% though with a clear trend from lower values obtained by the material flow account in the early 90s to higher values in comparison with the estimates based on constant demand coefficients towards 2000. But for some Member States of the EU and in particular for some of the ACC-13 countries, deviations between the two approaches to account for green fodder were significantly higher with maximum deviations at about – 50% and + 80%.

This result shows a serious limitation of the approach to estimate the amount of green fodder via constant consumption coefficients as done in the Eurostat-IFF study for the EU and MS (Eurostat 2002). This limitation is due to two points: (1) the composition of the cattle or ruminants population may change significantly over time altering also the total requirements for green fodder, and (2) the composition of the total diet for the ruminants' livestock may also change considerably over time with the same effect in principle. The second situation was found for Germany during the 1990s where the reported feedstuff consumption for cattle (German Ministry of Agriculture) developed towards less green fodder and more cereals and concentrated feed, with the overall result that the average consumption of green fodder per German cattle declined by 20% during the 1990s. The first situation is especially critical for some countries in Eastern Europe where the total cattle respectively ruminants' population declined partly dramatically during the 1990s, presumably associated with significant shifts of the composition of the total livestock. This, however, could not be further investigated in this study, as well as presumably associated shifts in the composition of the animals' diets.

Overall, it can be concluded that the approach to estimate total green fodder via supply data (material flow account, check 1) yields more reliable and realistic results than the demand estimate via (constant) consumption coefficients. The latter is not suitable to account for specific dynamics within the system and should rather be used as a second plausibility check yielding results that should be interpretable with respect to changes in livestock and diets.

2.1.2 Accounting for the total weight of metals and minerals

The EUROSTAT Methodological Guide on economy-wide MFA (Eurostat 2001a) requires accounting for the total weight of crude ores. This concerns especially metals and also some other minerals. Mineral statistics, however, often present numbers for metal contents of ores only. Exceptional from this are USGS mineral statistics which often provide data for the total mass of crude ores besides metal contents, or provide information on metal contents of ore deposits in the text. Still, for a number of ores, this information cannot be obtained directly. In this case, information on the metal or mineral contents of ores has to be acquired from other sources in order to derive the total weight of crude metallic and other mineral ores. An extensive source for such kind of information represents the series of the former U.S. Bureau of Mines (now USGS) which published in the 1980s and 1990s series of mineral commodity surveys with information on typical ore grades by commodity and country or region. In case such information was not available by country, a typical global or regional average of the respective metal content of ores was taken instead.

Besides metals, the total weight vs. mineral content accounting concerns mainly potash which is often reported in K_2O contents only. If no country-specific data were available, information derived from German mining statistics was used to account for the crude potash ore weight based on reported K_2O contents.

Derivation of consistent time series

Even using time series from one data source requires critical analysis of data and critical reading of commentaries and eventually further literature. E.g., USGS sometimes refers to different original data sources for the same mineral in time series resulting in highly variable data series. In general, if only international data sources were available, it was tried to use different data sources in a comparative manner, like USGS, UN production statistics, European Minerals Yearbook (EMY), and minerals statistics of the British Geological Survey (BGS), in order to derive a most reasonable and consistent time series.

Still, data gaps for individual years may occur, or time series derived from different sources do not cover the same periods, so that reliable estimation procedures have to be developed and tested for applicability. The problem of completely missing data for one or several years within one time series has hardly been encountered in this study, but the problem of diverting time series in different sources was quite common and concerned mainly the comparability of USGS vs. BGS minerals data for the overlapping reporting period 1997 to 2000. In case BGS data were found to be more comprehensive, this occurred especially for bulk construction minerals, the USGS time series prior to 1997 was adjusted by estimation based on the ratios of values from BGS to USGS for 1997 to 2000. Alternatively, data available from EMY for 1990 to 1995 were used, but these were rather scarce for bulk construction minerals, especially for the ACC.

Finally, the construction minerals data were submitted to plausibility checks, as described before, in order to find out where unreasonable variations within time series occurred and in order to submit these to critical re-examination and re-adjustment of estimation procedures applied. Inconsistent time series were also encountered in the Eurostat Comext foreign trade statistics and concerned mainly imports of The Netherlands as described before.

Use of international statistics
International statistical data sources had to be used for much of the data for EU-15 and ACC-13, except for those countries for which reliable national data sets were available as described before. And most of the data problems encountered and already described are actually due to using general data sources instead of specific and consistent national ones. Ideally, a specific national material flow study should be performed for every economy. As this is unrealistic at the moment, the most critical statistical data underlying material based indicators were submitted to plausibility checks for construction minerals and green fodder as described before. In the particular critical case of industrial minerals data for Estonia, a national expert was contacted for advice in order to avoid misleading results, as described before.

Estimation of missing data
Completely missing data for material flows concerned mainly domestic construction minerals and domestic biomass, and in particular green feed taken up by livestock by grazing, as well as other biomass not reported by official harvest statistics, in particular sugar- and fodder beet leaves for silage and straw for economic use. The comprehensive accounting for green fodder including grazing, based on plausibility checks, has been described. The amounts for the potential use of leaves and straw was estimated based on ratios derived from German agricultural statistics and from Eurostat (2002) which were found to be in good agreement. Estimation of obviously missing amounts of construction minerals has also been described before.

In most material flow accounts, the amounts of biomass from hunting and other biomass (honey. mushrooms, etc.) are missing. As this certainly does not represent a major data gap, no further efforts were undertaken to derive such missing data.

Much more critical were missing data for imports and exports of minerals and mineral products, metals and metal products, and other finished compound products for most of the ACC-13. Although we contacted all statistical offices in ACC for these original data, we were successful only in the case of Latvia, Romania, Slovakia and Slovenia, but only Romania and Slovakia provided complete time series for imports and exports from 1992 to 2000. Original data for Poland were available for 1992, 1995 and 1997 from the ECOPOL study performed by Wuppertal Institute with partners in Poland (Schütz et al. 2002).

For the remaining countries, resp. years, of ACC-13 and commodity groups mentioned above (comprehensive foreign trade data for fossil fuels were available from IEA, for biomass from FAO) an estimation procedure was applied based on Eurostat Comext foreign trade data of the EU with ACC. For this, exports of the EU to ACC were counted as imports of the ACC and, vice versa, EU imports from ACC were counted as exports of ACC. This represented thus a first minimum estimate for the external trade of ACC concerning trade with the EU only. In a next step, external trade of ACC with other economies than the EU was estimated by applying weighted factors derived from total trade divided by EU trade for Czech Republic, Poland, Latvia, Romania, Slovakia and Slovenia. During the final stage of data work, BGS statistics became available reporting specifically on imports and exports for 1997 to 2000 of ACC for crude minerals and metals as raw materials and semi-manufactured products. The estimates for these commodities were then replaced by the original BGS data and missing data for 1992 to 1996 were estimated on the country-specific ratios of total trade to EU trade for 1997 to 2000. So, finally, only foreign trade of the ACC for which no specific national data were available, and only for finished mineral products, finished metal products and other compound products had to be based on the estimation procedure described above. These data, however, were found to have no significant influence on the overall results for DMI and DMC, and it can be almost excluded from the experience with comprehensive data for Czech Republic, Poland, Latvia, Romania, Slovakia and Slovenia that significant amounts of material flows were not captured or severely overestimated by this approach.

2.2 Consistent set of data for material flows and resource use indicators for EU-15 and AC-13 in time series

Based on the acquisition and analysis of material flow data described above, 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.

The data for domestic extraction in EU and MS and in ACC-13 are provided 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 before.

This database thus allows for disaggregation of 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.

Annex 3 Three options to link DMC to life-cycle based environmental impacts

Three options are identified to solve the difference in system boundaries between DMC and the life-cycle based impacts of materials. All three conform to the notion of avoiding double-counting

1. We translate all DMC / MFA data into finished materials, to enable an apparent consumption system per material
2. We translate all DMC / MFA data into resources, defining materials at the level of extraction from the environment
3. We limit ourselves to 5 - 10 rough categories of materials within DMC and define an average impact factor for each of these categories.

Option 1 most closely connects with the materials method. In principle, we keep the same series of materials. Double counting is excluded by eliminating raw materials that are already part of the impacts per kg of the finished materials. Imported fertiliser is part of the agricultural chain and therefore eliminated. Harvested or grazed grass is part of the animal product chain and therefore is translated into animal products. For extracted sand, a division will be made over the finished materials sand, cement, concrete and glass. With the import and export data, separate material balances will then be drafted for sand, cement, concrete and glass. Etc. In this way, the DMC is translated into (a rough estimate of) apparent consumption per material. This option requires additional information regarding the division of raw materials over finished materials, and on the efficiency of the involved processes (factors, in kg/kg, from ore to metal and from grass to milk etc.). In formula:

*Impact consumption material A = apparent consumption material A * impact factor material A (1)*

Apparent consumption material A = import material A + estimated production material A – export material A (2)

Weight extracted resource 1 (kg) (weight fraction resource1 to material A (kg/kg)) * (1/(weight fraction resource 1 in material A)(kg/kg)) = estimated production material A (kg) (3)*

Equation (1) is the general equation following from Condition 1. The impact factors for material A and all others is already available. The consumption needs to be calculated from Equation (2). Equation (2) contains the estimated production, which in turn is calculated by Equation (3) out of the DMC and information on the fate of the resources. Extracted sand, for example, thus must be assigned to sand used as such, sand used in concrete and sand used in glass. The same approach must be followed for ores, fossil fuels and the other resource categories. For this translation, there are data from USGS, specifying the fate of a number of resources in percentages. These percentages are valid for the USA. The British Geological Survey is involved in making similar overviews for the British situation. These data are not yet available, but apparently the British materials use is rather similar to that of the USA (oral communication). A drawback is that there are no time series available, and therefore we have no information about developments over time. This reduces the usefulness of this approach somewhat. Option 1 combines, in our opinion, the best of both worlds. The main drawback is that it is inferior to the use of production statistics. This approach estimates a consumption level that is already known from production data. Moreover, changes over time in the division of resources over their finished products remain invisible, which would be visible when using production statistics. On the other hand, for countries with limited datasets Option 1 could lead to reasonable results where production data are not available.

Option 2 most closely connects to the idea of extractions and therefore resources. The general idea is the same as for Option 1 but the other way round: double counting is excluded by translating products and finished materials into the resources they come from. Instead of steel, we then see iron ore and coal, instead of plastics we see crude oil, and instead of glass or concrete we see sand. In formula:

*Impact consumption resource 1 = domestic consumption resource 1 * impact factor resource 1 (4)*

Domestic consumption resource 1 = import resource 1 + extraction resource 1 – export resource 1 + estimated embedded imported resource 1 – estimated embedded exported resource 1 (5)

*Weight material A * weight fraction of resource 1 in material A = embedded weight resource 1 in material A*

*Weight material A * weight fraction of resource 2 in material A = embedded weight resource 2 in material A ….. (6)*

*Weight material B * weight fraction of resource 1 in material B = embedded weight resource 1 in material B*
*Weight material B * weight fraction of resource 2 in material B = embedded weight resource 2 in material B ….. (7)*

Embedded weight resource 1 = embedded weight resource 1 in material A + embedded weight resource 1 in material B + …. (8)

*Impact factor resource 1 = (impact factor material A * fraction of resource 1 to material A) + (impact factor material B * fraction of resource to material B) + …. (9)*

The general equation , Equation (4), now is defined at the level of resources. Both consumption and impact factor now require elaboration. In Equation (5) the consumption is calculated using a term called "estimated embedded resources". This estimation of embedded resources takes place in Equations (6), (7) and (8). Additional information is required on the composition of the materials, f.e. glass is made out of sand but also chalk stone. This information is available in principle in the LCA database. It requires a lot of work to get it out for each material, however. In Equation (9), impact factors are calculated for resources instead of finished materials. Whereas Option 1 requires a distribution of raw materials over finished materials, we need the same information under Option 2 to arrive at weighted impact factors. The impact factor for "sand" then also includes the chains of cement, concrete and glass.

An advantage of Option 2 is that it connects to what one imagines as "natural resources". A disadvantage is that it is a lot more work. The uncertainties and rigidities included in the materials flows in Option 1 are included in the impact factors in Option 2. An additional problem might be the policy relevancy. A link with sectors of production is no longer possible. Only mining companies and crop producers can be addressed based on this information.

Option 3 boils down to defining average impacts per kg for rough categories of materials. This option is most suitable to DMC: in a general category "metals" one doesn't have to worry about a negative consumption of nickel, since this is invisible due to the much larger flows of iron and steel.

*Impact consumption category a = domestic consumption category a * impact factor category a (10)*

Domestic consumption category a = import category a + extraction category a – export category a (11)

Impact factor category a = (impact factor material A weight fraction material A in category a) + (impact factor material B * weight fraction material B in category a) + …. (12)*

In option 3, the work is on the side of the impact factors. New impact factors have to be drafted for the impact categories. In Equation (12), the proposal is to determine these impact factors based on the composition of the categories. Unfortunately, this composition is different per country. This would mean either that different impact factors have to be established for each country, or that we define an average impact factor for all countries together. A third option is to identify per category one material, which is considered representative for the whole category.

Option 3 is easily realisable, which is a clear advantage. On the other hand it remains rough. It would mean, for example, that the whole metals sector would have to do with 1 average impact factor for the group of metals. Policy relevancy is then at stake.

Annex 4: Data on materials and impacts per kg of material for thirteen impact categories, from ETH-database for LCA studies

In the following table, the data availability for materials is listed. The leftmost column contains the materials available in the LCA database. In the middle column, materials from the MFA database are listed. This list in fact is much longer; it contains a variety of products which we did not include in this study. The rightmost column shows the materials we included. The difference with the - considerably longer - lists in the two columns to its left arises from two reasons: (1) incompatibility between the two lists, we need to have both material flow data and LCA data in order to be able to include a material, and (2) excluding double-counting, for which reason almost all industrial and agricultural chemicals are excluded, because they are used in the chain of other materials. The second reason is the most important.

Materials in extended ETH database	Materials in MFA database	Materials included in this study
Fossil fuels	*Fossil fuels*	*Fossil fuels*
natural gas for heating in households	hard coal	natural gas for heating in households
natural gas for heating in households (LowNOx)	lignite	natural gas for electricity in households
natural gas for electricity consumed in households	peat	oil for heating and transport in households
oil for heating and transport in households	natural gas	oil for electricity in households
oil for electricity consumed in households	crude oil	hard coal for heating in households
hard coal for electricity consumed in households	crude oil gas	hard coal for electricity in households
hard coal for heating in households		brown coal for heating in households
brown coal for heating in households		brown coal for electricity in households
brown coal for electricity consumed in households		
PC	plastics	plastics
PE(HD)		
PE(LD)		
PET 0% rec.		
PP		
PS		
PUR		
PVC		
Ores and metals	*Ores and metals*	*Ores and metals*
aluminium 0% Rec.	Antimony	Aluminium
aluminium 100% Rec.	Bauxite	Copper
raw iron	Berylium	Iron and steel
cast iron	Chromium	Lead
chromium	Cobalt	Nickel
copper	Copper	Zinc
copper additive	Germanium	
lead hard	Gold	
lead soft	gold & silver-ore	
manganese	Iron	

nickel	Lead	
palladium	Magnesium	
platina	Manganese	
rhodium	Mercury	
steel (blown)	Nickel	
steel (electro)	Silver	
steel (high alloyed)	Tin	
steel (light alloyed)	Titanium	
steel (not alloyed)	Tungsten	
zinc	Uranium	
zinc additive	Zinc	
	Other ores unspecified	

Industrial materials	*Industrial materials*	*Industrial materials*
AlO3	Abrasives, natural	glass
ammonia	Andalusite, kyanite, related materials	salt
barite	Asbestos	
bentonite	Asphalt and bituminous rock, natural	
Ca(OH)2	Barite	
CaO	Borates, natural	
chemicals inorganic	Bromine	
chemicals organic	Chalk	
chlorine	Clays, industrial	
ethylene	Cryolite, natural	
ethylene oxide	Diamonds	
explosives	Diatomite	
FeSO4	Dolomite	
formaldehyde	Feldspar	
glass (coated)	Fluorspar	
glass (not coated)	Graphite	
gypsum (raw stone)	Gypsum and anhydrite	
H2SO4	Kieserite and epsomite	
HCl	Magnesite and magnesia	
HF	Mica	
HNO3	Moler	
hydrogen	Oil shale	
NaCl	Olivine	
NaOH	Peat	
paraxylene	Pegmatite	
phenol	Perlite and Vermiculite	
refrigerant R134a	Phosphates, natural	
refrigerant R22	Pigments, natural	
rubber	Potash	
soda	Pyrite and pyrrhotite	
styrene	Quartz and quartzite	
sulphur (secondary)	Salts	
vinylchloride	Sands, industrial	
zeolites	Sepiolite, meerschaum	
	Shells fished by buckets	
	Stones, industrial	
	Strontium minerals	
	Sulfur, natural	
	Talc, soapstone and related materials	
	Zeolites	

	Other industrial minerals	
	Missing industrial minerals	
Construction materials	*Construction materials*	*Construction materials*
cement	Sand and gravel	concrete
ceramic	Limestone, dolomite and marl	ceramics
clay / loam	Other natural stones	clay
concrete	Sand and gravel, stones, not further specified	sand and stone
gravel	Clays	
gypsum	Other construction materials, not further specified	
limestone		
rockwool		
sand (construction)		
Biomass (crops and animal products)	*Biomass (crops and animal products)*	*Biomass (crops and animal products)*
animal products	Cereals	starchy crops
crop or grass	Roots and tubers	fibre crops
	Sugar Cane	animal fibres
	Sugar Beets	protein crops
	Pulses	protein animal
	Nuts	protein fish
	Oilseeds	oil crops
	Vegetables	animal fats
	Fruit	
	Maize for Forage+Silage	
	Forage+Silage	
	Other agricultural biomass	
	Grazing	
	Fish	
	Hunting biomass	
Biomass from forestry	*Biomass from forestry*	*Biomass from forestry*
wood (board)	Wood	wood
wood (massive)	Other forestry products	
Paper and board	*Paper and board*	*Paper and board*
paper	Paper & board	paper and board
board		
Agricultural chemicals	*Agricultural chemicals*	*Agricultural chemicals*
AP		
CaNO3		
CAN		
DAP		
H3PO4		
KNO3		
MAP		
nitro AP		
NPK 15-15-15 (mixed acid route)		
NPK 15-15-15 (nitrophosphate route)		
PK 22-22		

SSP
TSP
UAN
urea
ureum
pesticides for crop production

The following table contains the impact scores for the materials included in the study. The scores represent problem causing equivalents per kg of material for thirteen different impact categories. Legenda can be found below the table.

	ADP (Guinee et al. 2001)	LC (Guinee et al, 2001)	GWP100 (Houghton et al., 2001)	ODP steady state (WMO, 1992 & 1995 & 1999)
Fossil fuels				
natural gas for heating in households	0.00036	0.0242	2.8	2.42E-07
natural gas for electricity in households	0.00471	0.016	7.51	1.77E-07
oil for heating in households	0.000599	0.0271	3.98	5.44E-06
oil for electricity in households	0.000454	0.0102	3.85	5.51E-06
hard coal for heating in households	0.0205	0.0161	3.06	4.30E-07
hard coal for electricity in households	0.0267	0.0221	3.35	1.46E-07
browncoal for heating in households	0.0168	0.0163	2.32	7.91E-08
browncoal for electricity in households	0.0157	0.0119	2.09	1.67E-08
plastics (impacts as PE)	0.002134	0.036594	5.386578	7.66E-06
Ores and metals				
Aluminium	0.038868	0.395666	13.117	6.73E-06
Copper	0.015808	0.226708	5.40954	3.34E-06
Iron and steel	0.020203	0.029518	2.060051	4.38E-07
Lead	0.82339	0.067971	1.609215	9.52E-07
Nickel	0.053961	0.508082	15.12475	9.07E-06
Zinc	0.027699	0.197684	4.951277	1.66E-06
Industrial materials				
glass	0.0021	0.017144	0.778279	1.31E-07
salt	0.000254	0.00301	0.0995	6.12E-08
Construction materials				
concrete	0.000285	0.006788	0.064932	3.19E-08
ceramics	0.000338	0.008801	0.370648	4.90E-08
clay	3.16E-06	0.001437	0.001797	1.91E-09
sand and stone	8.60E-06	0.00466	0.00999	1.23E-08
Biomass (crops and animal products)				
starchy crops	6.80E-05	0.079884	0.790963	1.45E-08
fibre crops	6.80E-05	0.079884	0.790963	1.45E-08
animal fibres	0.000616	1.245374	2.181991	1.38E-07
protein crops	6.80E-05	0.079884	0.790963	1.45E-08
protein animal	0.000616	1.245374	2.181991	1.38E-07
protein fish	0.000768	0.0221	2.32	1.79E-06
oil crops	6.80E-05	0.079884	0.790963	1.45E-08
animal fats	0.000616	1.245374	2.181991	1.38E-07
Biomass from forestry				
wood (impacts as massive wood)	0.000325	0.028231	-0.46151	6.30E-08
paper and board				
paper and board	0.002726	0.048015	2.014468	9.28E-07

	HTP inf. (Huijbregts, 1999 & 2000)	FAETP inf. (Huijbregts, 1999 & 2000)	MAETP inf. (Huijbregts, 1999 & 2000)	TETP inf.(Huijbregts, 1999 & 2000)
Fossil fuels				
natural gas for heating in households	0.0764	0.0061	53.3	0.00172
natural gas for electricity in households	0.297	0.0652	196	0.00209
oil for heating in households	0.302	0.0228	343	0.00731
oil for electricity in households	1.48	0.135	1.26E+03	0.0519
hard coal for heating in households	2.29	0.297	2.76E+03	0.0191
hard coal for electricity in households	1.72	0.366	5.62E+03	0.0134
browncoal for heating in households	0.541	0.0141	1.06E+03	0.00773
browncoal for electricity in households	0.316	0.00348	3.20E+03	0.00407
plastics (impacts as PE)	3.218841	0.283806	2259.516	0.084431
Ores				
Aluminium	5.475479	0.645604	29773.1	0.076158
Copper	2.260614	0.167931	2790.803	0.015548
Iron and steel	1.52407	0.288248	1433.128	0.007862
Lead	134.0039	0.321741	966.6053	1.34101
Nickel	18.00226	16.30184	23898.46	0.164593
Zinc	46.40231	1.043328	5561.504	0.559456
Industrial materials				
glass	0.194745	0.028185	1185.285	0.000958
salt	0.0349	0.00463	55.6	0.000737
Construction materials				
concrete	0.018015	0.003744	22.2126	0.000244
ceramics	0.342796	0.004017	4582.187	0.000448
clay	0.000276	3.59E-05	0.715176	4.21E-06
sand and stone	0.00126	0.000126	2.24	1.94E-05
Biomass (crops and animal products)				
starchy crops	0.011566	0.067762	13.30032	0.002755
fibre crops	0.011566	0.067762	13.30032	0.002755
animal fibres	0.101	0.510722	129.3001	0.021557
protein crops	0.011566	0.067762	13.30032	0.002755
protein animal	0.101	0.510722	129.3001	0.021557
protein fish	0.146	0.0169	231	0.00257
oil crops	0.011566	0.067762	13.30032	0.002755
animal fats	0.101	0.510722	129.3001	0.021557
Biomass from forestry				
wood (impacts as massive wood)	0.033471	0.006913	72.60162	0.000709
paper and board				
paper and board	0.498431	0.079527	775.6147	0.014454

	POCP (Jenkin & Hayman, 1999; Derwent et al. 1998)	AP (Huijbregts, 1999; average Europe total, A&B)	EP (Heijungs et al. 1992))	radiation (Frischknecht et al., 1999)	final solid waste
Fossil fuels					
natural gas for heating in households	0.000463	0.0024	0.000548	6.94E-10	0.0655
natural gas for electricity in households	0.000733	0.00809	0.00181	8.94E-11	0.151
oil for heating in households	0.000649	0.00927	0.000587	8.65E-10	0.0729
oil for electricity in households	0.00227	0.0498	0.0011	2.24E-10	0.0374
hard coal for heating in households	0.00605	0.018	0.000473	2.24E-10	0.619
hard coal for electricity in households	0.000812	0.0168	0.000865	2.48E-10	0.733
browncoal for heating in households	0.00296	0.00878	0.000385	1.14E-10	0.0637
browncoal for electricity in households	0.00108	0.026	0.000413	8.83E-11	0.00809
plastics (impacts as PE)	0.017602	0.022508	0.000884	1.33E-09	0.072075
Ores					
Aluminium	0.003749	0.078628	0.002961	1.31E-08	2.35689
Copper	0.006994	0.166628	0.001124	8.31E-09	3.34381
Iron and steel	0.001088	0.007356	0.000551	5.29E-10	1.525484
Lead	0.001957	0.046466	0.000367	2.48E-09	1.614527
Nickel	0.122254	3.028897	0.004471	1.98E-08	2.426319
Zinc	0.002192	0.043605	0.002026	7.77E-09	1.693776
Industrial materials					
glass	0.00019	0.002267	0.000262	2.67E-10	1.086442
salt	4.63E-05	0.000838	3.76E-05	6.41E-11	0.0479
Construction materials					
concrete	2.22E-05	0.000316	4.73E-05	4.06E-11	1.01007
ceramics	8.48E-05	0.001459	0.00016	2.13E-10	1.008673
clay (other uses)	7.88E-07	1.11E-05	2.05E-06	1.93E-12	1.00008
others (impact as sand)	3.06E-06	4.56E-05	5.98E-06	6.09E-12	0.000301
Biomass (crops and animal products)					
starchy crops	8.00E-06	0.000144	0.021369	3.81E-11	0.345376
fibre crops	8.00E-06	0.000144	0.021369	3.81E-11	0.345376
animal fibres	0.000288	0.01116	0.13743	3.57E-10	0.423971
protein crops	8.00E-06	0.000144	0.021369	3.81E-11	0.345376
protein animal	0.000288	0.01116	0.13743	3.57E-10	0.423971
protein fish	0.000833	0.0134	0.0133	4.79E-10	0.369
oil crops	8.00E-06	0.000144	0.021369	3.81E-11	0.345376
animal fats	0.000288	0.01116	0.13743	3.57E-10	0.423971
Biomass from forestry					
wood (impacts as massive wood)	5.74E-05	0.0008	8.97E-05	2.17E-10	0.009788
paper and board					
paper and board	0.000697	0.014434	0.000526	1.24E-09	0.117498

Legenda:

ADP: Abiotic Depletion Potential, kg antimony equivalents
LC: Land Competition, m2.year
GWP: Global Warming Potentials, kg CO2 equivalents
ODP: Ozone Depletion Potential, kg CFC-11 equivalents
HTP: Human Toxicity Potential, kg 1,4 dichlorobenzene equivalents
FAETP: Freshwater Aquatic Ecosystem Toxicity Potential, kg 1,4 dichlorobenzene equivalents
TETP: Terrestrial Ecosystem Toxicity Potential, kg 1,4 dichlorobenzene equivalents

MAETP (not included): Marine Aquatic Ecosystem Toxicity Potential, kg 1,4 dichlorobenzene equivalents
POCP: Photochemical Oxidant Creation Potential, kg ethylene equivalent
AP: Acidification Potential, kg SO_2 equivalent
EP: Eutrophication Potential, kg PO_4 equivalent
radiation: DALY
final solid waste: kg / kg

Annex 5 Calculation of environmental impacts related to the consumption of resources and materials

5.1 Required information

Basically two types of information are necessary to estimate the environmental impact related to the consumption of resources and materials by a country:

1. the environmental impacts related to the resources and materials
2. the consumption of the resources and materials by a country

ad 1. On a material level estimates of environmental impacts (global warming, toxicity, ozone depletion etc.) are available based on process descriptions in an LCA databases (ETH process database (Frischknecht, 1996)). The impacts represent the material from cradle to grave. That means that the impacts are based on emissions during the mining of the resources, the production of the material, the use of the material and the final waste treatment. A short description of the concept of LCA and the successive steps in environmental impact assessment are described in the appendix “the concept of environmental system analysis in LCA”.

ad 2. The consumption of resources, materials and products can be derived from the MFA accounts as composed by the Wuppertal Institute for EU-15 and AC-13 countries.

These two types of information must be combined. However the datasets represents economic goods on a different level of the resource-material-product chain. The impacts are described on a finished material level (e.g. glass), while the MFA accounts describe consumptions on all levels of the resource-material-product chain (e.g. respectively industrial sand, glass and products of glass). Therefore the combination of the information needs some additional processing of the data. In Chapter 3 of the main report, the possible options are discussed. In this study the first option is chosen, to translate all consumptions of minerals and ores into the consumption of finished materials. This means that the consumption of resources is used to estimate the domestic production of materials.

Below, the formulas and assumptions are described to calculate the impacts due to the consumption of materials by a country. Also the formulas and assumptions to estimate the production of materials based on the consumption of resources are summarized.

The impact of the consumption of materials by a country is described in the formula:

$$E_{c,m1} = S_{E,m1} * C_{m1}$$

$E_{c,m1}$ = Environmental impact due to the consumption of material ‘m1’ by a country
$S_{E,m1}$ = Environmental stress factor for material ‘m1’
C_{m1} = consumption of material ‘m1’ by a country

The environmental stress factor ($S_{E,m1}$) is the impact score per kg material consumption as derived from the LCA database.

The consumption of material “m1” by a country can be derived from the MFA accounts using the formulas given below.

$$C_{m1} = I_{m1} + P_{m1} - E_{m1}$$

I_{m1} = Import of material ‘m1’
P_{m1} = Production of material ‘m1’
E_{m1} = Export of material ‘m1’

The production of material ‘m1’ is not given in the MFA accounts but can be estimated using the formula given below:

$$P_{m1} = C_{r1} * F_{r1 \rightarrow m1} * \frac{1}{F_{r1/m1}}$$

P_{m1} = estimated production of material ‘m1’
C_{r1} = Consumption of resource ‘r1’
$F_{r1 \rightarrow m1}$ = weight fraction of resource ‘r1’ that is used for the production of material ‘m1’
$F_{r1/m1}$ = weight fraction of resource ‘r1’ in material ‘m1’

For example the main resource for the production of glass is industrial sand. So the production of glass in a country can be used to estimate the consumption of industrial sand by that country. According to USGS (United States Geological Survey) (USGS, 2004) about 37% of the consumption of industrial sand is used for the production of glass, so $F_{r1 \rightarrow m1}$ is 0.37. According to the LCA-database (Frischknecht, 1996) for the production of 1 kg of glass about 0.75 kg of industrial sand is necessary, so $F_{r1/m1}$ is 0.75. Table A1-1 summarizes the parameters that are used in this study to estimate the production of materials based on resource consumption.

So in this study the consumption of minerals, ores and biomass are translated into the consumption of a limited number of end uses of materials. To achieve this the consumption of minerals, ores and biomass are allocated to different end uses of materials (based on data from USGS, 2004).

In the materials method, the cradle-to-grave chains of the materials are the basis for the impacts per kg. There is a risk of double counting due to the use of cradle-to-grave impact factors. For example imported fertilizer is visible in DMC, but is also a part of the chain of agricultural products, which are also visible in DMC. Multiplication of both flows with a cradle-to-grave impact factor implies a double-counting of these chains. So to avoid double counting many resources (minerals and biomass) that are part of the DMC are not multiplied with the environmental stress factor ($S_{E,m1}$) because they are part of the cradle to grave systems of the end use materials. This particularly is relevant for the consumption of industrial minerals, energy from fossil fuels by industry and fodder crops and grass that for example are part of the production chain of iron and steel, concrete, paper, crops and animal products.

So finally the following groups of material end uses are multiplied with the environmental stress factor to estimate the environmental impact caused by the consumption of materials by a country:

- Fossil fuels: energy consumption of households and non energy use, for the production of plastics. relative consumption (average for EU15) is taken from energy balance sheets (Eurostat, 1999)
- Ores: as metal.
- Industrial minerals: only industrial sand and part of the salt is assumed to have an end use. Part of the industrial sand is assumed to be used for the production of glass. Part of the salt is assumed to be used for food and deicing of roads etc.
- Construction minerals: Part of the sand and gravel is used for the production of concrete. Part of the clay is used for the production of ceramics. The rest of the construction materials are used as end uses as such.
- Biomass: crops, animal products and fish for human consumption, wood and paper.

Table A1-1 shows the detailed assumptions that are used to estimate the production of materials based on the consumption of resources (minerals and ores).

			materials										
			plastics	iron	copper	lead	zinc	nickel	deicing roads, food etc	glass	concrete	ceramics	other end uses of clay
resources	natural gas	$F_{r1 \rightarrow m1}$[1]	0.05										
	crude oil		0.16										
	iron ores and concentrates			0.58									
	copper ores and concentrates				0.30								
	lead ores and concentrates					0.61							
	zinc ores and concentrates						0.61						
	nickel ores and concentrates							0.13					
	salt								0.50				
	industrial sand									0.37			
	construction sand, gravel and crushed stones										0.23		
	clays											0.60	0.40
		$F_{r1/m1}$	1	1	1	1	1	1	1	0.75	1	1	1
note 1: $F_{r1 \rightarrow m1}$ for metals the metal content in ores is given													

Table A1-1 Weight fraction of resource allocated to material ($F_{r1 \rightarrow m1}$) and weight fraction of resource in material ($F_{r1/m1}$)

5.2 Theory behind calculating the environmental impacts of materials

5.2.1 The concept of environmental system analysis in LCA

In figure 1 the concept of environmental system analysis as used in LCA is illustrated. In the *inventory analysis* (see paragraph 2.2) the system of processes is defined, the flowchart with unit processes is designed, the data are collected for each of these processes and the total of interventions of the system of processes is calculated (inventory table). The inventory table is the listing of quantified inputs from and outputs to the environment associated with the defined system, in terms of extractions of kg iron ore, kg oil and emissions of kg carbon dioxide, kg methane, kg xylene etc..

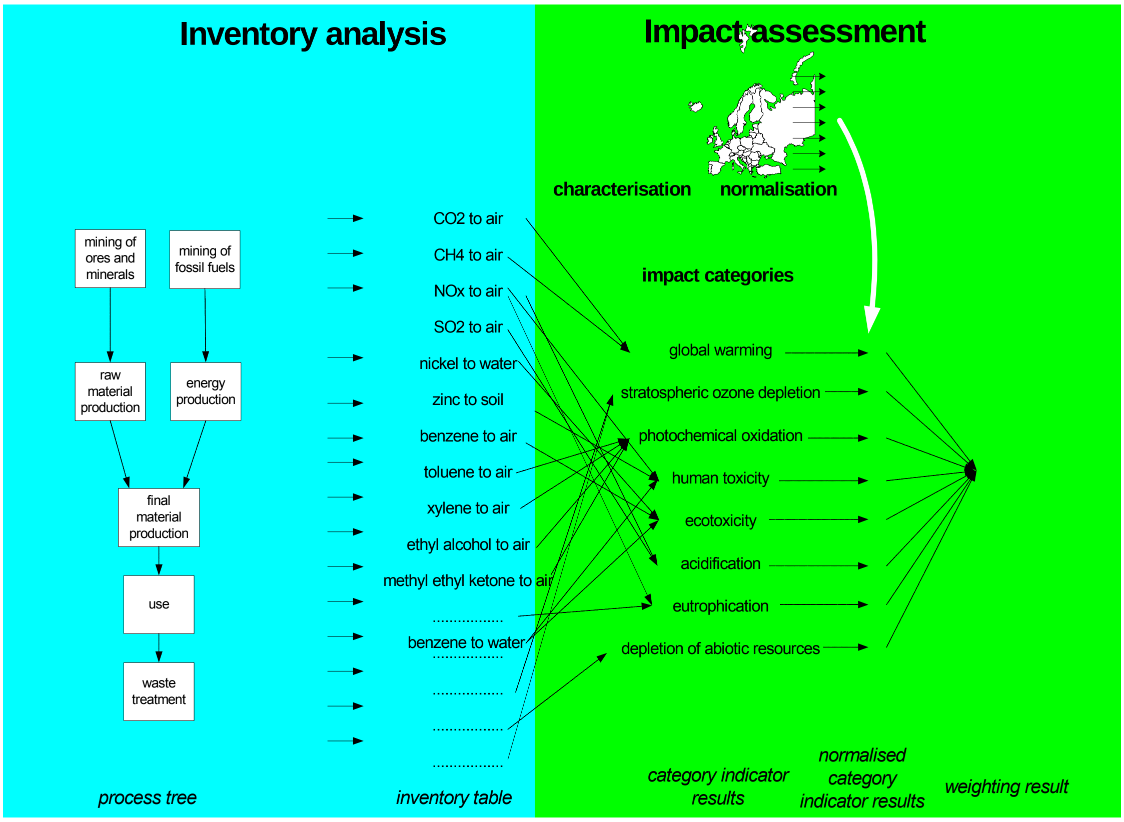

Figure 1 The concept of environmental system analysis in LCA

Each intervention as listed in the inventory table in fact is an environmental indicator. However if a complex system is analysed you may end up with a long list of hundreds of indicators (that is emissions and extractions). For this reason the environmental system analysis provides an aggregation procedure, the impact assessment.

Life Cycle Impact Assessment (LCIA) (see paragraph 2.3) is the phase in which the set of results of the inventory analysis – mainly the inventory table – is further processed and interpreted in terms of environmental impacts and societal preferences. To this end, a list of impact categories is defined, and models for relating the environmental interventions to suitable category indicators for these impact categories are selected. The actual modeling results are calculated in the characterisation step, and an optional normalisation serves to indicate the share of the modeled results in a worldwide or regional total (e.g. Europe). Finally, the category indicator results can be grouped and weighted to include societal preferences of the various impact categories.

The different phases of inventory and impact assessment are also explained in paragraph 2.2 respectively 2.3.

5.2.2 The inventory analysis

The flowchart with unit processes

The process flowchart forms a qualitative graphical representation of all relevant processes involved in the life cycle of the system (product or sector) studied. It is composed of a sequence of processes (represented by boxes), linked by material flows (economic flows, represented by arrows). The main goal of the process flowchart is to create an overview: you should focus on the most relevant processes rather than striving for 100% coverage.

The unit process

This step of the inventory analysis phase involves the collection of all relevant data on the unit processes and quantifying all flows connected to the unit processes. In LCA databases, process data are often organized around unit processes, relating a given economic output to economic inputs and environmental inputs and outputs (see figure 3). In LCA the unit processes relevant for a product or a sector are connected to each other by the economic inflows and outflows. The economic output of process A is economic input of process B.

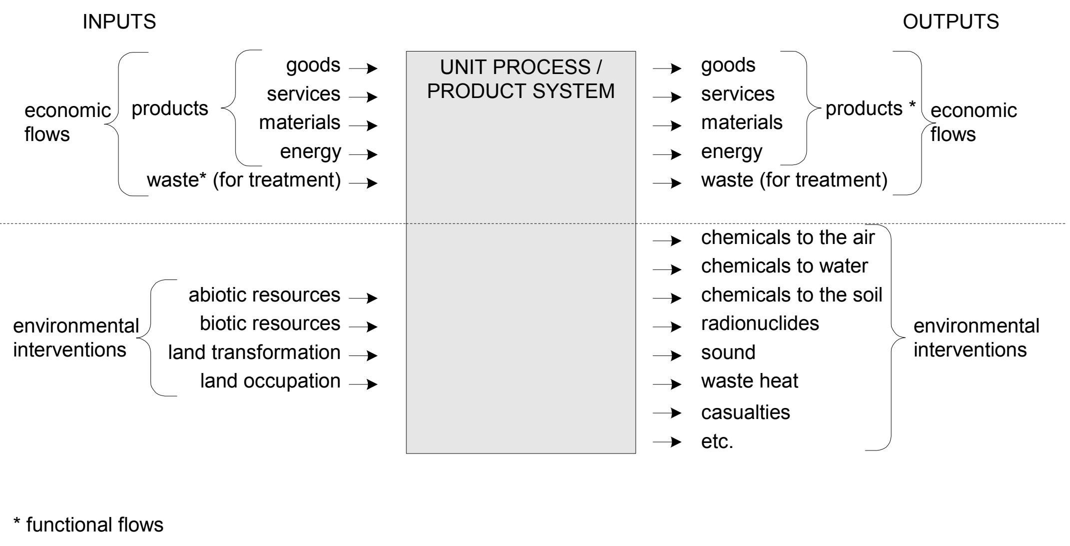

Figure 3: Basic structure of a unit process (or product system) in terms of its inputs and outputs.

5.2.3 the Environmental Impact Assessment

In LCA impact assessment the total of interventions (emissions, extractions) of a process chain is evaluated in terms of environmental problems (impact categories).

Basically the impact assessment involves the following steps:
- selection of impact categories and characterisation methods
- classification and characterisation
- normalisation
- weighting

Selection of impact categories and characterisation methods

At first relevant impact categories must be identified. In this study the impact categories that are used for the environmental assessment are based on the best available practice impact categories drawn up by the SETAC Working Group on Impact Assessment (Udo de Haes *et al*., 1999 & 1996). These impact categories is referred to below as the problem-oriented approach, because it is driven by environmental problems (the so-called mid-point of the cause-effect chain), rather than by damage (the end-point of this chain).

For each of these impact categories several alternative characterisation methods may be available. The characterisation method for a given impact category comprises a category indicator, a characterisation model and characterisation factors derived from the model. In the Dutch Handbook on LCA (Guinée *et al*., 2002) a list of 'baseline' characterisation methods is selected. These 'baseline' characterisation methods are used in this study.

Table A2-1 gives an overview of the environmental impact categories that are taken into account in the environmental impact assessment according to the baseline method that is recommended in the new Dutch LCA Handbook (Guinée *et al*., 2002). The baseline characterisation method for each impact category is specified in appendix 3.

Table A2-1 Impact categories based on the SETAC list of impact categories for which a 'baseline' characterisation method is available as recommended in Guinée et al. (2002)

impact category[1]	Baseline characterisation factor
climate change (global warming)	GWP_{100}
stratospheric ozone depletion	ODP_{∞}
Photo-oxidant formation (photochemical oxidation)	POCP
human toxicity	HTP_{∞}
fresh water aquatic ecotoxicity	$FAETP_{\infty}$
mariene aquatic ecotoxicity	$MAETP_{\infty}$
terrestrial ecotoxicity	$TETP_{\infty}$
acidification	AP
eutrophication	EP
depletion of abiotic resources	ADP
land competition	LC

1 A more detailed description is given in appendix 3.

Classification and characterisation

In the classification step the environmental interventions qualified and quantified in the Inventory analysis are assigned on a purely qualitative basis to the various pre-selected impact categories.

For a baseline list of interventions, for which characterisation factors have previously been derived, the classification step involves no actual work as these interventions have already been assigned to the various impact categories. Interventions with serial[1] and combined[2] impacts are fully assigned to all relevant impact categories in the proposed baseline method. The partial assignment of interventions with parallel[3] impacts is addressed, as much as possible, by means of fate models in the characterisation models, and does not need to be effected as part of the classification step. Where proper fate treatment is not yet possible, a full assignment to all relevant impact categories is to be made.

In the characterisation step of Impact assessment the environmental interventions assigned qualitatively to a particular impact category in classification are quantified in terms of a common unit for that category, allowing aggregation into a single score: the indicator result. The resulting figure for one particular impact category is referred to as a category indicator result, and the complete set of category indicator results as the environmental profile.

The characterisation step in general terms is expressed in a formula as:

$$\text{indicator result}_{cat} = \sum_i m_i \times \text{characterisation factor}_i$$

indicator result$_{cat}$	indicator result for impact category *cat* (i.c. kg equivalents);
m_i	magnitude of intervention *i* (emission, resource extraction or land use) associated with the functional unit of the system that is studied (i.c. kg);
characterisation factor$_{i,cat}$	characterisation factor for intervention *i* and impact category *cat* (i.c. kg equivalents · kg^{-1}); e.g. GWP_{100} (i.c. kg CO_2 · kg^{-1}), POCP (i.c. kg (ethylene equivalents · kg^{-1})

A spreadsheet containing the characterisation factors for the baseline methods and their alternatives can be downloaded from the internet
http://www.leidenuniv.nl/cml/ssp/databases/index.html

Normalisation

ISO 14042 defines normalisation as “calculation of the magnitude of indicator results relative to reference information”. The reference information may relate to a given community (e.g., the total of emissions and extractions in The Netherlands, Europe or the world), person (e.g. a Danish citizen) or other system, over a given period of time. Other reference information may also be adopted, of course, such as a future target situation. The main aim of normalising the category indicator results is to better understand the relative importance and magnitude of these results for each product system under study. Normalisation can also be used to check for inconsistencies, to provide and communicate information on the relative significance of the category indicator results and to prepare for additional procedures such as weighting or Interpretation.

The normalisation step expressed in a formula:

---

[1] emissions with serial impacts, i.e., emissions of substances that may in practice have successive impacts, e.g., emissions of heavy metals which may first have ecotoxicological impacts and subsequently, via food chains, impacts on human health
[2] emissions with combined impacts, i.e., emissions of substances having a mutual influence on each other’s impacts, e.g., synergistic or antagonistic impacts of mixtures of toxic substances, or NO_x and VOC, both of which are required for photo-oxidant formation
[3] emissions with parallel impacts, i.e., emissions of substances that may theoretically contribute to more than one impact category but in practice contribute only to one, e.g., an emission of SO_2 which may have either toxic or acidifying impacts

$$indicator\ result_{cat,ref} = \sum_i m_{i,ref} \times characterisation\ factor_{i,cat}$$

$$normalised\ \ indicator\ result_{cat} = \frac{indicator\ result_{cat}}{indicator\ result_{cat,ref}}$$

indicator $result_{cat,ref}$ indicator result for impact category *cat* and reference system *ref* (i.c. kg·yr^{-1}); the reciprocal of indicator $result_{cat,ref}$ is here referred to as the normalisation factor for impact category *cat* and reference system *ref*;
$m_{i,ref}$ magnitude of intervention *i* (emission, resource extraction or land use) associated with the reference system *ref* (i.c. kg·yr^{-1});
characterisation $factor_{i,cat}$ characterisation factor for intervention *i* and impact category *cat* (i.c. kg·kg^{-1});
normalised indicator $result_{cat}$ normalised indicator result for impact category *cat* (yr);
indicator $result_{cat}$ indicator result for impact category *cat* (i.c. kg).

Normalisation data and factors including underlying interventions of the reference systems (e.g. total of emissions and extractions in Netherlands 1997, West Europe 1995, World 1995 and World 1990) can be found in the impact assessment spreadsheet, which can be downloaded from: http://www.leidenuniv.nl/cml/ssp/databases/index.html
Background information on these normalisation data may be found in the normalisation report (Huijbregts *et al*., 2001)

In the project as a reference the total of emissions and extractions in the World 1995 is chosen.

Weighting

Weighting is an optional step of Impact assessment, in which the (normalised) indicator results for each impact category assessed are assigned numerical factors according to their relative importance, multiplied by these factors and possibly aggregated. Weighting is based on value choices (e.g. monetary values, standards, expert panel). A convenient name for the result of the weighting step is ‘weighting result’, of which there is generally one for each alternative product system analysed. Table A2-2 shows some weighting sets that are used in this study to relatively weight the environmental problems (impact categories) from the Problem Oriented Approach.

	Abiotic depletion of resources	Land Competition	Global warming	Stratospheric ozone depletion	Human toxicity	Fresh water ecotoxicity	Terrestrial ecotoxicity	Photochemical oxidant creation	Acidification	Eutrophication	Radiation (Frischknecht et al., 1999)	final solid waste
equal	0.10	0.10	0.10	0.10	0.033	0.033	0.033	0.10	0.10	0.10	0.10	0.10
NOGEPA	0.00	0.00	0.35	0.05	0.18	0.07	0.05	0.09	0.07	0.14	0.00	0.00
shadow prices	0.000	0.000	0.001	0.659	0.002	0.001	0.001	0.047	0.088	0.198	0.000	0.004

Table A2-2 Three different weighting sets used for the Problem Oriented Approach, that express the relative importance of the different environmental problems

5.3 Baseline characterisation methods used in this study for the impact assessment according to the Problem Oriented Approach

The baseline characterisation methods will be described in more detail below. Detailed information on the scientific background of the baseline characterisation methods and their alternatives may be found in the Handbook on Life Cycle Assessment (Guinée *et al*., 2002). Also for each separate impact category the primary literature sources are given. A spreadsheet containing the characterisation factors for the baseline methods and their alternatives can be downloaded from the internet http://www.leidenuniv.nl/cml/ssp/databases/index.html

5.3.1 Climate change

Climate change is defined here as the impact of human emissions on the radiative forcing (i.e. heat radiation absorption) of the atmosphere. This may in turn have adverse impacts on ecosystem health, human health and material welfare. Most of these emissions enhance radiative forcing, causing the temperature at the earth's surface to rise. This is popularly referred to as the 'greenhouse effect'. The areas of protection are human health, the natural environment and the man-made environment.

Table A3-1 climate change: category indicator, characterisation model and characterisation factors (for baseline)

impact category	climate change
LCI results	emissions of greenhouse gases to the air (in kg)
characterisation model	the model developed by the Intergovernmental Panel on Climate Change (IPCC) defining the global warming potential of different greenhouse gases
category indicator	infrared radiative forcing (W/m^2)
characterisation factor	global warming potential for a 100-year time horizon (GWP100) for each greenhouse gas emission to the air (in kg carbon dioxide equivalent/kg emission)
unit of indicator result	kg (carbon dioxide eq)

Houghton *et al*., 1994 & 1996

5.3.2 Stratospheric ozone depletion

Stratospheric ozone depletion refers to the thinning of the stratospheric ozone layer as a result of anthropogenic emissions. This causes a greater fraction of solar UV-B radiation to reach the earth's surface, with potentially harmful impacts on human health, animal health, terrestrial and aquatic ecosystems, biochemical cycles and materials. Stratospheric ozone depletion thus impinges on all four areas of protection: human health, the natural environment, the man-made environment and natural resources.

Table A3-2 stratospheric ozone depletion: category indicator, characterisation model and characterisation factors (for baseline)

impact category	stratospheric ozone depletion
LCI results	emissions of ozone-depleting gases to the air
characterisation model	the model developed by the World Meteorological Organisation (WMO), defining the ozone depletion potential of different gases

category indicator	stratospheric ozone breakdown
characterisation factor	ozone depletion potential in the steady state (ODP steady state) for each emission to the air (in kg CFC-11 equivalent/kg emission)
unit of indicator result	kg (CFC-11 eq)

WMO, 1999; WMO, 1992

5.3.3 Human toxicity

This impact category covers the impacts on human health of toxic substances present in the environment. The health risks of exposure in the workplace are also sometimes included in LCA. These latter risks are often included in a wider impact category encompassing more than exposure to toxic substances (e.g. accidents at work). In this Guide, no further consideration is given to the impacts of exposure to toxic substances in the workplace. The area of protection for this impact category is human health. Notice that the discussion on characterisation of toxicity-related impact categories is far from settled.

Table A3-3 human toxicity: category indicator, characterisation model and characterisation factors (for baseline)

impact category	human toxicity
LCI results	emissions of toxic substances to air, water and soil (in kg)
characterisation model	USES 2.0 model developed at RIVM, describing fate, exposure and effects of toxic substances, adapted to LCA
category indicator	acceptable daily intake /predicted daily intake
characterisation factor	human-toxicity potential (HTP) for each emission of a toxic substance to air, water and/or soil (in kg 1,4-dichlorobenzene equivalent/kg emission)
unit of indicator result	kg (1,4-dichlorobenzene eq)

Huijbregts, 2000; Huijbregts *et al*., 2000a

5.3.4 Fresh water aquatic ecotoxicity

This impact category covers the impacts of toxic substances on fresh water aquatic ecosystems. The area of protection is the natural environment (and natural resources). Notice that the discussion on characterisation of toxicity-related impact categories is far from settled.

Table A3-4 fresh water aquatic ecotoxicity: category indicator, characterisation model and characterisation factors (for baseline)

impact category	freshwater aquatic ecotoxicity
LCI results	emissions of toxic substances to air, water and soil (in kg)
characterisation model	USES 2.0 model developed at RIVM, describing fate, exposure and effects of toxic substances, adapted to LCA
category indicator	predicted environmental concentration/predicted no-effect concentration
characterisation factor	freshwater aquatic ecotoxicity potential (FAETP) for each emission of a toxic substance to air, water and/or soil (in kg 1,4- dichlorobenzene equivalents /kg emission)
unit of indicator result	kg (1,4-dichlorobenzene eq)

Huijbregts, 2000; Huijbregts *et al*., 2000a

5.3.5 Marine aquatic ecotoxicity

This impact category covers the impacts of toxic substances on marine aquatic ecosystems. The area of protection is the natural environment (and natural resources). Notice that the discussion on characterisation of toxicity-related impact categories is far from settled.

Table A3-5 marine aquatic ecotoxicity: category indicator, characterisation model and characterisation factors (for baseline)

impact category	marine aquatic ecotoxicity
LCI results	emissions of toxic substances to air, water and soil (in kg)
characterisation model	USES 2.0 model developed at RIVM, describing fate, exposure and effects of toxic substances, adapted to LCA
category indicator	predicted environmental concentration/predicted no-effect concentration
characterisation factor	marine aquatic ecotoxicity potential (MAETP) for each emission of a toxic substance to air, water and/or soil (in kg 1,4- dichlorobenzene equivalents /kg emission)
unit of indicator result	kg (1,4-dichlorobenzene eq)

Huijbregts, 2000; Huijbregts *et al*., 2000a

5.3.6 Terrestrial ecotoxicity

This impact category covers the impacts of toxic substances on terrestrial ecosystems. The area of protection is the natural environment (and natural resources). Notice that the discussion on characterisation of toxicity-related impact categories is far from settled.

Table A3-6 terrestrial ecotoxicity: category indicator, characterisation model and characterisation factors (for baseline)

impact category	terrestrial ecotoxicity
LCI results	emissions of toxic substances to air, water and soil (in kg)
characterisation model	USES 2.0 model developed at RIVM, describing fate, exposure and effects of toxic substances, adapted to LCA
category indicator	predicted environmental concentration/predicted no-effect concentration
characterisation factor	terrestrial ecotoxicity potential (TETP) for each emission of a toxic substance to air, water and/or soil (in kg 1,4- dichlorobenzene equivalents /kg emission)
unit of indicator result	kg (1,4-dichlorobenzene eq)

Huijbregts, 2000; Huijbregts *et al*., 2000a

5.3.7 Photo-oxidant formation

Photo-oxidant formation is the formation of reactive chemical compounds such as ozone by the action of sunlight on certain primary air pollutants. These reactive compounds may be injurious to human health and ecosystems and may also damage crops. The relevant areas of protection are human health, the man-made environment, the natural environment and natural resources.

Photo-oxidants may be formed in the troposphere under the influence of ultraviolet light, through photochemical oxidation of Volatile Organic Compounds (VOCs) and carbon monoxide (CO) in the presence of nitrogen oxides (NO_x). Ozone is considered the most important of these oxidising compounds, along with peroxyacetylnitrate (PAN). Photo-oxidant formation, also known as summer smog, Los Angeles smog or secondary air pollution, contrasts with winter smog, or London smog, which is characterised by high levels of inorganic compounds, mainly particles, carbon monoxide and sulphur compounds. This latter type of smog causes bronchial irritation, coughing, etc. Winter smog, as far as considered, is part of human toxicity.

Table A3-7 photo-oxidant formation: category indicator, characterisation model and characterisation factors (for baseline)

impact category	photo-oxidant formation
LCI results	emissions of substances (VOC, CO) to air (in kg)
characterisation model	UNECE Trajectory model
category indicator	tropospheric ozone formation
characterisation factor	photochemical ozone creation potential (POCP) for each emission of VOC or CO to the air (in kg ethylene equivalents/kg emission)
unit of indicator result	kg (ethylene eq)

Derwent *et al*., 1998, Jenkin & Hayman, 1999, values for inorganic substances from Derwent *et al*., 1996

5.3.8 Acidification

Acidifying pollutants have a wide variety of impacts on soil, groundwater, surface waters, biological organisms, ecosystems and materials (buildings). Examples include fish mortality in Scandinavian lakes, forest decline and the crumbling of building materials. The major acidifying pollutants are SO_2, NO_x and $NH_{x.}$ Areas of protection are the natural environment, the man-made environment, human health and natural resources.

Table A3-8 acidification: category indicator, characterisation model and characterisation factors (for baseline)

impact category	acidification
LCI results	emissions of acidifying substances to the air (in kg)
characterisation model	RAINS10 model, developed at IIASA, describing the fate and deposition of acidifying substances, adapted to LCA
category indicator	deposition/acidification critical load
characterisation factor	acidification potential (AP) for each acidifying emission to the air (in kg SO_2 equivalents /kg emission)
unit of indicator result	kg (SO_2 eq)

Huijbregts, 1999a

5.3.9 Eutrophication

Eutrophication covers all potential impacts of excessively high environmental levels of macronutrients, the most important of which are nitrogen (N) and phosphorus (P). Nutrient enrichment may cause an undesirable shift in species composition and elevated biomass production in both aquatic and terrestrial ecosystems. In addition, high nutrient concentrations may also render surface waters unacceptable as a source of drinking water. In aquatic ecosystems increased biomass production may lead to a depressed oxygen levels, because of the additional consumption of oxygen in biomass decomposition (measured as BOD, biological oxygen demand). As emissions of degradable organic matter have a similar impact, such emissions are also treated under the impact category "eutrophication". The areas of protection are the natural environment, natural resources and the man-made environment.

Table A3-9 eutrophication: category indicator, characterisation model and characterisation factors (for baseline)

impact category	eutrophication
LCI results	emissions of nutrients to air, water and soil (in kg)
characterisation model	the stoichiometric procedure, which identifies the equivalence between N and P for both terrestrial and aquatic systems
category indicator	deposition/N/P equivalents in biomass
characterisation factor	eutrophication potential (EP) for each eutrophying emission to air, water and soil (in kg PO_4 equivalents/kg emission)
unit of indicator result	kg (PO_4 eq)

Heijungs *et al*., 1992 with some modifications

5.3.10 Depletion of abiotic resources

"Abiotic resources" are natural resources (including energy resources) such as iron ore, crude oil and wind energy, which are regarded as non-living. Abiotic resource depletion is one of the most frequently discussed impact categories and there is consequently a wide variety of methods available for characterising contributions to this category. To a large extent, these different methodologies reflect differences in problem definition. Depending on the definition, this impact category includes only natural resources, or natural resources, human health and the natural environment, among its areas of protection. Note that the debate on the characterisation of depletion-related impact categories is not settled.

Table A3-10 Depletion of abiotic resources: category indicator, characterisation model and characterisation factors (for baseline)

impact category	abiotic depletion
LCI results	extraction of minerals and fossil fuels (in kg)
characterisation model	concentration-based reserves (ultimate reserves) and rate of de-accumulation approach
category indicator	depletion of the ultimate reserve in relation to annual use
characterisation factor	abiotic depletion potential (ADP) for each extraction of minerals and fossil fuels (in kg antimony equivalents/kg extraction)
unit of indicator result	kg (antimony eq)

Guinée, 1995, with modifications for crude oil, natural gas, hard coal and browncoal

5.3.11 Land competition

This subcategory of land use impacts is concerned with the loss of land as a resource, in the sense of being temporarily unavailable. The areas of protection are natural resources and the man-made environment.

Table A3-11 Land competition: category indicator, characterisation model and characterisation factors (for baseline)

impact category	land competition
LCI results	land use (in $m^2 \cdot yr$)
characterisation model	unweighted aggregation
category indicator	land occupation
characterisation factor	1 for all types of land use (dimensionless)
unit of indicator result	$m^2 \cdot yr$ (land use)

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Annex 6: Description of data and data sources for the regression analysis

As outlined in chapter 4, the variables have been categorized into five categories:

A. Circumstance variables

Average temperature and annual precipitation
Data coverage: All countries
Remarks: Data are from the TYN CY 1.1 dataset
This dataset contains average climate data of the period 1961-1990
Source: Tyndall centre for climate research

Size of country (1000km2)
Data coverage: all countries
Source: AC-13 Turner et al, 2003
Source: EU-15 Eurostat 2002

Population density :
Dividing the size of a country by the population estimates from FAO, as used in Chapter 2.

B. Economic variables relating to income and structure of production

GDP per capita
Data Coverage: The coverage of countries and years is complete.
Remarks: GDP corresponds to the cash value of all goods and services produced by the economic units in a country within a given period, less the value of the goods used in the production process. It is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources. Data are provided at constant 1995 prices. Valuation at constant prices means valuing the flows and stocks in an accounting period at the prices of the reference period. Unit: US dollars
Source: WORLD BANK, World Tables, 2002.

Structure of economy
Data coverage: Generally data coverage for each category is high (countries, years)
The historic time series on gross value added by industry sector are derived from EUROSTAT NewCronos online database (downloaded in October 2003)
The gross value added is given in constant 1995 prices.
The EUROSTAT NewCronos database contains three different levels of sectoral breakdowns following the NACE classification.

Missing values have been recalculated from UN-Statistics Division. GDP-breakdown by economic activity:
(http://unstats.un.org/unsd/snaama/resultsBreak.asp?Slevel=2&CCode=56,100,196,203,208,233,246,250,276,300,348,372,428,440,442,470,528,616,620,642,703,705,724,752,792,826&Ind=1%2C2%2C3%2C5%2C6%2C7%2C89&Series=26&Year=1988%2C1989%2C1990%2C1991%2C1992%2C1993%2C1994%2C1995%2C1996%2C1997%2C1998%2C1999%2C2000%2C2001&IndCount=7&Selection=Series
The category CE cannot be further broken down in this statistic. For Bulgaria and Ireland, no data for NewCronos were available and this division has been obtained from the National Statistical Institute. For other countries, the same division has been assumed as in the most nearby year. Belgium and Luxembourg figures have been added on the basis of GDP.

The following categories have been constructed:

NACE AB	Agriculture and fisheries
NACE C	Mining
NACE D	Manufacturing
NACE E	Production and distribution of electricity, gas and water
Nace F	Construction

C. Lifestyles 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;
Floorspace per new dwelling completed, as this gives an indication of qualitative aspects in the demand for housing with consequences for material consumption.

Household size
Data on the number of households have been taken from: Eurostat New Cronos Database General Statistics (Theme : theme1). Regional statistics (Domain : regio), Community. For AC13 and for missing years, values have been obtained from: : Euromonitor - European Marketing data and statistics 1997, 32nd edition + Statistical Compendium for the Dobris Assessment (table 26.1). These series differ and have been standardized on the Euromonitor 1997 using the 1995 values.

Car possessions
Data taken from @GW
Some countries report missing values for the year 2000. These missing values have been calculated taking into account the growth in car possession between 1998 and 1999.
Data indicator: Number of passenger cars per 1000 inhabitants.

Animal Fats
Data coverage: Luxembourg is not included.
Assumptions: Slovakia, 1992 standardized on Czech Republic; Value for Luxembourg is similar to that of Belgium.
Remarks: Unit is Cal/Cap/Day (Number)
It's not clear if fish is included or not (we are still waiting for reply from FAO for this question).
Source FAO database

Housing statistics

<u>Number of dwellings completed</u>
Data coverage: all countries included, for AC-13 countries data start from 1995
Source: UNECE, annual number of dwellings completed, number. Data coverage: very good. The few missing years for these series have been filled in using series from:
Source: EU-15 Eurostat yearbook: The statistical guide to Europe which gives numbers on the number of building permits, and for AC-13: Statistical yearbook on candidate and South-East European countries 2001, Eurostat.
Indicator: Number of dwellings completed per 1000capita.
Method of standardisation: multiplicative on the previous year.

Average floorspace of dwellings completed
Indicator is the useful floorspace of the dwellings completed. It is the average floor space of dwellings measured inside the outer walls, excluding cellars, non-habitable attics and, in multi-dwelling houses, common spaces.
Measurement: m2

The indicator of useful floorspace gives a better coverage than living floorspace.
Data manipulations: Germany: 1992-2000 = 1989; Belgium: Living floorspace has been used as indicator standardized on the difference for Luxembourg between living and useful floorspace. For Finland, the series have been based on the living floorspace of dwellings completed and multiplied by an average ratio of 1,15 for non-living but useful floorspace (This is the average of all the countries for which both series have been obtained). Data for the Netherlands have been obtained from CBS and contain m3 and have been transferred to m2 useful floorspace from data of the European Housing Forum for the Netherlands. Denmark, France and UK data have been retrieved from the European Housing Forum. UK: 1992-2000 = 1996. France: 1992-2000=2001. Denmark: 1992-2000=2000.

Dwelling stock per capita.
This indicator gives information on the dwellings per capita and is hence to be expected to correlate strongly with the household size. Divergences can be expected when a lot of house are not inhabited or secondairy houses are familiair in the country.
Source of data: UN-ECE Housing Statistics
Indicator: Dwelling stock per 1000 habitants
Manipulations: Latvia, Finland, 1992=1990.
Greece: 1992=1991. The annual growth rate has been assumed to be similar to Portugal. For Portugal and Sweden the annual growth rate between 1991 and 1999 has been obtained from the European Housing Forum. These growth rates have been standardized on the 1991 value from the UN-ECE statistics for Portugal. For Turkey, data are unreliable and uncomparable over the years.4 Here, annual growth rates have been assumed similar to those of Portugal. For the UK, data have been obtained from the European Housing Forum and standardized on the UN-ECE data. For Belgium, 1997-2000 have been obtained by assuming a similar growth rate as between 1995 and 1996. Luxembourg has no figures and data have been assumed to be similar to Belgium. Data from Italy from European Housing Forum. Missing years have been assumed to have a constant growth rate.

D. Variables indicating causes of technological innovation

Openess of economy
Data coverage: all EU-15 and AC-13 countries. The coverage over the years is good.
Subject coverage: Measured as the trade integration of goods as a % of GDP: Average of Imports and Exports of the item goods of the Balance of Payments divided by GDP. Balance of Payments statistics are compiled following the 5th Manual of the International Monetary Fund. If the index increases over time it means that the country/zone is becoming more integrated within the international economy.
Source: Eurostat

Public education as % of GDP.
Definition: Public education expenditure consists of public spending on public education plus subsidies to private education at the primary, secondary, and tertiary levels. Foreign aid for education is excluded; spending for religious schools, which constitutes a sizable portion of

[4] It appears that UN-ECE has for some years referred to total buildings.

educational spending in some developing countries, may also be excluded. There exists a small break in series between 1997 and 1998. No attempt has been made to correct for this. Missing years have been extrapolated or assumed similar to the most nearby year.
Datasource: The World Bank. World Development Indicators Online.

Patents per capita
The total European patent applications refer to requests for protection of an invention directed either directly to the European Patent Office (EPO) or filed under the Patent Cooperation Treaty and designating the EPO (Euro-PCT), regardless of whether they are granted or not. The data shows the total number of applications per country and are divided by the population size. Especially for Turkey this may represent an underestimation of the total patents.
Datasource: Eurostat, NewCronos.

E. Policy variables

Forestation/reforestation
Data obtained from: UNECE/FAO Temperate and Boreal Forest Resources Assessment (TBFRA) 2000. For detailed notes on data, see this report. The indicator constructed is the annual change in forested area's. For detailed information on the database and definitions, see the TBFRA - 2000 Report. (http://www.unece.org/trade/timber/fra/welcome.htm).
Data refer to @Gw year?

Renewable energy share
This indicator is the ratio between the electricity produced from renewable energy sources and the gross national electricity consumption calculated for a calendar year. It measures the contribution of electricity produced from renewable energy sources to the national electricity consumption.
1. Renewable energy sources.
They are defined as renewable non-fossil energy sources : wind, solar, geothermal, wave, tidal, hydropower, biomass, landfill gas, sewage treatment plant gas and biogases.
2. Electricity produced from renewable energy sources.
It comprises of the electricity generation from hydro plants (excluding pumping), wind, solar, geothermal and electricity from biomass/wastes. Biomass/wastes electricity comprises of electricity generated from wood/wood wastes and other solid wastes of renewable nature (straw, black liquor) burning, municipal solid waste incineration, biogas (incl. landfill, sewage, farm gas) and liquid biofuels.
3. Gross national electricity consumption.
It comprises of the total gross national electricity generation from all fuels (including autoproduction), plus electricity imports, minus exports.
Data is compiled through annual Joint Questionnaires (one for electricity and another one for renewable energy sources). These questionnaires are called « joint » because they are shared by Eurostat and the International Energy Agency (IEA, part of the OECD). The methodology is fully harmonised between both organisations.
Datasource: Eurostat, NewCronos.

Energy end-users prices and taxes
Remarks: If not specified otherwise, end-use prices
- include transport costs to the consumer;
- are prices actually paid, i.e., net of rebates;
- include taxes which have to be paid by the consumer as part of the transaction and which are not refundable. This excludes value added tax paid in many European countries by industry (including electric power stations) and commercial end-users for all goods and services (including

energy). In these cases value added tax is refunded to the customer, usually in the form of a tax credit.
The prices shown are the result of converting nationale currencies to U.S. dollars using quarterly and yearly averages of exchange rates as published by the IMF.
Source data: IEA statistics report (2002)

Data coverage for:

Light Fuel oil prices industry:

Data are missing for the Baltic States, Cyprus, Malta, Slovenia,Bulgaria The Netherlands, Romania, Portugal and Turkey. The coverage of data for the countries which are included is high

Natural Gas Prices for Industry in US Dollars/107 kcal (GCV basis)

Data are missing for the Baltic States, Cyprus, Malta, Slovenia, Bulgaria, Denmark, Luxembourg, Romania, Portugal and Sweden. The coverage of data for the countries which are included is high except for Belgium and Greece

Electricity Prices for Industry in US Dollars/kWh

Data are missing for the Baltic States, Cyprus, Malta, Slovenia, Bulgaria, and Luxembourg
The coverage of data for the countries which are included is high
except for Romania

Light Fuel Oil Prices for Households in US Dollars/1000 litres (incl tax)
Data are missing for the Baltic States, Cyprus, Malta, Slovenia and Bulgaria and Portugal. The coverage of data for the countries which are included is high except for Hungary

Electricity Prices for Households in US Dollars/kWh (incl tax)
Data are missing for the Baltic States, Cyprus, Malta, Slovenia and Bulgaria
The coverage of data for the countries which are included is high

Natural Gas Prices for Households in US Dollars/107 kcal (GCV basis, incl tax)
Data are missing for the Baltic States, Cyprus, Malta, Slovenia and Bulgaria, Greece and Portugal. The coverage of data for the countries which are included is high

Automotive Diesel prices, Premium leaded, and Premium unleaded Gasoline.

Diesel prices reflect commercial diesel prices, not for business.
Data coverage over the years is high. Data are missing for Baltic States, Malta, Cyprus and Bulgaria. For these countries, the Worldbank data have been used for the years 1995, 1998 and 2000. Years in between have been extrapolated. Based on information from the Estonian Statistical Office, we estimate that the 1992 price for diesel was about 22 $cents per litre and for Gasoline, 25 $cents. Intermediate years have been extrapolated. Prices of Bulgaria before 1995 follow same trend as in Romania, and for Cyprus as in Greece.

Energy price index
Calculated as the average price from Automotive Diesel prices, Leaded or Unleaded Gasoline (pending on which is the cheapest price in any year) and the Industrial Electricity prices, weighted by the specific country use of these three energy carriers, all calculated in US$/toe. Source of data for energy use: IEA, 2002.

Motorfuel price index

Calculated as the average price from Automotive Diesel prices, Leaded or Unleaded Gasoline (pending on which is the cheapest price in any year), weighted by the specific country use of these three energy carriers. Price in US$/toe. Source of data for energy use: IEA, 2002.

Production and product taxes

Data taken from Eurostat (Series: Taxes on production and imports % of GDP). Taxes on production and imports (ESA95 code D.2) consist of compulsory, unrequited payments, in cash or in kind which are levied by general government, or by EU institutions, in respect of the production and importation of goods and services, the employment of labour, the ownership or use of land, buildings or other assets used in production. In ESA95, taxes on production and imports comprise: taxes on products and other taxes on production.
Manipulations: For Spain, Hungary, Romania Lithuania and Cyprus, early data have been assumed to be similar to the earliest year where data were available. For Slovenia, no data could be found. Data have been assumed to be similar to the average of the Visegrad-countries. For Cyprus, additional information has been obtained from the National Statistical Office.

Total length of motorways and other roads

Data coverage: Data are missing for Malta, Bulgaria, Romania and Turkey. In general coverage is low.
Remarks: Data are the total length of motorways and other roads added
Indicator expressed in: km/km2
Source: EEA database;
Assumptions: data for Latvia have been assumed to be similar to that the average of Lithuania and Estonia. Cyprus: 1992=1993.
Indicator: @GEERT, WAT STELT DIT VOOR? Motorways per km2.

Total length of railway lines.

Data coverage: Data are missing for Malta, Turkey and Cyprus. Data coverage for most counties is more than 50%.
Source: EEA database

Waste policies

There are no good variables of waste policies. Waste statistics in general are extremely poor and hardly comparable between countries and/or over time. The best statistics in this respect are for municipal waste. From the municipal waste statistics (Data delivered from @GW) we constructed four indicators:

- Wrec
- Wfill
- Wcomp
- Wincin

This delivers the most comprehensible set of indicators for waste policies. For Greece we assumed, in absence of real data, the average of four more or less comparable countries with respect to GDP and geography: Cyprus, Bulgaria, Portugal and Turkey. In practice this implies that over 90% of the waste is landfill.

Recycling rates paper and board, glass and packaging

Data coverage: poor (countries, years)
Source: Waste generated and treated in Europe, data collected by Eurostat/OECD questionnaire

Recovery rates, paper and board, glass

Data coverage: 1997 until 2000 not included. AC-13 not included.
Remarks: Recovery operations include 'inceneration wih energy recovery'. The material in the slag is considered as waste.

RECOVERY OPERATIONS
NB: This Annex is intended to list recovery operations as they occur in practice. In accordance with Article 4 waste must be recovered without endangering human health and without the use of processes or methods likely to harm the environment.
R 1 Use principally as a fuel or other means to generate energy
R 2 Solvent reclamation/regeneration
R 3 Recycling/reclamation of organic substances which are not used as solvents (including composting and other biological transformation processes)
R 4 Recycling/reclamation of metals and metal compounds
R 5 Recycling/reclamation of other inorganic materials
R 6 Regeneration of acids or bases
R 7 Recovery of components used for pollution abatement
R 8 Recovery of components from catalysts

R 9 Oil re-refining or other reuses of oil
R 10 Land treatment resulting in benefit to agriculture or ecological improvement
R 11 Use of wastes obtained from any of the operations numbered R 1 to R 10
R 12 Exchange of wastes for submission to any of the operations numbered R 1 to R 11
R 13 Storage of wastes pending any of the operations numbered R 1 to R 12 (excluding temporary storage, pending collection, on the site where it is produced) (Source: Waste Framework Directive 74/442/EEC)

Source: Eurostat yearbook 2002

Annex 7: Estimation procedure for the regression analysis

In this annex we describe the estimation procedure we took for the regression analysis in detail.

7.1 Hypothesis setting

The main aim of the regression analysis is to test is whether the variation in the levels of DMC and EMC between countries can be explained by reference to selected socio-economic variables.

The hypothesis is that the selected structural, technological, lifestyle, policy and circumstance variables explain the differences between countries in their DMC and EMC properly.

Testing this hypothesis has some implications for the estimation procedure, as outlined below.

The estimated model has a functional form as outlined in equation (3),

$$M_i = \alpha_i + \beta_{(j),i} X_{i,j} + \varepsilon_i \qquad (3.3)$$

where M is the material consumption, X is the set of j variables (j=1..30) i = each individual country (i = 1..24) and α, β and γ are estimated parameters and ε is the normally distributed error term. With 30 variables, the estimated equation will hence contain the estimated slope parameters β_1, β_2, β_3….β_{30} for each variable.

With 30 variables and 24 countries, estimation of this full model would require 720 variables and with only 216 observations this is not achievable. Panel data analysis allows the researcher to estimate such a model by a-priori assuming certain variables constant among countries (Hsiao, 1986). The most common assumption is common slopes among the variables (i.e.$\beta_{j,i} = \beta_j$ for all j) and varying intercepts between the countries, as given in equation (4).

$$M_i = \alpha_i + \beta_{(j)} X_{i,j} + \varepsilon_i \qquad (3.4)$$

This would reduce the amount of estimated variables to 54 (30 dependent variables and 24 intercept terms) only and this can be estimated with 216 observations.

If we would use panel data analysis as outlined in equation (4), the null hypothesis would be:

H0: βj = 0 for all j

In other words, we would test for the influence of the variables on material consumption. However, the intercept is allowed here to vary between the countries. Hence, this test basically is a test on the influence of the variables on material consumption, given the fact that initial levels of DMC and EMC may differ between countries. This does not fully answer the hypothesis as formulated in the beginning of this paragraph as a large part of the variation between countries can still be explained by the intercepts. We take therefore a second null hypothesis to test whether one single intercept would suffice :

H2: αi = α for all i.

If only the first hypothesis is rejected (and the second not) we can safely assert that the variation in materials consumption is sufficiently explained by the socio-economic and circumstance variables we have selected. If both H0 and H2 are rejected, we can state that some of the variation in DMC and EMC can be explained by reference to the variables but that they do not explain all variation. The variation between countries is in this case also explained by other –missing- variables for which we have not found reliable indicators5. If only H2 is rejected, our variables are not able to explain any variation at all.6

7.2 Estimation procedure and model design**

Hsiao (1986, p15-17) describes a test procedure for H2. In essence this is a test on the explanatory value of a pooled cross-section estimate versus a panel data estimate using the model in equation (4). If the explanatory value of the pooled cross-section estimate is higher than the panel data estimate, H2 is rejected and we must assume that the intercepts do not vary among the countries.[7]

In principle, we could run this test with all 30 variables included, but this estimate is most likely not efficient. Many variables will show up as non-significant and hence only reduce the degrees of freedom. Besides, most variables will show serious forms of autocorrelation which makes the estimate unreliable (see Annex 5.4 on the presence of autocorrelation in the data), or correlations with each other which makes the estimates inefficient. So, first a more parsimonious model, which leaves out irrelevant variables, should be estimated which subsequently is tested for H2.

There are in the literature various ways to come to a more parsimonious model, using various selection criteria. We use here the stepwise backward elimination procedure using the Akaike Information Criterion as a guideline. This procedure starts estimating the full model and subsequently removing the least significant variable as long as the Akaike Information Criterion indicates that the overall fit of the model improves.[8]

As we want to test both H0 and H2 on this parsimonious model simultanously, we should run the stepwise elimination procedure from a pooled cross-section estimate, as this procedure rightly gives an answer to the question whether the variation in DMC and EMC between countries can be explained by the variables.[9]

The final model that will be estimated will hence have the form of (3.5). As the analysis in paragraph 3.3 showed that there is a tendency in the data for non-linear relationships, we

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[5] Sometimes there are no indicators for such variables. For example, the public support for environmentally friendly consumption and good-house keeping measures can be important variables for the DMC/EMC but as we have no good statistical measure for this, we cannot assess the influence of this variable on the DMC/EMC. The most interesting part is then presumably the variation that can be explained by the variables for which we have selected data

[6] Notice that the case where both H0 and H2 are rejected has no meaning as this would only occur when all countries have the same level of materials consumption.

[7] In the pooled cross-section estimate is similar to equation (4) with the restriction that $\alpha_i = \alpha$ for all i.

[8] The estimation that minimizes the AIC is the preferred one

[9] The other way around would be to use the stepwise procedure from the panel data estimate and to use this to test the results against the pooled estimate. However, this may result in a bias towards accepting H2, as not the most efficient estimate from the pool is selected and the pool estimate basically answers the research question involved here.

estimate (3.5) both for the normal variables, as well as for logarithmic transformation of the dependent variables (DMC and EMC).[10]

$$M_i = \alpha + \beta_{(j)} X_{i,j} + \varepsilon_i \qquad (3.5)$$

More technical details on the specific estimation procedure and model design in order to reduce potential errors stemming from multicollinearity and autocorrelation can be below.

7.3. Results of the hypothesis testing

First we estimated the model as in (3.5) for the DMC. The first results indicated serious problems of autocorrelation, and that is why we included an AR(1) procedure to correct for this.[11] The AR(1) can basically be interpreted as the influence on the dependent variable (DMC) from the value in the last year.

As expected, many variables were insignificant when we estimated the model with all variables. Using the stepwise procedure a more parsimonious model was achieved. Table X gives the model which finally proved to fit the data the most efficient, where C indicates the common intercept for all countries.

Table 3.5: Results from pooled cross-section estimate on the DMC.

	coefficient	t-stats		
C	26.417	(1.974)*	R2-adj.	0.98293
SURFACE	-0.0000179	(-3.13)***	DW	2.540632
PRECIP	-0.021	(-2.93)***	AIC	1005.938
WREC	-29.775	(-1.38)	SSR	156.297
POPDENS	-0.048	(-2.72)***		
OPENESS	0.025	(1.351)		
HOUSEHSZ	5.925	(2.748)***		
CARPOSS	0.017	(2.551)**		
GDPCAP	0.000467	(2.573)**		
RAILWAY	89.876	(1.506)		
NACEAB	-14.832	(-1.77)*		
NACEF	15.284	(1.377)		
FAT	-0.008	(-2.98)***		
EDUCATION	-56.786	(-2.21)**		
PATENTCAP	12.589	(1.749)*		
TIME	-0.847	(-1.59)		
COM	-7.779	(-1.79)*		
AR(1)	0.921	(35.18)***		

Note: *, ** and *** indicate significance levels at the 10, 5 and 1% two-tail conficence level respectively. DW gives the Durbin Watson Statistic, AIC the Akaike Information Criterion, SSR is sum of squared residuals.

[10] Alternative formulations (both variables in logarithmic transformations or only the explanatory variables in logarithmic transformations) did not perform well.

[11] One may be interested in higher orders of autocorrelation also, but this is not feasible given the short time-series available in the sample (1992-2000). Hence we assumed that the data would be detrended sufficiently by an AR(1) procedure.

As we see here, various variables are significant at the 1% level. Interesting is that both surface area, the amount of precipitation and the population density are signifcantly negatively correlated with DMC. Furthermore, both per capita GDP and car possessions seem to result in a higher DMC, as predicted. The amount of daily intake of animal fats is very significant but enters the equation with the wrong sign: more meat is now correlated with lower levels of materials consumption. Investments in education are, as expected, negatively associated with the DMC. Finally it is interesting that the autonomous technological improvements is not significant in this sample.

The most interesting part, however, is the AR(1) coefficient. This AR(1) coefficient is the estimated influence on the DMC in a specific year from the level of DMC in the previous year. The value of 0.92 indicates that the DMC is almost entirely determined by the value in the previous year. This is a serious sign of model misspecification and the coefficients, as presented in this Table, run the risk of being spurious (Granger and Newbold, 1974).[12] This suggestion of misspecification is aggravated by the Durbin and Watson statistic in the Table. This value should lay around the 2, otherwise the results are meaningless. The value of 2.54 is too high and indicates a serious problem of autocorrelation.[13]

The high value of the AR(1) component indicates something else: the initial levels of the DMC in each country are not explained by the variables in our model. This already indicates that assumption H2 is probably valid; presumably countries differ so that the intercepts are not equal over countries. By-re-estimating the model with the same variables as in Table (X) using a fixed effects specification, we can perform a simple F-test on H2 (see Baltagi *et al.*, 2001).[14]

Table X gives the result for this test on H2, as well as on H0, for both the DMC and the EMC and gives information on the AR(1) component in order to assess the quality of the estimations.

Table 3.6: Results from the H0 and H2 hypothesis for the DMC and EMC.

	DMC	EMC
R2pool	0.984	0.983
R2fixed effects	0.989	0.988
H0: F-stats	647.9***	662.6***
H2: Fstats	3.60***	3.08***
AR(1) Pool	0.921	0.896
AR(1) Fixed effects	0.278	0.372
DW_pool	2.54	2.20
DW_fixed effects	2.05	1.84

The F-statistics show that both H0 and H2 are rejected at the 1% confidence level even. Hence, the pooled specification is a misspecification: our state and slope variables do not correct sufficiently for the differences in the DMC and EMC between countries. Hence we should use a fixed effect model specification. Moreover, this has the advantage that the AR(1) component is drastically reduced with values that are more likely to result in the right estimation. This all implies that the fixed effect model provides reliable results for both the DMC and the EMC.

This result was not changed when we transformed the variables into logarithms and re-estimated the equation, either in a double-logarithmic form or a log-linear fashion.

[12] It basically implies that shocks to the equation will introduce a permanent drift in the data.
[13] In statistical terms this implies that the series are improperly detrended using an AR(1) process and an AR(2) process is more likely to produce satisfactory results.
[14] In the fixed effects estimation, all state variables (see paragraph 3.2.2) have of course been excluded as they would interfere with the fixed effects.

7.4. Treatment of interference in the regression model

Regression analysis can –like any other tool in statistics- only be used when the circumstances of regression analysis are well understood. Many statisticians and econometricians have warned against the dangers of regression analysis when the so-called “ideal circumstances” of the data do not apply. Unfortunately, such ideal circumstances almost never apply in economic statistics.

More specific, four aspects must be dealt with before the results from regression analysis can be properly interpreted. These are:

1. Multicollineairity
2. Heteroskedasticity
3. Autocorrelation
4. Other issues relevant

Here a short technical description how we have dealt with these various issues.

Multicollinearity

As shown in Table @, some variables are heavily correlated with each other. OLS cannot be performed when there is a singular matrix. Such a singular matrix may occur when we work with shares. The waste variables form together a linear equation and cannot therefore be included all in the analysis. The proper way is to delete one of these share variables and interpret the intercept as the resultant of the original intercept and the share of the deleted variable. Based on the properties of the data we will leave out the Wcomp (composted waste) as this showed the poorest results in a number of test regressions. Also the energy price index and the motorfuel prices are heavily correlated. Hence, both should not be included at the same time in the estimations.

Heteroskedasticity

Beck and Katz (1995) describe a procedure for correcting for heteroskedasticity in panel data. However, this method requires that the average number of periods used in estimation must be at least as large as the number of cross-section units. This condition is violated in our sample. For these reasons, there is no way to correct for heteroskedasticity in this sample. However, the use of a White heteroskedasticity consistent covariance estimators with ordinary least squares estimation in fixed effects models can yield standard errors robust to unequal variance along the predicted line (Wooldridge, 2002). As we selected out the fixed effects method already, we used this procedure in our estimates.

Autocorrelation

Autocorrelation is present when the errors of the estimates are best explained by the errors from the previous time. This will show many variables as significant while in fact they are not. Results in the presence of autocorrelation run therefore the risk of being spurious (Granger and Newbold, 1974). The normal procedure is to use some kind of differencing of the data. AR(X) estimates for example the model chosen with X lags of the dependent variable. In this specific case we have chosen to detrend the series with an AR(1) process. If we had longer time series we could more precisely determine the right lag length (i.e. X), but as the series are so short, we more ore less assumed that AR(1) would result in stationary residuals. The AR process can be assumed to be stationary if we assume that the sample collected (1992-2000) is ongoing for a long period of history and the AR(1) is not close to unity. As a rule of thumb we can say that an AR(1) below the 0.7 is satisfactory. However, the right procedure would be, of course, to test whether the residuals and variables contain unit roots and to establish the co-integrating relationship. This is not possible given the fact that we have only 9 years, although some fairly recent advances in econometrics have tried to estimate co-integration relationships from panels with short time-periods. These techniques are still in development.

Other issues: Fixed versus random effects
Although random effects estimates are considered as advantage if the time dimension is smaller than the cross-section dimension, it has the disadvantage of not being compatible with a control of the time-aspect by including ARIMA-components. We tried the random-effects models, but the DW-statistics showed that the errors were autocorrelated and the estimators can hence be biased. For this reason, we have used the fixed-effects estimates here.

Other issues: Test on the estimates
The specification used here as assumed that all ßi are the same for all countries. This assumption is most likely violated in the real world: the effects of economic growth on materials- and energy consumption tends to be different for former communist countries and the EU15, as indicated in De Bruyn, 2003b, for SO2 emissions. However, as our time-series run only for 9 years, we cannot test this and we cannot assess methods to correct for this, like Zelllner's SURE Method (see Judge et al., 1988 for a detailed description of this method).

7.5 Discussion on the robustness of the results

Finally, we want to address the question how robust these results are. First we note that the estimated variables have the expected signs which is normally a sign of a good specification and estimation procedure. Secondly, the Durbin Watson statistic does not show sign of first-order autocorrelation. However, there is still some form of higher order autocorrelation present. From the literature we know that materials consumption (Labson and Crompton, 1993), CO2-emissions (de Bruyn, 2000) and GDP (Nelson and Plossner, 1982) tend to have unit roots. If this is the case, the estimates here can be biased to a certain extent. However, there is no way to resolve this, except to construct much longer series (over 30 years) and testing for unit roots in the variables and to correct them using cointegration analysis (Engle and Granger, 1987).

As a third observation, we note that the conducted model was not tested for the homogeneity of the slopes (Hsiao, 1986). Instead we assumed that the socio-economic variables had the same influence for all the countries in the sample. If they do not have the same influences, the estimates may, however, not be efficient and biased towards the assumption. Again this issue can only be tested if we have more observations over time than variables included in the regression. Also in this case, the time-series of the DMC should be extended in order to allow for the heterogeneity tests.

Finally, one may question the reliability of the dependent variables, DMC and EMC. We have seen that Denmark, the Netherlands and Ireland constitute outliers in some aspects with respect to their EMC and that Estonia has a remarkably high DMC when compared to the other variables. As the data for both indicators are in the process of advancements, the question is to what extent eventual miscalculations in the data will have influenced the results from this regression analysis and identified the wrong driving forces. However, this is only the case if the time-related influences are important here. In other words: if Denmark, the Netherlands and Ireland already initially had higher levels of EMC per capita, the regression analysis is still valid, as these influences are captured by the fixed effects intercept. Inspection of the data learn us that this is the case. Hence, we believe the results hold, irrespective of eventual errors in the initial level of the data for individual countries.

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Annex 8: Estimation results not included in the main text

Table 8.1: The full model for DMC/capita with fixed effects and AR(1) term.

Variable	*Coefficient*	*Std. Error*	*t-Statistic*	*Prob.*	*Significant*
POPDENS	0.00523	0.00492	1.062849	0.2896	
OPENESS	-0.000871	0.000886	-0.983569	0.327	
LCARPOSS	2.65E-01	8.87E-02	2.988551	0.0033	***
LGDPCAP	0.197101	0.132401	1.488663	0.1388	
LMOTORWAY	8.51E-02	6.32E-02	1.347978	0.1798	
RAILWAY	4.656805	3.35374	1.388541	0.1671	
LNDWELCAP	0.00725	0.035738	0.202869	0.8395	
NACED	0.33517	0.229561	1.460047	0.1465	
NACEAB	0.338906	0.751834	0.450772	0.6528	
NACEC	1.386735	2.372027	0.58462	0.5597	
NACEF	2.583824	0.705007	3.664959	0.0003	***
LFAT	-0.069435	0.044077	-1.575325	0.1174	
LDWELCAP	0.535545	0.267928	1.998841	0.0475	**
LFLOORSPACE	-0.086722	0.085217	-1.017667	0.3105	
RENEW	-0.22893	0.126758	-1.806045	0.073	*
PRODTAX	0.24313	0.595848	0.408041	0.6838	
LENERGYPRICE	0.088646	0.072363	1.225031	0.2226	
LMOTORFUEL	-0.154837	0.078503	-1.972377	0.0505	*
LINDPRICE	-0.032116	0.028943	-1.109609	0.269	
LEDUCATION	-0.121296	0.056009	-2.165646	0.032	**
LPATENTCAP	0.01907	0.011895	1.603139	0.1111	
RENEW2	0.376894	0.357525	1.054176	0.2936	
TIME	-0.014691	0.007116	-2.064493	0.0408	**
AR(1)	0.296018	0.081432	3.635132	0.0004	***

R-squared	0.990116	Mean dependent var	2.712529
Adjusted R-squared	0.98689	S.D. dependent var	0.437319
S.E. of regression	0.050072	Sum squared resid	0.361037
F-statistic	306.9223	Durbin-Watson stat	1.976323
Variables	24	AIC	-147.60477

Fixed Effects estimators of the country specific intercept

BL—C	-5.030	HU--C	-3.749	SK--C	-3.499024
BU—C	-2.967	IR--C	-2.273	SL--C	-3.690213
CY—C	-2.851	IT--C	-4.532	SP--C	-3.706855
DK—C	-3.415	LA--C	-3.167	SW--C	-2.71744
ES—C	-2.183	LI--C	-3.261	TU--C	-2.749099
FI—C	-2.287	NE--C	-5.262	UK--C	-4.738143
FR—C	-3.942	PO--C	-3.389	GR--C	-3.345
GE—C	-4.728	PT--C	-3.428	RO--C	-3.338

Note: the suffix L indicates that the logarithmic transformation of the variable is used.

Table 8.2: The full model for EWC/capita with fixed effects and AR(1) term.

POPDENS	0.0040585	0.0037487	1.0826475	0.2807745
OPENESS	-0.0010158	0.001082	-0.9387306	0.349441
LCARPOSS	0.0279388	0.0965372	0.289409	0.7726846
LGDPCAP	0.2839394	0.1122774	2.5289089	0.0125191
LMOTORWAY	0.1658127	0.0532624	3.1131303	0.0022335
RAILWAY	0.2909395	2.3774522	0.1223745	0.9027731
LNDWELCAP	0.0166085	0.0246718	0.6731762	0.5019141
NACED	0.1762989	0.1698583	1.0379177	0.3010481
NACEAB	2.536695	0.7802574	3.2511	0.0014316
NACEC	1.6713199	2.0740292	0.8058324	0.4216682
NACEF	2.2305933	0.6346064	3.5149241	0.0005884
LFAT	-0.0375706	0.0492054	-0.7635459	0.4463871

LDWELCAP	0.6904009	0.245288	2.8146541	0.0055669	
LFLOORSPACE	-0.0158708	0.0727851	-0.2180496	0.8276991	
RENEW	-0.2503814	0.1129035	-2.2176588	0.0281448	
PRODTAX	0.8535969	0.6073756	1.4053855	0.1620605	
LENERGYPRICE	0.030179	0.0917768	0.3288301	0.7427618	
LMOTORFUEL	-0.0516993	0.0901685	-0.5733635	0.5672929	
LINDPRICE	-0.0066213	0.0300113	-0.2206288	0.825694	
LEDUCATION	0.0076939	0.057496	0.1338167	0.8937344	
LPATENTCAP	-0.003413	0.0115038	-0.2966887	0.7671317	
RENEW2	0.6100475	0.2484935	2.454984	0.0152805	
TIME	-0.0156913	0.0065371	-2.4003332	0.0176576	
AR(1)	0.24926	0.0818643	3.0447936	0.0027693	
Fixed Effects					
BL--C	-30.124	GR--C	-28.8508	PT--C	-29.2627
BU--C	-28.7593	HU--C	-28.7899	RO--C	-28.6351
CY--C	-28.9561	IR--C	-27.55	SK--C	-28.7836
DK--C	-28.8758	IT--C	-29.77	SL--C	-28.8977
ES--C	-27.9654	LA--C	-28.6217	SP--C	-29.3487
FI—C	-28.3922	LI--C	-28.4961	SW--C	-28.7457
FR--C	-29.3148	NE--C	-29.9256	TU--C	-28.4643
GE--C	-29.7486	PO--C	-28.1477	UK--C	-29.8461
R-squared	0.986114	Mean dep. variable		-22.4429	
Adjusted R2	0.981582	S.D. dependent var		0.360644	
S.E.of regression	0.048945	Sum squared resid		0.344962	
F-statistic	217.5755	Durbin-Watson st.		1.915997	
Variables	24	AIC		-156.349	

Annex 9 Data on land use

9.1 Standard Statistical Classification of Land Use – Economic Commission for Europe of the United Nations (UNECE)

Code Number	EN_Description
1	Agricultural land
1.1	Arable land
1.2	Land under permanent crops
1.3	Land under permanent meadows and pastures
1.4	Other agricultural land, n.e.s.
1.5	Total agricultural land, of which: - Fallow agricultural land
2	Forest and other wooded land
2.1	Total land under forest and other wooded land, of which: - Stands of exotic species; - Particularly fire-prone stands
2.1.1	With wood production the recognized major function
2.1.2	With protection, conservation and biological use the recognized major functions
2.1.3	With recreation the recognized major function
2.2	Land under coniferous forest
2.2.1	With wood production the recognized major function
2.2.2	With protection, conservation and biological use the recognized major functions
2.2.3	With recreation the recognized major function
2.3	Land under non-coniferous forest
2.3.1	With wood production the recognized major function
2.3.2	With protection, conservation and biological use the recognized major functions
2.3.3	With recreation the recognized major function
2.4	Land under mixed forest
2.4.1	With wood production the recognized major function
2.4.2	With protection, conservation and biological use the recognized major functions
2.4.3	With recreation the recognized major function
2.5	Other wooded land
2.5.1	With wood production the recognized major function
2.5.2	With protection, conservation and biological use the recognized major functions
2.5.3	With recreation the recognized major function
3	Built-up and related land (excl. scattered farm buildings)
3.1	Residential land
3.1.1	With mainly one- or two-storey buildings
3.1.2	With mainly three- and more-storey buildings
3.2	Industrial land, excluding land used for quarries, pits, mines and related facilities
3.3	Land used for quarries, pits, mines and related facilities
3.3.1	For peat cutting
3.3.2	For other open-cast mining and quarrying
3.3.3	Other, n.e.s.
3.4	Commercial land
3.5	Land used for public services (excluding transport, communication and technical infrastructure)
3.6	Land of mixed use

3.7	Land used for transport and communication
3.7.1	Land under roads
3.7.2	Land under railways
3.7.3	Land under airports and related facilities
3.7.4	Other land used for transport and communication, n.e.s.
3.8	Land used for technical infrastructure
3.8.1	Land used for the disposal of wastes
3.8.2	Land used for water supply and waste-water treatment
3.8.3	Land used for electricity generation and distribution
3.8.4	Other land used for technical infrastructure, n.e.s.
3.9	Recreational and other open land
3.9.1	Parks, green areas, hobby gardens, cemeteries, etc.
3.9.2	Recreational land mainly occupied by camping sites, secondary residences or vacation houses
3.9.3	Land under current construction
3.9.4	Land intended for future construction
3.9.5	Other, n.e.s.
4	Wet open land
4.1	Mires
4.1.1	Ombrogenous mires (upland moors)
4.1.2	Soligenous mires (lowland bogs)
4.2	Wet tundra
4.3	Other wet open land n.e.s.
5	Dry open land with special vegetation cover
5.1	Heathland
5.2	Dry tundra
5.3	Montainous grassland
5.3.1	Used for grazing of domestic animals
5.3.2	Not used for grazing of domestic animals
5.4	Other n.e.s.
6	Open land without, or with insignificant, vegetation cover
6.1	Bare rocks, glaciers, perpetual snow
6.1.1	Bare rocks
6.1.2	Glaciers and perpetual snow
6.2	Sand-beaches, dunes, other sandy land
6.3	Other, n.e.s.
7	Waters
7.1	Inland waters, of which: - in harbour areas
7.1.1	Natural watercourses
7.1.2	Artificial watercourses
7.1.3	Inland sea (freshwater or saline), lakes, ponds, coastal land-locked bodies of water
7.1.4	Artificial water impoundments
7.1.5	Other inland waters n.e.s.
7.2	Tidal waters, of which: - in harbour areas
7.2.1	Coastal lagoons
7.2.2	Estuaries
7.2.3	Other tidal waters n.e.s.

9.2 Inquiry for data on built-up and related land in EU-15 and ACC-13

9.2.1 EU-15 and Member States

Starting from the available NEW CRONOS 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 were as follows:

- Austria: data available for construction area (Baufläche), road traffic area (Straßenverkehrsfläche), and railway area (Bahngrund), for 1991-1998, 2000 and 2002 (Statistics Austria, personal communication by Peter Zeiszig on 22 march 2004).
  So, the informative value of the NEW CRONOS data could not be further improved by national data for Austria.
- Denmark: Statistic Denmark cannot provide economy-wide land use data for built-up and related areas (LA_3 after UNECE). Data using the CORINE Classification exist for 2001. Further information can be obtained on www.dmu.dk. The figures are a revision (not an update) of the collected data. The classification is based on the 3. digit CORINE land cover nomenclature, as a 4'th. number is added for national purpose. The figures are based on different primary data covering the period from the end of the 1980's to the middle of the 1990's (Statistic Denmark, personal communication by Jesper Lauritzen on 19 March 2004).
- Finland: Statistics Finland is not responsible for land use data, but the National Land Survey of Finland. However, no response was obtained from them.
- France: only the data contained in the NEW CRONOS database are available.
- Greece: no response.
- Ireland: Statistics Ireland is not responsible for land use data, but the Department of Environment. However, no response was obtained from them.
- Italy: no response.
- Spain: Statistics Spain refered to agricultural land use data only.
- UK: Statistics UK is not responsible for land use data, but the Office of the Deputy Prime Minister. From them, the following information was obtained: “It sounds like the Generalised Land Use Database might be helpful for your study. The data, and an explanatory paper, are available from the website of this Office at: http://www.odpm.gov.uk/stellent/groups/odpm_planning/documents/page/odpm_plan_023322.hcsp. The data most likely to be of use is that for Urban Areas, and Local Authorities (which I attach here). At the moment these experimental figures are only for two out of nine of the Government Office Regions of England. These are London, and the South East. This data classifies land into nine classes: Domestic Buildings, Non-Domestic Buildings, Gardens, Greenspace, Water, Rail, Road, Path, Others. The figures are in square metres, so are easily converted to hectares (Planning & Land Use Statistics Division, Office of the Deputy Prime Minister, personal communication by David Cross on 24 March 2004)”.
  So, data for built-up land in the UK are currently only available for 2 out of 9 regions in England. It is intended to collect these data for all of England, but this will take some more years, projections for Scotland, Wales, and Northern Ireland are also uncertain.

To sum up, 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.

9.2.2 ACC-13

Starting from the available NEW CRONOS 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 were as follows:

- Bulgaria: Statistics Bulgaria is not responsible for land use data, but the Central Government (www.mzgar.government.bg; e-mail: d.atanasova@mzgar.government.bg). However, no response was obtained from them.
- Cyprus: “The only available information refers to the year 2000; built-up and related areas is estimated at 205 square kilometres. This figure has been produced by the Department of Lands and Surveys and is based on a 1:50000 map. No further disaggregation is available”. (Statistics Cyprus, personal communication by Pantelis Protopapas on 23 march 2004).
- Czech Republic: no response.
- Estonia: “The latest official data refer for 1993 and the total built-up area, measured in thousands of hectares. This value includes land used for residential purposes, roads, technical infrastructure, industrial and commercial premises and recreational sites. See attached file, which is downloaded from Envstat. No later official data exits by my mind. The definition excludes scattered farm buildings, yards and annexes. Later on (1993 onwards) there are no data (caused by land privatisation) for compiling land use statistics in Estonia. You could try to contact Estonian Land Board (http://www.maaamet.ee/) for further information”. (personal communication by Kaia Oras, Head of Environment and Sustainable Development Statsitics Section, Statistical Office of Estonia, on 24 March 2004). No further information for Estonia was obtained.
- Hungary: Only data from the CORINE Land Cover programme are being prepared which, however, do not fulfill the requirement of comparability with the annual quantitative data from the NEW CRONOS land use database. (personal communication by George Büttner, head, Environmental Applications of Remote Sensing, FÖMI, Remote Sensing Centre, Budapest, HUNGARY, on 7 April 2004).
- Latvia: “In reply to your inquiry we inform you that we can not provide economy-wide land use data for built-up and related areas (LA_3 after UNECE), because information on land use in Latvia is compiled according to another classification”. (personal communication by Iveta Straume, Information, Publishing and Printing Department, CSB of Latvia, on 25 March 2004).
- Lithuania: no further data available (personal communication by Birute Stolyte, Statistical Information Division, on 22 March 2004).
- Malta: In addition to NEW CRONOS data, data for 2000 became available from National Statistics Office Malta (2002).
- Poland: no response.
- Romania: In addition to NEW CRONOS data, Statistics Romania provided data for land use categories “construction” and “roads and railway” for 1990 to 2000 (Statistics Romania 2002).
- Slovakia: In addition to NEW CRONOS data, Statistics Slovakia provided data for land use by built-up area for 2001 and 2002 (personal communication by Vladimir Cicmanec, Statistics Slovakia, on 23 March 2004).
- Slovenia: data available as given in the NEW CRONOS database, in addition, data for 2001 have been sent to Eurostat in Regional Environment JQ 2003 questionnaire in October 2003 (Danijela Šabic, Head of Statistical Geomatics and GIS Dpt., Statistical Office Republic of Slovenia, personal communication on 2 April 2004).
- Turkey: “In reply to your e- mail in the reference, I would like to inform you that the data on economy- wide land use for built up and related areas (LA_3 after UNECE) and the disaggregated level in addition(LA_3_1 to LA_3_9) are not available yet. But, the works on a standard statistical classsification as proposed by the EconomicCommission for Europe of the United Nations are carried out by State Institute of Statistics. They have not completed yet”. (personal communication by Burhanettin Korkmaz, Statistics Turkey, on 26 March 2004).

To sum up, only slight improvenments 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.

9.3 Productivities of built-up areas

We have discussed in the beginning of the chapter on land use 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. Transfering this approach to EU-15 we can derive comparable values for the absolute productivity of the GDP per unit built-up land and respective changes over the reporting periods. This is shown in the following table.

Built-up and related land
Productivity as EURO (1995) per m^2
DOMESTIC

	1990	1995	2000	Change over period	Average change over period
EU-15					
Austria	52	53	54	3%	0,3%
Belgium-Luxembourg	40				
Denmark	21	21	22	2%	0,2%
Finland	14	13		-5%	-1,1%
France	32	30	32	0%	0,0%
Germany	50	45	45	1%	0,2%
Greece					
Ireland					
Italy					
Netherlands	53	57	66	25%	2,5%
Portugal	5		6	14%	1,4%
Spain	21				
Sweden	16				
UK					
Belgium	39	40	43	9%	0,9%
Luxembourg					
Germany from FSOG		46	47	4%	0,7%

Productivities for built-up land were found to be as low as 6 EURO per m^2 in Portugal in 2000, to as high as 66 EURO per m^2 in the Netherlands in 2000. With the exception of Finland, all EU countries reporting time series for built-up land, had increased their respective productivities during the 1990s (France had kept it rather constant). Increasing productivities imply that economic growth has been above growth of built-up area, and vice versa. The strongest increase was observed for the Netherlands at plus 25% from 1990 to 2000. Only Finland had decreased its land use productivity in terms of built-up land by 5% between 1990 and 1995. This was, however, due to a period of economic recession in Finland lasting from 1990 to 1993 with the GDP in 1995 being still below that in 1990. The absolute extent of built-up land in Finland had still increased between 1990 and 1995. So, with the exception of Finland, relative de-coupling of domestic built-up land use and GDP had occurred in EU-15 countries during the 1990s. However, the absolute extension of built-up land had still increased. Consequently, considerable further increase of the area productivity would be required in all EU countries studied in order to achieve significant de-coupling of built-up land use and GDP.

The productivities of GDP per unit built-up land for ACC-13 are shown in the following table.

Built-up and related land
Productivity as EURO (1995) per m^2
DOMESTIC

	1990	1995	2000	Change over period	Average change over period
Bulgaria					
Cyprus			39,8		
Czech Republic	5,1	4,9	5,2	1%	0,1%
Estonia					
Hungary					
Latvia	2,6				
Lithuania	5,0	2,8	3,0	-40%	-4,0%
Malta			42,2		
Poland		5,1	6,5	27%	5,5%
Romania	3,0	2,6	2,5	-17%	-1,7%
Slovakia		4,0	4,8	21%	4,2%
Slovenia		25,4	23,8	-6%	-1,3%
Turkey					
ACC-13					

Productivities for built-up land in ACC-13 were found to be tentatively lower than in EU-15 countries, ranging from 2.5 EURO per m^2 in Romania in 2000, to 42.2 EURO per m^2 in Malta in 2000. Furthermore, among 6 countries reporting on time series, increases and decreases of built-up land productivities were evenly distributed. Whereas the Czech Republic, Poland, and Slovakia had increased their area productivities during the 1990s, the inverse development was found for Lithuania, Romania, and Slovenia. ACC countries like the latter three clearly point out the risk that economic development in the newly industrializing countries of Eastern Europe may occur at the cost of significant losses of reproductive and natural areas. Monitoring the development of built-up land in the course of economic growth provides an important alarm system for such kind of non-sustainable development pathways of the economy.

9.4 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. The largest share of this land for quarries, pits and mines etc. was found in Germany at 0.5% of the total area in 2000 (see following table). This is mainly because of the importance of large-scale open-pit mining for domestic construction minerals like sand and gravel, natural stones and clays, and for peat and lignite[15]. In contrast to the total of built-up land, land for quarries, pits and mines etc. has even decreased over time in 4 out of 7 EU countries studied. A significant increase until to the end of the observation period in 2000 was actually only found for the UK. In the case of the UK, however, it is reported that each survey that has been undertaken since 1974 in England is thought to be a more accurate reflection of the real extent of mineral workings (Survey of Land for Mineral Workings in England 2000). In addition, different references like 'permitted area' versus 'worked area', or the treatment of the area of underground mineral workings, which may be

[15] Langer, Landesamt für Bodenforschung Niedersachsen, Hannover, personal communication on 28.11.2001

magnitudes larger that its surface 'footprint', may further contribute to uncertainties in the interpretation of data across countries and over time.

Land for quarrying and mining
%of total area
DOMESTIC

	1950	1970	1980	1985	1990	1995	2000	Change over period	Average change over period
EU-15									
Austria					0,11%	0,09%		-22%	-4,4%
Belgium-Luxembourg					0,18%				
Denmark					0,08%	0,05%	0,05%	-39%	-3,9%
Finland									
France						0,12%	0,12%	3%	0,6%
Germany				0,30%	0,34%	0,53%	0,50%	-4%	-0,9%
Greece									
Ireland									
Italy									
Netherlands			0,19%	0,17%	0,16%	0,16%	0,12%	-35%	-1,7%
Portugal							0,24%		
Spain									
Sweden			0,06%		0,08%	0,08%		25%	1,7%
UK				0,15%	0,21%		0,23%	48%	3,2%

Similar rather low ratios for domestic land used for mining and quarrying of minerals and fossil fuels were found for the ACC countries Malta, Poland, and Slovenia, with Malta at 0.8% of the total area ranging a little higher than Germany (0.5%). The only time series available for Poland indicates a slight increase from 1950 to 2000, but values during the 1990s had remained rather constant (see following table).

Land for quarrying and mining
%of total area
DOMESTIC

	1950	1970	1980	1985	1990	1995	2000	Change over period	Average change over period
Bulgaria									
Cyprus									
Czech Republic									
Estonia									
Hungary									
Latvia									
Lithuania									
Malta							0,81%		
Poland	0,11%	0,09%	0,12%	0,13%	0,13%	0,13%	0,12%	13%	0,3%
Romania									
Slovakia									
Slovenia							0,07%		
Turkey									
ACC-13									

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.