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Environmentally extended input-output tables and models for Europe

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Institute for Prospective Technological Studies

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Preface

Being a part of standard national accounts, input-output tables describe the value of transactions between the different sectors in the economy. If such tables are extended coherently to also include environmental information, such as sectoral emissions or resource use, then they have the potential to provide powerful tools for environment-related policy analysis, for example in the areas of integrated product policy and sustainable use of natural resources.

The currently available versions of such tables have already proved their value, for example in the JRC-IPTS-led EIPRO ([1]) project, in which they served to identify those products consumed in Europe that have the greatest environmental impact throughout their life cycles. It is also clear however, that for other important applications — for instance, to study the link between the economic output of the EU and the environmental impacts over time — the data situation would have to improve. The availability and quality of environmentally extended input-output tables varies a lot between different European countries, and there are no such tables based on official statistics for the EU as a whole.

As a further contribution to developing the knowledge base for the EU thematic strategy on the sustainable use of natural resources and for environmental policies in general, the JRC-IPTS therefore set up a project to explore the full potential of environmentally extended input-output tables and models for Europe and commissioned a study to a consortium of TNO and Leiden University with the aim to show the ways how the required data can be obtained. The results of the study are presented in this report.

The report starts with an overview of the input-output tables and environmental extensions available in Europe today and then sketches the principal application areas in modelling and policy analysis. They include identifying the main sources of environmental problems within the economic system, ex-ante impact assessment of environment-relevant policies, as well as informing policy-making at the strategic level about trends in the environmental performance of the economy and their drivers. The report then translates the analytical requirement of such applications into technical specifications for the environmentally extended input-output tables. Finally, it produces a number of alternative roadmaps of how to produce such tables for Europe: an ambitious 'royal route' which, in the long term, would lead to a data situation that serves the analytical requirements in an ideal manner, and two 'realistic' options to achieve a reasonably good data situation within a few years.

Thus, the information contained in this report is relevant to both providers of statistical information about the environmental performance of the economy and to policy-makers and researchers looking for tools to identify priorities, assess impacts and make strategic goals such as eco-efficiency or decoupling environmental impact from growth operational.

(1) Environmental impact of products.

Executive summary

Introduction

Environmentally extended input-output (EEIO) tables and models have become a powerful element in supporting information-based environmental and economic policies. Briefly stated, monetary input-output (IO) tables give insight into the value of economic transactions between different sectors in an economy, including output for exports, capital formation and final government and private consumption. They allow for calculating the added value that each sector contributes to the final output of an economy. Such monetary IO tables can be 'extended' with environment-related information for each sector, such as its emissions, primary (natural) resource use, land use and other external effects per sector. These environmental externalities may be expressed in monetary terms as well. The same framework can be used to add other information, for example related to the third pillar of sustainability, regarding social aspects, such as the number and quality of jobs per sector. And, last but not least, such EEIO tables can be integrated in broader models, such as computable general equilibrium (CGE) models.

This ensemble forms an unrivalled toolkit for information-based policy-making because EEIO tables and models are based on a comprehensive accounting framework covering all economic activities. EEIO tables bring together economic and environmental data in a consistent, related sectoral framework. EEIO models based on them allow for analysing such data via a great variety of cross-sections of the economic system, such as the product perspective, or a sector perspective. If the EEIO tables and the related data collection system are set up rightly, it can fulfil multiple goals, and hence will probably greatly reduce the effort in data gathering for analysis, ex ante impact assessment and monitoring for a variety of environmental policy fields.

Background and goals of the project

Against this background, DG JRC/IPTS set up a call for tender for a project that would cover the following main tasks:

1. to describe the state of the art of IO tables with environmental extensions in Europe and outside, and to depict their usage and limitations;
2. to assess the potential application areas of IO tables with environmental extensions in European policy-making;
3. to evaluate the feasibility of producing and using IO tables with environmental extensions in European policy-making in the short, medium and long term;
4. to propose practical steps for exploiting the potential of European policy analysis based on IO tables with environmental extensions.

Below, we describe first the result of Task 2, culminating in desired design specification for an EU-25 EEIO table, and subsequently describe the current state of the art and available information (Task 1), options for developing an EU-25 EEIO table (Task 3), culminating in conclusions and recommendations (Task 4).

Potential application areas for EEIO models

EEIO tables and models based on them can be used in three main ways in support of environmental and other policy purposes. There are the following options for application.

1) Environmental problem analysis

This involves the analysis of the nature and causes of environmental problems, as related to resource use and emissions relevant for policy.

The most important application of EEIO models for this purpose include analyses of:

a) life cycle environmental impacts per consumer group (e.g. inhabitants of a city versus the rest of a country, car owners versus non-car owners, etc.);

b) life cycle environmental impacts of consumption expenditure categories, per consumption category (e.g. the impact of food consumption at home and the impact of food consumption in restaurants);

c) life cycle environmental impacts of product groups (e.g. cars, meat, houses, etc.);

d) life cycle environmental impacts of products (in combination with LCA via so-called hybrid LCA-EEIO. In such hybrid LCA-EEIO, the impact of a specific product is analysed with LCA, and the impacts of process chains not included or 'cut off' in the LCA are estimated with the help of EEIO);

e) life cycle impacts related to primary resources used (e.g. oil, copper, wood, etc.);

f) factors that are responsible for the main contributions to life cycle impacts mentioned under the above points. Examples include the relative importance of impacts in the resource extraction, production, use and waste management stages; the relative importance of domestic impacts and impacts embodied in imports; and the sector mainly contributing to impacts of a consumer group, expenditure category, or product (group).

2) Prospective effect analysis of policies

This involves the ex ante prediction of effects of policy measures and may include trend and scenario analysis. The most important application of EEIO models for this purpose include:

a) economy-wide environmental and other implications of changes in life styles and consumption expenditure patterns, such as a shift from travelling to educational and cultural services;

b) economy-wide environmental and other implications of incremental or radical technical change of products or processes, such as a shift to coal-based hydrogen production for large-scale fuel cell introduction, combined with carbon sequestration;

c) economy-wide environmental and other implications of emission reduction measures, such as fine dust reduction in all combustion processes, including shifts to prevention;

d) economy-wide environmental and other implications of price effects, such as environmental taxation and other ways to internalise external effects (or other price effects in the aforementioned scenarios).

3) Monitoring and ex post effect analysis of policies

This involves the ex post analysis of impacts and effectiveness of policy measures, including time series analysis:

a) analysis of the relation between environmental impact, be it emissions, total material requirement, or a specific impact, and economic output, via a variety of cross sections of the economy (for instance for a specific industry sector, a specific product group, a specific consumption expenditure category);

b) in relation to the former point: monitoring of eco-efficiency ratios (impact per unit of value created);

c) decomposition analysis of observed changes in the aforementioned ratios (for instance whether decoupling between CO_2 emissions and economic growth is caused by a change in consumption patterns, change in technology structure or a change in emission factors).

Required specifications of EEIO tables

These applications pose the following demands with regard to an EEIO table. For a comprehensive coverage of the different environmental issues, it must at least contain data on primary resource use, some 20–30 emissions of substances to water, air and soil relevant for global warming, ozone depletion, eutrophication, and photochemical oxidant formation and, if possible, land use. Other demands depend more on the application.

a) For *problem analysis* purposes, a detailed sector resolution is desirable, time series less relevant, and a basic EEIO model is usually sufficient. The relevance of detail was convincingly shown in the EIPRO study, which allowed for assessment of environmental impacts of very specific product groups.

b) For *prospective effect analysis of policies*, a detailed sector resolution is, in principle, even more desirable, time series are less relevant, and it is often desirable to use the EEIO table in models that make a number of exogenous parameters endogenous (2). The latter point is somewhat at odds with the demand for detail as it is usually more complicated with detailed tables. But, here too, detail is important: EEIO tables with one sector for 'agriculture' will not allow analysis of a shift in expenditure from animal protein sources to vegetable protein sources, whereas a table that discerns such sectors will do so.

c) Finally, for *monitoring and ex-post effect analysis of policies*, EEIO tables of moderate sector resolution are, in most cases, sufficient and time series are essential. But, here too, detail may have advantages if monitoring of policies directed at very specific resources, sectors or product groups is at stake.

In sum, this report pleads for detailed EEIO tables with several hundred sectors, as reached in the CEDA EU-25 tool developed in the study 'Environmental impacts of products (EIPRO) performed in 2004 and 2005' (3). Obviously, this desire must be balanced against efforts, costs and institutional impediments. Appropriate level of detail is at least needed for consumption areas with major effects, such as food, housing and transport. Below we will discuss how such a detailed EU-25 EEIO table can be constructed.

Available information

The EU has various elements already in place that could be used to build EEIO tables. The European System of Accounts (ESA95) requires that EU Member States send Eurostat make and use tables yearly, and IO tables five yearly, both with a resolution of 60 sectors. A main problem is that sectors in different countries are connected by trade, and the information obtained via ESA95 does not link domestic sectors which import with sectors abroad which export, and vice versa. This makes it difficult to construct an EU table from Member State tables, and Eurostat has not yet done this. At national level, several countries produce IO or EEIO tables with up to around 100–150 sectors. The United States and Japan produce IO tables with a resolution of about 500 sectors.

Concerning environmental extensions, EU Member States each year produce voluntary NAMEA (4)-Air tables that correspond with the ESA95 sector structure. These NAMEAs contains some 10–20 emissions to air, mainly greenhouse gases. NAMEAs on emissions to soil and water

(2) Examples include the relation of consumption expenditures with the cost of labour, including price elasticities, and dynamising the model with regard to changes in capital stock and technical development as a function of expenditure on capital goods.

(3) EIPRO was performed as a support for the EU's integrated product policy (IPP). The Comprehensive Environmental Database (CEDA) EU-25 is based on OECD IO tables for European countries with a resolution of several dozen sectors, and European totals for environmental extensions. Due to the lack of further available data at the moment, the level of detail of 500 sectors was reached by 'Europeanising' a detailed US EEIO table.

(4) NAMEA: National Accounting Matrices including Environmental Accounts.

and the use of resources are still largely absent. Examples of other environmental data sources in the EU are EMEP, EPER, UNFCCC, RAINS, GAINS, and the national PRTR data [5]. In most cases, these are built up for specific purposes and use detailed classification systems unrelated to ESA95 or UN industry sector classifications. When gathering information on NH_3 emissions, for instance, all sorts of animal stables may be distinguished, beyond any detail in standard classifications, such as the NOSE/NOSE-P process lists [6] which link processes to the European standard industry sector classification NACE. Lacking uniformity in classification means that representativeness of emission data for classes as distinguished in IO tables cannot be established, as the detailed data are not defined as being representative of specific standard classes.

Physical input-output tables might be established within the IO sector structure too. There are several options for specification of such flows, in terms of elements, chemical compounds, materials and total mass. Energy or exergy data can also be placed in this framework. Such material and substance flows are not recorded in any systematic way in relation to make and use tables. The measurements of flows within an economy remain limited and are hardly related to specific product specifications or to specific sectors of origin and destination. Only imports and exports are specified well and used for material flow analysis (MFA), especially in establishing domestic material consumption (DMC). Due to the use of a sound product classification system, imports and exports of product flows might be analysed systematically. When the composition is total mass, or is in terms of materials related to elements, as with aluminium and copper, mass balancing is possible, allowing for the derived computation of internal flows within countries. The currently available data sets do not fit into the IO framework, i.e. the make and use tables, nor do they link to the product classifications used in these make and use tables.

Available classification systems

A main problem in the existing situation is that data are not gathered in consistent classification systems. At statistical bureaus, much effort is currently spent on transposing sector and product data from one classification to another, rather than on gathering data themselves. Classification systems play an essential role, as actual data are always partial, with some degree of representativeness only relative to a well-defined class. Within a class, there will always be diversity. This holds both for sectors (where one pig farm system is different from the other) and for products (where one mobile phone type is different from another). The essential nature of classification systems for data gathering and modelling for analysis was recognised long ago and standardised classification systems have been set up, coordinated by the UN, and supported by the OECD. The main industry sector classification systems are ISIC [7] by the UN, the related but more differentiated and mutually incompatible NACE [8] and NAICS [9] approaches in the EU and US, and variants in almost all countries. Real progress is under way, however, as the EU and US will come up with a modernised and aligned system, comprising well over 500 sectors — here called new-NACE. It is expected that this system will become the UN standard too. It seems that any systematic

(5) EMEP: Cooperative Programme for Monitoring and Evaluation of the Long-Range Transmission of Air Pollutants in Europe.
EPER: European Pollutant Emission Register.
UNFCCC: United Nations Framework Convention on Climate Change.
RAINS: Regional Air Pollution Information and Simulation.
GAINS: Greenhouse Gas and Air Pollution Interactions and Synergies.
PRTR: Pollutant Release and Transfer Register.
(6) NOSE-P: Nomenclature of Sources of Emission — Process List.
(7) ISIC: International Standard Industrial Classification of All Economic Activities.
(8) NACE: Statistical Classification of Economic Activities in the European Community.
(9) NAICS: North American Industry Classification System.

data gathering in the future should adhere to this standard, with further detailing only within the classes with the highest resolution.

For products, the situation looks less bright. There are three internationally recognised systems which, at their highest resolution, are all mutually incompatible. They are:

- CPC (Central Product Classification) of the UN, which is linked to the ISIC Industry Classification. CPA (Classification of Products by Activity) with 2 608 classes is the European variant and is used in the realm of the ESA95 IO and make-use tables;
- HS (Harmonised commodity description and coding System) of the UN, with CN (Combined Nomenclature), 19 000 classes, as the European variant. They are used for classification of economic data on international trade;
- the COICOP (Classification Of Individual COnsumption by Purpose) system of the UN, slightly adapted for use in Europe, 157 classes, and a number of related final expenditure classifications.

It seems wise to gather base information on products only in relation to one system, making the other systems into derived, compatible, classification systems, not only compatible between product classifications but also linked to the make and use framework for linking to IO tables. The most detailed internationally recognised product classification system is HS, with 7 466 classes. Choosing this classification system or an improved internationally agreed-upon classification system as the base, the COICOP and CPA would have to be revised and become derived systems only. This would allow for systematic data gathering, including time series, on the composition of products, well linked to the IO framework. Such options for streamlining classification systems of course have to fit in with other main uses of the data set, as for economic and social policy purposes. There is no a priori reason why these would require different classification systems. A revision of classification systems of course requires reclassification, which implies substantial work too for these other applications.

Options for developing a detailed EU-25 EEIO table

Introduction

When setting up EEIO tables, several steps need to be distinguished: the base data gathering; their incorporation into make tables and use tables with environmental extensions, and the linkage of make tables and use tables with product flow extensions; the transformation of these into squared IO tables with environmental extensions (the EEIO tables); the construction of physical input-output tables (PIOTs), as IO-linked SFAs and MFAs.

It goes without saying that the first step in any development strategy should be to use what is there: combining the national ESA95 tables and NAMEAs, complemented with other environmental data, into an EEIO table for the EU. This would result in a 60x60 EEIO table with a few dozen environmental extensions, a great leap forward compared to the current situation. How to make the step from national to EU-25 level requires a specific methodological decision to be made. Currently, the make and use tables are transformed into input-output tables at a national level. For integration to an EU-25 table, it is preferable to aggregate national make and use tables to EU-25 make and use tables, to link environmental extensions at that level, and then make the transformation to an EU-25 EEIO table. Further detail can be elaborated from this basis, via three distinct approaches. They range from rather simple improvements relative to the current CEDA EU-25 table, through the better use of basic data as are available especially in statistical bureaus, to the improvement in basic data gathering and classification. All three options incorporate a broad set of environmental data, but differ in their sector resolution.

1. High resolution CEDA EU-25++.

The current CEDA model has been built up from US data and has been Europeanised, with a limited set of European data. The procedure could be reversed by starting from the 60x60 sector EU-25 EEIO basis described above and then bringing in detail through technology transfer assumptions, using the US data as one (but not the only) main source. The 60x60 core table would be updatable given the link to the ESA95 reporting procedures. In the future, several improvements in data and methods will be possible compared to the CEDA model. However, it will be difficult to solve the relations between several classification systems in a transparent way, and US data especially will put their mark on the outcomes. Also, the starting point will probably remain in IO tables, not in make and use tables. This is the most simple and least expensive improvement option, not in line with the method rules as specified above, as with working from make and use tables with environmental extensions instead of starting with IO tables. The procedure for creating the improved CEDA model is that of a project.

2. Medium resolution EEIO tables: IO/NAMEA++

Currently, several EU countries have data gathered which are not used in reporting to Eurostat, and sometimes are not even published. A limited level of reclassification and adjusted methods could lead to national make and use tables at a higher level of detail than in ESA95, albeit differently for different countries and not available for all EU countries. For several countries, make tables and use tables are available for 100–150 sectors. Environmental data can be linked to these make and use tables, as can the material and substance flow extensions. By technology transfer assumptions using European data, the 'EU-content' is maximised, with only incidental recourse to data from abroad. The advised method for producing IO tables can then be followed at the EU-25 level. Up to 150 sectors could be distinguished, depending on how far one may go with technology transfer assumptions. Using official data as a main base, the construction of time series becomes possible. The main difference with the CEDA EU-25++ model is that, while using the same base data at the 60x60 sector level, the deeper level of detail is based on transfer of EU data available from national statistical offices. The updatability of the IO/NAMEA++ tables is easier to realise than for CEDA EU-25++.

3. High resolution tables: the 'royal route'

The central approach to this improvement option is to bring together the economic and environmental information at record level, through agreed-upon and regularly repeated procedures of statistical bureaus. Using detailed and uniformly standardised classification systems, including the new NACE classification, representativeness of data can be formally established and data quality can be strategically improved. The ESA95 system would have to be substantially upgraded. The import and export flows are linked, at least partially, to the record level, allowing for much improved regional EU-25 data and interregional data. Due to remaining data limitations, sophisticated statistical procedures also remain necessary in this option. Time series can be produced 'automatically' in the procedures specified. The long-term cost of this option need not be much higher than current expenditure.

Useful additional work

The result of all approaches will be a 'basic' EEIO table, which can be expanded in various ways. The table can be turned into a model, by making exogenous factors such as consumption, imports and capital formation endogenous. The first candidates for this seem to be imports and their embodied pollution: assuming that imports are made with domestic technology often leads to important under-estimations of environmental impacts. The ideal solution is to embed the EU-25

EEIO table in a regionalised world IO model such as the GTAP (10) model or MOSUS (11) model, with region-specific environmental extensions. If such extensions include topics such as land use, resource use and various emissions properly, by using various impact assessment methodologies the EEIO model can provide information as diverse as ecological footprints, external costs, scores on environmental themes, and the total material requirement related to consumption of products.

Conclusions and recommendations

Each of the three options has a clearly distinct character. Option 1 can be implemented in one to two years through low-key project work. Option 2 is a large three to four-year project that would require the active support of at least a number of statistical bureaus, and would also require the active cooperation of Eurostat. Option 3 requires a well-prepared political decision, related to UN alignment procedures and with input from several statistical bureaus and environmental data suppliers. The legal framework, especially ESA95, would also have to be adapted, though this might be phased to later stages. It is clear that this 'royal route' cannot be implemented on the short or even medium term.

The choice between option 1 and 2 is a matter of budget and taste, particularly with regard to the question of whether Europe's EEIO model should rely on foreign data. In the view of the authors of this report, option 2 is probably the best way forward. To some extent, it prepares and tests option 3. It is somewhat more expensive than option 1, but has — as a great advantage — that, in the end, a truly European table is built.

(10) Global Trade Analysis Project, a commercial database sold by Purdue University in the United States. An update on version 6 is due in 2006.
(11) Modelling Sustainability in Europe, an EU FP5 project.

1 Introduction

Environmentally extended input-output (EEIO) tables and models have become a powerful element in supporting information-based environmental and economic policies. Briefly stated, monetary input-output (IO) models give insight into the value of economic transactions between different sectors in an economy, including final output. They allow for calculating the added value that each sector contributes to the final output of an economy, being private household consumption and public sector consumption and exports. Such monetary IO tables can be 'extended' with environment-related information for each sector, such as its emissions, primary (natural) resource use, and other external effects per sector. These environmental externalities may be expressed in monetary terms too. The same framework can be used to add other information, for example related to the third pillar of sustainability, regarding social aspects, such as the number and quality of jobs per sector. And, last but not least, such EEIO tables can be integrated in broader models, such as computable general equilibrium (CGE) models.

This ensemble forms a powerful toolkit for information-based policy-making because EEIO models are based on a comprehensive accounting framework covering all economic activities. They allow for calculating the environmental impacts and external effects of economic activities from a variety of perspectives: for example, per sector, per product of final consumption activity, or related to the use of a specific natural resource. Furthermore, it is possible to analyse the effect of potential measures on environmental impacts (and, if wished so, on the costs of these externalities) but also on parameters such as economic output, productivity and employment. And, when time series of data are available, monitoring of decoupling of environmental impacts from economic growth and natural resource use is possible — including analysis of the factors that contributed mostly to this decoupling [12]. For some examples of the potential uses of EEIO models we refer to Box 1.

Potential applications of EEIO models for supporting environmental policy include policy dossiers such as integrated product policy, the strategy on the sustainable use of natural resources, the environmental technologies action plan, the emerging agenda on sustainable consumption and production, but also for filling in the Lisbon strategy in an eco-efficient way, and for the sustainability impact assessment of technologies and policies in general. Despite this potential of EEIO models for knowledge-based policy-making, at this moment there are no 'official' IO tables covering the whole of the EU, let alone EEIO tables, neither for the EU-15 nor the EU-25. Individual EU Member States have IO tables with some environmental extension, the latter coordinated by Eurostat in the NAMEA framework. In individual projects and by individual institutes, IO and EEIO tables and models have been developed that, in some cases, cover the EU or EU Member States, but usually they lack detail, have had to be based on transformation of data from non-EU countries to an EU context, or they lack transparency.

Given the above, the European Commission, DG JRC/IPTS, has asked for an analysis of the added value of developing environmentally extended input-output tables for the European Union (EU-25). This project has been executed by TNO and CML, and covers the following tasks.

- Task 1: State of the art in European environmentally extended input-output tables. The results of this task are given in

(12) For instance, change of consumption patterns, change of production patterns, change of technology of production, and change in emission factors.

Chapter 2 (which discusses EEIO tables in general) and Chapter 3 (which gives an inventory of existing EEIO tables and related information sources). Important questions dealt with in the chapter are:

- Which EEIO tables for Europe already exist?
- What are their characteristics and potentials?
- What basic data sources are available to build EEIO tables for the EU-25?

• Task 2: Identify application areas for supporting European policies. The results of this task are discussed in Chapter 4. Important questions answered in this chapter are:

  - For what policy fields and related questions do EEIO models have added value as support instruments?
  - What does this imply for the specifications of EEIO models in terms of sector resolution, amount of environmental impacts included, etc.?

• Task 3: Evaluate the feasibility of producing/using EEIO tables. The results of this task are discussed in Chapter 5, in which various options to develop EEIO tables for the EU-25 are analysed and compared.

• Task 4: Practical steps for exploiting the potential for European policy analysis. The results of this task are given in Chapter 6, which, on the basis of the former chapter, recommends the most promising routes for developing European EEIO tables.

Chapter 7 of this report gives final overall conclusions.

Box 1.1 Examples of applications of EEIO models

a) *Integrated product policy*
A variety of authors have used EEIO models to calculate and rank the environmental impacts of products (see Tukker et al., 2005 for a survey; and Weidema et al., 2005; Nijdam and Wilting, 2003), to analyse the contribution of impacts of each sector, or of foreign processes (Peters et al., 2005). If, in the models under a) external costs per sector are also included, the discrepancy between total societal costs of products/activities including externalities and actually paid costs can be calculated.

b) *Sustainable consumption and production*
EEIO models have been used for comprehensive analyses of the impact of life-styles, family compositions and cultural factors on the relation between consumption patterns and environmental impacts.

c) *Monitoring of decoupling*
Monitoring of decoupling of environmental impacts, such as resource use and economic growth. If time series are available, it is possible to analyse the relation between total final expenditure, resource use, greenhouse gas emissions, etc., and to analyse which factors determine changes in this relation: change of consumption patterns, change of production patterns, change of technology of production, and change in emission factors (compare Mäenpää, 2005).

d) *Impact of technical change*
By making a foresight of (technical) change in specific sectors, the consequences for decoupling and reduction of impacts can be calculated (compare, for example, the Dimitri model of the Dutch RIVM).

e) *Impacts of policies, including 'rebound effects'*
Policies may include restrictions on the use of certain products (which leads to a shift to the use of alternatives), or may include measures that have a price-enhancing or price-reducing effect of products (e.g. taxes and tax exemptions, or price-enhancing emission-reduction measures). IO models can predict the effects of such measures into shifts in consumption patterns, related production patterns and emissions/resource uses, and effects on employment.

2 Environmentally extended input-output analysis: options and data requirements

2.1 Introduction

The theoretical development of input-output analysis took place from the 1930s to the 1950s with Wassily Leontief playing a central role, first by developing the IO framework (Leontief, 1951), and then by developing the IO tables with environmental extensions (Leontief, 1970). The international standardisation of monetary input-output analysis started in the OECD (Stone, 1961), followed by the UN (UNSD, 2003, latest version). The standardisation of environmental extensions has taken place in the UN (2003). Interregional tables have been developed by Isard (1951).

Monetary IO analysis can be used to indicate effects of quantitative changes within the given structure of the economy and, on the other hand, as a means to describe structural changes in the economy. The energy crises in the 1970s and 1980s led to an enhanced interest in IO models. Simple IO models were linked to aggregate equilibrium models. They could be used to analyse which effects an energy policy (aimed at one sector) could have indirectly on other economic sectors (13). In the last decades, important progress has been made with the standardisation of sector and product (14) definitions, especially by the UN, which has facilitated gathering of data for IO modelling.

Monetary IO tables can be extended with environmental data. The systematic development of these extended tables took place at the end of the 1980s, by Statistics Netherlands under the name NAMEA (National Accounting Matrix including Environmental Accounts). As discussed in more detail in Chapter 3, several EU Member States and supranational agencies started to collect such data in the 1980s and the 1990s. However, they did so mostly with specific environmental goals and with specific policy applications in mind. This has led to a diversity of data gathering procedures, data formats, and different or lacking linkages to existing economic standard classifications for sectors and products. This makes building environmentally extended IO tables complicated and in general hampers progress both in rational data and model development and in extending policy applications. Eurostat is standardising the NAMEA data gathering at a country level, on a voluntary basis. The EIPRO study (Tukker et al, 2005) is an example showing the complexity now required in answering simple questions such as on the comparative environmental burdens of products for the EU-25, as such EEIO data are not available consistently for the EU.

This study aims to answer the question of how a comprehensive EEIO table for the EU-25 could be set up, and which policy questions such a table could answer. Before surveying which data sources and models are currently available (Chapter 3), we will first shortly describe the method in general, showing the model as developed by Leontief. Next, we will sketch in the main lines of how this model structure can be systematically filled in a transparent and adaptable way with both economic data and with environmental data on emissions, resource extractions and possibly other environmental interventions, such as land use, noise, radiation,

(13) The nomenclature is converging to sector, but in specific contexts alternative terms are used such as industry, process, activity and branch.
(14) There is diverging and overlapping nomenclature on products, goods, commodities and services. We use the most broadly accepted version as in UN CPC, where products comprise both physical goods and services.

etc. In the EEIO tables, these interventions are specified. How these environmental interventions are then transformed into environmental impacts (such as climate change and acidification) or into damages (such as biodiversity loss or health effects) is left open to users. Expressing these impacts in monetary terms, as costs of externalities, is also an option, for example followed in the ExternE method for assessing environmental impacts of energy production systems. All such options depend on basic data relating economic activities to environmental interventions.

Furthermore, we combine the data requirements with those on the broader physical analysis of the economy — as has developed in materials flow accounting (MFA) and substance flow analysis (SFA) (see EC, 2001; Nielsen et al., 2004; Femia and Moll, 2005). MFA and SFA refer to physical input-output tables (PIOTs). The extraction of natural resources, or primary resource extraction, constitutes the main material inflow in the economy. It is part of the environmental interventions linked to sectors. At the same time, these flows constitute the starting point at the inflow side for materials and substance flow analysis, by being transformed into products. A main distinction is in biotic resources (such as fish and forestry products) and abiotic resources (such as water, iron ore and sand). In physical input-output tables, the flows through the economy of extracted materials are not followed in a systematic way, as natural resources are transformed into products (such as oil into plastics) or used up (as when incinerating energy resources). For example, iron ore is extracted from the earth and then transformed together with other materials into stainless steel, as a product. The product 'rolled stainless steel' is not represented in the environmental extensions, but is covered in monetary terms, being sold by the primary materials production sector to almost all other sectors. By contrast, in a PIOT of iron, the starting point of 'iron ore extraction' is the same but then the flows of iron in the economy are also followed through all products and sectors, based on the iron content in all product flows (being, for example, around 80 % by mass of rolled stainless steel). More aggregate approaches, ultimately stating the total mass of all extractions and product flows, are also being used in MFA. When establishing basic data sets on product flows, the make tables and use tables can be used as a framework. The monetary products flows are first transformed into volumes of products, based on their prices. For each product, the composition can be specified in a number of ways, as in terms of total mass, of elementary composition (iron, carbon, etc.), in terms of a selection of compounds, or as materials contained in the product.

In this MFA and SFA, domain standardisation on sectors and products is lacking, meaning that the cumulative build-up of knowledge on the material functioning of our economy does not take place. Consequently, the EIPRO study on environmental impacts of products, based on EEIO analysis, cannot be related to the parallel study by DG Environment on environmental impacts of materials use (van der Voet et al., 2005). As, next to energy use, materials use is clearly a main driver of environmental impacts, the analysis of physical flows would preferably be made compatible with the overall environmental analysis of the economy. The description of the flows through the economy can be made using exactly the same sector structure as for EEIO tables or for monetary input-output analysis in general.

2.2 Environmentally extended input-output analysis: the method in general

In the original work by Wassily Leontief (see his survey publication, Leontief, 1961) the input-output table describes how industries are interrelated through producing and consuming intermediate industry outputs as represented by monetary transactions between industries, i.e. the purchase and sale of products, including both goods and services and also comprising capital goods. The input-output model assumes that each industry consumes outputs of various other industries in fixed ratios in order to produce its own unique and distinct output. Under this assumption of linear technology, an m×m matrix **A** is defined such that each column of **A** shows the domestic intermediate industry output (in monetary terms) that is required to produce one unit of output of the sector that corresponds to the column. **A** is usually referred to as the technology matrix. Let **y** denote the final demand by households and governments as final consumers, and by exports. The exports are left out for convenience here, the focus being on domestic consumption, including government purchases. Further, let **x** denote the total industry output. Then, in a situation of market balance, the amount produced (**x**) is exactly equal to the amount consumed by industries (**Ax**) plus the amount for final consumption (**y**). Thus, one has

$$\mathbf{x}=\mathbf{A}\mathbf{x}+\mathbf{y}$$

Then, the total domestic industry output **x** required to supply household and government purchases of domestic industry outputs is calculated by

$$\mathbf{x}=(\mathbf{I}-\mathbf{A})^{-1}\mathbf{y}$$

where **I** denotes the m×m identity matrix. This part of the analysis gives the economic structure in terms of production, consumption and inter-industry links.

The next step is that a matrix is specified representing environmental interventions for each industry involved, as an environmental extension. Environmental extensions of IOA can be made with the same assumption of linear technology as above. It is assumed that the amount of environmental intervention associated with an industry is proportional to the amount of output of that industry. Let us define a q×m matrix **B**, which shows the amount of pollutants emitted and natural resources consumed to produce one unit monetary output of each industry. We will refer to **B** as the intervention matrix. Then, the total direct and indirect pollutant emissions and natural resources extraction by domestic industries implied in satisfying a certain amount of final demand **y** is calculated by

$$\mathbf{m}=\mathbf{B}(\mathbf{I}-\mathbf{A})^{-1}\mathbf{y}$$

where **m** (dimension q) is the total domestic direct and indirect vector of environmental burdens. For the purpose of getting to know the contribution to the total burdens from different final demand categories, one can diagonalise **y** and obtain a matrix of environmental burdens **M** (dimension q×m), in which each column gives the burdens attributed to the corresponding category of final demand.

So, in its most basic form, environmentally extended input-output analysis can be performed making use of two matrices and one vector, as follows.

1. The final consumption vector, **y**. This vector basically distributes the total available income in a region/country over products used for final consumption. This final demand, as purchases of goods and services, drives all production activities and their related environmental effects. The number of products that can be discerned can be at maximum the amount of industry sectors discerned in the technology matrix (see below) ([15]).
2. The technology matrix **A**. This matrix gives the interrelations of production activities, based on the ratio between inputs and outputs in monetary terms. The production system of the economy is divided into a number (m) of sectors, and the base matrix shows the monetary value of the goods exchanged between each pair of sectors and delivered to final demand. Most countries gather such data, though often at a high level of aggregation, i.e. a limited number of sectors.

(15) Since not all industry sectors deliver goods and services for final consumption, the number of final products purchased for final consumption is lower than the number of industry sectors.

3. The environmental intervention matrix **B**. For each sector, the direct resource use (as inputs from nature such as ores)and the direct emissions (as outputs to nature such as CO_2 emissions) can be inventoried. This results again in a matrix (of *q* types of environmental interventions by *m* sectors). The matrix gives the environmental interventions per monetary unit of production of each industry, here as euro of turnover. In principle, in the same way as direct resource use and emissions are included, a value for external costs per sector can also be included as an 'impact' in the environment matrix.

Essentially, environmentally extended IOA distributes the (known) total environmental impacts generated by a production–consumption system over different final expenditure categories, on the basis of the extent that a final expenditure category 'demands' input of one of the preceding production processes in the technology matrix, and the emission per euro production of that process. Although this all suggests that the principle of EEIO analysis is simple, applying EEIO analysis is, in practice, hampered by the problem of finding reliable and up-to-date data. Also, for a cradle-to-grave analysis — as is required in consumption analysis — the use stage and the post-consumer disposal management (waste management and recycling) are to be covered. Such data are normally not included in IO tables.

There are different types of IO tables. They all show how industries (also called 'sectors' or sometimes 'activities') interact; specifically, they show how industries provide input of products (goods and services, also sometimes called 'commodities') to each other and how they use output of products from each other. All these tables provide detailed information on the flows of the goods and services between industries, but they all do so in a different way. There are four types of IO tables: use tables, supply tables, direct requirements tables and total requirements tables. The supply and the use table together contain the basic information from which the other tables are derived. The use table shows the inputs to industry production and the products that are consumed by final users. The supply table shows the commodities that are produced by each industry. Four different tables are derived from the use and supply tables. First, the direct requirements table shows the input of products for an industry to produce a monetary unit of output (say, one euro). In addition, there are three total requirements tables. In the commodity-by-industry table, the column shows the commodity delivered to final users and the rows show the total production of each commodity required to meet that demand. In the industry-by-commodity table, the column shows the commodity delivered to final users and the rows show the total production of each industry required. In the industry-by-industry table, the column shows the industry output delivered to final users and the rows show the total production required by each industry. It is this last table, a square matrix, which is usually called the input-output table. Environmental data are linked to sectors, as these represent the activities directly requiring natural resources and leading to emissions.

Over the last decades, environmentally extended input-output tables have found their way into various applications and have been worked out in various forms. Various authors have developed dynamic IO tables, i.e. tables in which the industry structure and the related monetary flows between sector changes over time as a result of technical progress (for example, Wilting et al., 2001). LCA practitioners started to use EEIO work in hybrid LCAs (i.e. LCAs where primary data are gathered for the main process chains, but where life cycle impacts of smaller inputs to these process chains are estimated on the basis of monetary value and environmentally extended IOA (see, for example, Suh, 2004). (Environmentally extended) IO tables are also becoming part of more complicated model systems, being complemented with general equilibrium systems and used as a tool in integrated assessments.

Theoretically, input-output modelling can make an important contribution to the development of environmental and sustainability policies within the EU. However, the lack of a detailed environmentally extended input-output table at the level of EU-25 may result in a suboptimal support for such policy development. This project sets out to investigate how, at the level of EU-25, the data problem with regard to EEIO tables can be solved, given the demands of an environmentally extended IOA model in relation to the potential questions posed by policy-makers.

2.3 Data and methods for environmentally extended IO tables

All monetary input-output tables are derived from supply and use tables. The supply and use tables represent data for a specific geographical region. The supply table refers to the products produced per sector and, for the environmental extension to the table, the direct emissions to the environment for each sector in the region. The use table refers to products consumed per sector and, for the environmental extension to the table, the natural resources taken from the environment by direct extraction in the region.

The supply table and the use table form the basis tools to analyse interactions between production activities and between production and final consumption. They are rectangular, as usually sectors produce more than one product. The rectangular monetary make and use tables can be combined into monetary IO tables, with sectors on both axes. The result is a square monetary input-output table, relating the supplying sectors to the using sectors. This base table gives totals sold and purchased and is then transformed into input and output coefficients. The methods used are well described in general. Most relevant here are the framework of economic system accounting as described in the European System of Accounts (ESA95) (EC, 1996) and the framework of Integrated Environmental and Economic Accounting as described in SEEA2003 (UN, 2003). Both frameworks describe the structure of tables and methods to develop for monetary tables and for environmentally extended input-output tables, but leave open a number of practical choices.

The development of environmentally extended input-output tables including PIOTs ([16]), as for MFA ([17]) and SFA ([18]), will be described below in six steps.

- Step 1: Gathering of basic data for a region.
- Step 2: Combining basic data in accounts: the supply table and the use table.
- Step 3a: Allocating of multi-product sectors to single-product sectors in the supply table.
- Step 3b: Adjusting of the monetary use table to the sector structure of the allocated monetary supply table.
- Step 3c: Adjusting the environmental flows in the environmental supply and use table according to the method used in 3b.
- Step 4: Combining allocated (symmetric) supply table and adjusted (symmetric) use table into symmetric input-output tables with environmental extensions.
- Step 5: Transforming the allocated supply and adjusted use table into material flow and substance flow tables.
- Step 6: Relating the regional table to other regions.

Step 1: Gathering of basic data for a region

Table 2.3.1 shows the basic data that are necessary in order to build the supply and use tables with environmental interventions linked

(16) PIOT: physical input-output table describing in physical terms the exchange of materials between sectors, possibly extended with the exchange of materials between sectors and the environment.
(17) MFA: material flow accounting, mostly describing the inflow and outflow of materials for the economy in a specific region for a specific year
(18) SFA: substance flow analysis, mostly describing the inflow, outflow and exchange of a specific substance for the economy and the environment in a specific region for a specific year.

to them and, from these, the environmentally extended input-output tables. For the supply and use tables, it is data on transactions which are to be gathered, usually from business administrations, but additionally also involving, for example, taxing data. Producers should also be able to indicate what types of products they have produced and what types they have purchased and used. For imports and exports, data may be obtained from firms, and also from import and export statistics gathered for taxing purposes. In principle, the base data on extractions and emissions are available at a producer's level, as, for example, originating from the emission registration and similar data gathering procedures described in more detail below. It is only direct extractions and emissions which are to be gathered. Ideally, the basis for all data is one type of activity of one firm at a specific location, with all its purchases and sales specified both in money terms and in terms of the substances and materials involved, and all its resource extractions and emissions at that location. In practice, basic data on sectors hardly ever cover both sales and purchases; emissions are not gathered in combination to economic flows; nor is the physical composition of the products involved specified in the economic statistics. So, data in make and use tables are always based on diverse sources of information, different for economic analysis, for environmental analysis and for material/substance flow analysis. By linking the samples, in a separate statistical step, the sectors and flows are brought into a single framework.

Theoretically, all transaction data might be expressed both in monetary units and in physical units. In practice, the economic data are expressed in monetary units only. Adding data on substance and material composition of product flows is not done regularly now, making the construction of detailed PIOTs difficult. Environmental data are expressed in physical units, mostly in kilogrammes. Supply and use tables are built for a national economy taking into account only the direct environmental interventions due to the economic activities of this economy, hence only inside the national territory. Emissions due to imports are not in the supply and use table of the region analysed but are emanating from activities abroad. Including them requires a link to these activities abroad as linked to import flows. The imports and exports are specified as to the sector of origin or destination relative to the region studied. However, for building regionally linked tables, each export flow would not only have to be linked to the receiving region but also to the sector abroad involved, and each import flow would have to be specified as the region and also the sector of production (see Isard, 1951, Table 1). This subject will be further discussed in step 6.

Table 2.3.1 Basic data to build a monetary and environmental supply table and use table for a region

	Supply table	Export table	Use table	Import table
Economic data: flows of products, (products in monetary terms)	Output by product and by sector (19)	Products by exporting sectors	(Intermediate) consumption by product and by sector	Products by importing sectors
Idem but additionally (kg, numbers)	Products specified in physical units	Products specified in physical units	Products specified in physical units	Products specified in physical units
Environmental data: emissions and extractions (flows of compounds)	Emission by compound and by sector	Outflow by compound (20)	Extraction or re-absorption by compound and by sector	Inflow by compound
Materials and substance flows (possibly also exergy)	Materials/sub-stances per product	Materials/sub-stances per product	Materials/sub-stances per product	Materials/sub-stances per product

(19) All industry sectors, households, government, non-profit institutions.
(20) Transboundary inflows and outflows of compounds are toned down. These flows are presented here to complete the analogy between the economic flows and environmental flows. However, transboundary in- and outflows in the environment are often not taken into account in input-output tables.

Basic data that have not been gathered and derived through statistical analysis in this step 1 are not available for further analysis. The poor level of data gathering at the moment is one main factor hampering the development of both EEIO tables and PIOTs.

Step 2: Combining basic data in accounts: supply table and use table

The data presented in Table 2.3.1 are the basic data made available. They refer to a region, usually a national economy, here also the EU as a region. IO tables may also be constructed for regions within a country and regions composed of several countries, ultimately for the whole world. These basic data for a region can be combined into basic accounting tables, the supply table and the use table. The data in supply tables and use tables are still 'real' data, i.e. untransformed data, referring to the total volumes of 'real' sectors. Therefore the information in the environmentally extended supply and use tables are the platform where basic empirical information is entered. If, in step 1, information is lacking, estimation methods through technology transfer approaches may have to be applied. The estimation method, in principle, uses this basic accounts framework to link in the information referring to other entities and derived from other sources.

Monetary supply and use tables

Monetary supply and use tables are matrices of sectors by products describing the outputs respectively inputs of products for the sectors of a region. A supply table shows the sales by type of product and sector, distinguishing output by domestic sectors and sales of imports (see Table 2.3.2). A monetary use table shows the purchases by type of product and sector, distinguishing between inputs as intermediate use (by industrial sector), as final consumption (by households, government, etc.), and gross capital formation (by households, government, etc.), and exports, as sales to sectors abroad (see Table 2.3.3). The quantification of the monetary supply and use tables is in standardised monetary units.

Environmental supply and use tables

Environmental supply and use tables are matrices by sectors and compounds describing the exchange in compounds between the environment (domestic) and sectors of a national economy. A supply table shows the pollution by type of compound and sector, distinguishing emissions by domestic sectors and possibly indicating (net) transboundary inflow (see Table 2.3.4) as additional information. An environmental use table shows the use by type of resource and sector, distinguishing extraction by industrial sector and possibly net transboundary outflow by resource type (see Table 2.3.5). The flows between the economy and the environment are mostly expressed in physical units such as kg, but may also refer to other units such as Becquerel, Watt-hour or volumes [21].

Table 2.3.2 A simplified monetary supply table

Supply	***Sectors***	***Rest of the world***	***Total***
Products	Output by product and by sector	Imports by product	Total supply by product
Total	Total output by sector	Total imports	Total supply

(21) Through further modelling these environmental interventions may be translated into environmental effects, like climate change and acidification, and from there further on to effects on human health, human welfare and natural ecosystems (eg in terms of biodiversity). In a final step, these welfare effects may be transformed into monetary units. See Wrisberg et al. (2002) for a survey of impact assessment modelling methods and DEFRA (2004) for a survey of data for economic evaluation of environmental effects.

Table 2.3.3 A simplified monetary use table

Use	Sectors	Final consumption (public; private; non-profit)	Gross capital formation	Rest of the world	Total
Products	Intermediate consumption by product and by sector	Final consumption expenditure by product	Gross capital formation by product	Exports by product	Total use by product
Components of value added	Value added by component and by sector				
Total	Total inputs by sector				

Table 2.3.4 A simplified environmental supply table

Supply	Sectors	Rest of the world	Total
Compounds	Emissions by compound and by sector	(Net) inflow by compound	Total direct supply to environment by compound
Total	—	—	—

Table 2.3.5 A simplified environmental use table

Use	Sectors	Final consumption	Gross capital formation	Rest of the world	Total
Compounds	Extraction of natural resources (and pollutants) by industrial sectors	—	—	—	Total direct use of natural resources by compound
Total	—				

Monetary and environmental supply and use tables

The monetary supply table and the environmental supply table can be combined and this also holds for the use tables. Any emission to the environment links to a sector, as also each product links to a sector producing it. Each extraction from the environment, including negative emissions such as CO_2 extraction by agriculture, links to a sector, as do all products purchased. Note that the vertical addition of products makes sense in the economic tables, as they are expressed in the same monetary units. This is not the case for totals of emissions and extraction, which go in different units, such as kg, Becquerel, kWh, m^3, which cannot be added up. Even if only one dimension is used (as in kilograms) adding up is possible, of course, but the meaning of such sums may not be clear at all. For example, adding up emissions of CO_2 and dioxins gives a total in kg, which cannot easily be interpreted in a policy context. Such options are, of course, open to users but are not dealt with here.

Data requirement for physical input-output tables

The physical flows in material and substance flow accounting do not initially link to sectors (activities and processes) but to the product flows. This is a very basic difference from emissions, which belong to a sector and not to a product flow. The information required is the physical composition of the products, made and used. For that purpose, two additional tables are required. The first relates monetary flows for each product to its physical flows, such as 'kg of high-tension steel'; 'number of cars'; 'number and hours of telephone calls'; and 'trip numbers times distance by airplane'. Furthermore a table is required, specifying all products in their physical units to their constituting materials, compounds and elements. Product flows not only refer to intermediate demand and final consumption, but also to capital formation, involving both capital goods and stocks.

If materials are specified as specific products (paper; steel), the flows remain within a limited part of the economic system. However, flows may be specified in terms of compounds or elements. Then the material and substance flows may refer to emissions and extractions, connecting to environmental interventions. Such options of substance flow and material flow analysis do not require additional information, as the resource extractions and emissions are given in the environmental accounts already. The nature of the operations involved is indicated in step 5.

Step 3: Transformation of asymmetric tables to symmetric tables

In order to make an input-output table, the sector by product information in the supply and use tables should be converted into product by product or sector by sector form. This involves a change in format, i.e. from two asymmetric tables to one symmetric table. So, before supply and use tables can be translated into input-output tables, three transformation steps are needed:

- allocating of multi-product sectors resulting in single-product sectors in the monetary supply table;
- adjusting of the monetary use table to the sector structure of the allocated monetary supply table;
- adjusting the environmental flows in the environmental supply and use tables according to the method used in 3b.

For a detailed description of converting supply and use tables into symmetric input-output tables we refer to the *UN handbook of input-output tables* (UNSD, 1999) and the work of de Haan (2004).

Step 3a: Allocating of multi-product sectors to single-product sectors in the monetary supply table

As stated above, a monetary supply table describes the output of products by sectors of a national economy. A sector may produce more than one product (multi-output). So, for the conversion to a symmetric matrix, it is necessary to translate heterogeneous industries, i.e. industries that may have more than one output (primary and secondary products), into homogeneous sectors, i.e. sectors that have a single product output. Of course, homogeneous is relative to a given level of product specification, e.g. 'CPC level 3' (22). If one went to CPC level 4, the sectors would not be homogeneous any more. 'Really homogeneous' does not exist in classifications of activities. Usually, the number of products is reduced to the number of sectors. Allocation by partitioning, as in LCA, would expand the number of sectors to the number of products.

The first step to convert an asymmetric table into a symmetric table is the allocation of secondary products in the monetary supply table, creating, artificially, sectors each of which has one product as an output only. Suppose that (heterogeneous) industry A produces two products, X and Y, and that, in monetary value (23), X represents 90 % of the total production and Y the remaining 10 %. Product X is thus the primary product and product Y the secondary product. These secondary products may be treated as additions to industries for which they constitute the principal product and removed from the industries in which they were produced as a secondary or by-product. The primary product is defined as the economic output of

(22) CPC: Central Product Classification is a hierarchical classification system for products. The classification code distinguishes five levels of aggregation. An overview and description of classification systems is given in paragraph 3.5.2.

(23) For PIOTs, the allocation based on monetary units may be replaced by allocation based on one or several of the mass or energy flows. Mass balancing allows for the construction of internally consistent tables. However, remaining consistent between several of such physical tables may well pose challenging problems.

the newly defined homogeneous sector A and the monetary value is 90 % of the original value of the heterogeneous industry A. The monetary value of the secondary product Y is allocated to the industry which has this product as its primary product, say industry B.

If there is no sector which produces Y as a primary product, an artificial sector is then created by economic allocation, leading to a constructed sector for each such secondary and by-product. By adding up all these constructed sectors for the production of Y, a single new sector is created, producing all Y in the economy.

The result of this step is a new supply table with newly defined homogeneous sectors. Each homogeneous sector has only one product output and the supply value is adapted accordingly.

Step 3b: Adjustment of the monetary use table to the sector structure of the allocated supply table

The second step to convert an asymmetric table into a symmetric table is to adjust the use of products in the monetary use table from inputs into heterogeneous industries to inputs into homogeneous sectors. There are basically two methods to allocate the inputs of heterogeneous sectors to homogeneous industries:

1. industry-technology assumption (or also: technology-technology assumption);
2. product-technology assumption (or also: commodity-technology assumption).

In LCA terms, method 2 involves substitution and then possibly economic allocation, and method 1 is economic allocation alone, see Suh and Huppes (2005).

Industry–technology assumption

In this allocation method, the input of a heterogeneous industry is allocated proportionally to the outputs of that industry, in monetary terms. Suppose that industry A produces two products, X and Y and that X represents, in monetary values, 90 % of the total production and Y the remaining 10 %. Now this allocation method assumes that exactly 90 % of all inputs are required to produce X and 10 % of the inputs are required to produce Y. So the input of the newly defined homogeneous sector A, that produces primary product X, is adapted to 90 % of the original monetary value of the heterogeneous industry A. The remaining 10 % of monetary value of the inputs of the industry A is added to the input of the industry B which has product Y as its primary product, thus creating B. If there are two or more products which are not produced by another sector, new sectors can be created. This is not common at the moment, but is quite possible. This method then is equivalent to economic allocation in LCA. If a detailed product classification is used, many 'made-single' sectors could be created.

Product–technology assumption

In this allocation method, it is assumed that all Y is produced in the same way that is shown by the inputs for an industry which produces only Y, say industry C. From the pattern of the monetary inputs of C, the proportion needed to make an amount of Y equal to 10 % of the monetary output of A is then calculated. By deduction of this amount from the monetary inputs of A, the remaining inputs of the homogeneous sector A must be those used to produce only X ([24]). Where no industry C with only one product is available for the remaining multiple product industries, the industry–technology assumption may then be used. This procedure has a high 'done by specialists' content, since judging if products are similar enough to do the subtraction is quite subjective. This method is equivalent to the substitution method in LCA, also called 'avoided burden method'.

(24) Note that the product–technology assumption is not always possible because deduction might lead to negative values.

Step 3c: Adjusting the environmental flows according to the method used in 3b

The previous steps described the transformations necessary in the monetary supply and use table. However, the environmental supplies (emissions) and uses (extractions) should also be allocated to the homogeneous sectors. The allocation method that is used in 3b, 'industry–technology assumption' or 'product–technology assumption' should also be applied to the environmental flows. Note that the environmental flows are expressed in physical units. The allocation of the environmental flows to the homogeneous sectors should be proportional with monetary values of the economic flows.

Step 4: Combining allocated (symmetric) supply tables and allocated (symmetric) use tables into symmetric input-output tables with environmental extensions

The result of step 3 is two transformed tables, an allocated supply table and an allocated use table. In each table, the monetary sub-matrix, the sector by product table, is symmetric, i.e. the number of homogeneous sectors is equal to the number of products. In the supply table, every homogeneous sector produces only one product. In the use table, a homogeneous sector will still use several products. These two tables can now be combined into one symmetric input-output table. There are four ways to present this table:

- sector by sector matrix;
- product by product matrix;
- sector by product matrix;
- product by sector matrix.

Theoretically all these matrices are fully equivalent because of the allocation procedures in step 3. After these procedures, every made-homogeneous sector produces only one product, so sector name and product name tend to become very similar. However, in the context of environmentally extended tables there is only one right version: the sector by sector matrix, as direct emissions and resource extractions are characteristics of activities as represented by sectors, not of the products flowing between them. Substance and materials flows between sectors are based on the product flows (see step 5 below). The monetary sector by sector matrix A_m forms the basis for the technology matrix A which is expressed in terms of coefficients.

Producing the extended environmental table is a technical matter after step 3. The total direct emissions given there are expressed per monetary unit of output of the made-homogenous sector they belong to, using matrix A_m.

Step 5: Transforming the allocated supply and allocated use tables into material flow and substance flow tables

For the development of a physical input-output table, additional information is necessary. Information is needed on the material or chemical composition of the products, depending on the specification of the physical flows desired. The physical and chemical composition of products can be highly variable, such as knives being made from steel, stainless steel, wood and several types of plastics. When, at this very detailed level, the composition is specified for a representative product sample, the next step is to aggregate these sample characteristics into the aggregate product flows produced by sectors. For example, at the detailed level 3 of product specification in COICOP [25], corresponding to a several hundred sectors IO table, one product category is '05.3.1 Major household appliances whether electric or not' This COICOP category covers the following items: 'Refrigerators, freezers and fridge-freezers; washing machines, dryers, drying cabinets, dishwashers, ironing and pressing machines; cookers, spit roasters, hobs, ranges, ovens and

(25) Classification of Individual Consumption According to Purpose, http://unstats.un.org/unsd/cr/registry/regcst.asp?Cl=5&Lg=1

microwave ovens; air-conditioners, humidifiers, space heaters, water heaters, ventilators and extractor hoods; vacuum cleaners, steam-cleaning machines, carpet shampooing machines and machines for scrubbing, waxing and polishing floors; other major household appliances such as safes, sewing machines, knitting machines, water softeners, etc. Includes: delivery and installation of the appliances when applicable. Excludes: such appliances that are built into the structure of the building (capital formation).'

It is clear that the data requirements for establishing MFA/SFA tables corresponding to detailed monetary input-output tables requires a very substantial amount of work in terms of basic data gathering. It should also be kept in mind that the allocation procedures involved in step 3 for defining homogeneous sectors involve the redistribution of product flows. The many MFA and SFA being produced now build on the methods as described in Konijn, de Boer and van Dalen (1997), Stahmer, Kuhn and Braun (1998), Femia and Moll (2005) and Gilium and Hubacek (2001).

If enough representative data on real products is available, each flow of a product can be translated into a flow of a material (e.g. steel, wood, etc.) or substance (e.g. iron, cadmium, nitrogen, carbon, etc.). The first step of aggregation is to the level of systematic product classifications. For analysis of domestic flows, the product classification CPC and derived classifications are used, while for international transactions, products are classified in the Harmonised System (HS) (see Chapter 3 for a detailed description). These systems cannot now be linked at the detailed level where products may be analysed as to their material composition. Ultimately, but beyond the scope of this report, an integration of CPC and HS would be extremely useful for better insight into the material aspects of our global economy. After aggregation in still quite detailed product classes, these classes are linked to the sectors producing them, for a full correspondence to the monetary sector by sector tables. However, for PIOT purposes, the product by product table gives a more correct correspondence. These product by product tables may be fully corresponding to their sector by sector counterparts, but they may be developed independently, and then differently, as well.

In principle, the scope of a PIOT can be the entire economic system highlighting the supply and use between different sectors of the intermediate products and the exchange with the environment of emissions and natural resources. In practice, such extensive PIOTs do not exist, with only a few countries having experience with more aggregate versions, focusing on primary production, recycling and a few main sectors (Germany, Denmark, the Netherlands, Finland, Austria, Japan). Existing PIOTs differ greatly in level of aggregation of sectors as well as in number of materials and compounds distinguished (Femia and Moll, 2005; EC, 2001).

Physical input-output tables may either show the material flows between sectors (sector by sector tables) or show the materials used to produce other materials (material by material tables), which, in practice, is not a deep difference once sectors have been transformed into homogeneous sectors. Separate sub-tables per material category are usually set up. For non-degrading flows, such as elements, mass balancing is quite possible, especially if emissions are also specified in a way that their elementary composition is known. At a more aggregate materials level, PIOTs might first focus on water, exergy/energy, and other main materials such as metals, non-metals construction materials, wood, biomass, etc.

Step 6: The regional table related to other regions: interregional input-output tables

The input-output table is a regional table describing, for a national economy, the interactions between sectors or products and, in the case of an environmentally extended table, the accompanying produced residuals and consumed natural resources. Part of the input-output table is the import and export with foreign countries. So, the regional input-output table may be connected to a larger table 'the interregional input-output table' and, ultimately, all regions in the world may be connected to a world input-output table [26]. For the world input-output table, import and export are zero; it is a simple addition of all world regions. A number of interregional input-output tables are described in Kurz, Dietzenbacher and Lager (1998). Additional information is necessary for the development of an interregional input-output table, specifying the linkages between regions. These linkages are in terms of product flows, but at a level of detail not normally recorded in import and export tables. Between each pair of regions, say A and B, two tables are required. One states the exports from A to B, for each producing sector and product specifying the destination sector. The same table is to be constructed for exports from region B to A. If, for all regions, the same m sectors are specified, according to Isard (1951), all sectors can be linked to all other sectors in the world.

Though the principle is well established, the actual data availability for interregional IOA is poor. Mostly, import and export statistics are set up from the point of view of one country, without establishing the country of origin or destination. The products are standardised in the global HS (Harmonised System), which cannot directly be linked to sectors of origin or destination. At best, flows of products between countries are given, without specifying the sector of origin or destination in the other country. We will not work out options for generating data for these interregional flows. Both for EEIO tables and for PIOTs, this lack of data restricts the options and validity of global analysis.

2.4 Conclusions

Methods and models for environmentally extended input-output analysis have been developed in a unified framework. The options for using these models in public and private decision-making have developed substantially in the last decades, especially based on UN-directed standardisation of classifications on sectors and products. Environmental extension have two basic forms, one linking to sectors (for emissions and resource extraction in EEIO tables) and one linking to physical products (including installations and capital goods) first relating monetary flows to physical product flows and next relating physically defined products to their composition in terms of materials (for MFA) and substances (for SFA), the two main variants of PIOTs, differing only in level of aggregation of the flows concerned.

Though restricted by all sorts of procedural and legal considerations, a relatively simple structure can accommodate all data gathering and method choices in a transparent and flexible way. Basically, a set of economic activities representative for all sectors distinguished is to be described in terms of its economic inputs, as purchases, and economic outputs, as sales, and with their direct environmental inputs, as resource extraction, and outputs, as emissions. With more indirect and partial measurements as are available now, statistical procedures will have to be used for producing the data set required for make and use tables with environmental extensions from which EEIO tables can be derived. For PIOTs, additional data on product prices, product volumes and product composition in terms of materials and substances are to be added. Data gathering on products now takes place in different and only partially linked classification systems, one for domestic product flows (CPC and the related European CPA) and one for imports and exports (HS and the related European CPA). This makes data gathering and data processing for both EEIOA and PIOTs unnecessarily complex.

(26) An example of such a world input-output table is GTAP, which will be discussed in Chapter 3.

3 Existing European environmentally extended IO tables and data sources

3.1 Introduction

This chapter makes an inventory of:

- existing input-output tables and existing environmental extensions available in the EU-25;
- data sources available in the EU-25 that may support the setting-up of environmentally extended input-output tables for the EU-25 which
  - cover a broad set of environmental interventions,
  - have a high resolution in terms of sectors discerned.

Transactions between sectors in physical terms, for construction of PIOTs, receive limited treatment in this chapter. One reason is that this study focuses on environmental extensions that can be linked to EEIO tables. The PIOTs then require the same sector resolution as the EEIO tables. In addition, PIOTs would require a specification of product flows between sectors in terms of materials and substances contained in these products, (see step 5 in Chapter 2). However, no systematic data gathering on the material composition of products takes place in the EU, and available studies mostly focus on specification of flows at a higher level of aggregation or even a macro level (27).

The quality of EEIO tables depends on the following factors:

1. the resolution or number of sectors discerned, and the reliability of the data on economic ransactions between sectors;
2. the completeness and reliability of the set of environmental extensions, i.e. emissions and resource extractions.

Systematic and mutually consistent data gathering in 25 countries does not develop spontaneously, and both factors hence ultimately depend on the supporting institutional context. This chapter consists of the following parts; in each part, the institutional context will be the starting point of the analysis.

Existing IO tables (Section 3.2)

- analysis of the institutional structure and requirements for IO tables (3.2.1);
- inventory of existing IO tables in the EU-25 (3.2.2);
- state of affairs and options for developing high resolution IO tables.

Existing EEIO tables (Section 3.3)

- analysis of the institutional structure and requirements for EEIO tables;
- analysis of the existing EEIO tables in the EU-25;
- state of affairs and options for developing detailed environmental extensions.

Available underlying, basic data sources (Section 3.4)

- classification systems used, and developments therein;

(27) New data sources on the material composition of products may come up due to new regulations, such as for potentially toxic substances in the realm of REACH procedures.

- analysis of basic data sources in the EU-25, concerning
  - economic transactions,
  - international trade,
  - environmental interventions per sector;
- options for a better use of data sources.

The chapter ends with conclusions.

3.2 Data sources — existing input-output tables

3.2.1 Institutional context in the EU-25: ESA95 of EU and SNA 1993 of UN

Several institutional incentives and structures influence the availability and structure of IO tables from national Member States in the EU-25. The most important is formed by Council Regulation (EC) No 2223/96 of 25 June 1996, on the European system of national and regional accounts in the Community — in brief, the European System of Accounts (ESA95) ([28]).

ESA95 provides, in considerable detail, the rationale, definitions and structure, potential uses etc. for national and regional accounting systems, and, by doing so, aims to harmonise their structures across EU Member States. It also provides obligations on the frequency with which national statistical offices have to provide the thus-specified accounts to Eurostat (the Statistical Office of the European Union). Supply, use and input-output tables are part of ESA95. EU Member States are obliged to transmit to Eurostat requirements ([29]):

- annual supply table at basic prices, including a transformation into purchaser's prices ([30]), containing 60 products, classified by CPA, and 60 sectors, in line with the NACE classifications (see the ESA sectors discerned, in Table 3.2.4 and, for comparison, see in Table 3.2.5 the sectors discerned in GTAP, discussed in Section 3.2.2);
- annual use table at purchaser's prices, containing the 60 sectors in line with the NACE classification, and the 60 products, in line with the CPA classification;
- five-yearly symmetric product by product input-output tables at basic prices, containing 60 products, classified by CPA. Similar tables have to be developed for domestic output and imports.

SNA 1993 is the System of National Accounts as developed by the Inter-Secretariat Working Group of National Accounts of Eurostat, the IMF, the OECD, the UN and the World Bank (UN 2003) ([31]). The system is a comprehensive, consistent and flexible set of macroeconomic accounts intended to meet the needs of government and private-sector analysts, policy-makers and decision-takers. The SNA is intended for use by both national and international statistical agencies. ESA95 is the legal (and more specific) elaboration of the SNA for the EU-25, and hence for the further discussion in this chapter SNA is less relevant.

3.2.2 Inventory of existing IO tables

Apart from the 60x60 tables that EU Member States have to supply to Eurostat, other IO tables for countries and regions are produced. We made an overview of tables published in the EU-25 via an Internet search, gathering publications of national statistical bureaus, information from the OECD on existing IO work in their member countries, and an occasional check with scientists or officials involved in setting up IO tables. We

(28) ESA was first published in OJ L 310, 30.11.1996, p.1. A consolidated version including all subsequent revisions is available from the EU's Consleg system at: http://europa.eu.int/eur-lex/en/consleg/pdf/1996/en_1996R2223_do_001.pdf
(29) Usually, for the EU-15, the first transmissions had to take place well before the publication data of this report, though a variety of derogations for single variables still may apply. [PM 10 new Member States – situation not clear from ESA]
(30) These are basic prices plus product taxes.
(31) For the latest integral version, we refer to: http://unstats.un.org/unsd/sna1993/toctop.asp

were able to inventory the IO tables available from statistical offices from most EU Member States; in total, countries with over 85 % of the population in the EU-25 are included (see Table 3.2.2). We consider this sufficient coverage.

We further inventoried work of organisations that publish supranational tables relevant for the EU-25. The latter organisations include:

- the OECD, who have now produced, for two base years, IO tables in a standardised format for a number of their member countries;
- GTAP, a global IO table discerning some 70 regions, set up by Purdue University in the United States.

It turns out that, at European level, despite the obligation laid down in the ESA95, the situation is not without problems. The target dates set by the ESA95 could not always be met and the input-output domain is not prioritised in the Eurostat production programme. By 2004, the situation was as depicted in Table 3.2.1 (Ritzmann, 2004).

3.2.3 Overview and discussion

Table 3.2.2 gives a structured overview of the main characteristics of the IO tables inventoried. With regard to the IO tables compiled by individual EU Member States, the following general characteristics stand out.

Table 3.2.1 Availability of supply, use and symmetrical input-output tables as transmitted to Eurostat by mid-2004 (Ritzmann, 2004)

		1500 Supply						1600 Use						1700 Siot		1800 Domest		1900 Import				
Code	Country	1995	1996	1997	1998	1999	2000	1995	1996	1997	1998	1999	2000	1995	2000	1995	2000	1995	2000	pp/ii	Addit.	cop
BE	Belgium	X		X		X	X	X		X		X	X	X		X		X		pp		
DK	Denmark	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	ii		X
DE	Germany	X		X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	ii		X
GR	Greece	X	X	X	X	X		X	X	X	X	X		X						pp	17 also for 1997, 98	X
ES	Spain	X	X	X	X			X	X	X	X			X		X		X		pp		
FR	France	X		X		X	X	X		X		X	X									
IE	Ireland																					
IT	Italy	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	pp		
LU	Luxemburg																					
NL	Netherlands	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	ii	17, 18, 19 also for 1996 to 1999	
AT	Austria	X		X		X	X	X		X		X	X	X	X	X	X	X	X	pp		
PT	Portugal	X	X	X	X	X		X	X	X	X	X										X
FI	Finland	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	ii		
SE	Sweden	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	ii	SUT01 already transmitted	X
UK	U.K.	X	X	X	X	X	X	X	X	X	X	X	X	X		X		X		pp		
CY	Cyprus																					
CZ	Czech Rep.																					
EE	Estonia			X						X				97		97		97		pp		
HU	Hungary				X	X	X				X	X	X	98	X	98	X	98	X	pp/ii		X
LT	Lithuania																					
LV	Latvia																					
MT	Malta																					
PL	Poland	X	X	X	X	X		X	X	X	X	X		X								
SK	Slovak Rep.	X	X	X	X	X		X	X	X	X	X										X
SI	Slovenia		X						X					96		96		96		pp		
BG	Bulgaria																					
RO	Romania																					
TR	Turkey																					

	Derogation
YY	Different year

Table 3.2.2: Overview of IO tables published by EU Member States, some international bodies, other countries and research institutes

Geographical scope		Name	Author	Resolution	Year
International		GTAP IO tables	GTAP	57x57; split up by 87 regions	2001, published in 2004
International	About 15 OECD countries	OECD IO tables	OECD, STI Directorate, EAS Division	41x41	1995; published November 2001
Australia (OECD, 2001)		Input-output tables 1994–95, (107x107 industries)	Australian Bureau of Statistics (ABS)	107x107	1994–95
Canada (OECD, 2001)		Medium and large supply-use tables, 1997	Statistics Canada	167x167	1997
Japan (OECD, 2001)		Input-output tables, 1995	Ministry of Economy, Trade and Industry and Ministry of Land	Approx. 450x450	1995
US (OECD, 2001)		Input-output tables, 1997	Bureau of Economic Analysis	500x500	1997
EU	Per EU Member State; not integrated to one EU-IO table; 10 new Member States still to be completed.	Eurostat IO tables	Eurostat	60x60	1995–2002
Belgium		IOA	Federaal planbureau	60x60	2000, published in 2004
Denmark		Danish input-output tables and analyses. Import, employment. 2002	Danmarks Statistik	130x130 (Weidema, 2001)	2002; publication 01.06.2004
Estonia		Input-output table	Statistical Office of Estonia	Approx. 70x70	1997
France		Input-output tables	National Institute of Statistics and Economic Studies (INSEE)	40x40	2002
Germany		Volkswirtschaftliche gesamtrechnungen — Input Output Rechnung	Federal Statistic Office Germany	71x71	2000, extrapolated to 2002
Ireland		Input-output table	Central Statistics Office	48x48	1998 (published 2004)
Italy		Input-output tables up to 2001	National Institute of Statistics (ISTAT)	60x60	2001
Latvia		IOA	Latviar Statistika		2000; published in 2004
Netherlands		Domestic use and supply-use table	Central Bureau of Statistics	135x135	2003
Poland		IOA Poland	Statistics Poland	58x58	1995 extrapolated to 2000
Spain		Supply–use tables 1995	National Institute of Statistics	70x70	1995 (symmetric); 2000 (use)
Spain	Galicia	Input-output table for Galicia	Instituto Galego de Estatistica	Approx. 110x110	1998 (published on the web: 2001)
Spain	Cataluna	Input-output table for Cataluna (provisional)		184x184	Not yet ready
Sweden		Input-output table for Sweden	National Statistics Sweden	60x60	1995 and 2000
UK		Input-output table for the UK	National Statistics	123x123	2002 (latest table)
UK	Scotland	Input-output table for Scotland	Office of the Chief Economic Adviser	128x128	2001 (latest table)
UK	Wales	Input-output table for Wales	Welsh Economy Research Unit, Cardiff Business School	74x74	2002, publ. May 2004

How dealt with import and exports	Classification of sectors	Reference
Fully integrated	Own classification	http://www.gtap.agecon.purdue.edu/databases/v6/default.asp
	ISIC rev. 3, several sectors aggregated	http://www.oecd.org/document/1/0,2340,en_2649_34445_34062721_1_1_1_1,00.html
Not differentiated by foreign sector	Australia New-Zealand Standard Industrial Classification (ANZSIC)	http://www.statcan.ca/english/search/browse-economy.htm
Not differentiated by foreign sector	CanSic80	http://www.statcan.ca/english/search/browse-economy.htm
Not differentiated by foreign sector	ISIC rev. 3 consistent	http://www.meti.go.jp/english/
Not differentiated by foreign sector	US SIC87	http://www.bea.doc.gov/bea/an2.htm
Differentiated by EU and rest of world, not by foreign sector	CPA (products) based on NACE rev. 1.	http://europa.eu.int/comm/eurostat/newcronos/reference/sdds/en/iot_sut/iot_sut_base.htm http://epp.eurostat.cec.eu.int/portal/page?_pageid=1996,45323734&_dad=portal&_schema=PORTAL&screen=welcomeref&open=/&product=EU_MASTER_national_accounts&depth=2
Not differentiated by foreign sector	Seems linked to NACE	http://www.plan.be/nl/db/ActieveDB/DetailDB.php?DB=iot00
		http://www.netboghandel.dk/PUBL.asp?page=publ&objno=250000507
Not differentiated by foreign sector	Probably own classification	http://pub.stat.ee/px-web.2001/I_Databas/Economy/23National_accounts/03Input_output_tables/03Input_output_tables.asp
Not differentiated by foreign sector	NAF, consistent with NACE	http://www.insee.fr/fr/home/home_page.asp
Not differentiated by foreign sector	Unclear	http://www-ec.destatis.de/csp/shop/sfg/sfgsuchergebnis.csp?pagenr=1
Not differentiated by foreign sector	Classification derived from NACE (at times aggregated)	http://www.cso.ie/releasespublications/1998_input_output_tables.htm
Differentiated per sector or destiny and origin	NACE	http://www.istat.it/
		http://www.csb.lv/Satr/cat2004.cfm?dala=02&nr=18
Not differentiated per foreign sector	SBI-NACE	http://www.cbs.nl/
Not differentiated per foreign sector	CPA	R.Popinski@stat.gov.pl
Differentiated by EU and not EU, but not per sector	NACE, own aggregation into 70 final sectors	http://www.ine.es/
Unknown	Not clear, could be NACE	http://www.ige.xunta.es/en/economicas/contas/input_output/
Unknown	Sistema Europeu de Comptes (SEC95)	http://www.idescat.es/cat/economia/tioc/
Not differentiated by foreign sector	NACE level 2	anders.wadeskog@scb.se
Not differentiated by foreign sector	Own classification linked to SIC and NACE	http://www.statistics.gov.uk/about/methodology_by_theme/inputoutput/
Differentiated in UK and rest of world, not per sector	Own classification linked to SIC	http://www.scotland.gov.uk/about/FCSD/OCEA/00014713/index.aspx
Differentiated in UK and rest of world, not per sector	Own classification linked to SIC	http://www.weru.org.uk/output.html

1. The Member States compile the IO tables for their respective economies only. In some larger EU Member States, where regions have a certain degree of autonomy, these regions publish their own IO tables. This is, for instance, the case with Scotland and Wales in the UK, and Catalonia and Galicia in Spain.

2. Most IO tables neither specify from which sectors imports come, nor to which sectors exports are delivered. Since most EU countries have very open economies, e.g. trade can be over 50 % of national product, this implies that, for a large part of the production and consumption in such countries, the tables cannot be completed.

3. A number of countries publish IO tables with a resolution of 100–150 sectors. However, many countries do not reach this level of detail, and publish IO tables with a resolution of 30–70 sectors.

4. The sector classification used in the different IO tables for different countries seem not to be uniform. Though most sector classifications are derived from similar standards (e.g. NACE [32], ISIC [33]), the ultimate classification systems are not always comparable since different countries sometimes aggregate different sub-classes in NACE or ISIC in a different way. An overview of classification systems is given in paragraph 3.5.2.

Table 3.2.3: Share of EU-25 covered in Table 3.2.2 based on population per country [34]

Country	Population (in mio)	Covered in Table 3.3.2	Covered by Eurostat (see Table 3.3.1, 1995)
Austria	8.1		8.1
Belgium (*)	10.2	10.2	10.2
Cyprus	0.8		
Czech Republic	10.3		
Denmark	5.3	5.3	5.3
Estonia	1.4	1.4	1.4 (1997)
Finland	5.1		5.1
France (*)	60.4	60.4	60.4
Germany (*)	82	82.0	82
Greece	10.5		10.5
Hungary	10.2		10.2 (1998)
Ireland	3.7	3.7	
Italy (*)	57.6	57.6	57.6
Latvia	2.4	2.4	
Lithuania	3.7		
Luxembourg (*)	0.4		
Malta	0.4		
Netherlands (*)	15.8	15.8	15.8
Poland	38.6	38.6	38.6
Portugal	10.8		
Slovakia	5.4		
Slovenia	2.0		2.0 (1996)
Sweden	8.9	8.9	8.9
Spain	39.4	39.4	39.4
United Kingdom	58.6	58.6	58.6
Total	**446.6**	**384.3 (86 %)**	**414.1 (93 %)**

(32) NACE: Classification of Economic Activities in the European Community.
(33) ISIC: International Standard Industrial Classification of all Economic Activities.
(34) These data taken from http://www.europa.admin.ch/eu/expl/staaten/e/, accessed on 4 May 2005.

5. The statistical basis for the national data differs between countries and even differs between sectors within countries. These differences were pointed out in discussions with statistical bureaus but are not documented in any systematic and publicly available way.

The overview also lists some IO work of non-EU countries. The US and Japan publish tables with a resolution of about 500 sectors. Australia and Canada publish tables with a resolution of 120–150 sectors. All these countries take the International Standard Industry Classification (ISIC) of the United Nations as a basis, but modify it.

With regard to the tables published by organisations that focus on supranational tables, the following can be remarked.

a) The work of organisations such as the OECD and GTAP has the advantage that IO tables of different countries and regions are created that largely use an identical sector classification [35]. GTAP, however, deviates from generally used international standards. We refer to Tables 3.2.4 and 3.2.5 that give the ESA95 classification and the classification used in GTAP.

b) The resolution of such tables, however, is limited. The OECD tables of 1995, representing the early 1990s, discerned 35 sectors, whereas the OECD tables of 2001, representing the mid-1990s, discerned 41 sectors. The latest version of GTAP (2003) discerns 67 sectors.

c) The geographical coverage is not always the full EU-25. The latest OECD work covers Denmark, Finland, France, Germany, Greece, Italy, the Netherlands, Spain, and the UK, or about 70–80 % of the EU-25 counted by population [36]. GTAP covers the whole EU.

d) The statistical basis for the aggregated multinational tables is weakened by the lack of data on the sector origin and destination in the countries involved in import and export flows.

3.2.4 Conclusions

Under the current institutional arrangements formed by ESA95, EU Member States must transfer supply and use tables on an annual basis to Eurostat, and product by product IO tables with a 60x60 resolution on a five-yearly basis. It must be possible therefore to construct an IO table for the EU with this resolution. Eurostat has not yet constructed such a consolidated table, probably due to the import/export problem discussed below. This is the same level as that reached by the GTAP and OECD.

But some trivial problems seem still to exist.

- Firstly, not all EU Member States seem yet to deliver ESA95 IO tables.
- Secondly, although in principle the number of sectors/products and classification systems is mentioned in ESA95, this seems not yet to give a full standardisation.
- Thirdly, the imports and exports are specified only in two main classes: 'intra EU' and 'extra EU'. The countries and sectors to which exported and from which imported are not indicated. This implies that linking imports and exports from tables from different EU Member States to the right sectors needs to be done by estimation and extrapolation (see van der Linden, 1999).

Going to a higher level of resolution than required by ESA95 is likely to be problematic. It may be possible to create a table with a resolution of some 100–200 sectors by combining

(35) The word 'largely' is used here for the following reason. Since countries may use classification systems different from the mentioned organisations to which they report to, they may face transformation problems that cannot be solved totally satisfactorily — implying that, in the end, sectors are still not totally comparable. See, for example, the document The OECD input-output database (1995).

(36) And Norway, which is a European, but not an EU country. The OECD further covers Australia, Canada, Iceland, Japan, Korea, Mexico, New Zealand, Turkey and the United States.

Table 3.2.4 Sectors in ESA95 ([37])

No	Code	Description
1.	01	Agriculture, hunting and related service activities
2.	02	Forestry, logging and related service activities
3.	05	Fishing, operation of fish hatcheries and fish farms; service activities incidental to fishing
4.	10	Mining of coal and lignite; extraction of peat
5.	11	Extraction of crude petroleum and natural gas; service activities incidental to oil and gas extraction excluding surveying
6.	12	Mining of uranium and thorium ores
7.	13	Mining of metal ores
8.	14	Other mining and quarrying
9.	15	Manufacture of food products and beverages
10.	16	Manufacture of tobacco products
11.	17	Manufacture of textiles
12.	18	Manufacture of wearing apparel; dressing and dyeing of fur
13.	19	Tanning and dressing of leather; manufacture of luggage, handbags, saddlery, harness and footwear
14.	20	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials
15.	21	Manufacture of pulp, paper and paper products
16.	22	Publishing, printing and reproduction of recorded media
17.	23	Manufacture of coke, refined petroleum products and nuclear fuel
18.	24	Manufacture of chemicals and chemical products
19.	25	Manufacture of rubber and plastic products
20.	26	Manufacture of other non-metallic mineral products
21.	27	Manufacture of basic metals
22.	28	Manufacture of fabricated metal products, except machinery and equipment
23.	29	Manufacture of machinery and equipment n.e.c.
24.	30	Manufacture of office machinery and computers
25.	31	Manufacture of electrical machinery and apparatus n.e.c.
26.	32	Manufacture of radio, television and communication equipment and apparatus
27.	33	Manufacture of medical, precision and optical instruments, watches and clocks
28.	34	Manufacture of motor vehicles, trailers and semi-trailers
29.	35	Manufacture of other transport equipment
30.	36	Manufacture of furniture; manufacturing n.e.c.
31.	37	Recycling
32.	40	Electricity, gas, steam and hot water supply
33.	41	Collection, purification and distribution of water
34.	45	Construction
35.	50	Sale, maintenance and repair of motor vehicles and motorcycles; retail sale of automotive fuel
36.	51	Wholesale trade and commission trade services, except of motor vehicles and motorcycles
37.	52	Retail trade services, except of motor vehicles and motorcycles; repair service of personal and household goods
38.	55	Hotel and restaurant services
39.	60	Land transport and transport via pipeline services
40.	61	Water transport services
41.	62	Air transport services
42.	63	Supporting and auxiliary transport services; travel agency services
43.	64	Post and telecommunication services
44.	65	Financial intermediation services, except insurance and pension funding services
45.	66	Insurance and pension funding services, except compulsory social security services
46.	67	Services auxiliary to financial intermediation
47.	70	Real estate services
48.	71	Renting services of machinery and equipment without operator and of personal and household goods
49.	72	Computer and related services
50.	73	Research and development services
51.	74	Other business services
52.	75	Public administration and defence services; compulsory social security services
53.	80	Education services
54.	85	Health and social work services
55.	90	Sewage and refuse disposal services, sanitation and similar services
56.	91	Membership organisation services n.e.c.
57.	92	Recreational, cultural and sporting services
58.	93	Other services
59.	95	Private households with employed persons
60.	99	Services provided by extra-territorial organisations and bodies

(37) Source: http://forum.europa.eu.int/irc/dsis/nfaccount/info/data/esa95/en/een00540.htm

Table 3.2.5 Sector definition in GTAP, version 6.2 (38)

No	Code	Description
1	PDR	Paddy rice
2	WHT	Wheat
3	GRO	Cereal grains nec
4	V_F	Vegetables, fruit, nuts
5	OSD	Oil seeds
6	C_B	Sugar cane, sugar beet
7	PFB	Plant-based fibers
8	OCR	Crops nec
9	CTL	Bovine cattle, sheep and goats, horses
10	OAP	Animal products nec
11	RMK	Raw milk
12	WOL	Wool, silk-worm cocoons
13	FRS	Forestry
14	FSH	Fishing
15	COA	Coal
16	OIL	Oil
17	GAS	Gas
18	OMN	Minerals nec
19	CMT	Bovine meat products
20	OMT	Meat products nec
21	VOL	Vegetable oils and fats
22	MIL	Dairy products
23	PCR	Processed rice
24	SGR	Sugar
25	OFD	Food products nec
26	B_T	Beverages and tobacco products
27	TEX	Textiles
28	WAP	Wearing apparel
29	LEA	Leather products
30	LUM	Wood products
31	PPP	Paper products, publishing
32	P_C	Petroleum, coal products
33	CRP	Chemical, rubber, plastic products
34	NMM	Mineral products nec
35	I_S	Ferrous metals
36	NFM	Metals nec
37	FMP	Metal products
38	MVH	Motor vehicles and parts
39	OTN	Transport equipment nec
40	ELE	Electronic equipment
41	OME	Machinery and equipment nec
42	OMF	Manufactures nec
43	ELY	Electricity
44	GDT	Gas manufacture, distribution
45	WTR	Water
46	CNS	Construction
47	TRD	Trade
48	OTP	Transport nec
49	WTP	Water transport
50	ATP	Air transport
51	CMN	Communication
52	OFI	Financial services nec
53	ISR	Insurance
54	OBS	Business services nec
55	ROS	Recreational and other services
56	OSG	Public administration, defense, education, health
57	DWE	Dwellings

individual tables of some EU Member States with higher resolution (e.g. the UK, Denmark and the Netherlands) and extrapolate this information to the EU-25. But this is a cumbersome task as one still has to overcome the problem of differences in sector and product classifications, and — above all — find a solution for the problem that imports and exports are not allocated to individual sectors. Extrapolations and estimations seem inevitable, which will affect the quality of the EU-25 IO table created, also at higher levels of aggregation.

3.3 Data sources — existing environmentally extended economic tables

3.3.1 Institutional context in the EU-25: SEEA 2003 (UN) and Eurostat work

The UN, EC, IMF, OECD and World Bank have produced as a part of the *Handbook on national accounting* the publication *Integrated environmental economic accounting*, commonly referred to as SEEA. The handbook provides a common framework for the inventory and classification of economic and environmental information. It is intended to meet the needs of policy-makers by providing indicators and descriptive statistics to monitor the interaction between the economy and the environment and to serve as a tool for planning and policy analysis for sustainability. SEEA is a system of satellite accounts related to the System of National Accounts (SNA) discussed earlier, consisting of four categories of accounts:

1. physical data relating to flows of materials and energy, marshalled as far as possible to the accounting structure of SNA;
2. specification of elements of the regular System of National Accounts that make the environment-related transactions more explicit, such as expenditure of environmental production and environmental taxes;

(38) Source: https://www.gtap.agecon.purdue.edu/databases/v6/v6_sectors.asp

3. accounts for environmental assets measured in physical and monetary terms;
4. accounts that consider how existing SNA might be adjusted to account for the impact of the economy on the environment ('green national income'). This would include adjustments related to depletion, degradation and defensive expenditures.

Category 1 deals with the type of accounts relevant in this project. This category covers a number of tools and instruments discussed in Chapter 2, such as physical supply and use tables, physical input-output tables, and so-called 'hybrid flow accounts', which combine physical flows with monetary data. Interestingly, SEEA (39) refrains where possible from the use of the term 'NAMEA' (40), since it can be argued that it has become a rather loosely defined term that, for instance, does not specify if it is a supply-, use- or input-output table that is extended with environmental accounts, and, indeed, which environmental accounts have been included. The problem from the point of view of this project is that, where SEEA provides a well-elaborated standard for producing environmentally extended input-output tables, it forms no formal requirement to statistical offices to deliver and publish such statistics.

ESA95, which constitutes the EU formal and legal requirements to Member States for transmission of national accounts data to Eurostat, does not require any transfer of physical/environmental accounts (41). However, Eurostat does organise working groups and projects in this area. The results of this work will be discussed in the next section.

3.3.2 Inventory of existing EEIO tables

Eurostat activities have led to reports such as a compilation guide for a NAMEA for air emissions (Eurostat, 2004), a report on material use indicators for the European Union (Bringezu and Schutz, 2001), and a working paper on a physical input-output table for Germany (Stahmer et al., 1998).

Eurostat work on the NAMEA for air emissions, referred to as 'NAMEA-Air', is now the best elaborated in most EU Member States. One very important remark has to be made, though.

Table 3.3.1: NAMEA Air data availability for EU-15 countries (from Eurostat, 2005b) E and Ed are estimated data

	BE	DK	DE	GR	ES	FR	IE	IT	LU	NL	PT	FI	SE	UK	AT
1990		X		X		X		X		X				X	X
1991		X	X	X		X		X		X				X	X
1992		X	X	X		X		X		X				X	X
1993		X	X	X		X		X		X			X	X	X
1994	X	X	X	X		X	X	X		X			X	X	X
1995	X	X	X	X	X	X	X	X	X	X	E	E	X	X	X
1996	X	X	X	X	X	X	X	X	X	X	X	E	X	X	X
1997	X	X	X	X	X	X	X	X	X	X	X	E	X	X	X
1998	X	X	X	X	X	X	X	X	X	X	X	E	X	X	X
1999	X	X	X	E	X	E	X	X	E	X	X	E	X	X	X
2000	X	X	X	Ed	X	Ed	X	X	Ed	X	Ed	X	X	X	X
2001	E	X	X	E	E	E	X	X	E	X	E	E	E	X	X
2002		X	X				X			X				X	

(39) SEEA, Point 2.73, p. 43.
(40) NAMEA, as discussed earlier, is the abbreviation of National Accounting Matrix Including Environmental Accounts.
(41) OJ L 310, 30.11.1996, p.1. A consolidated version including all subsequent revisions is available from the EU's Consleg system at: http://europa.eu.int/eur-lex/en/consleg/pdf/1996/en_1996R2223_do_001.pdf

In Eurostat terminology, a NAMEA is 'merely an overview of environmental interventions per sector, including some private household activities'. The NAMEAs discussed in this section are therefore just emission data per sector discerned in the ESA95 IO tables, but do not include the IO tables themselves nor are EEIO tables in themselves. Furthermore, in a recent review, Eurostat openly stated that 'the full use of the NAMEA-Air framework is highly dependent on the different countries delivering the actual data. This they do not do today. '**The response rate is quite low and missing data has had to be estimated'** (emphasis in original; Eurostat 2005b: 17). From the new Member States, in 2005, data was available only from Cyprus, Poland and Lithuania, although some improvement is foreseen since four other new Member States are compiling NAMEA-Air data within the framework of a Phare programme. As for the EU-15, Table 3.3.1 reviews the data availability, without any statement about the quality of the data involved.

The current NAMEAs have another limitation. For instance, the Italian NAMEA-Air includes 10 pollutants: carbon dioxide (CO_2), sulphur oxides (SOx), nitrogen oxides (NOx), nitrous oxide (N_2O), ammonia (NH3), methane (CH_4), carbon monoxide (CO), non-methane volatile organic compounds (NMVOC), lead (Pb) and particulate matter (PM10) (Tudini and Vetrella, 2004). This is in line with the NAMEA-Air compilation guide, which lists just some 20 substances for inventory, but in different priority classes (Eurostat, 2004). Priority 1 includes greenhouse gases (CO_2, CO_2 from biomass, N2O, CH_4, HFCs, PFCs, and SF6); Priority 2 some other substances (NOx, SOx, NH3, NMVOC, CO, PM10, CFCs, HCFCs, Hg, Pb and Cd), and Priority 3 some heavy metals (As, Zn, Cr, Se, Cu, Ni); furthermore energy accounts are included. This reflects the fact that there is no obligation (in, for example, ESA95) for EU Member States to construct NAMEAs. The priority levels in the NAMEA air compilation guides only want to give EU Member States guidance on where to start if they have too limited resources. There is no legal obligation to provide such data, not even for what has been termed Priority 1 substances.

The latest comprehensive EU-wide overview of national NAMEAs was published by Eurostat in 2001, covering the EU-15 and focusing on CO_2, CH_4, N2O, NOx, NH3, NMVOC and CO for the EU-15, Norway and the Czech Republic. But this rather good geographical coverage does not imply at all that a European EEIO table is available or might easily be produced. First, all NAMEAs are merely lists of air emissions per sector per country. They are not linked to an IO table. Second, the NAMEA data and IO data (see paragraph 3.2) are available at individual Member State level only, and not aggregated to a larger geographical entity such as EU-15 or EU-25 ([42]). Third, without wanting to give any judgement on the important effort of compiling this NAMEA, it is clear that the 10–20 substances covered are just a small number in comparison of the (usually) hundreds of different emissions to air that are inventoried in comprehensive emissions registration systems ([43]) and product life cycle assessments. The consequence, in turn, is that where such NAMEAs may give usable information for impact categories such as global warming (Eurostat, 2005) and maybe some other impact categories such as acidification, for which just a few substances are relevant, they may not give a comprehensive picture for other impact categories. Fourth, there are no NAMEAs on emissions to other compartments and on resources extracted from nature. The availability for NAMEAs with regard to other environmental media, i.e. emissions to water and soil and the use of natural resources, is clearly lagging behind the work on NAMEA-Air. No formal Eurostat publications that cover the EU-15, let alone the EU-25, are available

(42) Again, this is likely to do with the problem that imports and exports in the individual country tables are not linked to foreign sectors, and linking country tables to one consolidated entity is hence not straightforward.
(43) Such as the Dutch emission record systems, and the US Toxic Release Inventory, and EPER (see next section).

yet. At individual EU Member State level, the situation differs considerably. Some countries are very active in developing this tool, where others pay much less attention to it (44). For water, the Netherlands, Sweden, Denmark and Germany are quite advanced, and several other countries have developed tables for natural resources. Some countries have developed physical input-output tables, but this work is currently published on an incidental basis only (Stahmer et al., 1998), and never reaches the 60x60 sector resolution of, for example, ESA95.

In addition to this work done by or commissioned by official statistical bureaus, other studies at the level of Member States are relevant. Examples include the following.

- For Denmark, Weidema et al. (2005) did an extensive study into the environmental impacts of products. They used the Danish NAMEA as a basis, added environmental information on the use and waste stage of products, and developed a solution for including imports. The resolution of this work was identical to that of the original Danish IO table and NAMEA.
- For the Netherlands, RIVM has elaborated Dimitri, a dynamic environmentally extended IO model. Here too, the resolution is not higher than the original IO tables published by the Dutch CBS (Wilting et al., 2001).

3.3.3 Conclusions

The overall picture is that, with the current state of affairs, comprehensive EU-wide environmentally extended input-output tables covering the EU15, let alone the EU-25, are non-existent. At the current pace, it will probably take several years before an environmentally extended input-output table covering a few dozen emissions to air and water, and the most important extraction of natural resources, at the level of the EU-25 will be available. This table will have at best a 60x60 resolution. This result can be reached in the next years if the following is undertaken:

- each EU Member State reports per sector emissions to air, emissions to water and resource use to Eurostat;
- each EU Member State reports IO data to Eurostat;
- Eurostat aggregates all these data into a complete overview for the EU-25.

At national level, the work on EEIO tables is almost invariably an extension of the work on the existing IO tables in a country. This implies that the limitations with regard to resolution and other problems already summed up in Section 3.3 in general are unlikely to be overcome without additional efforts.

Work on PIOTs is not systematically required from Member States and is at a much higher level of aggregation than ESA95 sectors, and only incidentally available, specified for a limited number of products.

3.4 Data sources — economic transactions, imports/exports and environmental interventions per sector

3.4.1 Introduction

The statistical basis for monetary IO tables is transactions between actors, which are recorded with sales and purchases and income and expenditure. Actors themselves have no reason to classify themselves or to specify their transactions in terms other than what is required for trade, employment and taxing purposes, and, with most of the larger firms, for corporate accounting. In order to create standardised IO tables, a classification step has to be made, grouping the actors into specific classes, as

(44) For instance, the Federal Statistics Office in Wiesbaden alone has produced some 50 publications on its environmental economic accounting (FSO, 2001).

sector classifications, and grouping the sales and purchases in classes, as product classifications. This also has to be done with income and expenditure flows specifying savings, investments and expenditure on final consumption, and imports and exports. In practice, a tiered procedure is used in which specific data on firms are added and updated based on surveys, coordinated by the European Union in the Prodcom process (45). Environmental effects do not originate from transactions but from activities. They have no systematic bookkeeping as a basis, apart from environmental permit requirements which, however, will not usually correspond to actual environmental interventions. Location measurement, survey methods and indirect modelling form the sources here for producing the environmental accounts.

In creating the detailed IO tables which are desirable for several purposes, there are overlapping and possibly conflicting requirements. In general, the requirements cover the following elements:

1. a process/sector classification, including final demand activities and waste management activities;
2. entities abroad related to imports and exports;
3. a product classification;
4. an environmental module specification;
5. a full system specification linking all data;
6. a procedure for gathering and coding the empirical base information;
7. organisations responsible for carrying out the tasks involved;
8. a legal framework to have relevant parties cooperate.

In this section we focus on the current status regarding the first four: sector classification, entities abroad classification, product classification and environmental module. For most of these there is substantial international coordination, especially by the United Nations Statistics Division (UNSD). The potential of using these unified classifications in a systematic way is not tapped yet, in Europe due to conflicting aims superseding these classifications, and at a country level by deviations with a less clear but, as we heard, an often historical and cultural background (46). Chapters 5 and 6 will indicate how the unsatisfactory situation can be improved.

3.4.2 Development with regard to classification systems

Introduction

We start with an overview of International Families of Economic and Social Classifications (UNSD 2005). The families of economic and social classifications are specified at three levels of generality (UNSD, 2005):

1. ***Reference classifications*** of the family are those economic and social classifications that are a product of international agreements approved by the United Nations Statistical Commission or another competent intergovernmental board. Reference classifications have thus achieved broad acceptance and official agreement and are approved and recommended as guidelines for the preparation of classifications. They may be used as models for the development or revision of other classifications, both with respect to the structure and with respect to the character and definition of the categories.

(45) See: http://forum.europa.eu.int/irc/dsis/bmethods/info/data/new/prodcom_questionnaire_ en.pdf. This gives a survey of the actual practice of data-gathering in most EU countries.

(46) One example we encountered in discussions with specialists is how the yearly ESA95 updates in Denmark are produced easily and with high quality, based on VAT statistics, which there, and nowhere else in Scandinavia or north-western Europe are coded at a detailed level as to sector origin and destination and product type. There is no other explanation than ‘historical coincidence’.

2. ***Derived classifications*** of the family are based upon reference classifications. Derived classifications may be prepared either by adopting the reference classification structure and categories, and then possibly providing additional detail beyond that provided by the reference classification, hence remaining fully in line with the reference classifications, or they may be prepared through rearrangement or aggregation of items from one or more reference classifications, in principle deviating from the reference and making international comparisons difficult or impossible. Derived classifications are often tailored for use at the national or multinational but regional level.
3. ***Related classifications*** are those that partially refer to reference classifications, or that are associated with the reference classification at specific levels of the structure only, higher than the most detailed specification.

There are procedures for maintaining, updating and revising statistical classifications of the family, to encourage the resolution of problems of partial correspondence among related classifications, and ongoing activities for increased harmonisation (UNSD, 2005). For establishing input-output tables with high resolution, and with detailed environmental extensions, the uniform development and implementation of relevant classification systems is a *sine qua non*.

Review of classifications

Table 3.4.1 gives an overview of some of the classification systems that have been registered into the international family of economic and social classifications. A short description on main classification systems is given in the boxes below.

Relations between classifications

Figure 3.4.1 gives an overview of the relationships between international standard classification systems for economic data (adapted after CBS, 2005). The ISIC is the world standard classification system for economic activities of the United Nations. NACE is the classification system for economic activities of the European Union. NACE is based on the first two digits of ISIC. The last two digits describe the European details. SBI (Standaard BedrijfsIndeling, Standard Business Classification) is an example of the Dutch national classification system for economic activities, which slightly deviates from NACE. The national statistical bureaus are obliged by a EU directive to base their system on the first four digits of NACE. A US–EU working group is trying to unify NACE and NAICS. If successful, this would be a major input to a revision of ISIC, unifying the sector classification of all major industrial countries at the then more detailed UNSD reference level.

In principle the Central Product Classification (CPC) of the UN is the basis of the Classification of Products by Activity (CPA) of the EU. The industrial origin of the product is used as a criterion for further classification and this has resulted in CPA which is thus a further subdivision too of NACE, mixing product and sector classifications. The CPC is strongly related to the Harmonised System (HS). The subclasses in CPC are groups of reorganised categories from the HS. CPA is also based on HS, although less strict, because of the industrial origin criterion that is used. Prodcom is a list of products for the European inventory of production statistics. Prodcom is based on CPA and is linked with CN (Combined Nomenclature), the European version of the HS. The CN is a further detailing of the HS. Member States are obliged by an EU directive to use CN as a basis. NOSE-P is a list of technologies/processes capable of giving rise to emissions of any of a wide range of pollutants, into any medium, i.e. air, water or soil. The final intention is to structure the list by technical characteristics of the process. However the present list is a compromise between this consistently structured list of technologies and the requirement for a reasonable level of continuity with existing emission inventories, especially the SNAP (Selected Nomenclature for Sources of Air Pollution) nomenclature used in Corinair. NOSE (Nomenclature for Sources of

Table 3.4.1 International family of economic classifications of sectors, products and expenditure categories (after UNSD, 2005)

	Reference	Derived	Related
Economic activities	**ISIC rev 3.1**[47] International Standard Industrial Classification of All Economic Activities ***4 levels: 298 units***	**NACE** rev 1.1[48] General Industrial Classification of Economic Activities within the EU ***4 levels: 514 units***	**ANZSIC** Australian and New Zealand Standard Industrial Classification ***4 levels: 465 units***
			NAICS North American Industry Classification System ***5 levels: 1 179 units***
Products	**HS** 2002 Harmonised Commodity Description and Coding System ***4 levels: 7 466 units***	**CN** 2005 Combined Nomenclature within the EU ***5 levels: 19 000 units***	
	CPC ver 1.1 Central Product Classification ***5 levels: 2 096 units***	**CPA** 2002 Classification of Products by Activity within the EU ***6 levels: 2 608 units***	Trade in services[49]
		SITC rev 3 Standard International Trade Classification ***5 levels: 3 121 units***	
Expenditure according to purpose [50]	**COICOP 1999** Classification of Individual COnsumption according to Purpose ***3 levels: 157 units***	**COICOP/HICP 2000** COICOP adapted to HICP [51] ***3 levels: 93 units***	
	COFOG Classification of the Functions Of Government ***3 levels: 109 units***		
	COPNI Classification of the Purposes of Non-profit Institutions serving households ***3 levels: 30 units***		
	COPP Classification of Outlays of Producers by Purpose ***3 levels: 23 units***		

(47) A draft version of the revision ISIC rev. 4 is available containing four levels with 420 units.
(48) A draft version of the revision NACE rev. 2 is available containing four levels with 617 units.
(49) In development, see: http://unstats.un.org/unsd/tradeserv/default.htm
(50) Classifications of Expenditure According to Purpose, United Nations, Statistical Papers Series M No 84 (ST/ESA/STAT/SER. M/84). Classifications of Expenditures According to Purpose have been developed for Individual Consumption (COICOP), for Government (COFOG), Non-Profit Institutions Serving Households (COPNI) and Producers (COPP).
(51) Council Regulation (EC) No 2494/95 of 23 October 1995 concerning Harmonised Indices of Consumer prices (OJ L 257, 27.10.1995).

ISIC rev 3.1 International Standard Industrial Classification of All Economic Activities Four levels, 298 classes ISIC is a basic tool for studying economic phenomena, fostering international comparability of data and for promoting the development of sound national statistical systems. Thus, despite the word 'industrial' in its name, ISIC is not just a classification of industries but covers all economic activities.
NACE rev 1.1 Statistical Classification of Economic Activities in the European Community Five levels, 514 classes NACE is a more disaggregated European version of the international reference classification system of economic activities (ISIC). It is mainly in line with ISIC and therefore it seems to be a suitable basis for future developments in compliance with international agreements on classifications. Especially if aligned with the North American NAICS classification effectively, a more detailed version of ISIC might result. A large revision of NACE is foreseen in 2007 ([52]).
CPC version 1.1 Central Product Classification Five levels, 2 096 classes CPC, as a standard central product classification, was developed to serve as an instrument for assembling and tabulating all kinds of statistics requiring product detail. Such statistics may cover production, intermediate and final consumption, capital formation, foreign trade or prices. CPC provides a basis for recompiling basic statistics from their original classifications into a standard classification.
HS 2002 Harmonised Commodity Description and Coding System Four levels identified by six-digit numerical codes, 7 466 classes Why there are two different reference classification systems at an international level, i.e. CPC and HS, has a historical background, no other CPC has been developed in the realm on national accounting groups and HS has been developed for controlling, and taxing, international trade. At the highest levels the systems have been harmonised, but not at the base level, closest to reality.
CN 2005 Combined Nomenclature, derived from HS, with more detail Five levels identified by eight-digit numerical code, 19 000 classes The Combined Nomenclature is the products classification used within the EU for the purposes of foreign trade statistics. It is also used by the Directorate-General for Taxation and Customs Union of the European Commission for customs and duty purposes. The classification is maintained by Eurostat for the statistical aspects and by Taxation and Customs Union DG for the tariff aspects.
CPA 2002 Statistical Classification of Products by Activity in the European Economic Community Six levels identified by six-digit numerical code, 2 608 sub-categories CPA is the European counterpart of the CPC, but is more detailed being further structured according to NACE-sectors origin. As products can be outputs of different sectors and sectors most certainly deliver different outputs (see left part of Figure 3.5.2.3), it seems to be more transparent to keep these two dimensions, i.e. products and sectors, separate.
SITC rev. 3 Standard International Trade Classification Has mainly been replaced by HS, relevant still for longer time series not yet based on HS. Five levels identified by five-digit numerical code, 3 121 classes.
NOSE/NOSE-P version 1.0 Nomenclature for sources of emissions (draft) Four levels identified by seven-digit code, about 460 categories The NOSE system has been developed by Eurostat to facilitate the description of emission sources in relation both to NACE, using the NOSE process list (NOSE-P) which has evolved from the Corinair SNAP94 nomenclature. The basic idea is to develop a two-dimensional nomenclature based on (1) the standard European nomenclature for economic activities (NACE) with (2) a nomenclature of emission-generating processes (NOSE-P). The present list of processes/technologies is a compromise between a consistently structured list of technologies and the requirement for a reasonable level of continuity with existing emission inventories (especially the SNAP nomenclature used in Corinair). This has lead to a basically inhomogeneous list. The list contains interesting details but it lacks a systematic approach. The present list of processes is not a consistent list of processes structured by technical characteristics of the process. But, for practical reasons, many processes are ordered according to the industry branch in which they typically occur, which leads to problems in practical classification. Additional waste-generating processes need to be integrated into the processes list. As the NOSE system only loosely relates to the other classifications it builds on, updating the system seems a gruesome job, with many arbitrary choices to be made.

(52) Revision of NACE rev. 1.1 to NACE rev. 2. http://forum.europa.eu.int/irc/dsis/nacecpacon/info/data/en/index.htm

COICOP 1999 Classification of Individual Consumption According to Purpose Level 3 identified by four-digit code, 157 classes. Nomenclature: **Level 1:** Divisions (two-digit) **Level 2:** Groups (three-digit) **Level 3:** Classes (four-digit).	
COICOP/HICP 2000 Classification of Individual Consumption by Purpose Adapted to the Needs of Harmonised Indices of Consumer Prices (2000) Three levels identified by four-digit code, 93 classes The aggregation principle used in the COICOP and COICOP/HICP classification is not transparent and the hierarchical structure is not clear. For example, the criterion 'function of the product' in many instances does not seem to be used in line with more function-focused methods like LCA, such as adding at a higher level the apparatus and the electricity used in it, or the car and the petrol used in it. This is not done in COICOP at higher levels.	

Emissions) is a proposed standard nomenclature for sources of emissions. The basic idea is to develop a two-dimensional nomenclature based on (1) the standard European nomenclature for economic activities, classified by NACE code with (2) a nomenclature of emission-generating processes, classified by NOSE-P code. This system in development seems not to be ripe yet, but may have great potential if filled in adequately.

3.4.3 Economic transactions and imports/ exports

The ultimately existing statistical basis for monetary data is the book-keeping of firms, the records of tax authorities and duties and excise offices, and focused surveys. There is now no source where both sectors — their product flows and their environmental interventions — are recorded together. Transactions are recorded by public bodies for tax purposes, for direct and indirect taxes, and international transactions too for duties and excises purposes. Several national taxing authorities have a digital real-time system for VAT administration which could support additional classification and statistical analysis. Such systems are evolving for international transactions within the EU as well.

Council Regulation (EC) No 1798/2003 and the implementing Commission Regulation (EC) No 1925/2004 aim to improve administrative cooperation between Member States against VAT fraud by setting up a unified administration system. Clearly, this will create an improved basis for analysis of international trade flows within the EU-25 — if statistical offices have access to them [53].

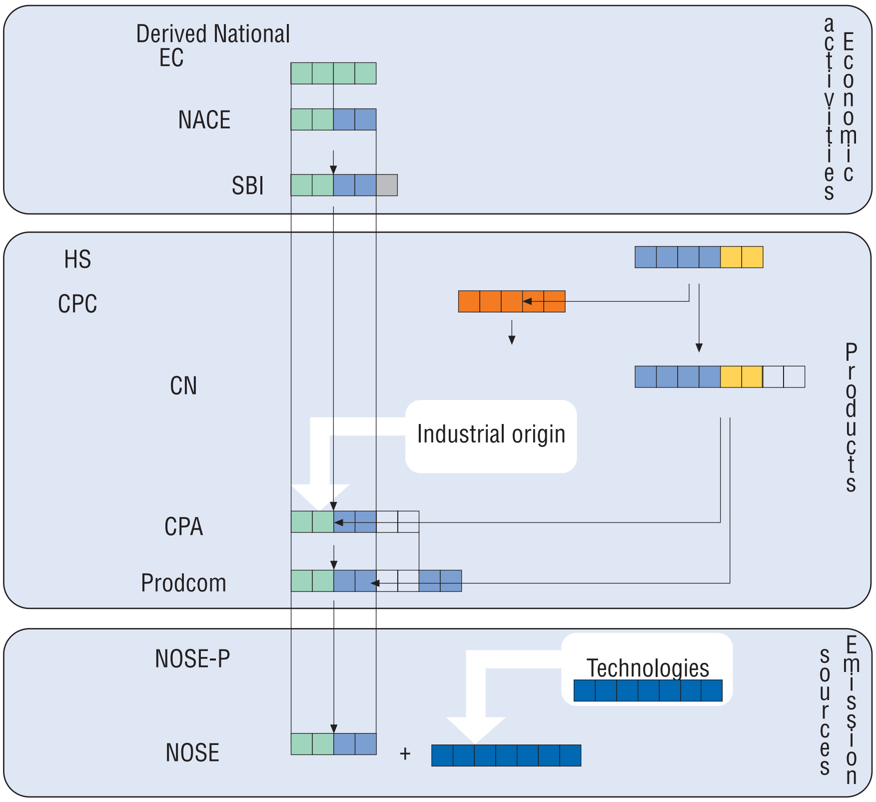
Only for international transactions outside the EU is the CPA classification applied systematically, due to EU requirements. As origin and destination are not classified systematically, the basis for internationally linked IO tables for the European Union is weak. Statistical means are used for connecting countries, based on limited data and similar-structure assumptions, such as using the RAS method, for constructing EU tables.

For many of the economic statistics at EU level, the European Central Bank (ECB) has sole statistical responsibility or shares responsibility with the European Commission (Eurostat). The ECB has published requirements in the field of general economic statistics as a basis for discussion with producers of base statistics, which usually takes place outside the ECB (ECB, 2004), especially Eurostat, and ultimately the country level, as with ESA95 reporting.

In this recent document, the ECB describes some general requirements concerning geographical coverage and branch and sector coverage, and emphasises the need for

(53) See http://europa.eu.int/vies for administrative support now already given by the Commission on this subject.

Figure 3.4.1 Relationships between standard classification systems for economic data (after CBS 2005)



comparability of statistical methods used by national statistical bureaus. National data must be transmitted by national authorities to the European Commission, more specifically Eurostat. Eurostat is the central source for European general economic statistics and must be in a position to supply data on individual EU countries to European users at the same time as the data are published at the national level.

The ECB also describes some specific statistical requirements, including requirements for annual national accounts and external trade statistics. The ECB states that, at an EU-25 level, supply and use tables are lacking and that improvement in this field and compilation of these data should have priority. For supply and use tables, the ECB requires an annual update with a level of detail conforming to ESA95 Table 15 (A60/P60). For input-output tables, the ECB requires a five-yearly update with a level of detail conforming to ESA95 Table 17 (P60/P60). The ECB requires external trade statistics expressed in current values and volumes. In addition to a breakdown by main partner region and country, a breakdown by commodity groups is used. A breakdown of the monthly data by the two-digit level of the Combined Nomenclature (CN) and a breakdown of quarterly data by the four-digit level is sufficient for the ECB, in particular for Intrastat. However other policy application areas need a more detailed resolution. Chapter 4 will discuss for what purposes 60x60 tables are sufficient, and for which policy questions EEIO models with a higher resolution are desirable.

As mentioned in step 6 in paragraph 2.3, for the linkage of countries in an interregional input-output table additional information is necessary concerning both the sector as well as country origin and destination of imports and exports. This kind of information is normally not recorded in import and export tables. The ECB also does not require this kind of information now. Available international IO tables are incidentally constructed, with the exception of the GTAP. The GTAP, however, does not link well to ESA95 and, though giving tables, has the same problems with lacking data on international transactions between sectors.

For an analysis of emissions embedded in the production of imported products, information on links to sectors in other regions is necessary. The simplest method is assuming domestic coefficients for the production technology of imports. Certainly, this estimate may be out of bounds — particularly if this national structure differs greatly from that in the region the imports originate from. This is mostly the case with imports of primary materials and including energy and agricultural products. Additional data might make this method slightly sophisticated, for example by correcting national coefficients using available trading partners' sectoral data or even only their aggregate emissions! (Harris, 2001; Eurostat, 2005).

3.4.4 Environmental interventions

Introduction

A survey is given of a number of focused environmental databases, including EPER, EMEP, UNFCCC, RAINS and Eionet, while more general sources have been consulted too such as Eurostat, the EEA, the OECD and the UN. The focus has been on broad encompassing datasets. No extensive search was performed on databases of national emission registers and other national institutes, because different national databases are most likely not to be comparable in the methods used for registering and calculation etc. Some general results will firstly be described and discussed, followed by a short description of the databases.

At a world and European level, there are several initiatives to gather emission data of economic sectors in individual countries. These databases of sector emissions contain relevant information for the implementation of emission data in environmentally extended input-output tables. Most important initiatives in respect of EEIO tables are the databases developed in the projects EPER, UNECE/EMEP and UNFCCC/IPCC. These databases are mainly focused on emissions to air. Only the EPER database also contains emissions to water. For emissions to soil, no databases exist at a European level containing comparable data for individual Member States. Waste databases do exist, but these mostly concern data on waste-to-be-processed, not on the emissions to water air and soil resulting from waste processing. Waste treatment is already part of economic input-output tables, though often inadequately, especially for post-consumer waste. Therefore, waste-to-be-processed should not be treated as an environmental intervention. The boxes below describe the most relevant data sources.

EPER
European Pollutant Emission Register (EC, 2005)
Pollutants: 50 pollutant emissions to air and water
Emission sources: 20 sectors classified with IPPC code. However facilities are reported by Member States using classification NACE ([54]) and NOSE-P ([55]), five digits. The five-digit NOSE classification distinguishes about 35 emission sources
Year: 2001 (published in 2004) updated every three years
Geographical region: EU-15 Member States and Norway and Hungary
EPER provides data for large and medium-sized point sources in the industrial sectors covered by the IPPC directive. EPER mainly covers industrial sources. It excludes, for example, emissions from the transport sector and from most agricultural sources. The present EPER can be considered as a first step towards the development of a fully integrated pollutant release and transfer register (PRTR) for Europe, in which emissions to air, water and soil of point sources and diffuse sources will be registered.

(54) Standard European Nomenclature for Economic Activities, National Classification of Economic Activities.
(55) The EC Statistical Office (Eurostat) classification scheme of sources of industrial process emissions (Nomenclature for Sources of Emissions — Process).

UNECE/EMEP ([56])
United Nations Economic Commission for Europe/Cooperative Programme for Monitoring and Evaluation of Long-range Transmission of Air Pollutants in Europe (UNECE/EMEP 2005). Pollutants: emissions to air

- main pollutants: the main acidifying and eutrophicating pollutants,
- heavy metals (HM): As, Cd, Cr, Cu, Hg, Ni, Pb, Se and Zn,
- POP: persistent organic pollutants,
- PM: particulate matter: PM10, PM2.5, TSP.

Emission sources: 100 'sectors/activities' classified with the EMEP code (NFR)
Year: 1980–2002 (HMs and POPS 1990–2002), data for 2000 (published in 2002), updated annually
Geographical region: worldwide, inclusive all EU-25 Member States.

UNFCCC/IPCC ([57]) greenhouse gas inventory data
United Nations Framework Convention on Climate Change Greenhouse Gas Inventory Data (UNFCCC, 2005).
Pollutants: emissions to air of greenhouse gases

- main greenhouse gases: carbon dioxide, methane nitrous oxide, perfluorocarbons, hydrofluorocarbons, sulphur hexafluoride,
- indirect greenhouse gases and other: carbon monoxide, nitrogen oxides, non-methane volatile organic compounds, sulphur oxides.

Emission sources: 170 'sectors/activities' classified with the IPCC code (CRF)
Year: 1990–2002, updated annually
Geographical region: worldwide, inclusive all EU-25 Member States.

GAINS
Greenhouse Gas and Air pollution Interactions and Synergies (IIASA, in development)
Pollutants: emissions to air of greenhouse gases (CO_2, CH_4, N2O, HFC, PCF, SF6)
Emission sources: 100 'sectors/activities' classified in RAINS model native format. It is also possible to aggregate emissions into EEA Corinair SNAP 1 sectors or UN/ECE NFR categories (level 1 and 2).
Year: in development
Geographical: EU-25 Member States
IIASA is now developing the GAINS model to address emission control strategies that simultaneously address air pollutants and greenhouse gases.

RAINS
Regional Air Pollution Information and Simulation (IIASA, 2005)
Pollutants: emissions to air of acidifying and eutrophicating substances and ozone precursors (SO2, NOx, VOC, NH3, PM2.5, PM10, TSP)
Emission sources: 100 'sectors/activities' classified in RAINS model native format. It is also possible to aggregate emissions into EEA Corinair SNAP 1 sectors or UN/ECE NFR categories (level 1 and 2)
Year: 2000
Geographical: EU-25 Member States
The RAINS model is an integrated model to simulate air pollution by economic activities of sectors in Europe. The model contains activity data and emission factors for economic sectors in Europe. Together with abatement factors, such as removal efficiencies of control technologies and economic growth factors, the model makes it possible to simulate scenarios. All emission data in the RAINS model are to the maximum possible extent consistent with the emission inventories reported by the Parties to the Convention on Long-range Transboundary Air Pollution to EMEP.

National Pollutant Release and Transfer Registers (PRTRs)
There are several national PRTRs (Pollutant Release and Transfer Register), for example in the Netherlands, United Kingdom, Sweden, Denmark, Germany, and more coming. A PRTR is defined as a national environmental database of harmful releases to air, water, land and waste. The data are reported annually by individual facilities. A PRTR is a comprehensive version of a national emission inventory or Pollutant Emission Register (PER). The development of most PRTRs is at an initial stage, and thus contains certain weaknesses and incompleteness in the system and validity of data. In some countries, such as Germany, the initiatives/activities to provide emission data to EPER are seen as a first step towards a comprehensive national PRTR database.
In most cases, the databases only contain data for large point sources. So, emissions from SMEs and diffuse sources, such as transport and agriculture, are not included. Some countries, such as Germany, intend to extend the database with emissions from small and diffuse sources. Furthermore, the databases mainly contain emissions to air and, to a lesser extent, water. Emissions to soil and the generation of waste are to be implemented in future, as is the intention, for example, with the German PRTR project.

EEA (transboundary)
The European Environment Agency compiles time series of emissions of acidifying pollutants, ozone precursors and greenhouse gases (EEA, 2005). The time series are based on the emission databases of EMEP and UNFCCC (see descriptions above).

(56) United Nations Economic Commission for Europe/Cooperative Programme for Monitoring and Evaluation of Long-range Transmission of Air Pollutants in Europe.
(57) United Nations Framework Convention on Climate Change/ Intergovernmental Panel on Climate Change.

WasteBase (European Topic Centre on Resources and Waste Management)
The ETC-waste lists a number of international waste databases. For Europe, the most important are WasteBase of the European Topic Centre on Resources and Waste Management and the Eurostat database, which is available online, formerly called New Cronos. WasteBase is an electronic database with information on waste and waste management in Europe. This includes waste quantities, policies, plans, strategies and instruments. The database on waste quantities in Europe contains information on generation, and sometimes treatment, of waste for the period 1980–2002. The waste is distinguished in 11 waste types, including waste by sector for about 11 sectors. Waste treatment is part of the economic activities, so should not be part of the environmental module of the environmentally extended input-output model.

Discussion

At a European level, there is an initiative to register industrial emissions to air and water, with first results becoming available. This initiative, called EPER, is particularly of interest for environmentally extended input-output tables because emission data are gathered on an installation level, i.e. emission sources using NOSE-P classification, but also classified per economic activity using the NACE classification. So, the potential of the register is to collect comparable emission data for all EU-25 Member States that can be aggregated per economic sector. Such a database of comparable emission data is of crucial importance for EEIO tables. However, at present, the EPER project is at an initial stage. A comparison of EPER with EMEP and UNFCCC for the EU-15 total emissions of some important greenhouse gases and air pollutants shows that EPER covers only a small and variable portion of the total emissions, ranging from 6 % to 70 %. Also, the economic data on purchases and sales of the facility are not gathered systematically.

So there are still some important drawbacks.

- There are still problems with comparability between Member States of available data, and due to different degrees of completeness of emissions covered.
- The database now only contains emissions of large point sources (LPS). So emissions of SMEs and diffuse sources, such as transport and agriculture, are missing.
- The database now contains about 50 pollutant emissions to air and water; for a more comprehensive assessment of the environmental problems, e.g. toxicity, ozone depletion etc., a broader coverage of emissions is necessary.
- Data concerning emissions to soil and generation of waste are missing and should be added for a more comprehensive assessment of the environmental problems.
- The resolution of presented economic sectors, using the IPPC classification, is about 20. However, the database itself probably contains a higher resolution because the reporting parties are requested to classify processes using the four-digit NACE classification, resulting in about 500 economic activity classes.
- In the format for reporting of emissions by Member States, at present the information concerning economic data is optional. For the implementation of EEIO tables on a European level, however, the simultaneous inventory of economic and environmental data would be of great help.

Future developments

In the guidance document for EPER implementation (EC, 2000) it is stated that the present EPER can be considered as a first step towards the development of a fully integrated pollutant release and transfer register (PRTR) for Europe. A PRTR is defined as a national environmental database of harmful releases to air, water, land and waste. The database contains information on emissions of polluting substances, reported annually by individual facilities. However, it may also contain information on releases from sources other than large industrial establishments. So, in future, EPER has the potential to be more comprehensive both in registered emissions (including emissions to soil and waste generation) and emission sources (including SMEs and diffuse emission sources).

For EEIO tables, it is crucial that economic activities, classified in NACE code, can be linked to emission sources, often classified in a classification related to the code of Corinair, i.e. SNAP. Furthermore, the classification should be performed in the highest possible resolution. In EPER, both the four-digit NACE code and the five-digit NOSE-P code are registered for a facility. However the successor of EPER, the European PRTR, will not include the NOSE-P code any longer. This omission in the classification of the emission sources will make it difficult or even impossible to relate emission data gathered in the European PRTR to emission data gathered in other emission databases, such as EMEP and UNFCCC. At this moment, there is a lack of a reference system for the classification of emission sources that also takes into account the relation of economic activities and emission sources. In addition, both EMEP and UNFCCC have developed their own classification systems for emission sources. Although these classification systems are also derived from SNAP, there is limited correspondence with NOSE-P. The aggregation level of the classification of emission sources used in EMEP and UNFCCC makes it difficult or even impossible to relate emissions to economic sectors as classified with NACE. So, to harmonise the gathering of emission data, it is necessary to develop a reference classification system for emission sources strictly corresponding to the lowest level of detail as described in (new) NACE. A substantial waste of effort in data gathering currently takes place due to lack of standardised classification systems and procedures.

3.4.5 Discussion

In the last decade, a framework has been developed which allows for the construction of detailed IO tables and even more detailed supply and use tables in an internationally standardised way. However, diverging developments are taking place which conflict with a clear and systematic approach. At present for Europe, the best developed emission data per economic sector are the NAMEA for air data (Eurostat, 2004; Eurostat, 2005). The data cover the EU-15 and some accession countries only and represent air emissions only, for about 20 substances. The resolution of the economic activities is about 60 sectors. The development of databases as for RAINS/GAINS and structured in NOSE may deliver results as desired at short notice, but are too unsystematic now in relation to standardised classification systems to form a basis for detailed tables with environmental extensions.

Such systems might be geared to this long-term purpose by using one set of sectors, i.e. economic activity classifications, aligning as well as possible with the emerging NACE/NAICS integration (58), and not using the CN but the CPC classification, or better still the to-be-integrated CPC/HS product classification system. From a systems analytical point of view, it most surely is better to use separate independent nomenclatures for products and for economic activities, a distinction which now gets to be blurred, especially in CPA classification of the EU. However, change within the EU to the reference classification system CPC requires regulatory adjustments because, at present, CPA is legally binding in the EU through ESA95, while CPC and HS are UN-recommended classifications.

Considering the use of the classification systems in systems analysis, such as EEIO analysis, it is then possible to use a combined nomenclature to identify a specific ‘record’ of data. For example, a transaction for a supply and use table could be identified by a three-dimensional nomenclature, containing the following elements, where NACE and CPC refer to ‘future NACE and CPC’:

1 the economic activity that supplies the product, by NACE code, or deeper;

(58) A major revision of NACE rev 1.1 integrating NACE and NAICS, ANZSIC and JSIC is foreseen in 2007, http://forum.europa.eu.int/irc/dsis/nacecpacon/info/data/en/index.htm

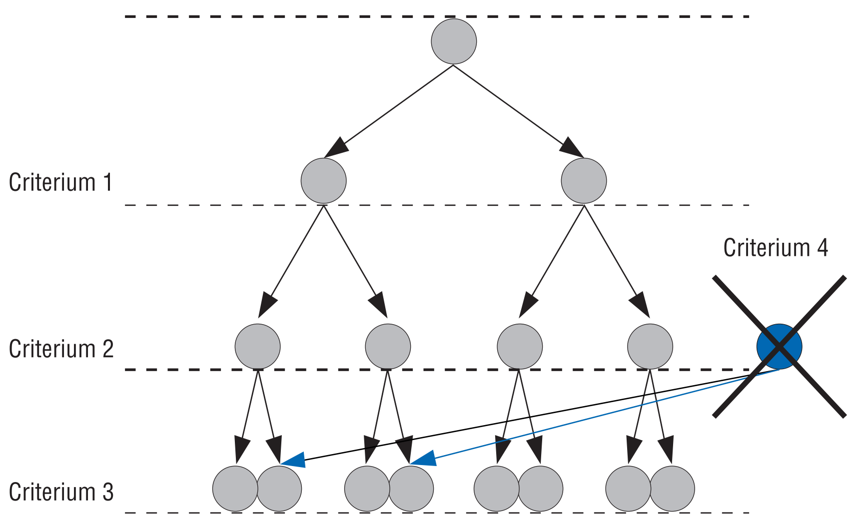
2. the economic activity that uses the product by NACE code, or deeper;
3. the products by their CPC codes, or deeper.

A product supplied can originate in several NACE categories and find its destination in several NACE categories. This would lead to a level of around 500x500 sectors, with much additional detail in the product definitions. Further developments in NACE/NAICS/ISIC may be envisaged already, based on current negotiations with the United States. CPA seems a less apt basis to work on. Environmental data would be satellites to this base structure. For specific purposes, the system could be further detailed, connecting detail at the lowest (59) level of standardised classification available. If done otherwise, incompatibilities will most surely result, as has been the case in the application of CN by national statistical bureaus. The typical approach — transhierarchical aggregation — is leading to incompatibilities as indicated in Figure 3.5.2. Transhierarchical aggregation means that new higher levels, i.e. more aggregated and less detailed, are defined based on aggregation of categories at a lower level which are hierarchically unconnected. Though using the lowest level, i.e. less aggregated and most detailed, for building the new framework, several of such new constructs will be mutually incompatible. This adaptation to the purpose at hand seems a main source of incompatibilities between data sources.

3.5 Conclusions

Under the current institutional arrangements laid down in the ESA95, EU Member States provide to Eurostat supply and use tables on an annual basis, and a product by product, input-output table on a five-yearly basis. The resolution is 60 sectors or products by 60 sectors or products, in line with NACE and CPA. At individual Member State level, a few statistical bureaus reach a higher level of resolution, typically 100–140 sectors. Hence, in the EU, such accounts have a considerably lower resolution as in the US and Japan, typically 500 sectors. The base information on which the tables are based in principle allows for more detailed classification, which is often available in-house at the statistical offices, but even less standardised. Getting detailed input-output tables would require a reclassification of currently available sources and possibly

Figure 3.5.2 Hierarchical structure of information and transhierarchical aggregation



(59) In a hierarchical structure, the lowest level means the less aggregated and thus the most detailed level (see also Figure 3.5.2).

an addition of sources to allow for improved representativeness of samples per class.

As for the situation with regard to environmentally extended input-output tables, the situation is as follows. For the EU-15, Eurostat now has available overviews per 60-sector and, for most countries, country for at least 10 emissions to air. In Eurostat terminology, this is called the 'NAMEA-Air', but it has to be stressed that these data are not yet placed in an IO framework [60]. Similar data will probably be available soon for the 10 new Member States, and the number of emissions to air registered will increase somewhat. However, the situation with other environmental media, i.e. emissions to water and soil and extraction of resources, is rather unclear. Furthermore, realising availability of a complete set of data will still take a considerable amount of time. This reflects the rather diverse situation at EU Member State level. Some countries already publish rather extensive EEIO tables with emissions/interventions for all or most environmental compartments, and even physical input-output tables, whereas in other EU Member States such data are not yet gathered. It seems clear that autonomous development will not yield an EEIO table at EU level with a resolution of more than 60 sectors and a few dozen emissions and other extensions in the foreseeable future. Furthermore, it is unlikely that Eurostat will extend such an EEIO table to a table that includes the use and post-consumer waste management stage which is necessary for analysing life cycle impacts related to final private consumption and government expenditure.

As far as individual data sources are concerned, data sets are available in principle which would allow the construction of detailed IO tables. It seems most logical to use the emerging new ISIC standards, essentially an improved version of integrated NACE/NACS, for that purpose, as choices made now will bind the statistics for the coming decade, or more.

Linking-in environmental data may, for some purposes, still require disaggregating of readily available data from, for example, the EPER. Fast routes to results for specific domains of application hinder the development of more systematic approaches, which would allow for cumulative data gathering based on better applicability of statistical methods. The base load of broad environmental data will have to be gathered based on statistical approaches and on a further development in EPER and similar national systems into a European PRTR. In order to be able to relate environmental data gathered in PRTR to other large environmental databases, such as UNFCCC and EMEP, more attention should be given to a reference classification system for emission sources, while special attention should be given to relate emission sources with economic sectors as described with NACE. The review did not show any example where external costs related to environmental extensions were related to an IO framework.

The overall conclusion is that, due to a lack of standardised classification systems and procedures, data gathering is much more expensive than necessary. The positive side of this statement is that, by better coordination and alignment, the current effort in terms of manpower could produce vastly improved data for supporting sustainability policies.

(60) As indicated before, other authors use the term NAMEA sometimes for environmental extensions that are directly related to an IO table. Since the sector definitions used in NAMEAs are identical to the ones used in supply and use tables, the link can be easily established, but it has to be clear that a NAMEA in terms used by Eurostat is not identical to an IO table with environmental extensions.

4 Application areas of environmentally extended input-output tables for supporting European policies

4.1 Introduction

4.1.1 Relevant policy stages

In this chapter, we will analyse the different applications of EEIO tables and models to support policy-making. For instance, a detailed analysis of the effects of certain improvement options requires information at a quite different level of detail than the monitoring of macro-trends. In this context, Femia and Moll (2005) suggest a distinction in seven different policy stages, basically extending the well-known 'plan-do-check-act' Deming cycle with some additional phases:

1. problem analysis and identification;
2. target setting;
3. anticipation of potential policies (measures);
4. decision on policy measures;
5. implementation of policy measures;
6. success-control and monitoring;
7. correction of policy measures.

In this report, we will use a slightly different and more condensed list as suggested by Femia and Moll. We will discern three main policy stages.

a) Environmental problem analysis:

This involves the analysis of the nature and causes of environmental problems, and the identification of environmental 'hot spots' in the economic system.

b) Prospective effect analysis of policies:

This involves the ex ante prediction of effects of policy measures and may include trend and scenario analysis.

c) Monitoring and ex post effect analysis of policies:

This involves the ex post analysis of impacts and effectiveness of policy measures, including time series analysis.

4.1.2 Relevant EEIO specifications

In this chapter, we will discuss the specifications of EEIO tables and models needed to fulfil support functions in the three policy stages mentioned above. As can be deducted from the former chapters, the following main specifications can be discerned.

1. Resolution: the level of detail in terms of sectors or products that the EEIO table discerns.
2. Number and type of environmental interventions: the number of emissions and number of resource inputs per sector that the EEIO model discerns.
3. Inclusion of physical flows: if the model also includes, apart from monetary relations, physical relations between sectors,such as PIOTs.
4. Time series: if time series can be easily made available of the data related to the EEIO model — a feature which is highly relevant for the usefulness of the model for monitoring purposes.

Apart from this, there are a number of modelling issues that, in principle, go beyond the scope of setting up an EEIO table in a strict sense, but which have important implications for how the model can be used and to what questions a model can provide answers. Basic IO and EEIO models are 'open' with regard to final consumption, investment and exports (i.e. specified from outside the model). 'There is no way to assure that, under alternative scenarios, outlays for consumption will be consistent for the endogenous earnings of labour, that investment will be consistent with earnings on capital stock, and that exports and imports will shift in consistent ways' (Duchin, 2004:12). If one is interested in scenarios about sustainable development, such consistency is essential. Consumption, capital formation and trade need to become endogenous, for instance, by relating labour earnings to consumption, to relate product flows to capital stocks via a dynamic IO model, and to close the one region model by linking it to all potential trade partners, resulting in a world trade model (Duchin, 2004 and 2005).

4.1.3 Structure of this chapter

In order to develop the right specifications for environmentally extended input-output tables, we will now analyse which applications of EEIO models have already been seen or have been suggested in support of the three main policy stages, i.e. environmental problem analysis (Section 4.3), prospective effect analysis of policies (Section 4.4.), and monitoring and ex post effect analysis of policies (Section 4.5.). Of course, EEIO models are not the only tools that can be used for such applications, and therefore Section 4.2 discusses first the position of EEIO models compared to other tools.

The analyses in Section 4.3 to 4.5 will be done relatively disconnected from the current policy dossiers — such dossiers evolve in content and importance over time — though it will be possible to relate the subjects described relatively easily to existing dossiers such as integrated product policy (IPP), the thematic strategy on the sustainable use of natural resources, and others. This information in general has been gathered through:

- literature analysis and in-house expertise of TNO and CML with the relevant policy fields and policy applications (among others based on reports such as EC (2003), van der Voet et al. (2005), and Femia and Moll (2005);
- external consultation of relevant policy officials and other stakeholders.

Each section will end with the demands to EEIO tables in terms of the aforementioned specifications, i.e. the level of detail, the number of environmental interventions, the need to include intersector material flows, the potential of producing time series, and the need for making factors such as consumption, capital formation and trade endogenous.

4.2 The relevance of detailed EEIO models as compared to other tools

For environmental problem analysis, prospective effect analysis of policies and monitoring and ex post effect analysis of policies, different levels of analysis may be used. For broad strategic analysis, such as developments with regard to decoupling at the level of a country, aggregate analysis of trends and broad scenarios suffice. However, if specific policy measures are analysed as to their environmental effects, the model should indicate the causal relation between the policy measure and the effect. Hence, the level of detail required directly varies with the level of detail of the policy measures considered or implemented. EEIO tables and models with a detailed sector resolution can obviously support more detailed and specific policies. Differentiating value added on services and products requires a model distinguishing between services and products. A policy on energy efficiency of refrigerators requires a model specification at the level of different types of refrigerators. The latter is beyond the level even of detailed EEIO modelling, and is usually covered by life cycle assessment (LCA) [61].

(61) As will be discussed later, LCAs necessarily cannot include the full process tree, since then, in essence, all processes in the world have to be included since every production process is linked to other production processes. Hence, minor inputs into a process are usually 'cut off' and neglected. In some cases, these 'cut offs' can be responsible for several dozen percent of the life cycle impact of a product. EEIO models can be used to provide estimates for the economy-wide environmental impacts of such minor inputs. This combined use of LCA and EEIO models has been termed 'Hybrid LCA-IOA'.

EEIO models have a unique feature: there are no other environmental models and tools that give such an integrated view of the economic system. There are tools that give a more partial view, which may sometimes be sufficient. For problem analysis, there is an independent role to play for risk analysis, environmental impact assessment (EIA) and health surveys. Lead in gasoline was detected as a source of serious health impacts and did not require EEIOA for further investigation. Policies have been implemented forbidding tetra-ethyl lead, and their success has been monitored by taking blood samples of those living close to heavy traffic. For problems having a solution which does not substantially lead to problem shifting, the focus only on direct emissions, the resulting local concentrations and final effects is well justified. If the substance can be removed, or replaced by a more benign substance, problem shifting is limited. Traditional LCA can give an impression if other processes in the chain may interfere with the local solution.

However, when all environmental cherries have been picked, such clear solutions become more seldom and complexity enters in further environmental quality improvements. This is the case now in all industrialised countries. Substances emitted cannot now be fully avoided and can be reduced only by increasing activities with other emissions, and a resource extracted can be reduced in volume only by increasing other extractions. This complexity not only results from having picked the nicest cherries, but also from the increasing complexity in the production processes of our globalising world. An integrated view on policies is then required, even for formerly 'local' problems.

The first round of integration of policies has been based on combining several substances into problem areas, such as acidification, nitrification and climate change, and the focused solution per problem. For example, for acidification, the single problem, source-oriented approach with end-of-pipe solutions may still be a very relevant one, requiring an inventory of main sources per problem area only. However, it must also be considered that these solutions have a trade-off: they require substantial amounts of chemicals and energy. Therefore, in many cases, the in-process improvement now seems more adequate. Then, it is not only the balancing of different environmental impacts involved, but also different routes towards the different emissions involved. Somehow, the relations within the system have to be taken into account, the subject of the second round.

The second round of policy integration involves the combined analysis of several problem areas, and not looking at single source only but analysing systems as in the LCA type of cradle-to-grave system analysis. This analysis can give insight into problem shifting and is extensively used in many policy domains, not only as a formalised quantitative tool but often as a concept, as a more qualitative type of reasoning, related to other types of reasoning and tools which each give some relevant insight (see, for example, Wrisberg et al., 2002). The shortcomings of LCA have been described, related to the diverging methods for inventory analysis, to the different levels of incompleteness, and to the high cost of economy-wide application, requiring detailed process data bases of all activities.

We may now see the third round of policy integration emerging. It does not start bottom up, from specific activities and systems, and specific problems and their solutions, but starts top down, from a survey of problems but with enough detail in the analysis to point to specific solutions. In this approach, different policy approaches and specific policy options can be analysed in the same framework covering the total of all economic activities and all relevant environmental impacts. Though clearly not 'the only' tool, the EEIO models as developing now for the first time give full consistent totals, and different entries for insight into contributing factors and in the drivers present in the system. As with LCA, adjoining tools such as partial market analysis, and combination with other tools, such as general equilibrium models, will be essential for grasping the outcomes of stand-alone EEIO tables and models and placing them in broader perspective.

There is no real alternative to EEIOA for society-wide analysis at a level of detail allowing for links to specific technology choices and product choices. The most relevant alternative analysis seems to be the strategic approach based on general assumptions. The 3R initiative: 'reducing' material input and saving energy, and closing cycles by 'reuse' and 'recycling' gives principles to guide both environmental policy and private environmental behaviour, specifying numerous policy options in practice. However, it seems that the actions filling in such strategies would still have to be placed in a more detailed framework allowing for priority setting.

Finally, for this introduction on the relevance of the EEIOA for policy, the relevance depends on policy instrumentation. Two extremes may be distinguished: the planning type of instrumentation versus the boundary condition setting type, exemplified by permits with technology specification for the first, and market correcting emission taxes and tradable emission permit systems for the second. Clearly, with real internalisation of all external effects, the world may develop towards sustainability without further insight required for environmental policy-makers, or regulatees, on the environmental effects of specific economic activities. Monitoring environmental quality, related to total emissions and concentrations, suffices to adjust the levels of payment for externalities. This monitoring is relatively easy, as all direct emissions are known in detail, for reasons of taxing and tradable emission permit control. No insight in systems relations is required. By contrast, the planning type of policy requires full insight in all consequences of technology and volume choices, from a systems point of view. For such purposes, EEIO tables and models are needed with the highest level of detail that, reasonably speaking, can be reached given financial and institutional constraints, with additional tools like LCA for detailed analysis on major choices. In reality, policy instruments are in between these extremes. This implies that there will be a useful role for detailed EEIOA. In the next sections, we will discuss requirements more specifically per policy application.

4.3 Environmental problem analysis

4.3.1 Typical applications and related policy fields

IO tables give comprehensive insight into the (monetary) relations in the economic system. When environmental extensions are added, insight is given into the direct resource use and emissions per sector, and on the indirect ones. Due to these features, EEIO tables form an excellent means for analysing priority environmental problems and the contributing processes from a system perspective. EEIO tables have been used to make analyses of the following causes and priority environmental problems from the following perspectives:

1. life cycle environmental impacts (62) per consumer group (e.g. inhabitants of a city versus the rest of a country; car owners versus non-car owners, etc.);
2. life cycle environmental impacts of consumption expenditure categories, per consumption category (e.g. expenditure on car driving, package holidays, and medical services);
3. life cycle environmental impacts of product groups (e.g. different categories of foodstuff, such as meat, poultry, fish and groceries);

(62) When using the term 'life cycle environmental impacts', the following is included. First, it concerns impacts of all economic activities that are needed to realise the activities of the consumer group, are related to the expenditure category, or related to the product ('cradle to grave'). Second, it usually concerns the large majority of the following environmental interventions: the volume of (primary) biotic and abiotic resource input into the economy, the output of final waste, land use, and the output of emissions. Often, these interventions are aggregated to 'impact categories' making use of Life cycle impact assessment methodologies (e.g. Guinée et al. 2002). It is also possible to calculate the external costs related to such interventions, giving insight in externalities.

4. life cycle environmental impacts of products (in combination with LCA via so-called hybrid LCA-EEIO);
5. life cycle impacts related to resources used (see, for example, van der Voet et al., 2005).

Apart from analysing the total impacts related to consumer groups, consumption expenditure, products or product groups, and resource use, via techniques such as contribution analysis or structural path analysis, the contributing factors of impacts can be traced. In essence, such techniques analyse how many economic activities in different sectors have to take place for e.g. producing a specific product group, and how many impacts this causes per sector. This makes it possible to specify where in the system the highest environmental impact caused by this product group takes place. This gives a very strong guidance for prioritising policy measures. Examples of contribution analyses include:

a) the relative importance of impacts in the resource extraction, production, use and waste management stages;
b) the relative importance of domestic impacts and impacts embodied in imports;
c) the industry sector mainly contributing to impacts of a consumer group, expenditure category or product (group).

The very high relevance for policy lies in the different approaches which can be followed in analysing and solving the problem. Emissions causing accepted problems may be analysed from the perspective of specific consumption items or product groups, indicating how changes in consumption patterns may solve the problem. Contribution analysis may show which sectors are responsible for the emissions, indicating how technology requirements may help solve the problem. It may also show the shares of specific substances in the problem, indicating options for substance policy. Finally, linking to life cycle stages in relation to material use may indicate if and how materials policy might contribute to the problem solution. It has to be stressed that there is no other framework which can deliver this comparative analysis in a consistent way.

Figure 4.3.1 to 4.3.3 gives some illustrative examples of applications. The applications mentioned above are obviously highly relevant for policy dossiers such as sustainable consumption and production, integrated product policy, and the EU thematic strategy on the sustainable use of natural resources.

Figure 4.3.1: Impacts per consumer group. CO_2 emissions per household, per age group of the highest earner, in tonne per person, and tonne per 100 Norwegian kronor (NOK) spent, Norway (Peters et al., 2005)

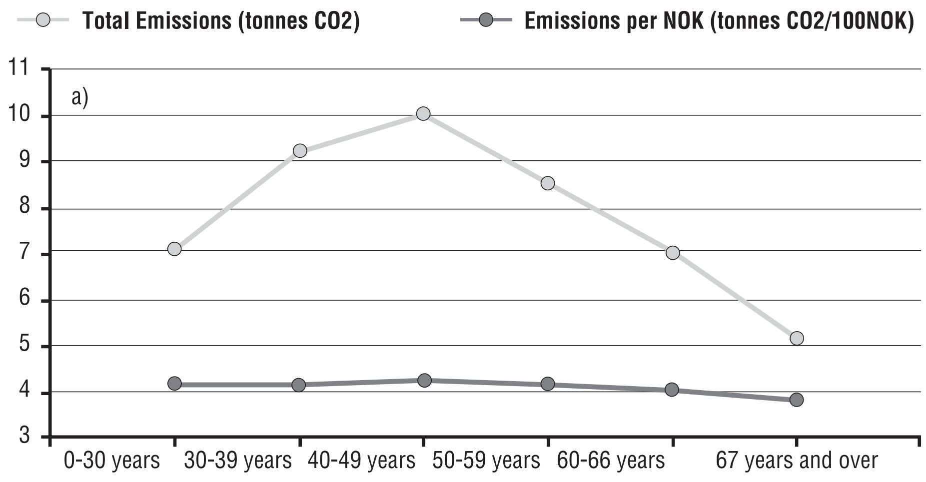


Figure 4.3.2: Impacts of final consumption expenditure categories/product groups. Impact per euro for 278 product groups versus % of the final consumer expenditure, for the EU-25, the surface reflects the total impact of the category (Tukker et al., 2005)

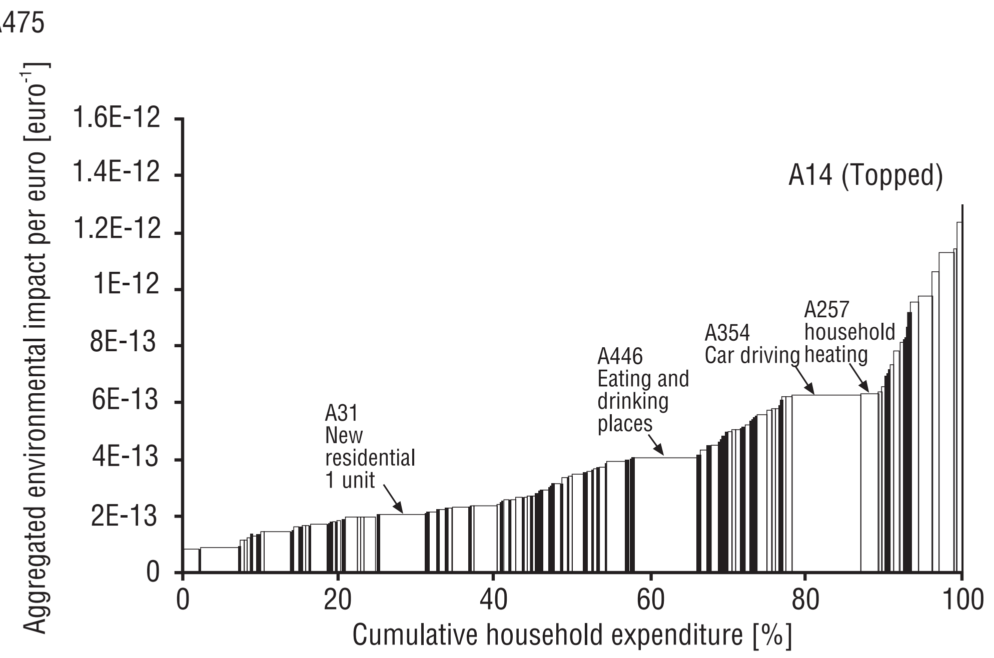
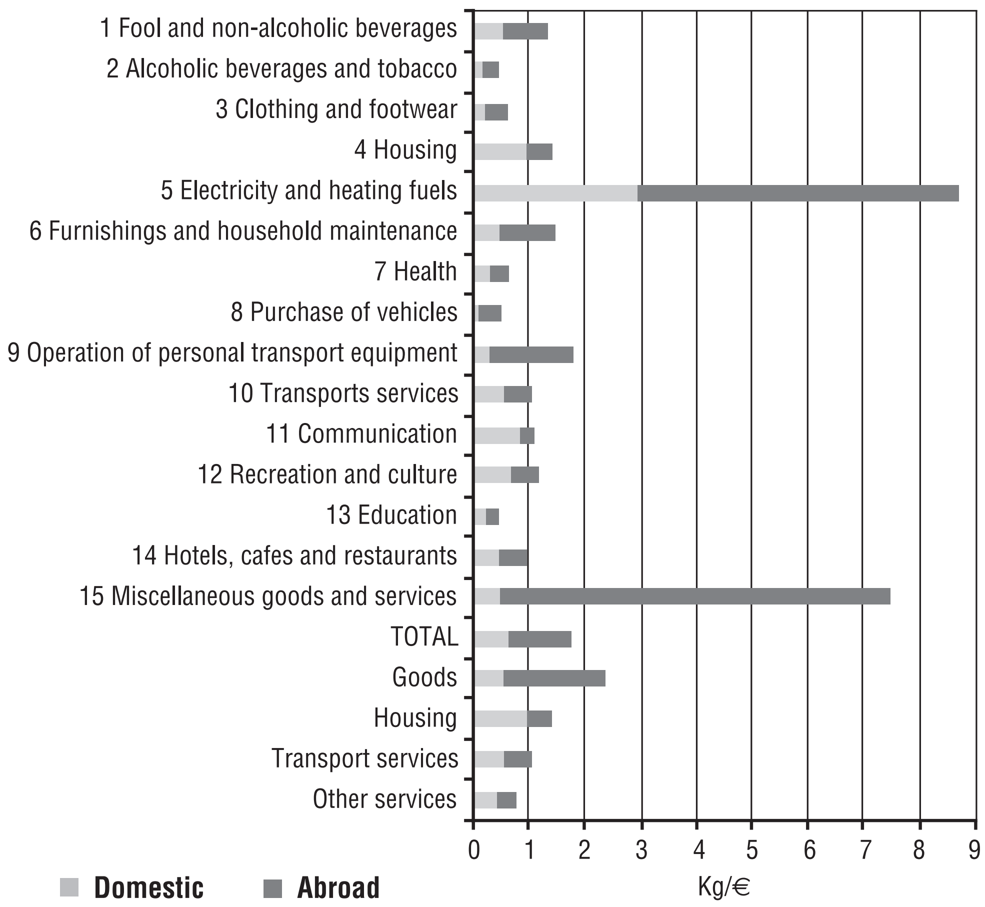


Figure 4.3.3: Contribution analysis and impact of product groups. Total material requirement per euro specified by processes domestic an abroad, Finland, 1999 (Maënpää, 2005)



4.3.2 *Demands with regard to the EEIO model*

Application areas 1 to 3 (life cycle impacts of consumer groups, consumption expenditures, and product groups) are all dealing with the total output of the economic system. Application 4 (assessing the life cycle impacts of individual products) also deals with the output of the economic system, partially only, but at a high level of detail. Application 5 (impacts related to resources) looks the other way around, and tries to attribute impacts in the economic systems to a specific input of a resource.

For these applications, the demands with regard to the EEIO model can be specified as follows. A summary is given in Table 4.3.1.

Sector resolution

For most of the applications mentioned, a useful priority setting and contribution analysis can be done with EEIO tables of 50–100 sectors/ final products. As shown in studies of, among others, Nijdam and Wilting (2003) and Weidema et al. (2005), such a level of detail allows for identifying the main groups of final consumption activities that cause the main environmental problems. A higher resolution of several hundred sectors, as reached in (for example) the EIPRO study (Tukker et al., 2005) has added value though. Such a higher level of detail allows for a more detailed analysis and priority setting of consumption activities and product groups (63). Furthermore, sectors will be more homogeneous. This point is of clear relevance for policy. Homogeneity is important since otherwise EEIO analysis may have strange results. For instance, the study of Nijdam and Wilting (2003) indicated that the consumption category 'clothing' was linked to depletion of fish resources. This was because fishing and meat production in their IO model was one sector. The clothing sector was buying leather from meat plants, but the model showed the clothing sector receiving some of the input of fish resources to the combined fish/meat sector. Such problems may easily remain hidden in an aggregate model.

In practical terms, it is not possible to build an EEIO table and model with sufficient resolution to analyse the life cycle impacts of a single product. This is the domain of life cycle assessment of products, and EEIO models can only have a supplementary value in so-called 'hybrid LCA'. Data supplied with the EEIO model are used to make estimates of impacts related to truncated ('cut-off') process chains no longer included in the LCA system. Also here, the more detailed the EEIO model is, the better its potential to correct the truncation problem.

Number of environmental interventions

For an encompassing assessment of environmental impacts, the environmental interventions should describe the extraction and emission (to air, water and soil) of a broad spectrum of different substances contributing to different environmental problems, like:

- climate change or global warming (mainly caused by emissions of CO_2, CH_4, N_2O, HCFCs, HFCs, PFCs and SF_6 to air);
- stratospheric ozone depletion (mainly caused by emissions such as HCFCs to air);
- acidification (mainly caused by emissions of SO_x, NO_x and NH_3 to air);

(63) For instance, an EEIO table with one sector 'agriculture' and one sector 'food processing' will probably not make any difference between meat, dairy and vegetable foodstuff on the one hand and domestic versus imported foodstuff on the other hand. There are obviously important differences in impacts between such foodstuffs and having this visible is an important point of departure for the next step, ex-ante impact assessment of policies (improvement analysis). A great level of detail may not be so important for consumption categories like mobility (a distinction between automotive transport, public transport and air traffic will be sufficient), shelter and house heating, but is relevant for categories such as food and energy using products in the house (compare Tukker et al., 2005).

- eutrophication (mainly caused by emissions of NH_4^+ and PO_4^{3-} to water);
- photo-oxidant formation or photochemical oxidation (caused mainly by a variety of organic emissions to air. These are sometimes taken together as sum parameter NMVOC, but it is difficult to determine impacts reliably on the basis of such a sum parameter);
- human toxicity (caused by a great variety of emissions to air, water and soil);
- ecotoxicity (caused by a great variety of emissions to air, water and soil);
- depletion of abiotic resources (caused by the use of a great variety of abiotic resources);
- depletion of biotic resources (caused by the use of a great variety of biotic resources);
- land use competition;
- a variety of other, environmental problem types, such as radiation, noise, odour, etc., which are less used.

One cannot therefore rely on having data on just a few emissions if one wants to cover even a limited number of environmental problem types. The voluntary, recently published 'compilation guide' for NAMEA-Air (Eurostat, 2004), lists as 'priority 1' the substances mentioned above under climate change — but even this theme is not covered in full, since HCFCs are excluded from the list. Priority 2 concerns emissions to air of HCFCs, CFCs, CO, SO_x, NO_x and NH_3, NMVOC, Hg, Pb and Cd. This list will allow covering climate change, ozone depletion and acidification in a comprehensive way, and allows for rough assessments of problems related to photo-oxidant formation. The third priority covers the metals As, Zn, Cr, Se, Cu and Ni, which allows analysing direct emissions of these substances, but does not give a comprehensive picture of toxicity impacts. The current NAMEA-Air therefore covers just a very limited number of environmental problem types. When zooming in on specific product classes, such as food, this leads in most cases to important shortcomings. The toxics involved, especially pesticides, are all missing, relevant especially for ecotoxicity but also for human toxicity analysis. The eutrophicating emissions to water and soil are all missing, as is land-use competition and other primary resource uses. When further zooming in, more differentiation becomes possible, with specific emissions being overall less important, but very much linked to specific products. Phthalates are linked to a small number of products using soft PVC, but then they may have a main share in human and ecotoxicity orders of magnitude than for functionally comparable polymers.

In conclusion, for a useful application of EEIO models, a quite broad set of emissions to air, water and soil preferably have to be included. This list should at least consist of the three categories mentioned in the Compilation Guide for NAMEA-Air, and NH_4^+ and PO_4^{3-} to water, but preferably the 50 + substances listed in EPER. This gives good coverage of climate change, ozone depletion, acidification, eutrophication and photochemical oxidant formation. Furthermore, the primary resource use per sector and preferably land use need to be included. This would cover abiotic depletion, biotic depletion and land use competition (64). Inclusion of primary resources allows for the data in the EEIO model to be used as well to calculate indicators such as the total material requirement (TMR) of an economy (see Section 4.3.3). A comprehensive coverage of human and ecotoxicity would additionally require inclusion of a few dozen other emissions to air, water and soil. Only if one wanted to use the EEIO model for just one specific environmental problem would a much smaller amount of environmental interventions suffice. For instance, for policies on global warming, inclusion of the most important greenhouse gases would be sufficient.

(64) An interesting application of EEIO models that include land use is the following. As shown by Wiedmann et al. (2005), such a model can be used to calculate the 'ecological footprint' related to consumption at national, regional and city level.

Demands with regard to intersector flows

For all applications mentioned, there is no need to have insight into the relations between sectors in physical terms, except when explaining emissions due to resource use. There are various approaches that analyse the impacts of material use, such as the well-known economy-wide material flow analysis of the Wuppertal Institute in combination with the 'environmentally weighted material consumption' (EMC) approach of van der Voet et al. (2005). However, these approaches do not allow for analysis in which several life cycle stages or specific sectors are important. If it is necessary to give insight into the causal relation between certain emissions and (the flow of) materials in the economic system, it is inevitable that the intersector flows are accounted for in physical terms as well. This then has to be done at the level of detail of resources that one wants to follow through the system. The environmental policy reason for doing so may be the depletion of specific abiotic resources. However, if the materials analysis is in the same sector framework as the emissions analysis, the link to materials policy for emission reduction can also be formulated.

Time series

For priority-setting purposes, a snapshot at a given moment in time is usually sufficient. It is not absolutely necessary to have time series available. However, for a perspective on the relevance of policies, it is of course elucidating to see if the problem is increasing, decreasing or constant in time.

Other

The pollution embodied in imports is usually important, particularly for open economies, and particularly if imports take place from countries with a different technology structure and/or emission factors from the country of analysis. In that case, dedicated modelling of imports is highly desirable.

In order to support LCA, EEIO tables are to be linked to LCA to allow for hybrid analysis. This is hardly possible with very aggregate tables. Here too, there is no numerical threshold but more detail is clearly always better.

4.3.3 Advantages and disadvantages of EEIO compared to other tools

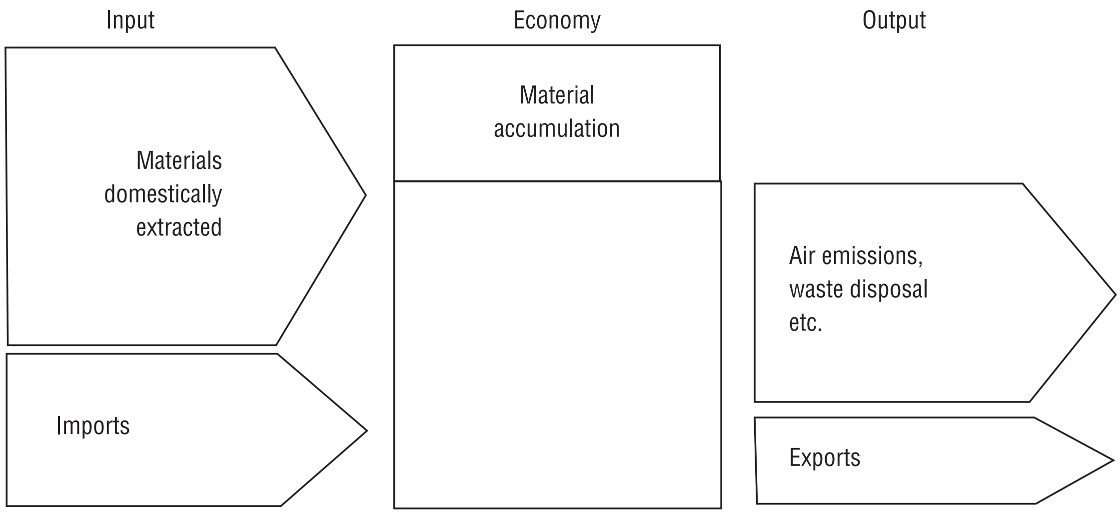
Using EEIO models for most of the applications mentioned has a number of obvious advantages. EEIO models give a comprehensive and internally consistent picture of an economic system and its emissions and extraction of resources, capturing the interdependence of all parts of an economy. Such models also inherently avoid cut-offs of process trees, as is usual in LCA.

Table 4.3.1: Demands with regard to EEIO tables for problem analysis purposes (including contribution analysis)

Application	Sector resolution	Number of environmental extensions	Need for physical intersector data	Time series needed?
Output-related impacts (consumer groups/life styles, expenditure categories, product groups)	Several dozen (the more the better)	Large	Not very relevant	Not highly relevant
Impacts of individual products	Use (hybrid) LCA, for specifications see above			
Impacts of resource use (*)	Several dozen (the more the better)	Large	Some relevance	Not highly relevant

(*) EEIO only has a function if one is interested in a detailed contribution analysis of sectors where the resource use leads to impacts. If this is not the case, simpler approaches, such as economy-wide MFA and environmentally weighted material consumption (EMC) may suffice.

Figure 4.3.1: Scope of economy-wide material flow accounts (after Eurostat, 2001)



As indicated in Section 4.2, there is no other tool that gives such a comprehensive and consistent picture of the impacts of an economic system. The combination of economic and environmental information in one framework allows for several types of eco-efficiency analysis. From the final demand side, one may specify the environmental effects per monetary unit of consumption, indicating how shifts may contribute to decreasing, or increasing, emissions. When analysing specific products, this eco-efficiency score may be used as a guiding rule, to see if the product is in line or highly deviating in its scores. It is also possible to track where in the value chain the emissions per unit of value added are high or low, indicating where shifts might be sensible or installations policy most useful.

As also discussed in Section 4.2 there are other environmental evaluation tools, but they have different domains of application, such as LCA and economy-wide material flow analysis. LCA is better suited when analysis at a high level of detail is required, such as the analysis of impacts of variants of an individual product. EEIOA and LCA are hence complementary tools. EEIOA may strengthen LCA, in the form of the aforementioned hybrid LCA, where LCA and EEIO are used in combination.

With regard to analysis of resource depletion, an alternative tool is the economy-wide material flow analysis as, for example, developed by the Wuppertal Institute. This approach sees the economic system as a black box, and basically measures material inputs (domestically extracted materials and imports), outputs (emissions, waste disposal and exports) and material accumulation (see Figure 4.3.1). Emissions are not inventoried in any detail, only as loss of material. All this information in principle can be delivered via an EEIO table. EEIO tables include, for each sector, the primary resource input and hence, in principle, indicators such as total material requirement (TMR) can be calculated ([65]). Only if one considers a policy for emission reduction via measures related to material use would the link to the same sectors as in EEIO tables be required.

One of the critiques on economy-wide MFA is that materials are just added up on the basis of mass, where it is obvious that the impacts related to, for example, the use of sand are probably much less severe as the use of a similar quantity

(65) Economy-wide material flow analysis also includes indicators such as direct material consumption (DMC), which is defined as domestic extraction used, plus imports, minus exports. For this indicator, one also needs insight in imports and experts in physical terms (tonnes) (Femia and Moll, 2004).

of gasoline. Recently, van der Voet et al. (2005) proposed an approach that can link the material mass-based and impact-based to allow for depletion and emissions-based resource policy. They developed 'impact factors' for different resources that reflect the (potential) impact in LCIA terms that can be allocated to the use of a resource. This is the 'environmentally weighted material consumption' (EMC). The approach roughly follows the following steps.

a) Define resources as 'finished materials' such as crops, steel, copper and concrete, derived from one or more primary resources as extracted from the environment.

b) Calculate the cradle-to-gate environmental interventions for producing these materials making use of standard LCA databases, and add for subsequent steps in the production-consumption chain — processing to products, use and waste management — only those environmental interventions that are inherently linked to the use of this finished material, e.g. lead emissions from the use and waste phase in the case of lead, but not the energy use of a product in which lead is used.

c) Develop per environmental impact type a score related to the use of 1 kg finished material.

d) Multiply with the total use of finished materials in society to identify the materials with the greatest environmental impact. Similarly, define for a product or product group the role of materials in its life cycle emissions.

In an elegant sort of way, this approach gives insight into the 'impact weighted' relevance of materials for environmental policy weighting. The main challenge is to gather data on 'finished material use' (rather than primary resource extraction) and such information is typically not available (nor used) in an EEIO table, unless it is extended with physical intersector flows. The added value of EEIO with physical intersector flows is that environmental impacts of a product due to materials use can be specified, indicating the room for materials-oriented policy regarding such products.

4.4 Prospective effect analysis of policies

4.4.1 Typical applications and related policy fields

Due to their comprehensive and systematic coverage of interrelations in the economic systems, EEIO forms an excellent tool to assess the economy-wide impacts of policy measures, and to assess the environmental implications of 'what if' scenarios. EEIO models have been used, or are suitable to analyse, the impacts of the following autonomous or policy-driven scenarios:

1. economy-wide environmental and other implications of changes in life styles and consumption expenditure patterns, such as a shift from travelling to educational and cultural services;
2. economy-wide environmental and other implications of incremental or radical technical change of products or processes, such as a shift to coal-based hydrogen production for large-scale fuel cell introduction, combined with carbon sequestration;
3. economy-wide environmental and other implications of emission-reduction measures, such as fine dust reduction in all combustion processes, including shifts to prevention;
4. economy-wide environmental and other implications of price effects, such as environmental taxation and other ways to internalise external effects (or other price effects in the aforementioned scenarios).

This list is the environmental equivalent of the application areas that ESA95 (EU, 1996) mentions for regular IO models. For instance, ESA95 mentions as applications of IO models:

a) effects of changes in prices or tax rates on the value of supply or use;

b) effects of changes in volumes on the value of supply or use;

c) effects of changes in prices of supply on prices of use;

d) effects of changes in the volume of use on the volume of supply;

e) effects of changes in the volume of supply on the volume of use;

f) impact analysis of new technologies;

g) sensitivity analysis of the effects of changes in tax rates and regulations.

For consumption changes, such economy-wide impacts may include mechanisms that have been termed ‘rebound effects’, especially if EEIO models are combined with or incorporated into broader modelling types, such as with general equilibrium models. In principle, such models are suitable for assessing what has been termed ‘direct rebound effect’, using more of the same product as it becomes cheaper; ‘indirect rebound effects, the effects of spending saved income on other expenditure categories, and further economy-wide effects, as a change of price of one good usually has effect on all other prices in the economy. EEIO models are probably less apt to predict ‘transformational effects’, i.e. long-term changes in technology structures, habits, norms, values etc. due to a cheaper supply of a specific product or service. For example, once abundant energy became available in homes in Europe in the 1960s, daily showering rather than weekly bathing became the social norm.

Box 4.4.1 gives some illustrative examples of such applications. The applications mentioned above are highly relevant for virtually all environmental policy dossiers for which impacts of measures on the economy have to be analysed.

Box 4.4.1: Examples of ex ante impact assessment of policies

Ad 1 and 2): Changes in production and consumption patterns
Hubacek and Sun (2005) have made scenarios for the future water demand in China making use of EEIO modelling. They modelled expected change in consumption patterns as a function of demographic developments (population growth and urbanisation) and expected changes in diets. Furthermore, they took into account technical changes in their technology matrix and made adjusted water consumption per unit of monetary turnover per sector for the future. With their EEIO model, they were then able to estimate the total future freshwater demand for China in 2025, and to compare this demand with the available water supply. Since the model was regionalised they could assess potential shortages per region.
Ad 1–3): Changes in production and consumption structures and emission factors
In their book *The future of the environment: ecological economics and technological change*, (New York: Oxford University Press) Duchin and Lange (1994) developed a 16-region input-output model of the global economy. They used it to analyse how different scenarios for economic growth and technical change will influence energy and material use and waste generation. Their main conclusion was that, even with the adoption of clean and efficient modern technologies throughout the world, sustainability goals established at the 1992 Rio de Janeiro UN Conference on Environment and Development (UNCED) will most probably not be met.
Ad 4): Changes in price levels and costs
Washida (2004) used EPAM, a general equilibrium model based on a 33-sector IO table, to calculate the impacts of improvements of the energy efficiency and related reduction of expenditure on energy of consumer goods on the total CO_2 emissions of the Japanese economy. He showed that the direct, positive effects of better energy efficiency on CO_2 emissions are almost offset by a rebound effect of 35 to 70 %.
Ad 4) Changes in price levels
Faehn et al. (2004) used a CGE model to analyse the effects of various scenarios for ‘recycling’ of carbon taxes in the Spanish economy on unemployment. The ‘recycling’ is the use of the revenues of carbon emission auctions for purposes such as transfer to households, reduction of payroll taxes for labour, reduction of indirect taxes like VAT, reduction for payroll taxes for unskilled labour and reduction of payroll taxes for skilled labour. In their model, the last option results in the highest rise of employment.

4.4.2 Demands with regard to the EEIO model

Basic EEIO models are 'open'. This openness is related to the fact that consumption, investment and exports are all exogenous to the model (i.e. specified from outside). This is fine for the environmental problem analysis discussed in the former section, but less appropriate if one wants to build scenarios. It may well be that, in alternative scenarios, there will be inconsistencies with regard, for example, to the consumption expenditures and (endogenous) earnings of labour, investments and growth or decline of capital stock, etc. This implies that, in some of the applications mentioned in this section, the basic EEIO model has to be 'closed'. Examples include the construction of a social accounting matrix (SAM), that makes explicit links between different categories of value added and final deliveries and making the IO model dynamic by including stocks and flows of capital goods explicitly. Below we will discuss such demands per application in more detail.

Sector resolution

For ex ante impact assessment and scenario analysis, in general a higher level of detail is desirable than for merely a problem analysis (Section 4.3). This is, for instance, commented by Duchin (2005) in her work on environmental impacts of different food consumption scenarios: '[This] requires a decision about the level of detail: 30 food categories, 300 or 3 000? Thirty categories is probably an adequate order of magnitude to distinguish, say, the average US diet, another European one [etc.]'. This example already indicates that a typical 60-sector IO table will not give sufficient detail to assess the implications of changes in life styles and consumption expenditure patterns, if to be specified at this level of detail. The same applies for the assessment of implications of technical changes in industry sectors where, in low resolution IO tables, one sector will usually cover very different processes. It is useful to re-assess Table 3.2.4 'Sectors in ESA95' in this respect. The 60-sector table, for example, includes a sector 'Manufacture of food products and beverages' which, of course, covers all food and drinks, and a sector 'Manufacture of fabricated metal products, except machinery and equipment', which covers all intermediate products of that nature and all such consumer goods, from staplers, to metal cupboards, to grills and radiators, all in one sector and one product group.

Number of environmental interventions

For the number of environmental interventions required, the same analysis as in Section 4.3.2 can be given. If one wants to cover the most commonly used types of environmental impacts, at least a set of general emissions to air, water and soil should be monitored for all sectors (e.g. the 50 pollutants/emissions to air and water monitored in EPER, with additional emissions to soil). Furthermore, the primary resource use per sector needs to be included. Again, if one is not interested in the general picture of environmental interventions but just the substances and resources relevant for a specific policy field, fewer interventions may be monitored. This implies, however, that the EEIO model will only be supportive to this specific field. For instance, an EEIO model which includes only greenhouse gases, or the use of energy carriers as a proxy for that, will give good support to policies in the field of climate change, but will not show side effects on other environmental problem areas. It surely will be of less use for dossiers such as 'Integrated product policy' and 'Sustainable consumption and production'. For these dossiers, one has to look at other types of environmental problems and related emissions and resource uses as well, such as depletion of biotic resources, impacts due to acidification and eutrophication, etc.

Demands with regard to intersector flows

With regard to intersector flows, the same analysis as done in Section 4.3 is valid. For all applications mentioned, there is no need to have insight into the relations between sectors in physical terms, except when explaining changes in emission patterns due to resource use. In that case, it is inevitable that intersector flows are accounted for in physical terms as well, at the level of detail of the number of resources one wants to follow through the economic system. Changes in resource use and related emissions will be particularly large in the case of implementation of radical technical changes of products and processes

Time series

In principle, time series (in the sense of actual, observed values from the past) have limited direct value for the prospective effect analysis of policy. However, time series from the past can be helpful to assess if the predicted trends and developments are reasonable. Past trends are also often used to derive model parameters via which the EEIO model can predict future situations. Collecting such time series from the past is essentially monitoring, which is discussed in the next section.

Other

As discussed in the introduction of this section, it is often helpful if the basic EEIO model is expanded with additional model elements that make exogenous elements such as consumption, trade and technical development endogenous. For instance, with a basic EEIO model, rebound effects of a measure such as taxing polluting products (internalising external costs) can be assessed only very roughly. One could, for example, assume that the loss in available income is proportionally distributed over all consumption categories. General equilibrium models would use a much more sophisticated approach, by taking price elasticities of demand into account, and by linking available income of consumers with earnings of labour. Such linkages make the models obviously much more complicated, and there is usually a trade-off between realistically achievable sector resolution and sophistication of the model with regard to internalising exogenous parameters.

4.4.3 Advantages and disadvantages of EEIO compared to other tools

For the applications mentioned in this section, EEIO models are most suitable tools if quantitative assessments of economy-wide implications of change are required. A host of EEIO models have been developed for such purposes, such as the Dutch Dimitri model (a dynamic environmentally extended input-output model) and the GEM-E3 [66] model for EU Member

Table 4.4.1: Demands with regard to EEIO tables for analysis and priority-setting purposes (including contribution analysis)

Application	Sector resolution	Number of environmental extensions	Relevance of physical inter-sector data	Time series needed?
Economy-wide implications of change in life style and consumption patterns (*)	Detailed preferred	Detailed	Not relevant	Not relevant
Economy-wide implications of technical change in products or processes, including emission reduction (*)	Detailed preferred	Detailed	Some relevance	Not relevant
Economy-wide implication of taxation and internalising external costs (*)	Detailed preferred	Detailed	Not relevant	Not relevant

(*) In all cases, it is desirable that the basic EEIO model is extended to make items such as consumer expenditure and investment in technical change endogenous.

(66) General equilibrium model for energy-economy-environment interactions.

States (a general equilibrium model build around an aggregate input-output model, with various modules that made consumption expenditure, technology evolution and trade endogenous) (see Chapter 3). There is no real alternative approach that can give such a comprehensive insight into economy-wide effects of (policy) choices.

The existing EEIO and IO models have been discussed by and large in Chapter 3. The sector resolution of models now incorporating EEIO tables is low, for instance around 30 in Dimitri and about 20 in GEM-E3 [67]. This implies that only rough technology specifications can be entered in such models. This, in turn, means that they may be adequate to specify overall trends and scenarios based on very general technology developments. The E3 models focus on options for energy supply and energy efficiency, with some rough and limited specification of further environmental effects. They are not apt for making a more detailed analysis of technologies. Combining them with detailed EEIO tables would increase the technological resolution, but would also require additional data and model detailing for the economic mechanisms incorporated in these models.

4.5 Monitoring and ex post effect analysis of policies

4.5.1 Typical applications and related policy fields

Monitoring and ex post analysis typically look at time series of environmental impacts to analyse the drivers for observed situations and trends. For such purposes, the following types of analysis become possible, especially if consistent EEIO tables for a series of years are available.

1. Analysis of the relation between environmental impact, be it emissions, total material requirement, or a specific impact, and economic output, via a variety of cross-sections of the economy (for instance for a specific industry sector, a specific product group, a specific consumption expenditure category).
2. In relation to the former point: monitoring of eco-efficiency ratios (impact per unit of value created).
3. Decomposition analysis of observed changes in the aforementioned ratios (for instance if decoupling between CO_2 emissions and economic growth is caused by a change in consumption patterns, change in technology structure, or a change in emission factors).

All these monitoring purposes are a very important help for understanding the reasons and drivers for observed changes in environmental impacts, which in turn can help to assess ex post the impacts of policy measures.

Figure 4.4.1 and 4.4.2 give some illustrative examples of such applications. The applications mentioned above are highly relevant for virtually all environmental policy dossiers for which impacts of measures on the economy have to be analysed.

4.5.2 Demands with regard to the EEIO model

The demands with regard to the EEIO model are the following.

Sector resolution

For general monitoring purposes, the sector resolution is less critical than in the case of ex ante impact assessment. Often, for issues such as decoupling, one is interested in the decoupling between impact and economic growth for the economy as a whole, or specific sectors and product groups. In Figures 4.4.1 and 4.4.2, an example is given of an aggregate analysis. The figures show the total final consumption expenditure versus a number of macro pressure indicators for the full Finnish economy, and a decomposition analysis as apt for this level. A

(67) GEM E3 actually uses the GTAP database for its IO data, in an aggregated form.

Figure 4.4.1: Monitoring decoupling: total consumption in Finland versus various environmental pressure indicators (Mäenpää, 2005)

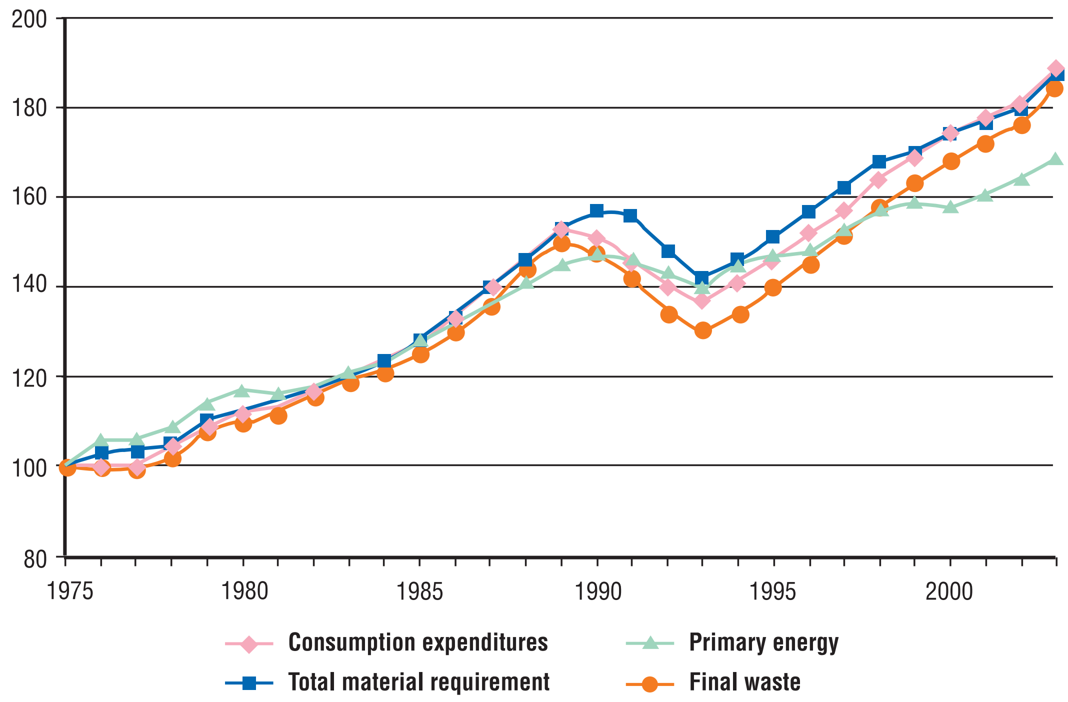
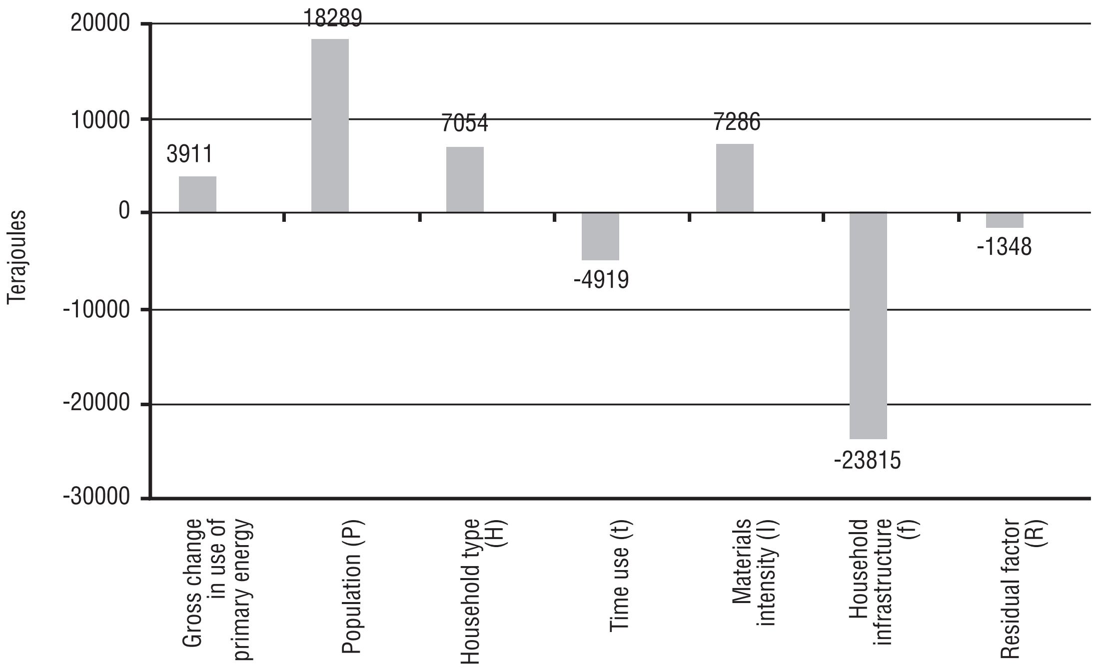


Figure 4.4.2: Decomposition analysis. Change in the gross energy requirements (TJ) of Finnish private final consumption from 1987–1990 to 1998–2000 (Jalas, 2005)



detailed EEIO model is not needed to produce such a figure. However, a more detailed EEIO model would first allow for producing similar figures, but then for specific consumption expenditure categories or product categories.

However, when examining the effects of past policies, the sector and product resolution has to represent the policies analysed, in relation to other changes which have taken place in the economy. Then a detailed model is required, decomposing the actual overall development to the factors contributing to the development, environmental policies being among them. Statistical analysis would require detailed time series.

Number of environmental interventions

For the number of environmental interventions required, the same analysis can be given as in Section 4.3.2. Again, if one wants to have an EEIO model that covers most environmental impacts, apart from a variety of resource uses some 50 emissions to air, water and soil must be included (e.g. greenhouse gases, acidifying substances such as SOx and NOx, eutrophicating substances such as PO_4 and NO_3, ozone depleting substances and some heavy metals, pesticides as a group, etc.). As discussed in Section 4.3.1, this list goes considerably further than the existing *Compilation guide for NAMEA-Air* (Eurostat, 2004), but is probably still not able to cover all monitoring needs arising from current policy priorities. Monitoring of greenhouse gases (relevant for the Kyoto protocol), ozone depleting substances, acidifying substances and eutrophying substances will be covered. But most substances relevant for their toxic properties are still not included, such as persistent organic pollutants, and toxic substances that require monitoring within the framework of international water quality control treaties. This would probably require the inclusion of a few dozen to a hundred additional emissions. If one is not interested in the general picture of environmental interventions but just the substances and resources relevant for a specific policy field, one can concentrate on such specific substances. As indicated before, however, this implies that the EEIO model will only be supportive to this specific field.

Time series

Time series (in the sense of actual, observed values from the past) are essential for monitoring and ex post effect analysis of policies. It is very important that time series are consistent, i.e. that the sector definitions and basis for making estimates of emission and resource use data is the same for the full time series used. New data sets should become available on an annual basis.

Other

Since this case concerns monitoring of actual data from the past, unlike the case for ex ante impact assessment, it is not necessary that the basic EEIO model is expanded with other modelling features. The time series must be available as basic EEIO tables, and this allows for the type of analysis described earlier in this paragraph.

Table 4.5.1: Demands with regard to EEIO tables for analysis and priority setting purposes (including contribution analysis)

Application	Sector resolution	Number of environ-mental extensions	Need for physical intersector data	Time series needed?
Monitoring of decoupling and eco-efficiency ratios	Several dozen (the more the better)	Detailed	Not relevant	Yes
Decomposition analysis: drivers behind change in ratios	Several dozen (the more the better)	Detailed	Possibly relevant	Yes

4.5.3 *Advantages and disadvantages of EEIO compared to other tools*

It is possible to make inventories of emissions and economic data and use them for monitoring purposes without putting them in an EEIO format. This is frequently done, and can also give insight into, for example, the development of eco-efficiency within a specific industry sector (if emissions and added value are monitored at this industry sector level), or the decoupling of resource use and economic growth of a country (for instance, if one has time series of economy-wide material flows available; compare Matthews et al., 2000). In such simple cases, it is not needed to have insight in the sector relations and other features provided by an EEIO table.

The strength of EEIO is clearly that it can bring such data for monitoring in a consistent format, and allows for deriving indicator values from a great variety of perspectives on the economic system (e.g. individual sectors, product groups, consumption expenditure categories, etc.). This can help greatly to reduce the effort for gathering data for monitoring, since now one tool can provide monitoring data for a number of different purposes. Above all, one of the unique features of time series of EEIO tables is that they allow for decomposition analysis, which provides insights into the underlying drivers and reasons for observed changes in indicator values. For assessing the effects of past environmental policies, the most demanding data set is required, to allow for a decomposition analysis indicating the role of environmental policy measures in the overall development. This requires detailed time series, at a level of detailed corresponding with the policy measures analysed.

4.6 Summary and conclusions: policy support by detailed EEIO tables and models

Table 4.6.1 summarises the conclusions with regard to the potential of EEIO tables for policy support. The table shows that such a tool can play an important role in environmental problem analysis, prospective effect analysis of policies, and monitoring and ex-post effect analysis of policies from an economy-wide and systemic perspective. This makes the EEIO tool valuable for a great variety of policy fields, such as integrated product policy, resources policy, polices in the field of climate change, etc. The strength of EEIO analysis is that it brings together economic and environmental data in a consistent, related sectoral framework. EEIO models allow for analysing such data via a great variety of cross-sections of the economic system, such as the product perspective, or a sector perspective. If the EEIO model and the related data collection system are set up rightly, it can therefore fulfil multiple goals, and hence will probably greatly reduce the effort in data gathering for analysis, ex ante impact assessment and monitoring for a variety of environmental policy fields.

Such applications pose the following demands with regard to an EEIO table. It must contain, as a minimum, data set on primary resource use and 20–30 emissions of substances to water, air and soil relevant for global warming, ozone depletion, eutrophication, and photochemical oxidant formation. After all, a table with just eight greenhouse gases can support global warming policies, but little more. Other demands depend more on the application. For problem analysis purposes, a detailed sector resolution is desirable, time series are irrelevant, and a basic EEIO table is usually sufficient. For prospective effect analysis of policies, a detailed sector resolution is, in principle, even more desirable, time series useful as a background but not essential, and it is preferable that the basic EEIO table is expanded to make exogenous parameters endogenous. Examples include the relation of consumption expenditures with the cost of labour, including price elasticity, and making the model dynamic with regard to changes in capital stock and technical development as a function of expenditure on capital goods. This, clearly, implies an interesting challenge: adding such additional features to a basic EEIO table is usually more complicated for detailed tables.

Table 4.6.1: Review of applications of EEIO and desired specifications

Application	Sector resolution	Number of environmental interventions (3)	Need for physical intersector data	Time series needed?
Environmental problem analysis				
Output-related impacts (consumer groups/ life styles, expenditure categories, product groups)	Several dozen (the more the better)	Detailed	Not relevant	Not relevant
Impacts of individual products	Use (hybrid) LCA, for specifications see above			
Impacts of resource use (1)	Several dozen (the more the better)	Detailed	For each resource	Not relevant
Prospective effect analysis of policies				
Economy-wide implications of change in life style and consumption patterns (2)	Detailed preferred	Detailed	Low relevance	Not relevant
Economy-wide implications of technical change in products or processes, including emission reduction (2)	Detailed preferred	Detailed	Possibly relevant	Not relevant
Economy-wide implication of taxation and internalising external costs (2)	Detailed preferred	Detailed	Low relevance	Not relevant
Monitoring and ex post effect analysis of policies				
Monitoring of decoupling and eco-efficiency ratios	Several dozen (the more the better)	Detailed	Not relevant	Yes
Decomposition analysis: drivers behind change in ratios	Several dozen (the more the better)	Detailed	Possibly relevant	Yes

(1) *EEIO only has a function if one is interested in a detailed contribution analysis of sectors where the resource use leads to impacts; if this is not the case, simpler approaches such as economy-wide MFA and environmentally weighted material consumption (EMC) are more appropriate.*

(2) *In all cases, it is desirable that the basic EEIO model is linked to broader models to make items such as consumer expenditure and investment in technical change endogenous.*

(3) *For specific policy applications, the number of environmental interventions may be limited. For instance, analyses, ex ante and ex post impact assessment focusing on climate change policies can be done very well with EEIO tables that just contain greenhouse gas emissions as environmental extensions, disregarding effects on other environmental policy domains.*

And finally, for monitoring and ex-post effect analysis of policies, an EEIO table of moderate sector resolutions are (in most cases) sufficient, time series are essential, and a basic EEIO table will do. Overall, this analysis suggests developing rather more detailed tables, acknowledging that this must be balanced against efforts, costs and institutional impediments. Priorities for realising detail are consumption areas with major effects caused by rather different products or industry sectors contributing to the production of these sectors, such as food, housing and transport (e.g. Tukker et al., 2005).

A special remark has to be made with regard to use of EEIO tables for support to resources policy. If one is interested in having a very detailed insight in the relation between (primary) material use and subsequent environmental interventions per sector in the system, that are causally related to this material, the EEIO table should be extended as well with physical flows between sectors (so called PIOTs or physical input-output tables). This, obviously, is a considerable additional demand. Much simpler and less time-consuming approaches have been developed that, at least for problem analysis and monitoring proposed, may be sufficient. Such simpler approaches include the economy-wide 'material flow analysis' and the recently developed 'environmentally weighted material consumption' approach, which simply counts total input of materials in the economy, or the 'finished material use' multiplied by a weighting factor. Neither economic relations nor environmental extensions are relevant in these methods.

Chapter 5 will discuss the most realistic options for developing EEIO models for the EU-25 that, to different extents, match the demands reflected in Table 4.6.1. After that, Chapter 6 will confront these options with the demands and, on the basis of an analysis of trade-offs such as required efforts and costs, will recommend a preferred approach to developing an EU-25 EEIO model.

5 Options for the production and use of an EU-25 environmentally extended IO table

5.1 Introduction

This chapter will bring together the options for the future situation with regard to the availability of an EU-25 environmentally extended input-output table for environmental analysis of production and consumption activities. It distinguishes five scenarios with regard to the future of a European EEIO table and model.

1. CEDA EU-25 as it is now: this is the environmentally extended input-output model as developed in the EIPRO project.

2. Autonomous development NAMEA: this is the situation that will exist in about three to five years from now. This option basically relies on the progress of the activities currently set in motion by Eurostat for the development for all EU-25 countries of an IO table with a related NAMEA at 60x60 level, with increasing broadness of environmental interventions covered.

3. Improvement option 1: High resolution CEDA EU-25++.

In this option, extra effort is made to elaborate and improve the CEDA EU-25 model.

4. Improvement option 2: Medium resolution EEIO tables: IO/NAMEA++

This option goes further than (2), but still relies on existing data reporting procedures.

5. Improvement option 3: High resolution tables: the 'royal route'.

This option for detailed EEIO tables for the EU-25 makes use of new data reporting procedures. In this 'royal route', the data reporting procedures will be adapted in such a way that a rather detailed EEIO table based on systematically gathered basic data can be produced and updated regularly.

The general framework we keep in mind is as developed in Chapter 2. It distinguishes between a base level, where data are gathered, and a number of steps to produce environmentally extended input-output tables and models. These would cover emissions and primary resource use, and materials and substance flows in the economy. In practice, this systematic approach has never been applied, and will not be applied in options 1, 2 and 3, in each for different reasons. The CEDA approach has a high level of resolution and covers a broad set of environmental interventions but is badly linked to basic data. The applicability is broad, but the quality of data is lower than in NAMEA. The NAMEA data link much better to sources, but remain at a lower level of sector resolution, thus reducing the domain of useful applications. Their production in terms of EEIO tables for the EU still requires a substantial effort, probably beyond 'autonomous development'. Also, PIOTs of either SFA or MFA type are not produced systematically in Member States or at EU level.

Option 4 to some extent, but especially option 5, the 'royal route', would have the explicit separation of primary data generation, for environmentally extended supply tables and use tables, and the further steps towards derived tables and models. This ideal serves as a reference for discussion of the more practical improvement options 2, 3 and 4. SFA and MFA data could be produced linked into this framework as well, requiring substantial research into the physical and chemical composition of all product flows concerned. At least a pilot on some major materials and substances seems useful, and the possible link to developing substance databases, such as due to the REACH regulation, should be investigated.

The framework as has been set up in Chapter 2 involves six steps, from primary data in step 1; through a number of method steps, Nos 2 and 3; to EEIO tables, in step 4; into linked PIOTs, in step 5; and relating to the global system, in step 6. The last point could be realised by embedding the EU model in GTAP, as this is a 60-sector model, with a similar resolution as ESA95. GTAP is interesting and broadly used in Europe, though mostly for purposes of economic analysis. There are two main reasons for not further investigating this option. The first is that GTAP sector definitions are fully incompatible with ESA95 categories (see Table 3.2.4 and 3.2.5). This means that the basis for data gathering would deviate not only from ESA95 and NAMEA data gathering and classification procedures but also from (new) NACE, and the UN conventions behind these. If not yet reason enough, the second reason relates to data quality and updatability. GTAP is based on national statistics, transforms and groups these, and adds the international trade flows. How these trade flows are added is not transparent. Even if the current linkages are 'the best possible', underlying data on which estimates for linkages are made in general will be available according to the new-NACE (and for the US the aligned new-NAICS) classification system. It seems wise to restrict basic data-gathering efforts to standardised models and classification systems. The problem is that there are too many incompatible systems being used already.

When considering applications of the five options, it should be kept in mind that going from a standardised EEIO data set, or related material and substance flow accounts, to a model giving insight into relations will usually require some further modelling steps. Firstly, for production and consumption analysis, the data set not only has to cover production but also the use and the post-consumer waste stage, which is now the case in a detailed but rough way in CEDA, and in a partial way in country level NAMEAs. Then the most simple model applications result, as by assuming a certain demand, or shift in technology, and seeing how the system reacts. Mostly, however, applications will involve additional modelling steps, such as linking consumption structure to age or social status. Several of the policy applications indicated in Chapter 4 require the link to partial equilibrium models, as for assessing the consequences of taxes on volumes of production and consumption, and shifts in technologies. One further extension which seems most useful is the link to more specific partial models on technologies, at the level of detail usual in LCAs, building hybrid models, with some parts expressed in monetary units and others more detailed in physical product terms. Also, in all general equilibrium models as have developed mostly in the energy domain (GEM-E3; Nemesis) the technology base is in the Leontief-type IO tables, usually of a quite aggregate nature of around 30 sectors. Such models are mostly dynamic, with some assumed technology shifts due to market elements in the model, and are usually optimisation models. Dynamic models closer to EEIOA have been constructed too, as in models where endogenised investments influence technologies and hence the input-output coefficients. An example is the Dimitri model (Wilting et al., 2001). More generally, complex mechanisms in the dynamics of product and consumption can be linked to the EEIO base model.

In setting up the models, such applications, in a modelling technical sense, should be kept in mind. This is not self-evident. The first IO models in the United States could not be used for broader analysis due to too-specific choices on how environmental variables were specified. For instance, specifying waste flows as environmental flows and specifying the sectors for processing such wastes may well lead to inconsistent modelling.

In the following sections, we will discuss each of the five options, with a view always to arriving at detailed European tables with environmental extensions, possibly in an interregional framework. After an introduction, each paragraph will discuss:

- the characteristics of the improved EEIO tables;
- the effort and investment needed to develop them.

Chapter 6 will combine this information with the potential for solving policy questions as discussed in Chapter 4, and in fact give a kind of 'cost-benefit' assessment of the different options, and provide recommendations [68].

Before describing the five scenarios we will first summarise the data and modelling goals strived for in some more detail, in the next section.

5.2 Ideal goals, without limitations

5.2.1 Introduction

Practical procedures limit options for producing an ideal detailed European input-output table with broad environmental extensions, both of a legal and financial nature. Before going into the practical limitations let us first sketch the ideal, as a reference.

Environmentally extended input-output tables form a group of an analytical tool which, firstly, represents the economic structure, covering production and also consumption and post-consumer waste handling, with all relations specified in monetary terms, and, secondly, combines this information with all relevant environmental interventions, such as resource extractions, hazardous emissions and disturbances, in physical terms, linked to sectors and the physical substrate of the economy linked to flows between sectors.

For the aggregate analysis of the economy, i.e. for answering questions such as how will total emissions develop in the next years and which sectors contribute most to changes, how does rising consumer expenditure influence developments, etc, an aggregate analysis usually suffices. This is a macro/meso level of analysis.

For the detailed analysis of (changes in) specific consumption activities and production technologies, a more detailed analysis gives a more valid result. However, knowing all details of reality is not possible, so a more aggregate picture has to be used, grouping 'similar' activities into sectors. Contrary to the macro/meso analysis, the focus is micro, going up to the meso level only because systematic knowledge at the micro level is not possible. In this second case, the aggregation is as limited as is practically possible, i.e. results are as detailed as possible, in terms of data sources available and in terms of still being manageable in software. The latter limitation, computational power, has been a serious impediment in the past. Leontief had to limit his first IO computations to a 9x9 table, based on the first mainframe computers becoming available! In the last decades, computational power has been increasing at such a pace that there is no practical limitation at that level, though of course implementation in handy software is required. Input-output tables in the order of up to 10 000 sectors can now be managed technically on PCs, while this number is doubling every few years.

5.2.2 Basic information

In both cases, for the macro/meso aggregate analysis and micro/meso less aggregate analysis, the 'real information' used is at the micro level. It is transactions between actors (firms, consumers, public organisations, non-profit organisations, employees) which form the basis for the monetary input-output tables, and it is their direct environmental interventions which link the activity to its natural environment. So the central question here is: at what level can data be gathered, allowing for a most detailed analysis? We assume that the base framework into which data for input-output analysis are put, as specified in Section 2.2, consists in the supply table and use table, with emissions in a satellite linked to the sectors, and the mass flows linked to the product flows. All other types of environmentally extended input-output tables and related PIOTs can be derived from this basic set. As there are several types of IO tables and as there are competing methods to produce them, it is quite essential to link the data to this base level, allowing operations as users of

(68) Note that this new organisation of the report implies that task 3 and part of task 4 of the original project proposal are now combined in this chapter.

these data consider most useful. So the question is how to set up and fill these supply and use tables. In the following we use the terms supply and use tables and input-output tables referring to the tables extended with environmental data.

Basically, the lowest level where the IO data are gathered is the firm or the installation within the firm. All other sector information is derived information: it is either augmented as through modelling of missing information, or it is an aggregation, linking different sources in a higher-level class. (A third transformation is for updating where, for example, a rise in total sales of several activity classes may be used to adapt sales within a class, assuming the changes are equal between these classes.) The data gathered refer to the units with an independent administration, usually a smaller firm, a business unit, or an installation at a specific location. For a given lowest-level data unit, for example an installation, the first step is to classify to which sector it belongs. The level of detail used in that classification is the maximum resolution possible in later analysis. The classification should preferably refer to an operation or activity, like 'painting' or 'distilling'. However, in practice, the activity class often refers to the product resulting, like 'production of chairs', 'production of window panes' and 'production of cars'. The highest-level resolution is not restricted very much, as operations types are limitless. However, the trends towards integrated production and flexible production pose serious problems of detailed classification. For example, in steelmaking there is a tendency for coil coating the plate material coming from the rolling press, while in manufacturing there is a tendency to integrate forming and coating. Some steelmakers integrate coating, cutting, forming and mounting of parts in one flexible productionline, sometimes producing car parts, sometimes building materials, and sometimes furniture. Current sector classification systems have difficulties in this respect. The best available classification is the new NACE classification (NACE rev. 2) here referred to as new-NACE, which, aligned with the NAICS classification, will probably become the UN standard within a few years. It has 617 production sectors. (The new UN standard for ISIC will now have 420 classes.) Some countries have a more detailed classification for sectors which, in their country, have a dominant role in the economy, as for the pulp and paper industry in the Scandinavian countries.

What is purchased and sold are products, goods and services, the difference between the value of these being value added paid to labour and capital, plus product taxes paid. Conventions in registering payments to labour and capital are determined by tax rules, reporting rules and management requirements neither of which is discussed here. The recording of purchases ('use' in IO terms) and sales ('supply' in IO terms) also has these backgrounds. There is limited reason for firms to systematically classify purchases and sales according to detailed classifications. There are a few exceptions, related to duties and excises on imports and exports and for classifying products in buyers guides. So base administrations do contain some information on products but do not systematically classify.

As for environmental interventions, firms record a number of them — if they are required to do so in their permits. Continuous measurement is limited to some stationary sources. For most sources, it is incidental measurements (often combined with some modelling) which produces data. For mobile sources, real measurement is even more seldom, with measurements per type in a typical situation being the basis for most emission inventories. Some emissions can be measured indirectly quite adequately. Spraying of coatings will emit all solvents, unless there are techniques to contain them. Emissions can then be modelled, based on solvent purchases and the use and effectiveness of, for example, incineration installations for burning these solvents. Sulphur dioxide emissions may be measured but usually data are based on sulphur content of the fuel and the expected effectiveness of the desulphurisation technology applied. Burning of coal, oil and gas will emit virtually all carbon contained as CO_2.

Data on sales and purchases of oil, coal and gas are easily available in administrations.

The composition of goods in terms of total mass, chemical composition and elementary composition, required for the production of PIOTs and hybrid IO tables, is administered even less systematically. To link to the monetary framework, the price of the product (EUR/kg product) and composition of the product (kg substance/kg product) is required. For some base materials like aluminium, iron, steel and copper, the price per kg and composition are well known. For most manufactured goods, being combinations of several base materials, special chemicals and organic products, the composition is less well known. Such information can be gathered based on the composition of the products sold and purchased. Incidentally this may be the case. In general this type of analysis is quite cumbersome with no real incentives for firms to engage in. For the analysis of physical flows, the basis hence will not be in the firm's administration directly; it is based on linking monetary flows and administration of numbers of pieces etc. to other sources specifying the composition of products. This will be based on sampling for each of the product classes distinguished. As CPC and HS classifications contain up to 7 000 classes, this is a cumbersome activity, especially as even such detailed classes are not yet homogeneous. Children's bicycles, spectacles, cups and saucers, cutlery — take any class of consumer goods and it is really diverse. The same holds for intermediate goods, i.e. goods traded between firms. Simple measurement is on total mass. Relatively simple, but several orders of magnitude more expensive, is the analysis of elements in products. As at least their mass is constant, modelling can be based on mass balancing. For chemical compounds which form, transform and break down, the systematic analysis seems very tedious and difficult to put into the input-output framework. The best that seems practically possible is samples on main product flows, especially as related to exports and imports. In terms of a detailed sectoral PIOT, the quality will remain limited. A substantial effort is required to systematically produce mass flows for micro/meso types of analysis for main elements. However, if mass flow studies now executed used the new-NACE framework for classification (with added detail where required for the specific purpose of such studies) a gradual build-up of knowledge could well be possible.

5.2.3 Conclusions on basic data for supply and use tables

In this section, we will discuss the conclusions that can be drawn, on the basis of the former section, for how to produce basic data for supply and use tables, which form the basis for the construction of an EU-25 IO table.

The first conclusion is that, for the basic data units, firms and their installations, there is detailed information on sales and purchases, both in terms of the product flows and in terms of the firms of origin and destination. Neither firms and installations nor products are classified systematically however.

So, the second conclusion, a separate step of classification is always required before data can be entered into supply and use tables. This classification refers both to the activities, clustering them into standard sector classes (like new-NACE), and to the sales and purchases, clustering them into standard product classes (CPC and HS). It would be of great help if CPC and HS were integrated into one system. The current correspondence between them may suffice for macro/meso studies but not, for example, for detailed consumption analysis.

Thirdly, the quality of the basic data set resulting for the supply and use depends on three elements. It is the quality of the unclassified data, the quality of the classification procedure, and the representativeness of the sample analysed for the economy investigated. The unclassified data have a level of detail surpassing any classification. The quality of the classification procedure will depend on the clear description of the classes. But even very precise described classes will still lead to different attribution of items (e.g. processes, products) into classes by the different decentralised national statistical bureaus. The representativeness of the sample depends on the number of firms investigated and their stratification in terms of coverage of all sector classes. This holds irrespective of the level of later aggregation. Also, for a 10x10 IO table, the quality depends on the underlying data in relation to the diversity of the underlying reality. Aggregating sectors increases their inhomogeneity, requiring larger samples to make them representative. The inhomogeneity can be measured only based on a specific classification: how diverse are the firms in this specific class? The more detailed the sector classification used, the more homogeneous the sector will be in terms of diversity of firms. Statistical bureaus internally use a very detailed sector classification, much more detailed than new-NACE. So, for a given NACE class, they know the composition of that class one level deeper, **and** have some basic data on the larger group of firms involved in that class, such as turnover and number of employees. When making a sample for filling in the NACE class, they can use their deeper-level data to see how representative the sample is. Conversely, they can use these deeper data to make the sample into a stratified sample. A given sample may be used to either supply data at a detailed sector level, with lower reliability and higher validity, or at a higher level of aggregation, with a higher reliability and a lower validity. In both cases, validity and reliability increase with a larger base sample from which to derive the data.

Apart from the substantial but more or less one-off cost of reclassification, production of more detailed sector data does not seem to involve substantially higher cost. A rough indication for established statistical bureaus is several hundred thousand euro per country. For countries now establishing their IO data gathering procedures, the cost would be lower, as they will have to establish samples and classify them anyway.

A fourth conclusion on basic data is that, ideally, both sector characteristics, product flows, and environmental interventions refer to the same base unit of information, the single firm or installation. Gathering the information on this base information carrier in one round seems a most logical choice from a pure data gathering point of view. It would avoid all statistical procedures that are now required to link the make data, the use data and the environmental data.

5.2.4 Routes and steps for producing input-output tables for the EU-25

Routes

Assuming data gathering is to take place at the national level, the results are to be transformed to an EU level, preferably with a minimum loss of information. There are three routes for producing EU-25 IO tables, see Figure 5.1 below, making the jump from national level to EU level in different steps of the data transformation procedure:

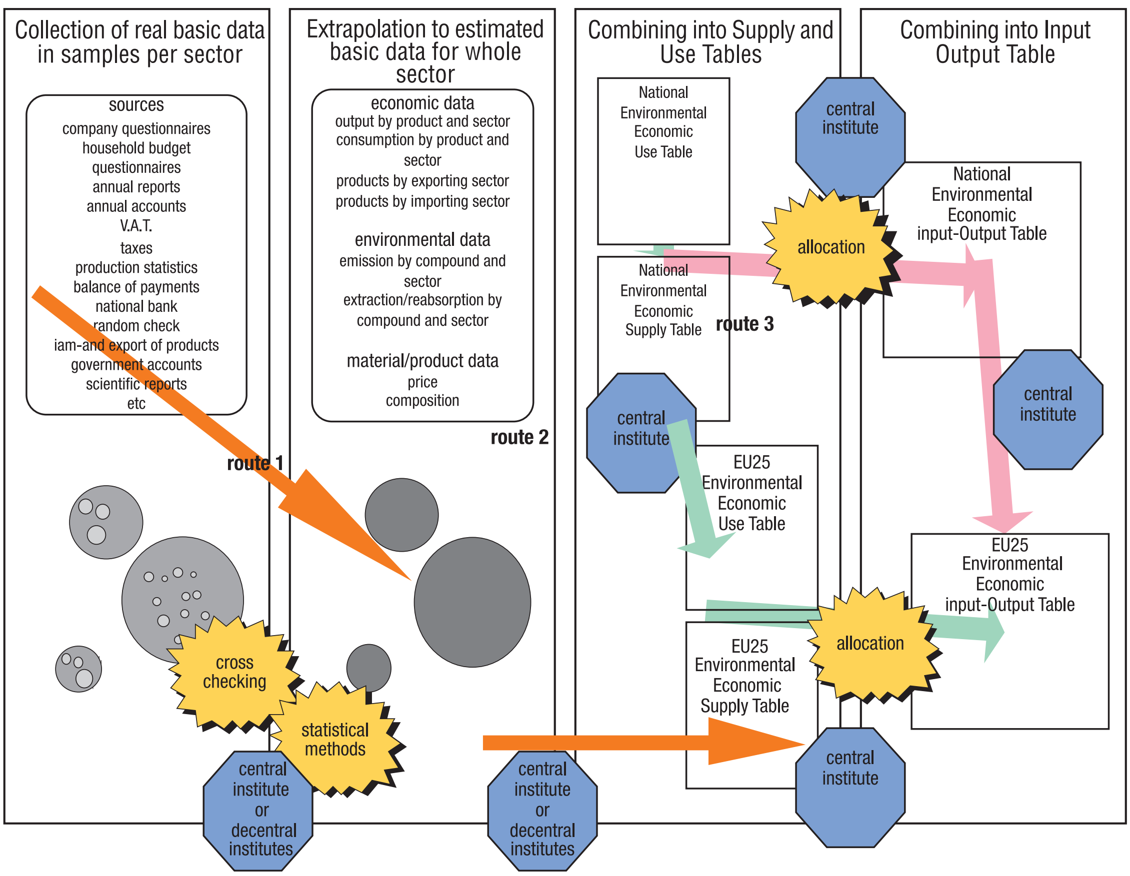
1. producing supply and use tables for the EU-25 directly from the sampled data in several countries, and producing the desired supply and use tables and the IO tables from these;
2. aggregating national supply and use tables into EU-25 supply and use tables and then producing the EU-25 IO tables from these;
3. producing national IO tables, and aggregating these into EU-25 IO tables.

Referring to the six steps specified in Chapter 2 the routes for the jump from the national level to the EU level can be made after step 1 (as in route 1), after step 3 (as in route 2, or equivalently after step 4), or after step 5 (as in route 3). The third route has some disadvantages, for instance discrepancies created by having different methods for making IO tables in different countries. The reason to see the supply and use tables as the basis for several types of IO tables using different methods in their production also holds at the level of the EU. So we leave out the third option.

The starting point for building the supply table and use table are the classified sample data on firms and installations resulting from step 1, the basic data in samples per sector in Figure

5.2.1. This sample of firms and installations is representative for the sector as a whole, to some extent. In most cases, these real data are available for a too-limited set of installations only. Statistical methods are then used to estimate missing data and to model data to the sector level as a whole. The result is a set of estimated basic data for the whole sector. These estimated basic data are combined into the rectangular supply table and use table. The sectors in these tables are called heterogeneous sectors, i.e. 'real' sectors that usually have more than one economic output (main product and by-products, or just several products). To combine these supply and use tables into an input-output table, a preceding transformation step is required. In this transformation step, the 'real' heterogeneous sectors are transformed into 'virtual' homogeneous sectors, i.e. sectors that have a single product as their output. So this transformation into an input-output table involves the redefinition into homogeneous sectors and the allocation (see Box 5.2.1) of economic inputs and environmental inputs and outputs to the newly defined homogeneous sectors. The type of redefinition/allocation method may have a large influence on the size and coefficients in the square matrix resulting. If economic data and environmental data are not treated simultaneously, the possibility of mistakes increases, for example linking real emissions data to a made-homogeneous sector, which still has the usual name, but may be a fraction of its original size. For example, the chlorine and caustic soda production sector has these two outputs as more or less equivalent outputs, though the sector is named chlorine production. Subtracting the more expensive caustic soda single production, which exists, (or similarly economic allocation) will leave about half of the production volume in the sector, chlorine alone, to which then all emissions

Figure 5.2.1Data collection and transformation steps in the development of an environmentally extended input-output table for the EU-25



would be allocated. After having made sectors homogeneous, the addition of environmental data is possible only with severe and unknown flaws.

In terms of the three routes distinguished above, route 1 produces sectoral data in supply and use tables directly at the EU-25 level. In the sample, the origin and destination of its product inputs and outputs are specified as to firm and may be specified not only by sector of origin and destination but also by country of origin and destination. In this way, the basic data on imports and exports can be used directly, but information on within-EU imports and exports is lost.

Box 5.2.1: Redefinition and allocation

The redefinition and allocation step deals with the problem of making a rectangular matrix square. The economic part of the environmentally extended supply and use tables is a rectangular matrix describing the sales respectively purchases of products by sectors. There are more products than sectors so the matrix is rectangular. To combine the supply and use tables into an input-output table, the rectangular matrices should be transformed into a square matrix. After all, in an input-output table, the rows and columns have the same variable, sectors by sectors, or products by products. This involves disaggregation of sectors to the product level or aggregation of products to the sector level, or a combination of both.

Heijungs (2001) describes several solutions to solve this problem (pp. 114–135). For developing input-output tables the most relevant are:

a) reducing the number of products by aggregating products;

b) expanding the number of sectors (processes) by splitting sectors (processes);

c) treating by- products as main products of another sector.

The first way of solving the problem of rectangularity is to merge products, so as to merge rows. Assume that the number m of products exceeds the number n of sectors. Now a square matrix can be formed by aggregation of the product classification so that there will be exactly n products. It will be clear that this is not a very elegant solution: things that are different are lumped together and treated as being similar for computational reasons. It also illustrates the relative meaning of 'heterogeneous' and 'homogeneous' sectors. If products such as potatoes, cereals, milk and flowers are lumped into 'agricultural products' the agricultural sector is a 'homogeneous' sector. With the need for high resolution of the matrix (500x500 instead of 60x60 as in ESA95) the need for some form of allocation will become evident.

The second solution is to split a multiple output sector (process) into a number of virtual single output sectors (processes). Reallocation (sometimes referred to as redefinition) of secondary production requires that the inputs of a sector (process) are allocated between the production of main and by-product products, assuming there are two products only and one of them is the main product. In the case of an environmentally extended matrix, the extractions (environmental inputs) and emissions (environmental outputs) should also be allocated in the same way. In effect, it is necessary to break the sector (process) into two independent sub-sectors — one a producer of the first product and the other a producer of the second product. In economic input-output analysis, this allocation is often referred to as industry–technology assumption or technology–technology assumption. In life cycle assessment of product systems (LCA) this allocation is called economic allocation. The number of processes after splitting up equals the number of products distinguished.

The third solution assumes that there is a sector (process) A that produces a single output Y. The input of this sector (process) is subtracted from a multiple output sector B (process) that produces output X and Y. In the case of an environmentally extended matrix, the extractions (environmental inputs) and emissions (environmental outputs) of sector (process) A should also be subtracted. Thus, a newly defined single output sector B′ results, producing only product X. In IO economic literature, this procedure is referred to as product–technology assumption. In the literature of life cycle assessment, the terms substitution method and avoided impacts are used in connection to this procedure. If this procedure can be followed, the number of sectors remains constant. However, for many products there is not one sector/process which produces only this output. For example, a dairy farm produces both beef meat and milk, by necessity, as really joint products. For such sectors, economic allocation can be applied, or the less satisfactory addition procedure.

In route 2 and 3, the first step is the specification of rectangular supply and use tables at the country level. How to deal here with import and export data as contained in the sample data? They may be compressed to *exports* in the supply table and *imports* in the use table. Then data on the sectors of origin and destination abroad is lost, the opposite to route 1. The other option is to specify the sectors of destination the country's export goes to, for each of the countries distinguished. This procedure has the advantage of multi-level specification of all inputs and outputs, but implies a huge data set. For the new-NACE 600 sectors and 25 countries, the total number of sectors is already over 15 000, beyond current computational capacity with a desktop PC. This capacity problem will however be solved within a few years. Not trusting on this development, routes 2 and 3 would discard import and export information at the base level and would produce sector data with only one, or better two (exports to other EU countries and exports abroad) export sectors. How to deal with imports and exports then becomes a matter of adding independently acquired import and export statistics and linking these to the sectors based on assumptions, modelling and statistical procedures. If base data are available, this seems an easily avoidable loss of information.

The next step is to make the supply table and use table rectangular, which can be done in several ways, see the box at the end of this section. There is no fundamental difference in doing this at country level or EU level. Current practice in IO tables production is too much focused on producing relatively small tables and is based on by-hand redefinition of sectors. This makes this step non-transparent, with diverging practices between countries and probably between the scientists involved in this tedious job. Shifting to the product–technology assumption, that is to economic allocation in LCA terms, would lead to larger squared supply and use tables, which are not a problem with current computational power on PCs, as opposed to the situation only five years ago. This option, not usual in national accounting statistics because all is added up again, clearly is preferable for detailed technology analysis. Whatever the procedure followed and the number of sectors resulting, the matrix produced has homogeneous sectors, see Chapter 2 and the text box below.

Step 5, the production of input-output tables, involves the linking of supply data to use data. If data have been gathered on the inputs and outputs of individual installations, this procedure involves using these base data. If they are not linked at that base data level, as is the case in all current supply and use tables produced by statistical offices, a statistical procedure is followed.

5.2.5 Conclusions on routes and steps

What are the conclusions on the routes and steps on the road towards detailed IO tables with environmental extensions?

Firstly, for setting up the EU-25 tables, route 1 seems the most adequate and simple in procedure, building the EU-25 supply and use tables, and derived IO tables directly from sample data on firms and installations. The route through import-export data mostly not linked to sectors may be avoided in this way. Later disaggregation to the country level seems relatively easy.

Secondly, the sample data ideally cover both economic data and environmental data combined for each record. If these data are added later, at the level of homogeneous sectors or at the level of IO tables constructed from these, unknown errors may be induced.

Thirdly, all steps beyond the rectangular supply table and use table, with the not yet homogenised sectors, is laden with methods choices and practical choices which are not now geared to environmental analysis, nor do they reckon with the computational capacity as has become available in the last decades.

Fourthly, computational limitations exist for the coming years in building up detailed new-NACE level IO tables for the countries of the EU connected by imports and exports, as these would involve over 15 000 sectors. However, computing capacity will catch up with this problem within a few years.

Fifthly, if detailed EU tables are constructed, their translation back into country level on the basis of the ESA95 country data is well possible, in contrast to the situation in the United States where such state-level data are not available and strong assumptions have to be made for this procedure.

5.3 Practical goals and limitations

5.3.1 Introduction

In developing environmentally extended input-output tables, three main factors determine the quality of the tables constructed:

a) the level of detail in sectors and products discerned in the make and use tables;

b) the broadness of environmental interventions covered;

c) the way product flows are described in terms of physical flows, as PIOTs, next to their monetary value.

Before discussing options for developing EEIO tables as a whole, in the next three sections, we will discuss the practical goals and limitations with regard to these three elements.

5.3.2 Sector and product definitions

How far may we go into detailing sectors? There is no a priori limit, but there are practical limitations. One most obvious limitation resulting from our survey is that whenever detailed data are gathered, 'tailor made' classes are developed for the specific purpose at hand, often going well beyond the detail of NACE. For example, the EMEP, EPER, UNFCCC, RAINS, GAINS, and the national PRTR data cannot be combined, as they all refer to very detailed but different classes. Though basic data are gathered at a level of detail going much beyond the 500 sector level, results are mainly reported at a very aggregate level. As the tailor-made classes are not systematically related, the actual data gathered cannot directly be related to the same classes between the different data sets, not even at an aggregate level. There is limited cumulative knowledge build-up and limited information transfer between domains. One problem is that even the ISIC classification system for sectors as agreed upon at UNSD is not being used, but differently formed aggregates are applied. Also, the classification system now distinguishes only 298 sectors. However, it is highly probable that, in the next year or so, a new classification system will be agreed upon, combining the European Union NACE, the North American NAICS, the Australia–New Zealand ANZSIC and the Japanese JSIC classifications (69), replacing the current 298 ISIC classes. This system is expected to cover slightly more than 500 sectors, as new versions of NACE and NAICS already cover over 500 sectors. For building EEIO tables, it seems wise to adhere to this new IO classification system as much as possible, both in data gathering and data reporting, in all domains. So as a practical goal for a future optimised data system, we assume the new harmonised NACE-NAICS system. It should be seen as the precursor of the new ISIC, which will take UN procedures of probably a few years before the new version is authoritatively established.

Detailing the number of product flows has advanced much further, but also for different purposes, different variants of product classifications have developed. It seems that the CPC, and if possible the HS (Harmonised System, used for international trade classification), of the UN can now be used as a systematic basis. If other categories are required, as with EU systems such as CPA, these would best be defined only as further subdivisions of the most detailed level

(69) A substantial revision of NACE rev 1.1 into NACE rev. 2 is foreseen in 2007, see http://forum.europa.eu.int/irc/dsis/nacecpacon/info/data/en/index.htm

of CPC. CPA will then have to be disconnected from its current links to NACE, which is required anyway due to the current NACE revision. Conceptually, the product classification should best be kept fully independent from the sector definitions, though of course empirically there will be a large correspondence. The square sector by sector input-output table by necessity has one to one correspondence between product and sector, by adapting sector structure and product categories.

CPC classes may directly be used for consumption analysis. However, a number of final consumption classifications have been developed under the COICOP umbrella. It seems wise to use the COICOP classifications for aggregating purposes only, and supply basic data in terms of CPC only, possibly further disaggregating (but never aggregating) CPC to cover specific COICOP categories.

5.3.3 Emissions and extractions

Finally, which emissions and resource extractions to cover? For emissions, current data-gathering procedures are mostly focused at specific environmental flows, such as EMEP, RAINS and GAINS, or have specified a limited set of relevant emissions, such as EPER and, differently between countries, PRTRs. The combination of several current data-gathering programmes would lead to a set of around 50 substances emitted. A pollutant nomenclature is currently being developed by the European Environment Agency. It is designed to be used in conjunction with NOSE. Until then, the nomenclature can largely be based on CAS numbers, which should be done explicitly.

For resource extractions, no such classifications and nomenclature exists, with the US Geological Survey, the World Resources Institute and the United Nations Statistical Office setting some practical standards. Effectively, ores are taken by the content of the desired elements, as with many metals, sulphur and phosphorus. Developing a classification system and nomenclature would be a prerequisite for systematic data gathering and presentation beyond this level of elements specification.

The current data on primary resource extraction are based on case-specific categorisation, for example, a different set-up for copper and for iron ores. They hence lack a firm statistical basis, as systematic research on flows can hardly be based on single case applications. Only sampling techniques within a well-defined framework can improve the data availability and quality, and can do so in a cost-effective manner. When product flows are systematically monitored at their physical level, annexed to the economic accounts, the materials and substance flows can be derived by investigating the composition of (most relevant) product flows using statistical approaches. This level of analysis will be referred to only incidentally.

5.3.4 PIOTs

Physical input-output tables are the equivalent of the monetary product flows in economic input-output tables as to their physical composition (see also Chapter 2). A physical supply table hence describes in-mass flow in terms of the deliveries of one sector to others, and the physical use table the intake of one sector from others. The question is now, in terms of which entities are the mass flows measured in such physical tables. Various parameters can be chosen to represent a product flow:

a) total mass — mostly kg, but possibly also volume;

b) materials — examples are wood, clay, baked stone, aluminium, pig iron, stainless steel, fertilisers;

c) chemical compounds — examples are methanol, polypropene, phthalates;

d) elements — hydrogen, helium, etc.;

e) energy — possibly as exergy.

At the highest level of aggregation, total mass of product flows is relatively easy to specify, but has only a limited environmental correspondence. Firstly, it indicates overall mass inflow and outflow in society. It is then equal to the mass total of primary resource extractions and emissions and final wastes as specified in EEIO tables, a nice overlap. It does not seem useful to add the intermediate mass flows, as it seems hard to imagine technology-specific environmental 'mass policy'.

The next option is to specify product flows in terms of materials, as has been done extensively. The materials which may be followed through the economy will then be close to mass balancing, such as materials consisting of elements, like iron, aluminium, copper and lead. This seems a good option for policy purposes, as the ultimate application of metals may be highly diluted, with copper for example being present in all electrical apparatus. The copper application in manufactured products drives the primary production which, for many materials, often has high environmental impacts.

The third option, specifying product flows in terms of chemical compounds, is not possible to follow in any systematic way, due to their large number. The specification seems relevant for compounds which stay stable through at least a number of consecutive process/product steps, like plastics, which however may also be seen as materials. The selection would be based on either the environmental impacts of primary production, but then often referring to materials; the options for secondary production to avoid primary production; the harmfulness in applications (phthalates); or the environmental burdens in waste processing (organo-chlorine compounds).

The fourth option, elements, has the attractive property of mass conservation and hence of mass balancing. Also, the number of elements is relatively small and the number of elements playing a major role broadly through the economy is even more limited. In many instances, the measurement of elements may be easier and more systematic than is possible for materials and chemical compounds, like for metals, carbon, sulphur, nitrogen and phosphorus. A limited number of compounds could cover a broad set of materials and link to an environmentally relevant set of compounds. When starting to make PIOTs in the IOA framework systematically, the elements choice and the related materials flow analysis seem most attractive.

Finally, the product flows may be specified in terms of their energy content (direct only, not adding the embodied energy from upstream processes) or in terms of the exergy content, indicating the amount of useful work the product could have (100 % for electricity, and 30 % for wood, as shares of total energy). Such an analysis has the attractiveness of a single indicator for all products on the one hand and the relevance to all environmental problems related to energy use, which is much more than the climate problem. Exergy analysis has developed in chemical process engineering and might well be extended to the societal metabolism. Before starting administratively embedded data gathering, separate studies would be due to assess the potential usefulness which clearly is there.

The use of PIOTs linked to EEIO tables would be to indicate options for environmental policy, and place them in the perspective of their overall environmental consequences in a systematic way. The options most interesting now relate to materials flow analysis, to support policies aimed at reducing the environmental impacts related to materials, possibly most practically implemented in terms of substance flow analysis of the elements playing a major role in materials such as metals, carbon and sulphur.

5.4 Status quo: CEDA EU-25

5.4.1 Introduction

The CEDA EU-25 model was developed within the context of the project 'Environmental impacts of products' (EIPRO; see Tukker et al., 2005; Huppes et al., 2006). Its aim is to support the selection of products for integrated product policy.

5.4.2 Description of the model and capabilities

CEDA EU-25 was developed as a part of the EIPRO study (Tukker et al., 2005) and was basically built around a rough European IO table and total European emissions, which were detailed into a 480x480 table using the detailed US table that was available from CEDA. This CEDA 3.0 model provides a 480x480 IO table of the US economy and associated with a broad set environmental emissions (Suh, 2004). The US technology matrix from CEDA was forced within the main structure of the European economy, using the latest authoritative IO tables from several European countries (OECD, 1995, 35 sectors). Furthermore, a number of sectors were adapted where European technology is obviously different from US technology. The environmental interventions from CEDA were forced to known total EU-25 environmental interventions (Oers et al., 2001; Huijbregts et al., 2001). For the construction of the waste management technology matrices, besides CEDA 3.0, Eurostat waste management statistics (Eurostat, 2003), price information for waste collection (Dutch household fees, for Dutch household waste generation) and prices of post-consumer recyclable commodities (Wisconsin state government survey; British market) have also been used. Both CEDA 3.0 and van Oers et al. (2001) are based on a very large number of sources and use some modelling as involving technology transfers between countries, as usually the best available data refer to a limited number of countries and sectors only. The data sources used to create the consumption phase have mainly been derived from EcoInvent (2001). Direct emissions from households have been specified for four consumption activities which contribute significantly to direct household emissions i.e. heating, cooking, car driving and use of pesticides. Data on the share of private households in total pesticides use were taken from Aspelin & Grube (1999). Use of electricity by household appliances has been taken from Fawcett et al. (2000). With these data, the full EEIO analysis framework of CEDA EU-25 became ready for use — provided that consumption expenditure data are available in the (US) BEA classification — slightly deviating from NAICS — that underlies this IO table. Hence, a transformation step was included that transforms European expenditure data, available in COICOP format, into CEDA expenditure categories. Making this transformation table 'by hand' was necessary as a COICOP-BEA transformation tables do not exist. The result is a very detailed EEIO table, both in terms of number of sectors (nearly 500) and in number of environmental interventions (around 1 300), which covers the EU-25.

CEDA EU-25 has a number of limitations restricting its potential use for new applications.

- First, the primary resource extractions specified refer to energy resources only, as most ores are not mined in Europe and the United States, and hence were not covered in the data well enough to be included.
- Second, the emission data of all activities cover production activities relatively extensively but consumptions activities and post-consumer waste management in a limited way only.
- Third, the way European data have been used has remained limited. For many activity domains European data on emissions are available which may be transformed to the CEDA format.
- Fourth, the sector structure of the IO tables could reflect the European situation in a better way than now has been accomplished.
- Fifth, the link to activities abroad could be better specified, when transforming other IO data to the CEDA framework.
- Sixth, the fast procedure followed makes the current model rather difficult to update and hence it cannot easily be developed to produce time series.
- Finally, there are no PIOTs linked to the current model version.

At a practical level, the software to support the model can be greatly improved, allowing for contribution analysis, sensitivity analysis, and for more easily linking in with hybrid analysis applications.

Nevertheless, with all its limitations, the model is useful already. Its main function is the overall and comparative life cycle perspective on the environmental consequences of consumption activities at a high level of sector detail. This feature is unique for the EU-25. Though one should be careful when interpreting the results at the highest level of detail given, the results are robust enough to distinguish high and low-level impact products, and to make this analysis in terms of the different environmental impact categories involved. When combined with additional information, as when developing product policy scenarios, the results can be placed in the overall framework in a consistent way. In terms of the policy stages developed in Chapter 4, the model can support environmental problem analysis and identification and help the prospective effect analysis of policies as by better seeing them in perspective and seeing their side effects. Since the CEDA EU-25 model has been built for a specific base year, monitoring is not possible. Table 5.4.1 gives an overview of the characteristics of this model. For broader application, the main limitations as surveyed should be alleviated, which is possible to a substantial extent.

5.4.3 Practical steps and effort required for development

Since this section describes the status quo, the practical steps and effort for further development are not relevant. Section 5.6 describes the possible further development of the CEDA model into CEDA EU-25++.

5.5 Autonomous development: Eurostat NAMEA

5.5.1 Introduction

Environmentally extended input-output tables started being produced by the Dutch Central Bureau of Statistics in the 1990s, under the name 'National Accounting Matrix with Environmental Accounts' (NAMEA). As discussed in Chapter 3, at European level the added value of such accounts was quickly picked up and Eurostat now fosters work on NAMEA at EU level and within Member States. The NAMEA concept, as pioneered by the Netherlands in the early 1990s, inherently links environmental extensions to an IO table, whereas Eurostat uses the term NAMEA for emission records compatible with sector classifications used in economic accounts, but not yet linked to them.

Table 5.4.1: Characteristics of CEDA EU-25

Aspect	Characteristic
Geographical coverage	EU-25
Sector resolution	500x500
Sector classification	BEA (incompatible with NACE, NAICS and ISIC)
Number of environmental interventions	> 1 300 emissions to air, water and soil, several dozen resource uses
Physical intersector flows	Absent
Time series / potential for monitoring	Due to the approach of 'Europeanising' foreign data, it is rather difficult to update the economic and emission data on a regular basis.
Available	Now
Remarks	The IO part of CEDA EU-25 has been Europeanised at the 35x35 sector level and with regard to emission totals, but uses US data for realising the high resolution. The model is not yet fully automated and has made various pragmatic assumptions for estimating emissions in the use and waste phase The model is owned by a private party.

5.5.2 Description of the model and capabilities

As discussed in Chapter 3, in the current situation no comprehensive European environmentally extended input-output tables exists. Eurostat has collected NAMEAs for air emissions from the EU-15, which cover some 10–20 substances (greenhouse gases, acidifying substances, some heavy metals and VOC) for 60 sectors. These NAMEAs have not yet been linked to IO tables, nor have the IO tables with the related air emissions been integrated to an EEIO table for air emissions for the EU-25. The accession countries have now started to produce NAMEAs, with results coming in more systematically in the coming years. The work done thus far is, of course, a significant step forward compared to a greenfield situation but, at present, the structure available probably has very limited capabilities to give comprehensive support to any of the policy fields listed in Chapter 4. For this purpose, at least a consolidated table for the EU must be available that includes, apart from air emissions also resource use, emissions to water and soil, and emissions in the use and waste stage, which largely lack in the current NAMEAs which are focused on air emissions. Alternatively, the existing 60x60 IO tables for the different EU Member States should be consolidated to a table for the EU, and emissions and interventions per sector could be added from other data sources that give EU totals. This would also form a basis for attaching material flows, such as PIOTs. However, there is to our knowledge no action of Eurostat that follows this route.

It is difficult to predict how this situation will develop. Efforts are clearly under way to get data from the 10 new EU Member States, and to extend the current framework with data on emissions to water, on resource use and waste flows. It is likely that, at some point in time, a more complete environmentally extended input-output data set for all EU Member States will be available at Eurostat; it is however difficult to predict when. A time horizon of five years or more seems likely, and may even be optimistic — after all, the individual country tables still have to be consolidated to obtain a truly EU-wide IO table with environmental extensions. On the basis of the work on NAMEA-Air, it seems safe to assume that such an environmentally extended input-output table will have the following characteristics:

- number of sectors: 60x60, based on an aggregated version of NACE;
- number of environmental interventions: 10–20 to air, 10–20 to water, soil: not clear, several key primary resources;
- inclusion of emissions from the use and waste stage: unclear.

Under the condition that the individual Member State tables will be consolidated to an EU-25 model, and the use and waste stage will be adequately covered, such a model would be able to give a relatively generic support to product policy, sector policy, other environmental policy analysis (foresight), and probably generic economic analyses too. It is also capable of relating primary resource use to final demand categories. Since the model does not include physical intersector flows, the model is less apt to link emissions to resource uses, and it cannot play a clear supportive role for substance policy. However, compared to CEDA EU-25, the model has severe drawbacks in the much lower resolution in sectors, and the limited number of environmental interventions covered. The advantage over CEDA EU-25 is its inherent use of European data. Another important advantage is that it will probably be regularly updated, so that time series will become available. Within the EU-15, most Member States have reported yearly NAMEA-Air data. ESA95 requires a five-yearly update of the IO table from each Member State. This availability of time series makes it most suitable for monitoring of overall development. For this purpose, the high level of aggregation of sectors is not a problem. However, for technology-oriented decisions, such as specific policies or environmental product design, such aggregate data are less apt and time series less important.

The advantage of this autonomous development is that it may produce one of the first environmentally extended input-output tables for an area as large as the EU-25 which are formally set up by an authoritative statistical bureau — where

Table 5.5.1: Characteristics of the European NAMEA

Aspect	Characteristic
Geographical coverage	EU-25
Sector resolution	60x60
Sector classification	NACE / CPA
Number of environmental interventions	10–20 emissions to air, water and possibly soil; several resources as extracted
Physical intersector flows	Absent
Time series / potential for monitoring	Environmental extensions: yearly Economic data: every five years under current ESA95 rules
Available	At best in five years or more for EU-25
Remarks	Not sure if Eurostat will combine national tables to an EU-25 table. Use and waste stage have to be modelled separately in any case

the United States produces detailed IO tables and detailed environmental information, the link between them, as environmental extensions, were attached by private parties. Table 5.5.1 gives the characteristics of this model.

5.5.3 Practical steps and effort required for development

Within the current framework set up for producing NAMEAs and IO tables by Eurostat, no data set using detailed sector definitions can be produced. The limitations in the environmental interventions covered will remain substantial, as compared to a broad set required to give insight in effects of activities on several environmental impact categories. With the current more or less voluntary status of NAMEA, and the weak link to ESA95 reporting, development may be slow, always slower then intended. Without additional efforts, the goal of full NAMEA implemented in the ESA95 framework for the EU-25 may be far away. However, there is no basic reason why this situation should be accepted, as substantial efforts at gathering of environmental data on economic activities takes place (see Chapter 3). Also, an agreed-upon framework for IO accounting has developed as new-NACE. The basic ingredients for a jump ahead are present. This is the case all the more as parallel efforts on implementing PIOTs may well be combined with the NAMEA efforts.

In this section, we will not pursue these options further, as in themselves they will not lead to the high resolution IO tables with broad environmental extensions which form our prime focus. The NAMEAs which are and will be produced are necessary and useful already in themselves. Their applications relate especially to monitoring of main elements in environmental performance, both overall performance of the EU and the countries in the EU, and in terms of performance of the sectors involved. Detailed support on the policy-induced development of products and sector activities will be possible in a very limited way only.

However, we should note already that NAMEAs are an essential ingredient in improvement options. They support other options, such as a much better 'Europeanised' improved version of CEDA EU-25 and as part of the study project approach for better using available data. In the ideal 'royal route', NAMEA does not disappear but transforms from ugly duck into royal swan.

5.6 Improvement option 1: High resolution CEDA EU-25++

5.6.1 Introduction

The CEDA EU-25 model could be developed further as by forcing the US economic data on Eurostat ESA95 data for the 60x60 level, and us-

Table 5.6.1: Characteristics of CEDA EU-25++

Aspect	Characteristic
Geographical coverage	EU-25
Sector resolution	500x500
Sector classification	BEA (incompatible with NACE, NAICS and ISIC); NACE at 60x60 level
Number of environmental interventions	> 1 300 emissions to air, water and soil, several dozen resource uses
Physical intersector flows	Absent
Time series / potential for monitoring	Environmental extensions: yearly, but probably not at 500 sector level. Economic data: every five years at 60x60 sector level under current ESA95 rules
Available	In around two years
Remarks	Further develops the CEDA EU-25 of the EIPRO study

ing European emission data per sector as reported in NAMEA and in data sources such as EPER directly. The use phase and post-consumer disposal phase would also be modelled with more European data. An improved incorporation of waste management and recycling data can also be realised, using technical coefficients on treatment techniques in Europe. A number of technical improvements are also possible, as related to the way the shift from consumer prices to producer prices has been made and in terms of the linking of COICOP categories to BEA/NAICS categories, and preferably for all into the new NACE framework. Such improvements require flexible, integrated software surroundings.

This option may be seen as a one-time project option, with usability for a certain period of time, and a possible later update. The most interesting version would be to develop the CEDA EU-25++ model in a double layer. The first layer involves the regular update of the base data for EU-25, base data in the sense of practically available main secondary sources. Two key elements therein are ESA95 supply and use or IO tables per EU Member States, and NAMEA data specified in the same ESA framework. These will have to be aggregated into EEIO tables for the EU-25 at a 60x60 sector resolution. The second layer then is to add more resolution to the IO tables, and link in more environmental interventions. This second layer may use the US data available in the CEDA 3.0 model, combined with total EU emissions available via, for example, EPER. This was the procedure followed in the CEDA EU-25 study. Alternatively, data sets could be used from other countries producing detailed EEIO tables, such as Japan and Australia. Explicit links to countries abroad, resource-producing countries such as Russia, Canada and Australia, and manufacturing countries such as several of the Asian countries, could improve the quality of the model. It would also expand the applicability as showing effects from and consequences of shifts in international trade, both autonomous and as possibly induced by environmental policies.

5.6.2 Description of the model and capabilities

The model combines IO-linked emission data with consumption phase use data and post-consumption disposal management data. Its IO component will be based on Eurostat data for the 60x60 sector level, using technology transfer assumptions for realising the further disaggregation to 500x500 sectors, including, but not exclusively, the more detailed US CEDA 3.0 model. Emissions will be, as far as possible, included from European sources, but probably are not available at a level of disaggregation of 500 sectors — implying that, here too, the lower level of disaggregation will be based on a US distribution of emissions over sectors.

In principle, this model will be updatable. Every five years, Eurostat will receive IO tables from EU Member States, allowing for an update of the IO component at a 60x60 level. EU emission and resource use data are usually updated yearly. For the environmental extensions, a similar analysis applies. Environmental extensions can probably be updated yearly, though not at the lowest level of disaggregation.

A general description of the model is given in paragraph 5.4.2, however in CEDA EU-25++ more European data will be used (see paragraph 5.6.3).

5.6.3 Practical steps and effort required for development

Improvements are possible at three levels.

1. Using IO tables for the EU-25 countries:
   a) The ESA95-based country tables can be transformed into a EU-25 table. This table can replace the older standardised OECD tables for a few countries, which have been used in the original CEDA EU-25 model.
   b) Investments may be treated in a more adequate way, going from gross investment to the share for replacement. Furthermore, government expenditure may be more adequately taken into account, by linking them to the adequate final consumption category used in the model.
   c) The upgrade of BEA to NAICS may allow a better correspondence to NACE and COICOP. However, updating is a substantial job. If done, the separate step to new-NAICS and the very similar new-NACE should be considered as slightly more complex but with clear long-term advantages, as for constructing time series.
2. Environmental data linked to sectors and consumption activities:
   a) Specific environmental data for Europe have been aggregated into the all EU-25 data set now used in CEDA EU-25. Often, they can be linked to sectors more specifically, see b) and following.
   b) Specific programmes for data collection, as recently developed, can be incorporated, including work for EPER, EMEP, RAINS, GAINS, UNFCCC/IPCC and several PRTRs. This requires classification of sources in the detailed sector classification used.
   c) As an overall framework, the NAMEAs can be used, using technology transfer assumptions for countries where specific NAMEA data are lacking still, and where overlap with the more specific sources under b) can be avoided.
3. System integration of disparate data sources:
   a) Producer-consumerpricetransformations should be done internally in the model.
   b) Model imports e.g. by using EEIO tables from the most important countries exporting to Europe.
   c) Hybrid analysis (IO combined with process description) should be used instead of transforming all physical process descriptions into monetary ones, which is especially relevant for the use and post-consumer disposal phase.

For all these adjustments adequate software is a prerequisite. Opening up the option of hybrid modelling would especially allow for a much more adequate incorporation of available European information. The activities above would require a one to two-year project, funded with roughly EUR 500 000 , and more if optional extras are involved as indicated above.

5.7 Improvement option 2: Medium resolution EEIO tables: IO/ NAMEA++

5.7.1 Introduction

Basic data on monetary flows as gathered by statistical offices refer to specific transactions which, in a process of aggregation, are used to produce IO tables of a currently aggregate nature. The basic data available could be reclassified so as to build up the desired system. For monetary data this would involve extra work, but less than for the environmental part. This holds for statistical bureaus with extensive base data sets. For the reclassification of environmental data, current source descriptions will often be insufficient. This means that, for reclassification, additional work of substantial proportions will have to be carried out, in cooperation with the organisations currently gathering data, as for EPER, EMEP, RAINS, GAINS, UNFCCC/IPCC and several PRTRs, and the organisations involved in NAMEA-Air (and in the future probably also Water) programme.

The central question on this option is who will be responsible for this task and how the co-operation of all decentralised parties can be obtained. Without active guidance from a political/administrative level, this option might well drown in procedural problems. Therefore, this option is only viable if implemented as a 'study project', for possible later advancement of administrative procedures. In this way, more advanced statistical bureaus can be involved in the project, bringing in the more detailed information which is already available in several countries. Separate funding then is required. The short name for this option is study project IO/NAMEA++.

5.7.2 Description of the model and capabilities

The model will use European data, both for the monetary part and for the environmental. Only where specific data are lacking, will technology transfer techniques supply data from different origins, such as the US and Japan.

In most countries, the basis from which the ESA95 data are produced is more detailed than reported. A number of countries have such more detailed tables available. From the 'old' Member States, these are Belgium, Denmark, France, Germany, the Netherlands and, to a lesser extent, Great Britain. Italy and Spain may be coming up with better data. From the 'new' Member states, Hungary seems to have a good statistical basis, while Poland will probably stick to ESA95.

Going into the detailed survey and other data on which national accounts are built is possible but requires very substantial amounts of work, in the same order as for producing the more aggregate accounts as are currently made available. So, doing this in parallel does not seem a worthwhile effort. Such extensive work can only be done to replace the current more aggregate tables, which would be the 'royal route', see below. So for producing more detailed tables, the limitations in the data base on which currently available national accounts are based are to be accepted to a large extent.

However, for the purpose of this study project NAMEA++, it may be expected that several countries can and will make available more detailed data than required for ESA95, and also beyond regularly published national data. For example, at CBS (70) in the Netherlands, supply tables and use tables are available at the level of 200 sectors and 800 products. In Denmark, the resolution is even slightly higher. In Belgium, the National Bank (71) is responsible for the development of supply tables and use tables. Information is available at the level of 121 sectors and 321 products.

Such more detailed data are available for quite some European countries, albeit for each country with a different focus on further detailing, mostly

(70) Centraal Bureau voor de Statistiek (CBS): National Statistical Bureau in the Netherlands information from Sjoerd Schenau, Rutger Hoekstra, Sake de Boer and Piet Verbiest.
(71) Information from Hans De Dyn from the National Bank of Belgium.

as related to its dominant economic sectors. So, for Germany, data are more detailed on the car industry and the chemical industry, while, for a more agricultural country like Denmark, more detailed data on agricultural sectors are available. Such levels of detail for specific countries dominant in the specific activities can give insight into the overall economic structure of Europe at a more detailed level than the common denominator available for each of the European countries in ESA95.

So, in this improvement option 2, the European supply and use tables and input-output table are based on the more detailed data that are available for some of the 'pilot' EU Member States. The more general data available for other countries are reclassified into the more detailed level based on the detailed data of the pilot Member States and some additional information on the sector structure of a country. It is expected that countries such as Germany and France, like Belgium, Denmark and the Netherlands, are able to produce an input-output table containing about 200–300 sectors. When establishing the more detailed sector data, choices on classification cannot be made in a straightforward way as data availability limits the options. When choices are due, it seems wise to use the new NACE rev. 2 ([72]) classifications which, in a few years, will find their way into ISIC, as a reference for nomenclature. However, current more detailed country classifications do not especially link to new-NACE.

The problem of linking sectors at a country level into a European IO table remains problematic due to missing import and export data linking exports to their sector of destination abroad and imports to their sector of origin. This problem is compounded by the fact that statistics available per country use different classifications. So the exports from country A to country B cannot be matched by data on imports in country B from country A. Adding up sectors in the sense of making a weighted addition of country level sector coefficients is possible as a shortcut to having consolidated totals specified. However, more sophisticated methods exist, as pioneered by van der Linden (1999) and by Beutel (2002). The work by OECD for standardising EU tables at country level should also be considered.

Based on the current programmes that gather environmental data (for example EPER, EMEP, UNFCCC/IPCC, several PRTRs, NAMEA for air etc.) a resolution of data can be expected of about 30–50 air emissions and about 20 water emissions. A major bottleneck is that environmental data are mostly gathered for emission sources and not for economic activities. In NAMEA-Air for some countries this translation has been made. The EPER programme should also be able to link emissions from emission sources to sectors because, within the programme, each emission is classified as to both emission source and economic sector. A significant drawback of the EPER programme is that the programme is incomplete in economic activities (i.e. only large emission sources and no SMEs and diffuse sources) and emissions (i.e. mainly air and some water and no soil emissions).

Linking in environmental data requires a classification of the firms and activities involved. The data available (see paragraph 3.5.3) may have very different backgrounds, such as being used for checking permits, survey questionnaires, technology models, distribution models with measurement in the environment, etc. They have in common that the base data refer to much more specific activities than the aggregates specified in the most detailed national accounts. The problem here is one of aggregation, using available data as a sample for the more aggregate level of a few hundred sectors. In general, data are available at statistical bureaus to construct a stratified sample in which available information can be systematically placed. This requires a reclassification of current data bases on environmental interventions by

(72) Revision of NACE rev 1.1 into NACE rev. 2 ('new-NACE') is foreseen in 2007 http://forum.europa.eu.int/irc/dsis/nacecpacon/info/data/en/index.htm

Table 5.7.1: *Characteristics of the short-term systematic improvement study project NAMEA++*

Aspect	Characteristic
Geographical coverage	EU-25
Sector resolution	200–300
Sector classification	new NACE, slightly aggregated (or close)
Number of environmental interventions	30–50 emissions to air, 20 emissions to water and in the future possibly some emissions to soil and several dozen resource uses. Higher numbers possible, with lower reliability
Physical intersector flows	A start-up on physical composition of products possible
Time series / potential for monitoring	The model should be built and data be selected in such a way, that the original data from the various sources used can be replaced easily by data of later years. In that case, the creation of time series is not problematic
Available	In around three to five years
Remarks	Based on more detailed data available for some dominant sectors in some Member States. This detailed information can be used to reclassify more general data from other Member States

economic activities. Doing this for a limited number of countries where detailed data are available, as in the Netherlands, would allow for reasonable estimates for other countries.

5.7.3 Practical steps and effort required for development

As no adapted standard procedures are yet developed in this option, the work will be at a project basis, requiring a very substantial project. As can be derived from the above, the project can be executed in different ways and with different level of detail of outcome. As an indication of the effort needed, work in the Netherlands alone on a detailed EEIO table cost some four person-years in the form of a PhD project. It is likely that a project covering the EU-25 will not cost 25 times as much, but several factors more, with some modelling and ICT work on top of this, so a budget of EUR 2.5 million seems a reasonable preliminary estimate.

5.8 Improvement option 3: High resolution tables: the 'royal route'

5.8.1 Introduction

This option can be seen as a substantial expansion of the IO and NAMEA framework developed in the last decade. The practical and legal framework for economic data collection is centred around the revised ESA95 requirements. These will have to be adapted substantially (see paragraph 5.2). Environmental data on processes as already gathered for diverse purposes will either at source stage or at the level of processing into national supply and use tables be classified according to NACE rev. 2 [73], here also referred to as 'new-NACE'. More detailed classifications as currently used for several environmental purposes can be maintained without problems, but only as subclasses to this standard, further differentiating the most detailed standard level only. Product flows will also be classified into standard products, using CPC or, if wished so for specific purposes, a more detailed level may be defined within the most detailed CPC classes, as in the (to be revised) CPA.

5.8.2 Description of the model and capabilities

The model refers to the EU-25 as a whole. It brings together:

- all economic information on sales and purchases by production and waste management sectors and on the purchases for final demand;

(73) A substantial revision of NACE rev 1.1 to NACE rev. 2 is foreseen for 1 January 2007, see http://forum.europa.eu.int/irc/dsis/nacecpacon/info/data/en/index.htm

- all direct emissions by each production and waste management sector;
- all direct emissions by main consumption activities;
- all resource extractions in the EU.

The data contained in the model are gathered and processed in a transparent way, with regular updates both in terms of volumes and technical coefficients of activities and also in terms of their environmental interventions. These interventions can be linked to major impact assessment and evaluation models. Since data gathering is based on structural demands to EU Member States, regular updates of both economic IO data as environmental extensions will be available.

The model connects the macro level of EU-25 with the meso level of sectoral technologies and the micro level of specific policies, technology developments and consumption activities. For the micro-level purposes, it can be formulated as an integrated hybrid model, systematically linked to physical process descriptions as used in LCA.

The model can be linked to a more detailed analysis of specific production and consumption activities, and can be placed in a broader framework of modelling structures for dynamic analysis.

5.8.3 Practical steps and effort required for development

The generation of the more detailed monetary data required needs additional sampling as compared to the current ESA95 obligations. Systematic sampling of product flows as to price and composition requires a larger effort too. Environmental data gathering can in principle remain as it is, but can be tailored more closely to needs and then will probably require less overall effort. The different data gathering procedures have to be harmonised with regard to sector classifications and product classifications. Resource extraction and flows (except if they are expressed as elements) do not yet have standardised classes and nomenclature, which should be developed.

For filling an institutionally embedded detailed IO table with broad environmental extensions — the 'royal route' discussed here — political support has to increase substantially, to improve on already too-limited efforts in implementing ESA95, and NAMEA, in both old and new Member States. The development implies the need for a major structural increase in manpower available for work on NAMEAs, both at national Member States and at the level of the EU (e.g. at Eurostat or EEA). However, current work on other

Table 5.8.1: Characteristics of the 'royal route'

Aspect	Characteristic
Geographical coverage	EU-25
Sector resolution	600x600, or slightly more
Sector classification	NACE rev. 2
Number of environmental interventions	>1 300 emissions to air, water and soil, several dozen resource uses
Physical intersector flows	Linked to product flows in CPC and HS, based on explicit sampling methods, with a focus on primary production and recycling and final waste management
Time series/potential for monitoring	Yearly updates of economic data and environmental extensions possible
Available	In around 5–10 years
Remarks	The actual development of the new procedural and legal framework will be the main impediment to fast introduction

environmental data can be substantially reduced, efforts being taken over in the 'royal route'.

5.9 Discussion and conclusions

The three improvement options are increasingly costly.

The first, the CEDA EU-25++ option, is by far the least expensive, but remains based to a substantial extent on US data and an old US sector classification (from BEA). The most interesting approach to this option is to use ESA95 60x60 national IO tables or make and use tables to construct a first updatable layer, an EU-25 60x60 table. The additional data of detail can then be realised by using the CEDA database. As there is a transformation link from BEA, to NAICS, to new-NAICS to new-NACE, the CEDA EU-25 data on the production structure can be transformed into the new-NACE sector structure. All environmental data further classified would then be brought into this sector framework, which will remain relatively stable for many years to come. The overall structure would fit to the main European data sets, with technology transfer data from outside Europe only for filling in missing details.

The second, the study project IO/NAMEA++, can be executed for a higher budget, up to about EUR 2.5 million. The work will use NACE rev. 2 as classification as the main common denominator across the EU-25, but must probably use an ad hoc detailing of sectors depending on what is available. Fitting in environmental data (a major task) would mean classification of them to this incidental sector framework. In Chapter 6 we will discuss options to overcome this problem. The main difference with the CEDA EU-25++ approach is that European data are used for reaching a higher resolution as the 60x60 sector level reached by ESA95.

The third, 'royal route' can develop only if a clear decision is made at EU level. The additional effort involved may be limited as compared to the full implementation of NAMEA, which is now developing at a different pace in different EU countries. The sampling for based data gathering may have to be expanded.

Overall efficiency improvements in data production are possible, learning from the different approaches present in several advanced countries. In producing the combined economic and environmental data, a main further improvement would be the link to current specialised efforts for environmental data gathering and the adjusted requirements on PRTRs, which now lack a systematic framework in terms of classification of activities and classification of products. The introduction of the new-NACE could be an occasion for starting up this 'royal route' improvement trajectory, which ultimately could evolve into the 'ideal' version as described in 5.2.

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6 Comparison of options and recommendations

6.1 Introduction

In this chapter, we will make a cross-analysis of the various options for developing a European EEIO table, as discussed in Chapter 5, indicating the potential of such EEIO tables to support European economic and environmental policies, as discussed in Chapter 3. As shown in Chapter 5, developing a European EEIO table can be done in various forms, with different price tags and with different lead times. Here we want to analyse if going for more complicated and costly options has added value or not.

In discussing the options, as concluded in Chapter 5, we will consider primarily IO tables with environmental extensions, and not physical input-output tables (PIOTs) at the level of elements or materials. Setting up these, and particularly regularly updating these, is relatively costly, and from Chapter 4 it was already clear that full-swing PIOTs have limited value for policy-making. From the discussion in Chapter 5, there seems only one feasible and productive way in somehow including information on physical flows in EEIO tables: simply denoting the total mass, in kg, that is related to a monetary flow in the IO table (which reflects a product or production output of a sector). In a next step, on the basis of this information on total mass, the name of the product and information on the composition of this product / production output, information on other physical flows (elements, specific materials) may be obtained.

In sum, this implies we will discuss in this chapter the characteristics of five main options for developing an EU EEIO table, with (as an optional addition) a product-PIOT. Of the first two, CEDA EU-25 as already present and the autonomous development of NAMEA does not require specific action. So the three active improvement options remain:

1. high resolution CEDA EU-25++;
2. medium resolution EEIO tables: IO/NAMEA++;
3. high resolution tables: the 'royal route'.

The analysis of their benefits for supporting EU policy will concentrate on three main domains of application:

a) environmental problem analysis;
b) prospective effect analysis of policies;
c) monitoring and ex post effect analysis of policies.

This confrontation will be discussed in Section 6.2. There, we will also conclude which options are to be recommended. The recommended options will be (as far as still necessary in comparison to the description in Chapter 5) elaborated in Chapter 6.3.

6.2 Comparing options and support to European policies

Table 6.2.1 gives a detailed analysis of the three improvement options described with the benefits for the six policy fields distinguished. As already indicated in the conclusions of Chapter 4, the table shows that EEIO tables, in whatever form, can play an important role in problem analysis, ex-ante impact assessment of policy measures and scenario building, and monitoring and ex-post impact assessment from an economy-wide and systemic perspective. This makes the EEIO tool valuable for a great variety of policy fields, such as integrated product policy, resources policy, polices in the field of climate change, impact assessment of environmental policies in general, etc.

The strength of EEIO analysis is that it brings together economic and environmental data in a consistent, related sectoral framework. EEIO models allow for analysing such data via a great variety of cross-sections of the economic system, such as the product perspective, or a sector perspective. If the EEIO model and the related data collection system are set up rightly, it can hence fulfil multiple goals, and hence will probably greatly reduce the effort in data gathering for environmental problem analysis, prospective effect analysis of policies and monitoring for a variety of environmental policy fields.

Concerning the demands with regard to EEIO models, from Table 6.2.1 and the text in Chapter 4, a number of issues stand out.

d) For problem analysis purposes, a detailed sector resolution is desirable, time series are irrelevant, and a basic EEIO table is usually sufficient.

e) For prospective effect analysis of policies, a detailed sector resolution is, in principle, even more desirable, time series are, in principle, not needed and it is often desirable to link the basic EEIO table with other models to make a number of exogenous parameters endogenous ([74]). The latter point is somewhat at odds with the demand for detail: adding such additional features to a basic EEIO table is usually more complicated for detailed tables.

f) Finally, for monitoring and ex-post effect analysis of policies, EEIO tables of moderate sector resolution are, in most cases, sufficient and time series are essential. A relatively aggregate EEIO table will do.

In sum, the common denominator for all these application is that, if possible, the sector resolution should be detailed (though some applications can do with less), a substantial set of environmental interventions (emissions and primary resource uses) should be covered (though for individual policy dossiers a dedicated list is sufficient, such as a concentration on greenhouse gas emissions for EEIO tables used to support climate change policy), and time series should be available.

With regard to the need to include intersector flows in physical terms (PIOTs) the following can be remarked. Policy with regard to resources or materials can already be given important support by EEIO tables without further extensions in the form of PIOTs — provided that the primary resource use is adequately covered. In that case, the monitoring of parameters such as the material intensity of society is already possible. By making inventories of masses per monetary flow in the IO table as well (i.e. counting the kilos of production output per sector discerned), further information can be delivered: insight into the material intensity of certain sectors and final consumption domains, etc.

When one compares these demands with what the different options for developing an EEIO table can offer, a first conclusion stands out. The current effort with regards to ESA95 supply-use and IO tables and NAMEAs needs a considerable boost in order to realise a comprehensive EEIO table that can be used for the application areas mentioned in Table 6.2.1. Complementary to the current efforts, the following activities are recommended to put at least the data already officially collected to good use.

a) Eurostat currently gathers 60x60 make and use and IO tables from individual EU Member States; it is recommended to integrate them on the basis of make and use tables to a total table for the EU-15 (and in due time for the EU-25).

b) The inventory of environmental interventions is currently limited to some 10–20 emissions

(74) Examples include the relation of consumption expenditures with the cost of labour, including price elasticities, and dynamising the model with regard to changes in capital stock and technical development as a function of expenditure on capital goods. With regard to time series, if one wants to do simple extrapolations to the future, it is of course helpful that one has time series from the past available (see under monitoring). But such time series are not the only basis for building scenarios for the future, and therefore it seems that having time series available is not an essential precondition for doing prospective effect analysis of policies.

Table 6.2.1: *Contribution of several options for European EEIO work to EU policy fields (score on fit on demand with regard to (1) required sector resolution, (2) number of environmental interventions, (3) the need for insight in physical input-output flows/PIOT, (4) the need for time series. Good fit: +, Moderate fit: o, Bad fit: -)*

Policy field and role of EEIOA				**Option**	**CEDA EU-25** (see note)	**Eurostat NAMEA**	**CEDA EU-25++** (see note)
				Sector resolution	500x500	60x60	500x500
				Environmental interventions	>1 300 emissions to air, water and soil, several dozen resource uses	10–20 emissions to air, water and possibly soil; several resources	>1 300 emissions to air, water and soil, several dozen resource uses
				Intersector flows	Absent	Absent	Absent
				Available / costs	Now	At best in five years or more for EU-25	1–2 years, up to EUR 500 000
				Remarks	Europeanised US data, not yet automated, privately owned	It is not sure if use and waste stage will be covered and if Eurostat will combine national tables to an EU-25 table	European at 60x60 level, and for emissions; cross-checked US technology coefficients at lower level
	Demands to EEIO tables (*)						
	Sector resolution	**No environ. extensions**	**PIOT**	**Time series?**			
Environmental problem analysis							
Output-related impacts (consumer groups / life styles, expenditure categories, product groups)	Several dozen (the more the better)	Detailed	Not relevant	Not relevant	: + + ++	— 0 ++	+ + ++
Impacts of resource use	Several dozen (the more the better)	Detailed	For each resource	Not relevant	+ + -+	— 0 -+	+ + -+
Prospective effect analysis of policies							
Economy-wide implications of change in life style and consumption patterns, technical change and internalising external costs	Detailed preferred	Detailed	Not relevant	Not relevant	: + + + + See note	— + -+ + See note	: — + + + See note
Monitoring and past effect analysis of policies							
Monitoring of decoupling and eco-efficiency ratios	Several dozen (the more the better)	Detailed		Not relevant	+ + + -	0 0 + +	+ + +?
Decomposition analysis: drivers behind change in ratios	Several dozen (the more the better)	Detailed		Not relevant	+ + + -	0 0 + +	+ + +?

NB: For many ex ante analyses it is desirable that the basic EEIO model is extended to make items such as consumer expenditure and investment in technical change endogenous.

Table 6.2.1 (continued): Contribution of several options for European EEIO tables to EU Policy fields

Policy field and role of EEIOA			Option		Medium resolution IO/NAMEA++, existing data reporting	High resolution 'royal route', new data reporting
			Sector resolution		250–500 x 250–500	Any, probably 500
			Environmental interventions		around 150 emissions to air, water and soil, several dozen resource uses	Any, around 150 emissions to air, water and soil, several dozen resource uses
			Intersector flows		Optional ('product related PIOT')	Optional ('product related PIOT')
			Available / costs		3–4 years, EUR 2.5 million (+ 1 million PIOT)	Probably 10 years, various million
			Remarks		Would use underlying data of SCBs in some large EU countries to create a high sector resolution	Requires fundamentally different data reporting procedures; may even require institutional changes in relation of Eurostat and national COSs
	Demands to EEIO tables*					
	Sector resolution	**No environ. extensions**	**PIOT**	**Time series?**		
Environmental problem analysis						
Output related impacts (consumer groups / life styles, expenditure categories, product groups)	Several dozen (the more the better)	Detailed	Not relevant	Not relevant	+ + + +	+ + + +
Impacts of resource use	Several dozen (the more the better)	Detailed	For each resource	Not relevant	+ + - +; + + + + if with PIOT	+ + - +; + + + + if with PIOT
Prospective effect analysis of policies						
Economy-wide implications of change in life style and consumption patterns, technical change and internalising external costs	Detailed preferred	Detailed	Not relevant	Not relevant	+ + + + See note	+ + + + See note
Monitoring and ex post effect analysis of policies						
Monitoring of decoupling and eco-efficiency ratios	Several dozen (the more the better)	Detailed	Not relevant	Yes	: + + + +	+ + + +
Decomposition analysis: drivers behind change in ratios	Several dozen (the more the better)	Detailed		Not relevant	+ + + +	+ + + +

NB: For many ex ante analyses it is desirable that the basic EEIO model is extended to make items such as consumer expenditure and investment in technical change endogenous.

to air (mainly greenhouse gases as a first priority). Where such a list is sufficient to support climate change policies, for most other policy dossiers a more comprehensive list is necessary. It is recommended to expand this list at least to emissions of greenhouse gases, acidifying and eutrophicating emissions, and ozone-depleting emissions to air and water so that a reasonably comprehensive set of emissions is covered. Furthermore, primary resource uses (e.g. data that will be gathered within the framework of economy-wide material flow analyses) should preferably be gathered including information on the sector of primary use.

c) Any remaining gaps with regard to the use and waste stage should be filled.

Via this approach, the EU would probably realise an EEIO table that can be considered the minimum option that is of use in view of the applications mentioned in Table 6.2.1. It would be a 60x60 EEIO table for the EU-15 (and in due time the EU-25) with limited but still reasonably comprehensive environmental extensions included. An important feature of this option is that time series of data would become available (for extensions as a yearly update; for the IO part at least as a five-yearly update but with the yearly update of make and use tables required by ESA95 it may be possible to construct yearly updated EU IO tables too).

Furthermore, it is clear that the most elaborated improvement option, the 'royal route', aiming at new data reporting requirements, in theory would be the most appropriate to fulfil the policy needs. Yet, it is also clear that important institutional impediments exist for realising this option. First, the current requirements in the ESA95 with regard to transfer of data to Eurostat are just related to make and use and IO tables (rather than environmental extensions) and at an order of magnitude lower resolution than is seen as desirable here. One of the reasons for this is that, in the current situation, various national statistical bureaus are simply unable to collect data at a lower resolution: their country is too small, they do not have the manpower, or historically they have set up their data gathering systems in such a way that reaching a better level of detail is not possible. One solution could be to start from scratch at EU (Eurostat) level, more or less how the US Bureau of Economic Analysis operates, but at this stage such a model does not fit institutionally with how the Community and the Member States have divided competencies. Unlike the US, the EU is not a federal state and hence has no federal level. For all these reasons, we do not see this fifth option as a viable road for a considerable time to come. Even if efforts would be undertaken to proceed this route, results may be realised at best at a time horizon of 10 or more years. We hence will not recommend this option as a means to fill gaps in the short term, but see a clear long-term advantage in this route

The CEDA EU-25 model is already available but could be developed further and include new European data. It should be kept in mind though that the model is hardly suitable for making updates and hence cannot be used for constructing time series of data for monitoring purposes. This implies that there are, realistically speaking, only two options to go forward and realising results on a relatively short term: improving the CEDA EU-25 model, or embarking on a larger project that uses existing data reporting procedures to build a truly European EEIO table.

Table 6.2.1 shows that, in terms of practical value for EU policy support, the two options do not differ significantly. They would both start with the realisation of the aforementioned basis: building a 60x60 EU EEIO table from available national NAMEAs and ESA95 supply-use and IO data. The main difference is probably that the study project, at least potentially, may end up with a structure that can be regularly updated at the lowest level of sector detail. For both the CEDA EU-25++ model and the IO/NAMEA++ project updates at the 60x60 level can probably be done rather easily making use of the ESA95 data gathered by Eurostat. The approaches used in the study project to reach the higher level of detail will most likely rely on detailed data from individual countries;

if such countries update their data regularly it should be possible, making use of the same initial calculatory approaches, to realise updates at this lower level of detail as well. The IO/NAMEA++ project may also form a somewhat better support to resource-policy if PIOTs are added, but in principle such data may be added to CEDA EU-25 as well. As for the practical execution of a project, there will be some differences. The CEDA EU-25++ project can probably be executed by one institute in connection with Eurostat, and for the annual updating procedure too. The study project needs involvement of various statistical offices of EU Member States, and for updates too. As described in Chapter 5, it is unlikely that national statistical bureaus can deliver primary data at a detailed level. For some countries, it will most likely be possible to create a more detailed table based on underlying inventory data for specific industry sectors. Using these more detailed country tables, the situation in the rest of the EU has to be estimated. Hence, where CEDA EU-25 uses US data to reach the higher level of detail (below 60 sectors), in option 4 data from some EU Member States will be used to reach the higher level of detail. The political advantage of the last approach is obvious, but in terms of quality (and reflection of reality) the added value is probably limited. In terms of costs, our estimate that truly improving CEDA EU-25 to its limits would cost some EUR 500 000, with maybe another EUR 500 000 to EUR 1 million if mass flow data are added. Developing a EU-25 EEIO table via the study project IO/NAMEA++ would probably cost in the order of EUR 2 to 3 million, with a similar addition for the PIOT data. In principle, which option to choose is not ours to make. Yet, we would recommend to go for the truly European option — the extra costs is worth it since the project may be a step up to option 5), and avoids the somewhat undesirable image of Europe being dependent on foreign data for supporting essential European policy fields.

6.3 Additional options

All tables constructed via the aforementioned approaches will be a 'basic' input-output table, which can be expanded in various ways. The table can be turned into a model, by making exogenous factors such as consumption, imports and capital formation endogenous (compare Duchin, 2004). The first candidate for this seem to be imports and their embodied pollution: it is not enough to assume that imports are made with domestic technology (see Peters et al., 2005; Nijdam et al., 2003) The ideal solution is to embed the EU-25 EEIO table in regionalised world IO tables like GTAP or MOSUS, with region specific environmental extensions. If such extensions include topics such as land use, resource use, and various emissions properly, by using various impact assessment methodologies the EEIO model can provide information as diverse as ecological footprints, external costs, scores on environmental themes and the total material requirement related to consumption of products.

6.4 Conclusions: towards a roadmap for exploiting the potential

To conclude, there are three main improvement options. The ideal solution is *High resolution tables: the 'royal route'.* This option aims at a structural solution in the longer term, embedded in administrative procedures. It is clear, however, that this option implies a major adaptation of current institutional arrangements, which may be realised only in a long time-frame. Examples include an adaptation of ESA95, enlarging budgets at national statistical offices and Eurostat for gathering and processing data for supply/use and IO tables at a high level of detail, etc.

The more realistic options in the short and medium term are CEDA EU-25++ and the study project IO/NAMEA++. Where CEDA EU-25++ will probably still have to rely for a significant part on foreign (US) data to reach a level of detail that is higher than 60x60 sectors, the study project IO/NAMEA++ will use various European data sources. Another advantage is that the study project IO/NAMEA++ is supportive to the long-term option 'High resolution tables: the 'royal route'' both by showing results and by showing the way for how to produce more elaborate data. The study project IO/NAMEA++ could thus have a double aim: to produce improved data and model, and to indicate how this data and model may be further improved in regular work for and by Eurostat. For all these reasons, we believe that of the two realistic short/medium-term options, the study project IO/NAMEA++ is to be preferred over CEDA EU-25++.

Placing the study project IO/NAMEA++ in this longer-term perspective, a slightly more costly but inherently better variant might be developed. In the current proposal, we develop an EU table on the basis of detailed sector classifications as are available in ***some*** European countries. From these national details as compared to the ESA95 an EU table is constructed, with data added based on technology transfer assumptions. This has the clear disadvantage that the sector structure resulting does not correspond with any of the official classifications. Reclassifying all environmental data to this level is a one time job, without sensible updates as the future is to new-NACE. Taking the full consequence of the new-NACE, in a vision where Europe will produce better data in the long run, it might be better to shift to new-NACE in the study project IO/NAMEA++ already. Actually, it constitutes a variant going beyond IO/NAMEA++, as an exercise for developing the 'royal route'. This option would be more expensive, as it requires the reclassification of the base data as used by the statistical bureaus. The classification of sources of emissions would directly connect to new-NACE as well.

7 Conclusions

This report concludes that environmentally extended input-output tables form a powerful toolkit for information-based environmental policy-making. Such EEIO tables form a comprehensive accounting framework covering all economic activities that allow for calculating the environmental impacts and external costs of such economic activities via a variety of perspectives, for instance:

- per sector;
- per product or final consumption activity, or
- related to the use of a specific natural resource.

Furthermore, it is possible to analyse the effect of potential measures on the reduction of environmental impacts and external costs — but also on parameters such as economic output, productivity and employment. And, when time series of data are available, monitoring of decoupling of environmental impact from economic growth and natural resource use is possible — including of an analysis of the factors that contributed mostly to this decoupling. Examples include change of consumption patterns, change of production patterns, change of technology of production and change in emission factors. There is an obvious relevance for important EU policy dossiers, such as integrated product policy, the strategy on the use of natural resources, the environmental technologies action plan, the emerging agenda on sustainable consumption and production, but also the Lisbon strategy and impact assessment of (environmental) policies in general.

A main advantage of the EEIO approach is that all kinds of data (environmental, economic and social) can be inventoried and placed into a coherent framework. Whereas in the past, many dedicated studies and data-gathering exercises had to give answers for specific policy questions, an EEIO table allows for the gathering of all these data into one coherent and lasting form and to use the same dataset for multiple purposes. The analysis of information needs for policy-making shows that, preferably, and to be balanced against the cost and effort of its elaboration, such an EEIO table should:

- include a significant amount of environmental interventions (several dozen emissions to air, water and soil, and several dozen resource uses plus land use). EEIO tables which, for example, only greenhouse gas emissions can be a good support tool for climate policy purposes, but for almost all other policy dossiers a different or more comprehensive set of interventions must be included;
- be easily updatable, in order to produce time series that allows, for example, for analysis of what factors determine the relation between environmental impact and economic growth;
- preferably have a quite detailed sector resolution — a table with a moderate resolution of say 60x60 sectors will probably be sufficient for monitoring and ex post effect analysis of policies purposes, but for problem analysis and ex ante impact assessment of planned measures, technology interventions, etc., a higher resolution is desirable.

Individual EU Member States have IO tables, often to some extent with environmental extensions. In individual projects and by individual institutes, IO and EEIO tables have been developed that, in some cases, cover the EU or EU Member States, but usually they lack detail, have had to be based on transformation of data from non-EU countries to an EU context, or lack transparency.

This report analysed in detail the specifications of EEIO tables that are needed to provide support to the aforementioned policies, and also the options of how to build such EEIO tables. The 'null option' (doing nothing) seems no solution. The only comprehensive EEIO model for the EU-25, CEDA EU-25, was developed for a dedicated project. It relies on procedures in which US data were Europeanised. The model is not easily suitable for making updates, and hence not suitable as a monitoring instrument. At this stage, Eurostat has structural data-gathering procedures for national IO tables and national NAMEAs for air emissions (concentrating on greenhouse gases). These efforts can be a basis for the further development of a European EEIO table with a 60x60 sector resolution, but additional activities are still required and highly recommended for this, and to our knowledge none are yet planned. It concerns particularly the combination of national ESA95 tables and NAMEAs to a consolidated 60x60 EU table and the additional inventory of environmental interventions, so that at least a few dozen relevant emissions to air and water and the most important resource uses per sector are gathered.

Building further on this basis, three pathways can be distinguished to realise a European EEIO table with the desired, high level of resolution.

1. High resolution CEDA EU-25++

This option would vastly improve the current CEDA EU-25 model, and make as much use of true EU data as possible. It is the most cost-effective option (probably between EUR 0.5 million and EUR 1 million), but has the major disadvantage that, for a sector resolution higher than 60x60, the table still has to rely on US data. At the 60x60 level, regular updates can be realised due to the reporting obligations in ESA95. Since the higher level of detail is realised mainly based on a US technology-transfer assumption using a US table, regular updates at this level of detail will be problematic. This option is thus less suitable for purposes where time series are needed at a higher resolution than 60x60 sectors.

2. Medium resolution EEIO tables: IO/NAMEA++

Here, a European EEIO model is built based on existing data-reporting procedures. It would initially use the ESA95 IO tables already reported to Eurostat as a basis, while reaching a greater resolution by directly using more detailed sector data from national statistical offices. This project would be more expensive (EUR 2 million or more), but has several advantages. Firstly, it results in a model using only EU data; secondly, updatability and the generation of time series are probably easier than in the CEDA EU-25++ option.

3. High resolution tables: the 'royal route'

In this option, the EU would have to change the ESA95 directive considerably, and require EU Member States to report make and use tables and environmental extensions to Eurostat at a very detailed level (several hundred sectors or products). Many EU Member States at this stage have no data at such detailed level. It is very unlikely that this scenario will become reality in the next decade.

In the view of the authors of this report, option 2 is probably the best way forward. To some extent, it prepares and tests option 3. It is somewhat more expensive than option 1, but has as a great advantage that, in the end, a truly European model is built.

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