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System of Environmental-Economic Accounting
SEEA Applications and Extensions

Prepared by the Committee of Experts on Environmental-Economic Accounting

DEPARTMENT OF ECONOMIC AND SOCIAL AFFAIRS
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SEEA Applications and Extensions

Consultation Draft

SYSTEM OF ENVIRONMENTAL - ECONOMIC ACCOUNTING (SEEA)

SEEA Applications and Extensions

CONSULTATION DRAFT

The following text has been drafted for consultation as part of the process of finalising the SEEA Applications and Extensions. The material should not be considered final and should not be quoted.

SYSTEM OF ENVIRONMENTAL - ECONOMIC ACCOUNTING (SEEA)

SEEA Applications and Extensions

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Chapter 1: Introduction

1.1 The SEEA Applications and Extensions is a companion document to the SEEA Central Framework that highlights the potential of data from the accounts of the SEEA Central Framework to be applied to a range of policy and research questions and to be extended to integrate with data in other domains.

1.2 The SEEA Central Framework was adopted as the initial international statistical standard for environmental – economic accounting in 2012. It is a multi-purpose, conceptual framework that describes the interactions between the economy and the environment, and the stocks and changes in stocks of environmental assets.

1.3 SEEA Applications and Extensions provides a bridge between compilers and analysts and is an important document in promoting and supporting the implementation of the SEEA Central Framework. SEEA Applications and Extensions is not intended to be exhaustive in its coverage of potential applications nor does it describe all of the relevant data sources and methods in depth.

Analytical and policy focus

1.4 The focus in SEEA Applications and Extensions is on measurement and analysis at a broad, national level on topics such as sustainable resource use, environmental efficiency, environmental protection activity and the production of environmental goods and services, environmental assets and natural resources, and the household sector's behaviour with respect to the environment.

1.5 Analysis in these areas may feed into discussion of broader, cross cutting policy areas such as sustainable development, mitigation of the effects of climate change, pollution abatement, water and energy security, resource management and productivity, and land management. The applications and extensions described here may be relevant for both the development of policy and the monitoring and evaluation of policies, in particular assessment of the effectiveness of specific policy instruments.

1.6 For the compiler of environmental-economic accounts, SEEA Applications and Extensions can provide an introduction to the types of analysis that may be conducted using integrated environmental-economic accounts. The SEEA Applications and Extensions also provides an indication of the types of accounts that may be required to undertake the analysis.

1.7 For the analyst of environmental-economic topics, the SEEA Applications and Extensions provides an insight into the benefits that may be gained from utilising a common, integrated framework, reflected in the compilation of accounts, for the organisation of environmental and economic data. It is anticipated that this document will stimulate ideas for analysis and ideas for the presentation of data that may not be apparent from the description of the concepts and accounts in the SEEA Central Framework.

Nature of the SEEA Applications and Extensions

1.8 SEEA Applications and Extensions is not a statistical standard and the nature of the topics and examples presented is not intended to provide a basis for standardised reporting at national or international level. Further, consistent with the potential to implement the SEEA Central Framework in a flexible and modular way in line with available resources and national information demands, it is not required that countries seek to adopt all of the applications and extensions described here.

1.9 On the contrary, it is envisaged that through the course of implementing the standards of the SEEA Central Framework in a modular fashion – e.g. for water, energy, land, or air emissions – various applications and extensions might be adopted as appropriate to the topic of interest. At the same time, it is noted that many of the applications and extensions benefit from the development and regular update of integrated accounts containing a range of environmental and economic data. Hence, consideration of integrated approaches to data collection and organisation using the SEEA accounting framework is likely to be of long term benefit.

1.10 Completion of the analysis and extensions outlined here may require the use of information that is not described in the SEEA Central Framework – such as detailed information on the household sector. In addition, it may be necessary to make various assumptions about relationships between economic and environmental variables and undertake modelling of various types. The SEEA Applications and Extensions does not prescribe any assumptions, modelling approaches or the collection of information required for analysis and intends only to indicate the common requirements and considerations.

1.11 SEEA Applications and Extensions does not provide a complete coverage of all materials that may be relevant in the communication of information on environmental-economic accounts and nor does it cater to all possible audiences. Of particular relevance in this regard are the group of people that may generally be classed as policy makers – i.e. senior government officials and politicians. For these people, it is likely that summarised messages of environmental-economic data are required. This document provides some information that may be relevant in the preparation of these summarised messages including some examples of relevant charts and figures. Further examples of material that may best meet the requirements of this audience are on the UNSD web site.

Relationship to the SEEA Central Framework and related documents

1.12 Like the SEEA Central Framework, the SEEA Applications and Extensions was drafted in the context of the revision of the *Handbook of National Accounting: Integrated Environmental and Economic Accounting, 2003* (SEEA-2003). The revision of SEEA-2003 has been an ongoing process since February 2007 managed under the auspices of the Committee of Experts in Environmental and Economic Accounting (UNCEEA) and involving a wide range of statistical and subject matter experts, in particular the members of the London Group of experts on environmental accounting.

1.13 In this regard the SEEA Applications and Extensions builds on SEEA-2003 Chapter 11 “Applications and policy uses of the SEEA” and also the many examples described throughout the other chapters of SEEA-2003. The revision of the SEEA-2003 has adopted a different approach whereby the focus of the SEEA Central Framework is on the description of accounting principles and relevant concepts and definitions. Consequently, no country examples are included in its text.

1.14 There are close links between a number of the applications discussed in this document and the material presented in the SEEA Central Framework, Chapter 6 “Integrating and presenting the accounts”. Chapter 6 discusses the important characteristic of integration of environmental and economic data that is the hallmark of the SEEA. In particular, Chapter 6 discusses combined presentations of data in physical and monetary terms and the development of aggregates and indicators. Discussion of these aspects is expanded in the SEEA Applications and Extensions by providing a more complete discussion of indicators and aggregates for specific topics, by describing possible analytical approaches, and by providing relevant examples.

1.15 Particular mention is required concerning the discussion of indicators and aggregates. The SEEA Central Framework describes a number of indicators and key aggregates but does not recommend the measurement of any specific indicators. Rather it observes that the relevant indicator should be defined based on the particular issue under consideration. SEEA Applications and Extensions follows this approach but also provides a discussion on the role and function of indicators and on the selection, interpretation and presentation of indicators. This discussion is of relevance in considering how information from SEEA accounts may be best used to develop and populate the range of indicators sets that use environmental and economic information.

1.16 SEEA Applications and Extensions does not provide details of applications and extensions related to ecosystem accounting. This does not reflect on the relative importance of this area of accounting. Rather it highlights that the coverage of the SEEA Central Framework in terms of physical flows of materials, energy and residuals, expenditure and production related to environmental activities, and asset accounts for individual resources, is much further established than approaches to ecosystem accounting. The body of knowledge on ecosystem accounting is advancing with the main and generally accepted areas summarised in SEEA Experimental Ecosystem Accounting. In time it is anticipated that documents describing applications and extensions related to ecosystem accounting will be developed.

1.17 SEEA more generally comprises a number of other documents including SEEA-Water, SEEA Energy and SEEA Fisheries. Each of these documents highlights some specific applications and extensions relevant to the particular topics. Compilers and analysts are encouraged to consult these documents for further suggestions for analysis, extension and presentation.

Structure of the SEEA Applications and Extensions

1.18 Chapter 1 of this document outlines the rationale for SEEA Applications and Extensions and places this document in the broader context of the SEEA suite of publications.

1.19 Chapter 2 "Applications of SEEA data" describes range of commonly analysed topics using environmental-economic data. The four broad topics covered are (i) sustainable resources use and environmental efficiency; (ii) production, employment and expenditure related to environmental activities; (iii) environmental taxes and environmental subsidies and similar transfers; and (iv) environmental assets, net wealth, income and depletion of resources. For the different topics the material covers both the most commonly used indicators and aggregates, and the most common types of analysis. Chapter 2 also discusses the role and function of indicators within the context of the SEEA Central Framework and provides an introduction to the issues of selecting, interpreting and presenting indicators.

1.20 Chapter 3 "Analytical techniques" considers the application of SEEA data from the perspective of the type of techniques that may be applied across analysis of different topics. A particularly significant part of the chapter introduces environmentally extended – input-output tables, EE-IOT. These tables provide a statistical base for a wide variety of analysis – both more straightforward structural analysis and more complex modelling. The chapter describes a range of techniques including multipliers, consumption based modelling, decomposition analysis, and geo-spatial analysis.

1.21 Chapter 4 "Extensions of the SEEA" highlights examples in which data from the SEEA Central Framework may be augmented, disaggregated or reclassified in order to provide integrated data sets that may be used to address different areas of policy concern. One example is the use of a wide range of SEEA data to provide an integrated information set for analysis of the household sector in relation to the environment, and the other example connects SEEA data and data on tourism compiled within a Tourism Satellite Account. The extensions do not relate to alternative definitions of SEEA concepts.

1.22 Annexes are included to (i) provide additional detail on the derivation of various indicators and data presented in the document including explaining the links to the relevant parts of tables in the SEEA Central Framework, and (ii) describe additional technical detail related to the analytical techniques described in Chapter 3.

Chapter 2: Applications of SEEA data

2.1 Introduction

2.1 There are many topics to which data from the SEEA Central Framework may be applied. This breadth emerges from the range of accounts that form the SEEA Central Framework and the linkages between the accounts which enables the analysis of related data sets and the subsequent compilation of indicators.

2.2 An underlying premise in the application of SEEA data is that the accounting structures described in the SEEA Central Framework form the basis for coherent and comprehensive data sets. These data sets may then be analysed and, subsequently, key indicators and aggregates may be derived. Thus, the indicators emerge from the accounts and hence retain the key qualities of coherence and comprehensiveness.

2.3 Following a general introduction to indicators, this chapter presents some of the most common topics of analysis to which SEEA data are applied and about which indicators are derived. These topics include sustainable resource use and environmental efficiency; production, employment and expenditure for environmental activities; environmental taxes and subsidies; and environmental assets and natural resources. The chapter concludes with a discussion on the selection, interpretation and presentation of indicators.

2.4 Analysis of the topics listed above and the development of relevant indicators may require some additional, more detailed data beyond that described in the SEEA Central Framework and may also require the use of various assumptions and modelling. This chapter describes the relevant considerations and measurement issues.

2.2 The use of indicators in environmental analysis

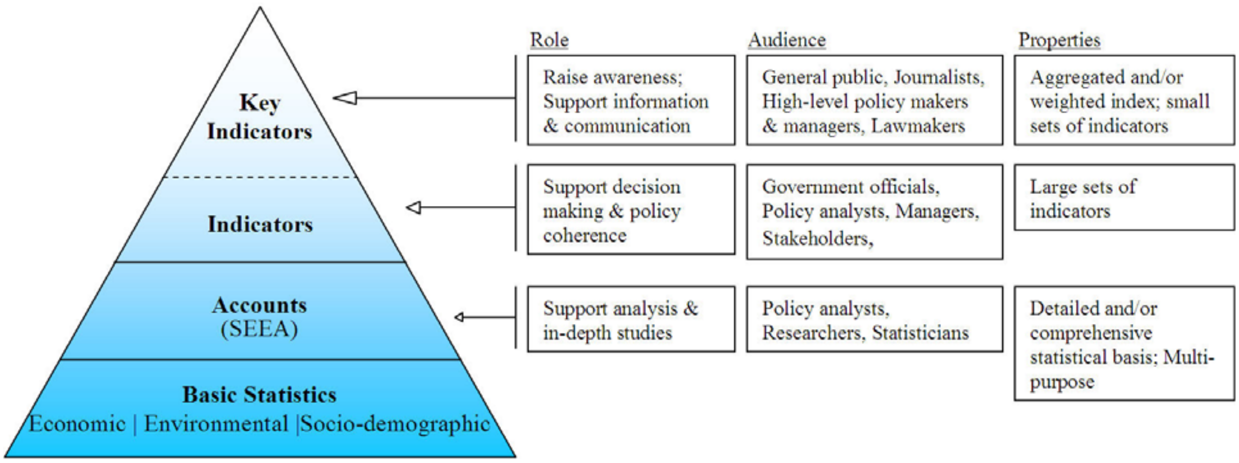
2.2.1 Roles and functions of indicators

2.5 Indicators may serve many purposes depending on the scale at which they are applied, on the audience to be reached, and on the quality of the underlying data. Indicators are useful tools for tracking progress with respect to the environment and sustainable development, and for raising the profile of these issues in the public debate. They help promote accountability by informing about how well policies are performing, and they support policy development and integration by drawing attention to major trends and structural change.

2.6 Among the main audiences are the general public, journalists, managers and decision makers in the business and government sectors, policy-makers including parliamentarians, and stakeholders from non-government organisations. Most of these audiences are not statistical experts. It is therefore important that the indicators are communicated in a way that is understandable and meaningful, and that reduces the complexity and level of detail of the original data.

2.7 Thus, a key function of indicators is to simplify the communication process by which the results of analysis and accounting are provided to the users and to adapt the information provided to users' needs. Due to this simplification and adaptation, the indicators may not always meet strict scientific demands to demonstrate causal chains. They rather represent trade-offs between their relevance for users and policies, their statistical quality, and their analytical soundness and scientific coherence. Indicators should therefore be regarded as summary measures that aim to be fit-for-purpose and should be embedded within larger information systems (e.g. databases, accounting frameworks, monitoring systems, models). The relationships between different types of information are shown in Figure 2.1.

Figure 2.1 Information pyramid



2.2.2 Compiling indicators

2.8 Many indicators may be compiled within the SEEA Central Framework. Some indicators are directly embedded in individual SEEA Central Framework accounts in the form of aggregates (e.g. total emissions for the economy). Other indicators can be calculated as ratios between variables from different SEEA accounts or by relating data from SEEA accounts to data from the national accounts or other sources (e.g. population census).

2.9 The connectivity and coherence of information sourced from the accounts of the SEEA Central Framework is particularly important when the indicators are to inform about both the environmental effectiveness and the economic efficiency of policies, or when they are to support structural policy analyses. Relevant examples include the measurement of progress towards sustainable development, and monitoring the integration of economic and environmental policies.

2.10 Indicators that benefit most from the SEEA Central Framework include those that relate to:

- resource use and environmental efficiency of the economy (e.g. water and energy productivity, waste and emission intensity)
- production, employment and expenditure relating to environmental activities (e.g. contribution of environmental activities to GDP, share of government expenditure on environmental protection)

- environmental taxes, environmental subsidies and similar transfers (e.g. total environmental taxes to GDP)
- environmental assets and their role in the economy (e.g. changes in stocks of natural resources, depletion adjusted value added for extractive industries).

2.11 The suitability of a data source depends on the purpose for which the indicators are to be used and on the level at which they are to be applied. The narrower the policy or management focus the more specific the information has to be, and the more detailed the underlying accounts and databases have to be. Often a combination of several sources is necessary to calculate the indicators and to support in-depth analysis. Consequently, the quality and usefulness of an indicator depends on the suitability of the underlying information and in this regard there may be limitations related to the use of an indicator in certain contexts.

2.12 The SEEA Central Framework Section 6.4 introduces a range of indicators. Others are described through this chapter or may be derived using the analytical techniques described in Chapter 3. The data underlying indicators may also be sourced from other statistical sources (e.g. environmental monitoring systems, emission inventories, pollutant release and transfer registers (PRTR), opinion polls, business surveys). These other statistical sources are often needed to populate SEEA accounts, but may also be used directly to calculate certain indicators. Adapting them to SEEA definitions and classifications helps structure the underlying data sets and improves their coherence. As a result, by drawing indicators from the accounts of the SEEA Central Framework, coherence between data sources is at least assured, so that, for example, comparisons between industry valued added and water use of particular industries (e.g. agriculture and mining) can be made with confidence.

2.13 In the following sections a number of indicators are described in the context of considering the application of data from the SEEA Central Framework for various topics. Annex 1 (to be developed) provides a more detailed explanation of the calculation of various indicators that are used as examples through this chapter. At the end of this chapter, Section 2.7 discusses a number of issues relevant to the selection, interpretation and presentation of indicators across the various topics.

2.3 Analysis of sustainable resource use and environmental efficiency

2.3.1 Introduction

2.14 The use of materials from natural resources in human activities and the related production and consumption processes have many environmental, economic and social consequences that often extend beyond the borders of individual countries or regions. This has a bearing on decisions cutting across many policy areas, ranging from economy, trade and technology development, to natural resource and environmental management, and human health.

2.15 From an environmental point of view, the use of natural resources and materials has consequences that occur at different stages of the resource cycle and that affect the quantity and quality of natural resource stocks and the quality of ecosystems and environmental media. It has consequences on:

i. the rate of extraction and depletion of renewable and non-renewable resources,

ii. the extent of harvest and the reproduction capacity and natural productivity of renewable resources,

iii. the associated environmental burden (e.g. pollution, waste, habitat disruption) and its effects on environmental quality (e.g. air, climate, water, soil, biodiversity, landscape) and on related environmental services.

2.16 The type and intensity of these consequences depend on the kind and amounts of natural resources and materials used, the way these resources are used and managed, and the type and location of the natural environment from where they originate.

2.17 From a social point of view, the use of natural resources and any residual flows (such as emissions and waste flows) have consequences on employment and on human health, and implications for leisure habits connected to the presence and accessibility of particular resources, landscapes and ecosystems. There may also be cultural implications when natural resources are a basic element of the cultural heritage of people. The way in which revenues and other financial flows related to resource production and supply are managed (particularly in resource rich countries) may also have a bearing on relative income levels.

2.18 From an economic point of view, the way natural resources and residual flows are managed has consequences on

i. short term costs and long term economic sustainability,

ii. the supply of strategically important materials,

iii. the costs associated with the downstream management of materials, and

iv. the productivity of economic activities and industrial sectors.

2.19 A development pattern that depletes natural resources without providing secure, long-term substitutes for the goods and services that they provide is unlikely to be sustainable. Similarly, a development pattern that generates significant flows of residuals (air emissions, polluted water, waste flows) is likely to have longer term consequences in terms of the environment and human health that will in turn have economic effects.

2.20 Economic growth is generally accompanied by growing demand for raw materials, energy and other natural resources with consequences on market prices and on trade flows of these resources. Worldwide use of virtually every significant material has been rising, and concerns about shortages of stocks of natural resources and the security of supply of water and energy and other materials have been recurrent. Growing economic and trade integration has shifted many policy issues from local and national levels to global levels. It has enlarged the size of markets, allowed greater specialisation and mobility in production, increased the role of multi-national enterprises and led to an overall increase in international flows in raw materials and manufactured goods.

2.21 Prices for energy and other material resources have also risen significantly amid growing global demand. This has implications for the ways in which natural resources are supplied and used in the economy. They also have a bearing on decisions concerning mineral exploration, technology development and innovation. Hence, natural resource consumption and efficiency in the use of materials have become important issues, adding to long standing concerns about the availability of resources.

2.22 The concept of sustainable resource use and environmental efficiency builds on an integrated and long-term approach to resource management. It encompasses aspects linked to the economic efficiency, productivity and effectiveness of resource use at the various stages of the production and consumption chain, as well as related social aspects. In other words, it aims at optimising the net benefits from resource use within the context of economic development, by:

i. Ensuring adequate supplies of renewable and non-renewable resources to support economic activities and economic growth.

ii. Managing the environmental pressures associated with the extraction, processing, use and end-of-life disposal of materials, to minimise adverse effects on environmental quality and human health.

iii. Preventing natural resource degradation and depletion.

iv. Maintaining non-market ecosystem services.

2.23 For analytical purposes the concept of sustainable resource use may be considered in two main streams. First, analysis of sustainable production and consumption and resource productivity, and second, analysis of residual flows. The following sub-sections describe various types of indicators and analysis related to these two streams.

2.24 Data for the analysis of sustainable resource use and environmental efficiency may be sourced from a number of accounts described in the SEEA Central Framework. Most important are the Physical Supply and Use Tables (PSUT) and the associated construction of Environmentally Extended Input-Output Tables (EE-IOT) which link the physical flows recorded in PSUT (natural inputs, products and residuals) with monetary input-output tables defined following the System of National Accounts (SNA). EE-IOT are a particular type of combined presentation of physical and monetary data as described in the SEEA Central Framework Chapter 6. They are discussed in more detail in Section 3.2.

2.25 Also relevant are accounts related to environmental protection expenditure and associated investments in goods and services that reduce or mitigate environmental pressures. Analysis and indicators related to these responses are discussed in Section 2.4.

2.3.2 Indicators and aggregates for resource use and environmental efficiency

2.26 Resource use and environmental efficiency may be analysed at a broad, economy-wide level through consideration of relevant aggregates and a variety of indicators, generically referred to as efficiency indicators. Important aggregates include flows of gross energy input and net domestic energy use; gross water input, net domestic water use and final water use (water consumption); total flows of air emissions, releases of substances to water and generation of solid waste. All of these aggregates are derived within the various physical supply and use tables described in Chapter 3 of the SEEA Central Framework.

2.27 Efficiency indicators compare trends in economic activity such as value-added, income or consumption with trends in specific environmental flows such as emissions, energy and water use, and flows of waste. Efficiency indicators are usually expressed as intensity or productivity ratios. Intensity indicators are calculated as the ratio of the environmental flow to the measure of economic activity, while productivity indicators are the inverse of this ratio. When monitoring trends over a given period, efficiency indicators can also be expressed as decoupling ratios or as decoupling factors.

2.28 Efficiency indicators are often grouped into two broad types:

- Environmental efficiency indicators characterise the environmental and economic efficiency with which pollutants and other residuals generated in production and consumption are mitigated, controlled and prevented. They are usually expressed as intensity or productivity ratios. They relate environmental variables such as emissions of pollutants and other residuals to economic variables such as output, income and value added; or alternatively to population. Environmental efficiency indicators can be disaggregated by institutional sector and by industry, as well as by emission source.

- Resource efficiency indicators characterise the efficiency with which natural resources, including water, energy and other materials are used in production and consumption. They are usually expressed as intensity or productivity ratios. They relate environmental variables such as the extraction, supply or consumption of natural resources and materials to economic variables such as output, income and value added.

2.29 All environmental and resource efficiency indicators can be presented at the aggregate national level and at more detailed industry and institutional sector levels. Many of them can be presented in the form of issue profiles or environmental-economic profiles (see Section 2.7). When associated with more detailed analytical tools such as ‘structural decomposition analysis’ (see Section 3.3), these indicators can further be decomposed to reflect the extent to which underlying drivers (e.g. technological factors) and structural changes, contributed to reducing or adding to environmental pressures over the considered period.

2.30 The measures of economic activity used in the calculation of the indicators should be measured in volume terms for time series purposes. That is, the measures should be adjusted for the effect of price change (inflation). If measures unadjusted for price change are used the resulting indicators may suggest a relationship between the environmental flow and economic activity that is misleading in terms of the degree of change in intensity or productivity. For example, an intensity indicator of flows of emissions relative to GDP will tend to show lower rates of growth using a GDP measure unadjusted for price change.

2.31 For indicators that show a country’s production, and the interaction of this production with the environment, gross output, industry value added or GDP are useful measures. Care should be taken in the choice of measure to represent production since output and value added are quite different national accounting concepts (in essence, value added is gross output less intermediate consumption of goods and services). Consequently, depending on the scope of the environmental flow measure that is part of the intensity or productivity indicator, quite different levels and growths rates in the indicators will be obtained using different measures of economic production. For indicators that show a country's domestic final demand for environmental flows (natural resources and residual flows), household consumption or real net income measures are preferred.

2.32 While intensity and productivity indicators can provide a good summary of overall change, of themselves they give no direct indication of whether environmental pressures are decreasing in absolute terms, whether environmental pressures are below a desired or critical level, or whether production processes are becoming relatively more resource efficient as a result of structural economic changes towards service industries. Consequently, the interpretation of indicators is likely to require additional contextual information which may commonly be found within the underlying accounts.

2.33 International comparisons of environmental and resource efficiency between countries must also be interpreted carefully. Differences in industry composition and geographical structures may account for some of the cross-country differences. As such complementary information will need to accompany efficiency indicators (e.g. information about economic structures, stage of economic development, and natural resource endowments).

Examples of environmental efficiency indicators

2.34 Greenhouse Gas (GHG) or CO_2 productivity, which relates economic activity to emissions of greenhouse gases (from energy use or from all sources), expressed in national currency per tonne of CO_2 or CO_2 equivalent emitted.

2.35 Air pollutant emission intensities, which relate emissions of greenhouse gases or air pollutants to economic activity, expressed in tonnes per unit of GDP.

2.36 Water pollution intensities that relate the volume of wastewater generated or the amounts of pollutants released in wastewater to economic activity, expressed in tonnes per unit of GDP.

2.37 Nutrient surplus intensities (nitrogen, phosphorous), which relate nutrient surpluses (or deficits) to economic activity. The most common indicators relate to nutrients in agriculture. They are usually expressed in terms of kilograms of nutrient surplus (or deficit) per hectare of agricultural land, and can further be related to agricultural output in physical or in monetary terms. Levels and changes in the physical quantities of nutrient surpluses (or deficits) can be used to indicate the trend and level of potential physical pressure of nutrient surpluses or deficits on the environment, such as declining soil fertility in the case of a nutrient deficit, or risks of polluting soil, water and air for a nutrient surplus. Due to regional differences in farming systems, climate, soil, crop types, and topography, such indicators benefit from a spatial breakdown.

- Agricultural nutrient balances are calculated as the difference between the total quantity of nutrient inputs entering an agricultural system (mainly fertilisers and livestock manure, but also natural inputs), and the quantity of nutrient outputs leaving the system (mainly uptake of nutrients by crops and grassland).

- The same approach can be applied at the macro-level to calculate economy-wide nutrient balance indicators (e.g. for reactive nitrogen) covering all major sources (agricultural, industrial, traffic, households, etc.).

2.38 Waste generation intensities that relate the amounts of waste generated to economic output. A distinction can be made between types of waste or waste materials (mineral or non-mineral, hazardous or non-hazardous, industrial or municipal). When monitoring municipal or household waste, the amounts of waste generated can be related to private final consumption expenditure. When monitoring industrial waste, the amounts of waste generated can be related to the value added by industry. They can also be compared to the amounts of primary resource inputs derived from material flow accounts. Other useful indicators include waste recovery ratios that relate the amounts of waste recovered (material recycling, biological recovery, energy recovery) to the amounts of waste generated or collected.

Examples of resource efficiency indicators

2.39 Material productivity or intensity indicators relate the use of material resources to the related economic activity. Such indicators can be calculated at an aggregate, economy-wide level, as well as by industry and by material groups (e.g. mineral resources (metallic minerals, industrial minerals, construction minerals); biotic resources (biomass for food, biomass for feed, wood biomass); energy carriers (oil, coal, gas, peat)). Other useful material related indicators include material dependency ratios which reflect the share of certain groups of materials imported within total gross material input.

2.40 Energy productivity or intensity indicators relate the net domestic energy use to the economic output generated. Such indicators can be calculated at the aggregate economy-wide level, as well as by industry and by primary energy source.

2.41 Other useful energy related indicators include: the share of energy from renewable sources or from fossil fuels in total supply, and by industry; energy dependency ratios that compare the energy produced in a country or a territory to the energy imported; and indicators linking energy production and consumption to resource use and air emissions, expressed as TOE or kWh per unit (e.g. tonne) of GHG or air pollutant emitted.

2.42 Water use productivity or intensity indicators that relate the use of water to the economic activity generated. Such indicators can be calculated at the aggregate, economy-wide level, as well as by industry and by water source. Indicator examples include:

- Water abstraction intensities that relate the amounts of water abstracted (Total Abstracted Water in the water PSUT) to economic activity or to population. Abstraction intensities can be broken down by source, (surface water, groundwater, desalinated water) and by abstracting industries.
- Water use intensities or productivity ratios that relate the amounts of water used (Net Domestic Water Use in the water PSUT) to economic activity and by industry. These intensity ratios can be compiled for individual industries and for households. They

can also be broken down by source, such as water from natural stocks (surface, groundwater), desalinated water, and reused water.

2.43 Other useful water related indicators include: the share of water consumption (or final water use) in water supply that reflects the share of the water used in an economic activity that is evaporated or incorporated into products and hence no longer available for use; water recycling rates, that show the share of reused or recycled water in water supply; water dependency ratios that show the share of water inputs from outside a territory (i.e. imported) in total water inputs. Dependency ratios can be calculated at country level or for regions within a country mostly from the water resources asset account between which imports and exports of water may be significant.

2.44 Land use efficiency indicators include ratios of the area of land used to economic activity (i.e. $/ha) or the value of land used to economic activity. The ratios can be calculated for industries, institutional sectors and for the country as a whole or for particular regions.

Production and consumption based indicators

2.45 Most environmental and resource efficiency indicators are production-based; they account for the environmental flows (extraction of natural resources and residual flows) directly “used” or “produced” by domestic production and the subsequent final consumption. It is also of interest to calculate indicators that account for consumption-based perspectives on environmental flows, i.e. those flows that are induced by domestic final demand.

2.46 A consumption based approach tracks the environmental flows (extraction of natural resources and residual flows) embodied in imports that have been delivered “upstream” by natural resources and ecosystems to production processes abroad. This indirect upstream use of environmental flows is added to the direct use of services for domestic production. In addition, the environmental flows embodied in the exports of products are deducted. The resulting indicators inform about the net direct and indirect environmental flows in domestic final demand, including household and government consumption and capital formation (investment). Prominent examples of consumption-based indicators are consumption-based carbon and GHG indicators.

2.47 Consumption-based indicators are not “leakage” estimates obtained from models (replete with assumptions about how actors may react to a price change). Rather they are estimates based on observed trends in production, consumption and international trade patterns. Ideally, consumption-based indicators should be based on multi-regional input-output tables which do not require use of domestic technology assumptions. However, in practice they are often based on bilateral trade statistics. Consumption-based indicators also have similarities with footprint indicators (e.g. carbon and water footprints) which may be compiled using a variety of methods. Section 3.3 discusses relevant measurement issues in more detail.

2.48 Two aspects are highlighted here concerning the development and use of consumption-based indicators:

- The appeal of a consumption-based method for calculating national-level efficiency indicators rises with the degree to which environmental issues are of a global nature. Greenhouse gas emissions are the most prominent case in point: no matter where they are emitted, they contribute equally to changes in the global 'climate system'. This provides a justification for adding together direct and indirect flows but the rationale is less clear when it concerns environmental flows that are associated with local rather than global environmental issues.

- Indicators that reflect the direct and indirect environmental flows in final demand are more difficult to link to policy than direct, production-related indicators. When a country reduces its production-based environmental pressures but increases its consumption-based pressures because domestic production has been substituted by imports, policy conclusions are likely to be complex, multi-dimensional and difficult to assess in their effects, involving trade issues, issues of international investment, and consumer and industry policy.

2.3.3 General analytical approaches for resource use and environmental efficiency

Decoupling analysis

2.49 A common analysis is to look at the degree of decoupling between natural inputs or residual flows and economic variables. Decoupling occurs when the growth rate of an environmental pressure is less than that of its economic driving force (e.g. GDP) over a given period. Decoupling indicators describe the linkages between environmental pressures and economic development, and show the extent to which growth in income and consumption is occurring with a decreasing use of environmental flows (e.g. decreasing air or GHG emissions, decreasing energy and water use, decreasing waste generation).

2.50 Decoupling can be either absolute or relative. Absolute decoupling is said to occur when the growth in the environmentally relevant variable is flat or decreasing while economic activity increasing. Decoupling is said to be relative when the growth rate of the environmentally relevant variable is positive but less than the growth rate of the economic variable.

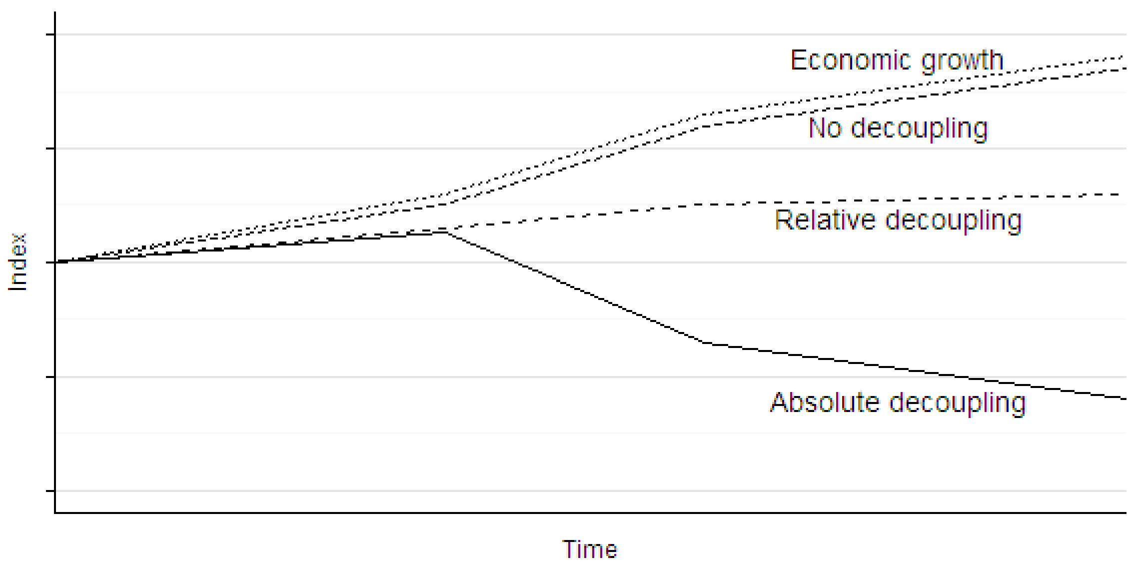
2.51 Many of the variables that feature in decoupling indicators also appear in the concepts of environmental and resource efficiency. Decoupling is usually conceived as an elasticity focusing on changes in volumes, whereas intensity and productivity are more concerned with the actual values of these ratios. Which usage is chosen depends on the context and, often, on the audience being addressed.

2.52 Decoupling can be measured by efficiency indicators that have an environmental pressure variable as the numerator and an economic variable as the denominator. Sometimes, the denominator (or driving force) may be population growth or some other variable.

2.53 When decoupling is presented as a single line in the form of efficiency/intensity ratios (i.e. a time series of the ratio of the environmental variable to the economic driving force), the idea of improvement in efficiency is well communicated. But it gives no indication on whether environmental pressures are decreasing in absolute terms, whether environmental pressures are below a desired or critical level, or whether production processes are becoming relatively more resource efficient as a result of structural economic changes towards service industries.

2.54 For such assessments, it is thus useful to separately identify and present the environmental and the economic components of indicators. This can be done in the form of decoupling trends, i.e. by displaying two indexed (e.g. base year=100) time series on the same graph. From such a graph, it is immediately clear whether the economic driving force is growing or shrinking, whether decoupling – absolute or relative – is occurring, when it started and whether it continues. An example of a chart showing decoupling trends is shown in Figure 2.2.

Figure 2.2 Indicative decoupling trends



2.55 To compare decoupling among countries, the ratio of the value of the efficiency indicator for a given country at the end and the start of a given time period can be normalised using:

$$\textit{Decoupling ratio} = (\mathrm{EP/DF})_{\text{end of period}} / (\mathrm{EP/DF})_{\text{start of period}}$$

where *EP* = Environmental Pressure and *DF* = Driving Force.

If the decoupling ratio is less than 1, decoupling has occurred during the period, although it does not indicate whether decoupling was absolute or relative. To avoid displaying (on a bar graph), small values when decoupling is significant, a decoupling factor can be calculated as follows:

Decoupling factor = 1 – decoupling ratio

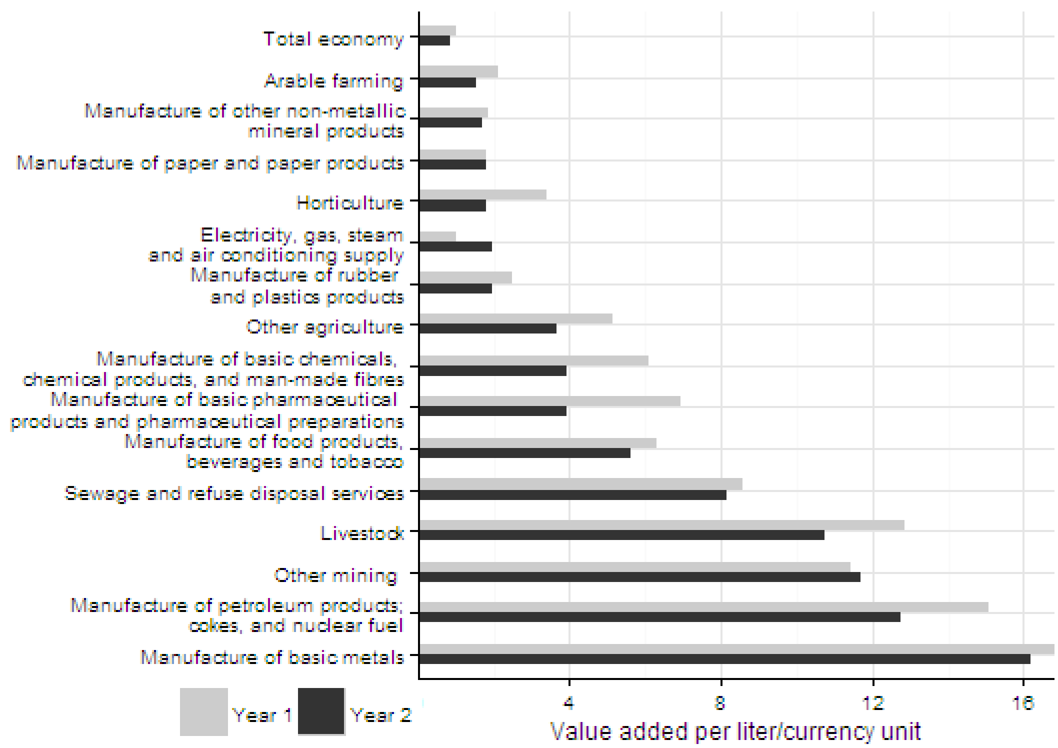
The decoupling factor is zero or negative in the absence of decoupling and has a maximum value of 1 when the environmental pressure reaches zero

Analysis by economic industry

2.56 In physical supply and use tables (PSUT) flows between the economy and the environment and flows within the economy are presented together, and are structured following standard classifications for economic statistics. Using information on individual material inputs for industries within the PSUT, measures of resource intensity and productivity can be estimated by taking the amount raw materials that are needed to produce a unit final product. These measures can be compared over time, across industries and between countries to assess trends in sustainable resource use and the effectiveness of policy responses. Similar to economy-wide analysis, decoupling graphs may be made for individual industries.

2.57 The following example in Figure 2.3 highlights use of water by industries in relation to their value-added. These are industry level intensity indicators and the presentation may be considered an issue profile as described in Section 2.7.

Figure 2.3 Industry level water use intensity indicators



2.58 The same basic approach can be used to track flows of emissions (e.g. GHG emissions, emissions to water) and flows of waste by industry to assess changes in the efficiency of production with respect to residual flows and the effectiveness of policy instruments.

2.59 The monetary supply and use tables (MSUT), estimated using standard national accounts data, provide economic information by industry on production, value added and can be supplemented with information on employment. Since PSUT and MSUT are structured following the same classifications additional industry analysis may be completed considering resource use per unit of production or value added.

2.60 Comparing PSUT and MSUT provides the possibility of analysing implicit prices at an aggregated level. For example, the average energy prices for different industries may be assessed by looking at the monetary and physical data from the physical energy flow accounts and the monetary data on energy products from the MSUT. These implicit prices should be taken as indicative rather than definitive since they will often be based on comparing data from different sources and they will represent unit values and as such may not take into account important qualitative effects.

Analysis for households

2.61 Using both PSUT and MSUT, focus may be placed on household use of resources and household residual flows (e.g. waste and emissions). In particular, measures of intensity and decoupling with respect to household consumption and population growth may be formed. Further, since these data are integrated with the industry data, it is possible to trace flows of individual materials from the point of entry to the economy to the point of use by households. Similarly, measures linking household consumption to residual flows (e.g. air emissions linked to transport activity) may be developed. These types of analysis are described further in relation to input-output analysis in Chapter 3.

2.62 Where information is available these measures may be further developed to consider resource use and environmental efficiency for different household types. This can be done by using information from the SEEA in combination with data from the SNA and household budget surveys. Accordingly, several different household characteristics can be analysed, such as the size of households, gender and age composition, income levels, etc. This kind of information may help policy makers and researchers better understand present and future developments in, for example, greenhouse gas emissions, and to develop measures that may influence associated consumption patterns. A spatial analysis based on the location of households may also be conducted if information is available. Chapter 4 provides additional detail on the analytical possibilities with respect to the household sector.

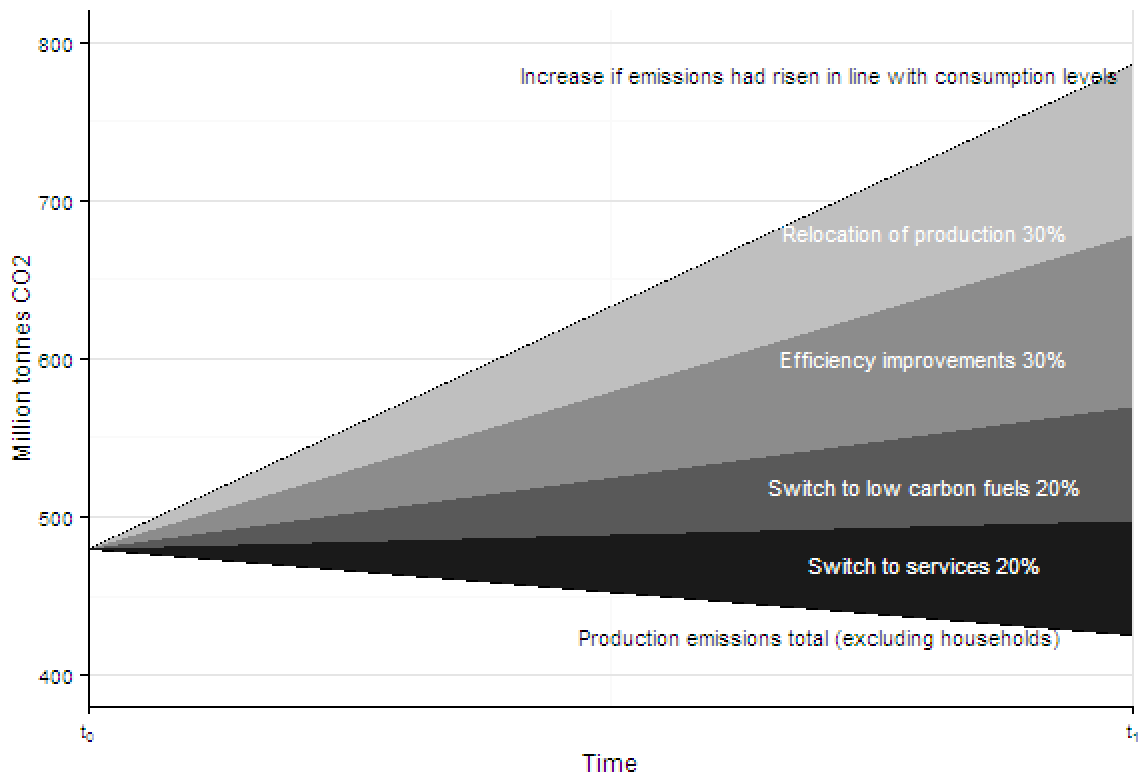
Decomposition analysis

2.63 Changes in the pressures on the environment from economic activities take place in a dynamic system of interactions, for example where the size and structure of the economy vary in response to changes in demand and in global trade. It is therefore often difficult to identify the extent to which specific consumption and production activities and measures to improve resource and environmental efficiency have actually contributed to changes in the levels of these pressures.

2.64 Decomposition analysis is a technique that can be used to account in detail for the factors underlying these changes. Typically, the variables taken into account in the calculations include changes in the size of the economy, in the structure of the supply chain and the structure of demand, in the energy intensity of production, and in efficiency improvements in the production process.

2.65 The example given below illustrates how changes in the level of carbon dioxide emissions from economic production can be attributed to a number of changes in the nature of the economy.

Figure 2.4 Decomposition of changes in CO_2 emissions



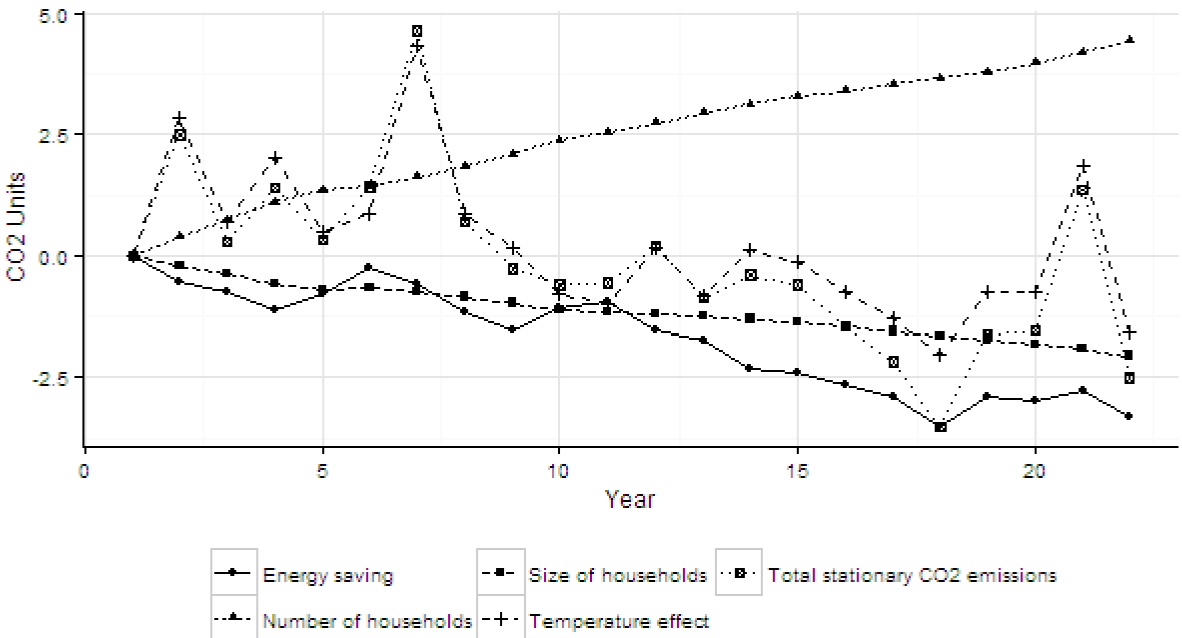
2.66 The figure shows that carbon dioxide emissions would have increased by 306 million tonnes if they had grown in line with consumption levels. This estimate may be obtained by using the relationship between consumption and emissions in t_0, and then estimating emissions in each subsequent year based on changes in measured consumption. This estimate is thus a derivation from SEEA based data set using certain assumptions.

2.67 However, rather than increasing, measured emissions decreased by 54 million tonnes. The difference between potential emissions and actual emissions can be decomposed and shown to be a combination of reduced CO_2 emission intensity (a switch to low carbon fuels) - 20% of the overall saving; the structural change in the supply chain - 30% of the saving; efficiency gains in energy use (resource efficiency) - 30% of the saving; and a structural change in demand (e.g. a change in the pattern of consumption of different products) - 20% of the saving.

2.68 This kind of analysis is important in assessing the success of policies aimed at reducing environmental impacts. For example, changes in the structure of the supply chain do not necessarily have any beneficial impact on global environmental pressures, as they simply reflect a relocation of the source of that pressure from one country to another.

2.69 Decomposition analysis can also be completed for resource use or residual flows for households. For example, the causes of the decrease in emission levels for stationary sources of emissions by households can be decomposed into several factors, including the number of households, the average size of households, the effect of the average temperature, and an energy saving effect. Likewise, the change in emission levels for mobile sources of emissions can be decomposed into several factors including population growth, car ownership, traffic intensity (kilometres travelled per vehicle) and a CO_2 efficiency effects (emissions per kilometre travelled).

Figure 2.5 Decomposition analysis for CO_2 emissions by households from stationary sources



2.70 Section 3.3 provides a summary of the mechanics of decomposition analysis. The analysis above is based on data from PSUT for emissions of carbon dioxide and input-output tables. Ideally the analysis would be undertaken in the context of a multi-regional input-output (MRIO) model to take account of cross-country effects more precisely. MRIO models are discussed in more detail in Section 3.2.

Input-output analysis – multipliers and footprints

2.71 Beyond the types of approaches described above, more detailed analytical approaches are possible that take advantage of the integrated nature of datasets that incorporate both economic and environmental flows. The development and use of Environmentally Extended Input-Output Tables (EE-IOT) is the key starting point and these tables can be developed based on the concepts and frameworks outlined in the SEEA Central Framework.

2.72 The use of EE-IOT generally involves modelling of flows through the economy and potentially linking to economies within more than one country using multi-regional input-output models. Some common outputs from modelling processes are multipliers and footprints that can be defined in relation to particular aspects of resource use and environmental efficiency. Section 3.3 discusses the measurement of multipliers and footprints and gives examples of their application.

2.3.4 Specific analysis for resource use

Analysis by type of resource

2.73 It is most common for PSUT to be developed for flows of particular resources or residuals. For resources the most common PSUT are for water and energy (see SEEA Central Framework Chapter 3). These targeted resource PSUT enable a complete mapping of relevant flows through an economy to be made and, given the structure of the PSUT, direct links can be made to associated monetary flows relating to the resource.

2.74 The types of analysis that are possible are broad ranging. In relation to water the SEEA-Water Chapter 9 highlights a number of potential applications including analysis of water use by purpose, final water use by industry and as a percentage of gross value added, water intensity by product. Using the same framework distinctions may also be made between the use of resources for intermediate consumption of enterprises or final consumption of households.

2.75 A particular question may lie in the area of resource dependency. PSUT for individual resources can be used to assess the relative importance of imports and domestic extraction of resources, such as mineral and energy resources. Also in the area of resource dependency it may be relevant to assess the relative importance of particular resources in the generation of GDP (e.g. by assessing the share of GDP of industries that are dependent on particular resources). Of interest may be analysis of the countries of origin and destination for imports and exports of products. Finally, on this topic understanding the availability of resources within the country will be relevant and for this purpose data compiled in asset accounts (described in SEEA Central Framework Chapter 5) are required. Analysis of the stock of resources is discussed in Section 2.5.

Material flow accounts and analysis

2.76 The focus in the SEEA Central Framework is on describing PSUT that pertain to specific materials, energy or residual flows. In concept, an economy wide PSUT can be compiled that traces all flows of all materials, energy and residuals from the environment, through the economy and back into the environment. A common approach that is an adjunct to a SEEA based PSUT are economy wide - material flow accounts (EW-MFA). These are introduced briefly in the SEEA Central Framework Chapter 3. EW-MFA focus on physical flows into and out of the economy, i.e. ignoring intra-economy physical flows. With this purpose in mind they are commonly compiled with some differences in treatment compared to the SEEA (see SEEA Central Framework 3.282-3.286). A variety of indicators reflecting aggregate material input, output and consumption can be derived (see OECD, 2008a and 2008b and Eurostat 2001 and 2011a).

2.77 One of the limitations with the EW-MFA indicators is that materials in different states of production (raw materials, semi-finished products and final products) are added together. Accordingly, some measures of consumption fall short in understanding the total mass of raw materials consumed by a country as it only accounts for the mass of the final goods imported, not the raw material used to produce them. In order to get a more genuine indication of the resource productivity of a country the material flows are expressed in the amounts of raw materials (raw material equivalents, RME) that were needed during the whole production chain of a product.

2.78 Material input and consumption indicators are sometimes used as proxies for the generic environmental pressure on the assumption that sooner or later every material input becomes an output in the form of waste or emissions, and that measuring the inputs therefore gives a first approximation of the potential overall environmental burden. This should however not be interpreted as reflecting environmental impacts. Aggregate weight measures do not consider any characteristic of materials other than weight. The actual environmental pressure of material flows and the subsequent impacts on environmental conditions depend on many factors, such as the chemical and physical properties of the materials, the locality at which ores are mined or pollutants released, or the way the materials are managed across their life-cycle.

2.79 Like other highly aggregated indicators, EW-MFA indicators can hide important variations in their constituent variables. For example, quantities of particular materials flows can vary considerably from year to year, while the aggregated figure may remain constant. Also, the total of highly aggregated indicators can be dominated by one single material group that masks developments in other material groups. This effect is the reason that flows of water are generally excluded from the scope of EW-MFA.

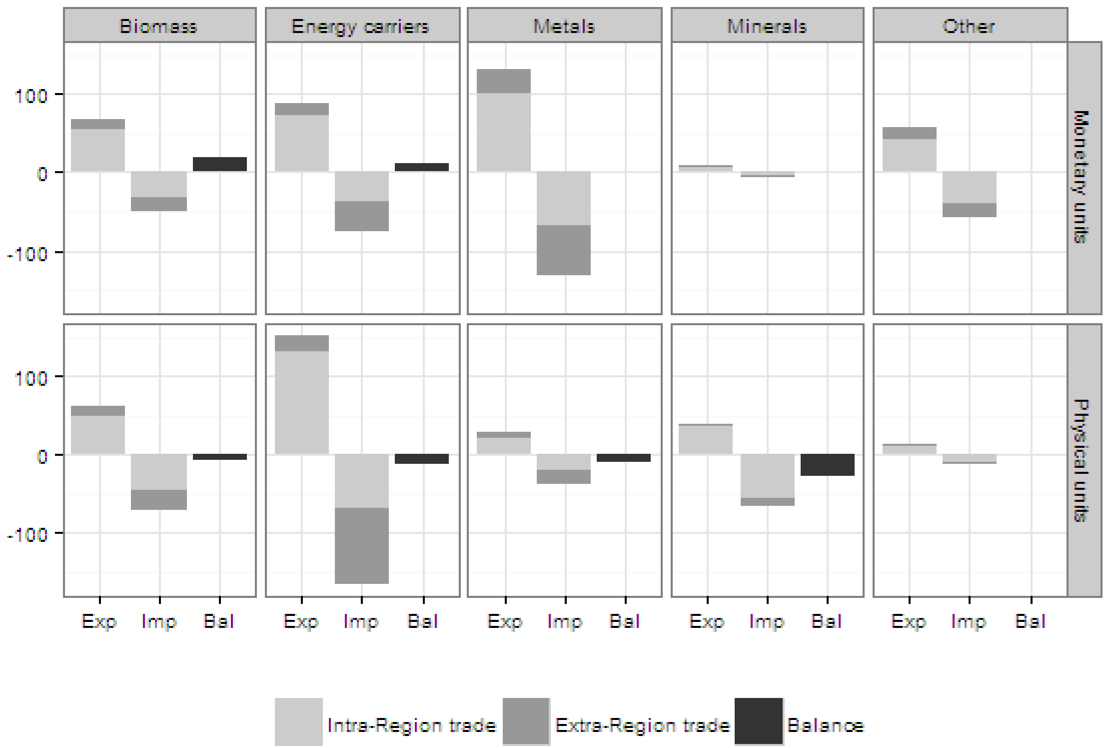
2.80 Proper interpretation of EW-MFA indicators therefore requires, wherever possible, a breakdown of the indicators into their constituent variables. EW-MFA indicators broken down by type of material inform about the mix of materials and help see the weights of different types of materials in the overall material basis of the economy and shifts in these weights over time. The most common material groups are: metals (metallic ores and metal-based products), non-metallic industrial minerals, construction minerals, fossil energy carriers (oil, coal, gas, others such as peat), and biomass (food crops, fodder crops, timber, wild animals, other). Materials can also be grouped according to the type of natural resource from which they are extracted (e.g. materials from renewable natural resource stocks versus materials from non-renewable natural resource stocks).

Analysis by product/ material groups

2.81 Resource productivity and intensity can also be estimated for specific materials and energy. From the monetary and physical supply and use tables, information is available for different types of materials, and commonly distinct PSUT are compiled for energy and for individual materials, such as water. Using this information the resource productivity of particular types of materials and energy for different industries can be estimated. Further, from this information, it is possible to determine the types of industries for which a particular material yields the most value added. Also the (economic) efficiency of the use of different materials to produce a similar product can be assessed and the substitution of materials can be monitored.

2.82 By combining data from the PSUT and MSUT it is possible to look in more detail at flows of imports and exports and analyse trade deficits and surpluses in monetary and physical terms. The example in Figure 2.6 shows the monetary (left hand side) and physical (right hand side) measures of exports (+) and imports (-) for five groups of materials.

Figure 2.6 Analysis of imports and exports in physical and monetary terms



2.83 The following three types of analyses focus on specific concerns related to environmental impacts, supply security and technology development that are associated to certain substances, materials and manufactured goods. They include:

- *Substance flow analysis* monitors flows of specific substances (e.g. Cd, Pb, Zn, Hg, N, P, CO2, CFC) that are known for raising particular concerns as regards the environmental and health risks associated with their production and consumption.
- *Material system analysis* (MSA) is based on material specific flow accounts. It focuses on selected raw materials or semi-finished goods at various levels of detail and application (e.g. cement, paper, iron and steel, rare metals, plastics, timber, water) and considers life-cycle-wide inputs and outputs. It applies to materials that raise particular concerns as to the sustainability of their use, the security of their supply to the economy, and/or the environmental consequences of their production and consumption.
- *Life cycle assessments* (LCA) are based on life cycle inventories. They focus on materials connected to the production and use of specific products (e.g. batteries, cars, computers,

textiles), and analyse the material requirements and potential environmental pressures along the full life cycle of the products. LCA can equally be applied to services.

2.84 In principle, all of these analyses may be supported by data organised following a PSUT structure. However, it is likely that detailed technical discussions related to the individual elements and substances would be required in order to populate a PSUT structure and no details pertaining to such tables are provided in the SEEA Central Framework.

2.3.5 Specific analysis for residual flows

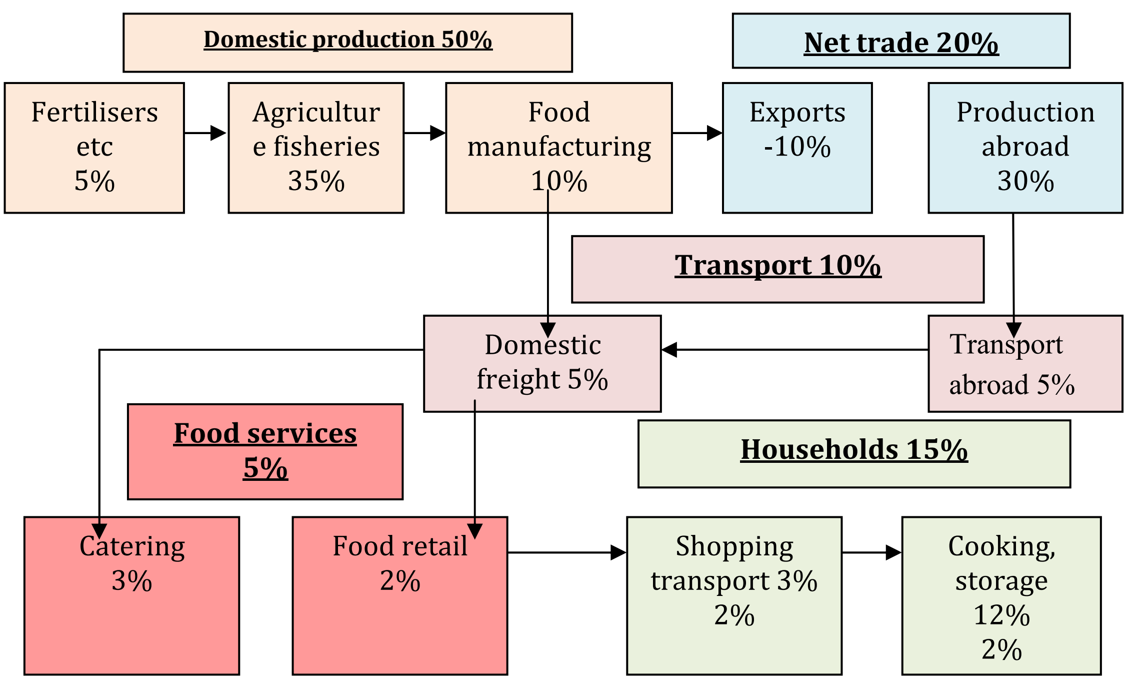
Describing residual flows in the supply chain

2.85 A complete PSUT also contains information on the supply and use of solid waste. Analysis of flows of solid waste with all other natural input, product and residual flows can provide resource efficiency indicators such as the solid waste generated per primary product and the share of secondary materials with regard to primary resource inputs.

2.86 A wide number of studies (e.g. EIPRO – ref needed) have highlighted the importance of the food chain as a major source of pressures on the environment. It is useful to have an understanding of where in the food chain such pressures occur, as policy interventions can then be targeted at the most significant areas.

2.87 The example given below illustrates how greenhouse gas emissions can be allocated to a range of actors within the economic food chain by attributing estimates of greenhouse gas emissions to relevant industries and products, and tracking the series of product interactions in an input-output context. It shows that although emissions relating to agricultural production (35%) are a major source of food chain emissions, transport and trade are also important contributors.

Figure 2.7 Food chain greenhouse gas emissions



2.88 Data for this type of analysis will need to be drawn from a wide range of sources. The main source is the PSUT for emissions of carbon dioxide (SEEA Central Framework, Section 3.6), which provides information on the emissions from the main food product related industries. Emissions relating to electricity use need to be allocated to the relevant parts of the supply chain. Emissions relating to households need to be based on household travel surveys and energy use in the home. Emissions relating to international trade need to be based on input-output analyses. This type of analysis highlights the potential for data organised using PSUT and input-output table structures to be used to trace residual flows through the economy, since all of the information is classified to common industry and product classifications.

Analysis of emissions according to different frameworks

2.89 Emissions may be accounted for in different frameworks yielding different results for some types of analysis. Well-known are the emissions reported to the UNFCCC (United Nations Framework Convention on Climate Change) and other frameworks include general environmental statistics and the air emission accounts of the SEEA Central Framework. Bridge tables can be developed which both, describe the differences between the various concepts and boundaries of emissions, and show the differences in the growth rates of emissions according to different definitions. For example, a bridge table can show the impact on emissions aggregates when international transport is taken into account.

Emissions with respect to transport and energy

2.90 A particular area of analysis may be the emissions generated from the use of energy and in particular from transport activity, including households. The air emission and energy accounts described in the SEEA Central Framework provide a basic set of information that is structured to permit linking emission flows to the energy use of particular industries and to households. In this regard the use of common classifications is central to the potential analytical usefulness of the SEEA.

2.91 Emission and energy accounts data for transport may also be connected to transport and traffic statistics. These statistics provide data on distance travelled and transport volumes by different transport modes. Combining this information with the SEEA data provides many kinds of analytical possibilities. For example, the emission efficiency of different transport modes can be assessed.

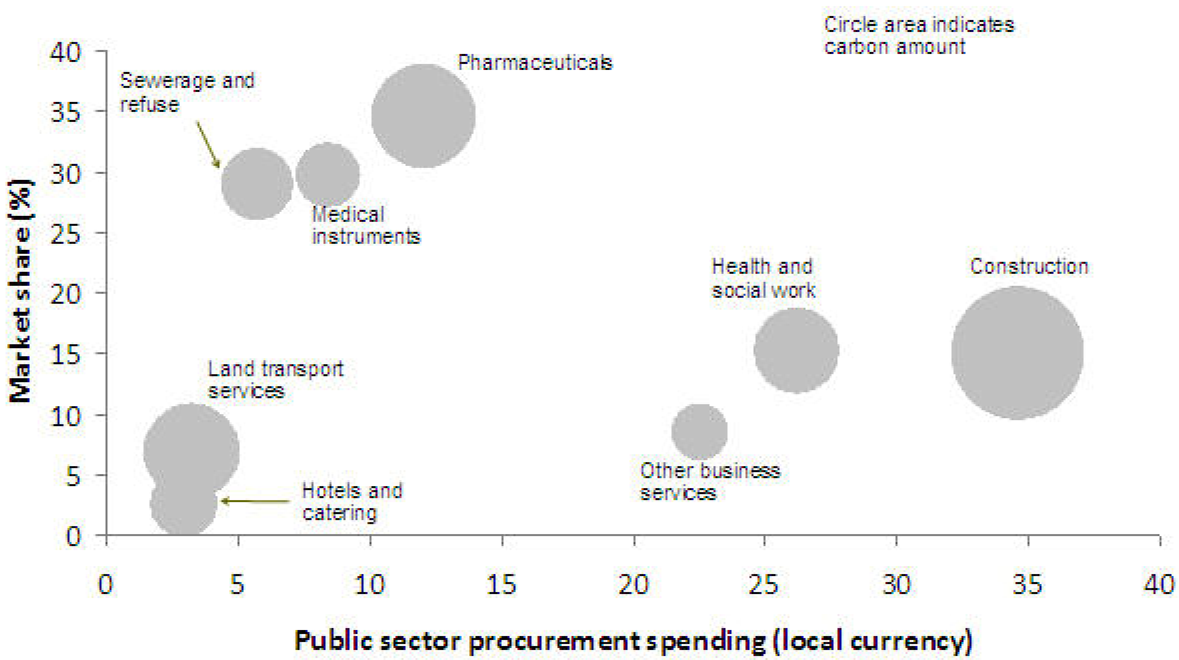
Linking residual flows and expenditures

2.92 Public sector agencies are significant purchasers of certain industries' output, and hence public sector procurement practices and choices can be used as a policy lever to improve sustainable resource use in those industries.

2.93 The example below shows a few selected areas where the emissions associated with public sector procurement are significant. For some industries, such as pharmaceuticals, public sector procurement accounts for up to 35 per cent of the total output of that industry. Although the proportion of total government procurement in this industry is only 10 local currency units, emissions from this sector relating to public sector procurement are larger than those from a number of other sectors, such as land transport, or sewerage and refuse.

2.94 The data used in this analysis is derived from a PSUT for emissions of carbon dioxide by industry (based on the air emissions account in the SEEA Central Framework Section 3.6), and by attributing emissions related to energy use (particularly electricity use) to the energy user (rather than the energy producer) based on the PSUT for energy (see SEEA Central Framework, Section 3.4). These data are then linked with information on public sector procurement drawn from monetary supply and use tables.

Figure 2.8 CO_2 emissions and public sector expenditure



2.4 Analysis of production, employment and expenditure relating to environmental activities

2.4.1 Introduction

2.95 The economic consequences of environmental measures and environmental concerns are of great interest to policymakers. They approach these topics from two perspectives. On the one hand, their interest focuses on the financial burden that is placed on the polluting industries, as they have to invest in pollution abatement control in order to comply with environmental regulations. On the other hand, environmental measures will bring about new economic activities that may create new jobs and stimulate economic growth. Policymakers therefore need information on enterprises and institutions that produce environmental goods and services and also information on the levels of expenditure on these goods and services by enterprises, governments and households.

2.96 The SEEA Central Framework presents two measurement approaches relevant to these information needs: statistics on the Environmental Goods and Services Sector (EGSS) and Environmental Production Expenditure Accounts (EPEA). EGSS and EPEA are described in Chapter 4 of the SEEA Central Framework. They are related but different sets of economic data that may be compiled for the purposes of analysing environmental activities.

2.97 Environmental activities are defined in the SEEA to consist of environmental protection activities and resource management activities and relate to economic activities aimed at reducing environmental degradation and safeguarding against the depletion of natural resources.

2.98 The EGSS consists of a heterogeneous set of enterprises that produce these environmental goods and services. Historically, the production of environmental goods and services focused on the demand for basic services, such as wastewater treatment or the collection of solid waste. However, with the drive towards cleaner and more resource efficient processes, products and materials, the activities of the sector have shifted toward ‘resource management’. Across both environmental protection and resource management activity, the EGSS includes enterprises created specifically to serve this emerging market (such as enterprises involved in renewable and sustainable energy systems) and enterprises in more traditionally defined industries (such as sewage and refuse disposal services).

2.99 The development of the EGSS can play a key role in a transition towards a more sustainable economy and society. Growth of the EGSS reflects more production of environmental goods and services for the benefit of the environment and contributes to economic growth. The EGSS is seen as a potential business opportunity (e.g. Eurostat, 2009) and an innovative environmental technology sector can help to stimulate growth if it is capable of tapping into rapidly growing export markets. In addition, the creation of employment opportunities in the EGSS (commonly referred to as ‘green jobs’) may help to reduce unemployment or balance reductions in employment in traditional industries.

2.100 Compilation of EPEA is motivated by identifying and measuring society’s response to environmental concerns through the supply of and demand for environmental protection services and through the adoption of production and consumption behaviour aimed at preventing environmental degradation. While the EPEA has a somewhat narrower scope than EGSS in terms of covering only environmental protection activity, it is relatively broader than EGSS in that it includes demand for all goods and services that may be used for environmental protection purposes not only those produced more specifically for those purposes. For example, EPEA will include vehicles purchased to undertake environmental restoration work even though the vehicles themselves were not designed for this specific purpose.

2.101 This section presents various types of indicators and analysis on issues of environmentally related production and employment that may be undertaken using data from the EGSS, and analysis of demand related to environmental activities from the EPEA as described in Chapter 4 of the SEEA Central Framework.

2.102 The SEEA Central Framework notes the potential to develop a parallel set of resource management expenditure accounts (RMEA). Although the development of RMEA has not been advanced to a great extent, conceptually, the same types of indicators and analysis as presented in this section in relation to EPEA could be presented for resource management activities.

2.4.2 Indicators and aggregates for environmentally related production and employment

Key EGSS indicators and aggregates

2.103 The most common indicators and aggregates show the importance of environmentally-related activities in the economy and characterise the activities by revealing their contribution to employment, to the economy as a whole, and to trade (exports, imports). Indicator examples include:

- The value added generated by the EGGS expressed as a % of GDP (Figure 2.9).
- Employment in the EGSS expressed as a % of total employment (Figure 2.9).
- Exports of EGS as a % the production of EGS
- Trade (exports, imports) in EGS as a % of total trade
- The share of enterprises that produce EGS in the economy, expressed as a % of the total number of enterprises.
- The level of investment in the EGSS and its developments over time.

Figure 2.9 EGSS contributions to GDP and employment

2.104 The production of environmental goods and services and employment in the EGSS reflect an important, albeit partial, aspect of the transformation to a more resource efficient and less waste intensive economy. Actions in 'traditional' industries (e.g. increased energy efficiency in steel production) can also move an economy towards a low carbon, resource efficient growth path.

These changes, while often driven by cost or competitiveness considerations rather than environmental concerns, can have a significant impact.

2.105 Employment in the EGSS should thus not be misunderstood as being "green" jobs. So far there is no internationally agreed upon definition of "green" jobs. "Green" jobs can by found in any sector or industry throughout the economy, independently of whether particular products serve environmental purposes. The advantage of using indicators based on EGGS statistics as described in the SEEA CF (chapter 4) is that there is an international agreement about the definitions and classifications to be used.

2.106 Indicators and aggregates on the EGGS can be usefully complemented with information on transformations in economic sectors and moves from traditional business activities to more resource efficient and less waste intensive activities, and information on technology development and innovation, including R&D expenditure, patents (in pollution abatement and waste management technologies, in energy and climate change mitigation technologies). Other important information includes the framework conditions in place for doing business and accessing financing.

2.107 The EGSS include a broad set of activities, including 'traditional' activities like waste and wastewater treatment, but also innovative activities like the development of new environmental friendly technologies. Also, EGSS activities often replace other, environmental harmful activities, for example through the production of renewable energy in place of the burning of fossil fuels. To provide useful indicators for policy for new economic activities it may be us useful to look at certain aspects of the EGSS, like the growth of enterprises involved in producing equipment for renewable energy production or research and development activities.

Key EPEA indicators

2.108 Efforts to reduce environmental pressures usually incur public and private expenditure, to:

i. finance environmental protection (EP) activities,

ii. finance resource management and preservation, and

iii. provide financial and technical support for environmental protection activities in other countries.

2.109 Monitoring the levels of these expenditure and their trends over time gives a general indication of how much a country or an industry spends on preventing, controlling and reducing pressures from pollution and resource use, and on managing natural resources and materials in an efficient way. This information may be helpful in informing of the extent to which an economy is transitioning towards one that is less resource intensive and less waste intensive.

2.110 The most common indicators show trends in expenditure on pollution prevention and abatement, and biodiversity; the shift to pollution preventing technologies; and how expenditure on EP compares to other types of expenditure. Such indicators are useful to inform about the financial efforts undertaken by society to prevent, mitigate or abate pollution. Key indicators and aggregates include:

i. The level of national expenditure on environmental protection, disaggregated by environmental activity domain (i.e. the classes of the Classification of Environmental Activities such as air and climate, soil and water, and biodiversity and landscape), by the institutional sector undertaking the measures (government, corporations, households), and by industry (by ISIC).

ii. The relative importance of investment expenditure compared to operating expenditure. In general, the investment-related share of EPE decreases as investment programmes progress, while operating expenses' share grows.

iii. The share of EP expenditure in GDP, and its relative importance compared to other types of expenditure such as expenditure on health or on education.

iv. Total financing of environmental expenditure disaggregated by institutional sector (government, corporations, households).

2.111 By relating data on environmental protection expenditure to data on the financing of this expenditure, one can calculate indicators that reflect the share of transfers from government or the rest of the world in the financing of the expenditure. Less experience exists with indicators on resource management expenditure for which internationally agreed definitions and classifications have only been elaborated recently.

2.112 EP expenditure is sometimes used as a proxy for measuring the implementation of and the costs of complying with environmental regulations and the level of integration of environmental considerations in a country or an industry. However, on its own, information on EP expenditure does not provide any information on the quality of the environment nor on the effects of EP activities on the environment, and hence requires careful interpretation in this regard.

2.113 Indicators and aggregates on EP expenditure can usefully be complemented with information on other environmentally-related activities, such as natural resource preservation and management, management of natural or industrial risks, and expenditure on workplace protection.

2.4.3 Types of analysis for environmentally related production and employment

Analysis by economic sector and industry

2.114 In comparing the private sector and government activities, this type of analysis provides information on, for example, the importance of public ownership and the evolution of privatisation. Corporations and government activities can also be analysed at a more detailed level providing information on the magnitude of environmental activities of the different ISIC sub-sectors (for corporations) and administrative levels (for general government), including through comparison to levels of value-added. For corporations, data can also be analysed to measure the importance of ancillary activities (i.e. activities commonly undertaken within enterprises rather than being purchased from other enterprises) and the evolution of outsourcing as well as the relative magnitude of market and non-market activities.

2.115 Analysis of environmental expenditure data by industry and sector can highlight those areas in which expenditure is most prevalent and in turn this can be compared to measures of other environmental flows such as emissions or flows of solid waste. The relative significance of environmental protection expenditure within overall intermediate consumption of goods and services by enterprises and gross fixed capital formation may also be assessed. Of particular interest is the expenditure of the government and how this relates to total environmental expenditure. Comparison to industry estimates of value added and operating surplus may also be relevant.

Analysis by environmental activity domain

2.116 Comparing data on the EGSS by environmental activity domains (i.e. high level classes within the Classification of Environmental Activities such as air and climate, soil and water, and biodiversity and landscape[1]) reveals which are the most important domains of specialisation for environmental producers in a country. This analysis is important because a large majority of environmental companies focus on only one of the environmental domains and the competitive conditions in each of the domains can vary significantly. Combined with environmental protection and resource management expenditure data, the analysis of the EGSS can also provide an indication of the opportunities for environmental activity within countries.

2.117 One area of particular interest is the part of the EGSS belonging to the so-called 'sustainable energy sector' which consists of all enterprises that physically produce renewable energy (exploitation phase) as well as enterprises active in pre-exploitation phases. Apart from the production of renewable energy, the sustainable energy sector also includes enterprises that focus on designing and producing energy saving activities and products.

2.118 Analysis of EPEA data by environmental activity domain would highlight the main areas of focus in response to identified environmental concerns. Such information may be useful to compare against aspects of environmental change and against policies to promote expenditure in particular domains (e.g. through use of environmental subsidies).

Analysis by type of environmental output

2.119 The SEEA Central Framework explains that the output of the EGSS may be considered in terms of environmental specific services, sole-purpose products, adapted goods, end-of-pipe technologies and integrated technologies. In comparing the figures for the different types of environmental goods, technologies and services, this analysis can highlight, for example, the importance of cleaner (less polluting) and resource-efficient technologies compared to end-of-pipe technologies. This is very important in the case of raising the awareness on the type of

[1] For details see SEEA Central Framework, Annex 1.

environmental output, in particular adapted goods[2] and integrated technologies for which its development represents one of the most important goals of policies towards sustainable development. Given the peculiarities of adapted goods, particular attention should be paid to the producers of this class of environmental goods and services.

2.120 More specifically, in addition to the standard economic indicators (value added, production, employment, exports, imports, capital formation) the sustainable energy sector may be further broken down into various product profiles and process profiles. The various product profiles include ‘solar photo-voltaic cells’, ‘solar CSP’, ‘solar thermal energy’, ‘bio gas’, ‘bio mass (solid) & waste’, ‘bio fuels’, ‘bio refining’, ‘wind on land’, ‘wind at sea’, ‘heat & geo thermal energy’, ‘energy from water’, ‘energy saving’, ‘electric transport’, ‘smart grids’, ‘hydrogen technology’ and ‘carbon dioxide capture and storage’. The process profiles include ‘research and development’, ‘consultancy’, ‘transport’, ‘preparation/raw material production’, ‘supply, assembly and construction’, ‘production of energy carriers’, ‘installation and maintenance’.

Regional analysis

2.121 Where information can be obtained, the activities of the EGSS may also the analysed at a regional level. Accordingly, it may be established whether EGSS activities are concentrated in certain areas and whether this is directly linked with other economic activities or particular environmental characteristics of the area. For example, the presence of electrical engineering and the technical university may play a key role for the development of companies specialised in the development of certain environmental equipment, such as solar panels (network economics). Or, the presence of significant natural features like coral reefs, may spur concentrations of businesses aimed at limiting the impacts of tourist activity or various forms of pollution.

Analysis of associated physical data

2.122 Data from the EGSS may be directly compared with physical data from the physical supply and use tables. For example, the physical data about the production of renewable energy and the data derived from the sustainable energy sector can be very valuable in supplementing each other.

2.123 For EPEA comparison of expenditure data to physical flows of emissions and waste may be particularly relevant and would enable an assessment of polluter pays principles – i.e. the extent to which the economic unit responsible for the residual flows incurs the cost to remediate any environmental degradation or limit the residual flows.

[2] Adapted goods are goods that have been specifically modified to be more “environmentally friendly” or “cleaner” and whose use is therefore beneficial for environmental protection (SEEA Central Framework 4.67)

Multiplier analyses

2.124 The economic and environmental effect of policies to stimulate particular industries often goes well beyond their direct effect on output, employment, or emissions. The growing interconnectedness of economic activities also leads to significant indirect or spill-over effects in the rest of the economy. These indirect effects can be determined by calculating multipliers derived from input-output (IO) analysis - see Section 3.3 for details. It is noted here that multipliers rely on assumptions regarding the relationships between economic and environmental variables. The multipliers discussed here assume linear relationships and while these may be applicable for economic variables they may be less appropriate in the case of environmental variables.

2.125 Multipliers and multiplier effect may be calculated for different activities of the EGSS. For the multiplier effects the direct and indirect effect may be distinguished. These may be compared to identify which activity induces the most indirect, or spill over, effects for the rest of the economy.

2.126 The multipliers and multiplier effects may also be compared to the average of the economy or with other industries. Accordingly, it may be established whether growth of this sector induces significant economic spill-over effects for the rest of the economy in terms of new jobs, value added and output.

Figure 2.10 Output and employment multipliers for EGSS and relevant subsectors

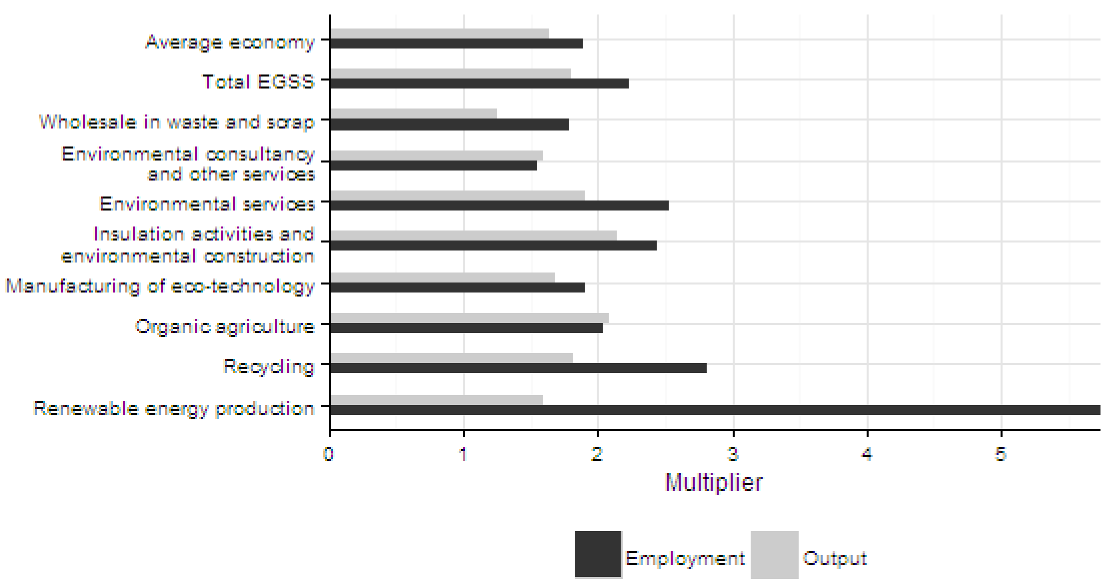
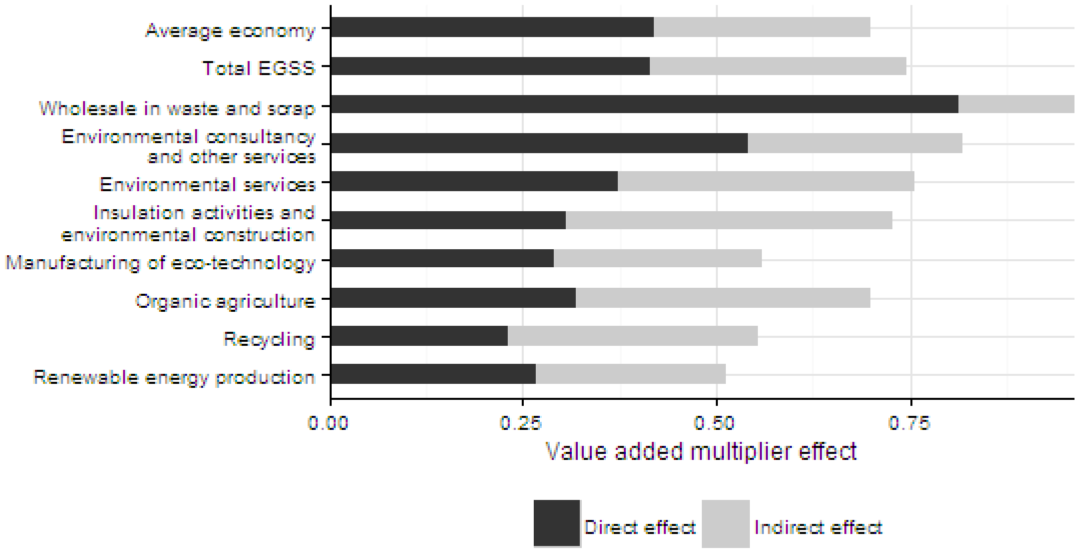


Figure 2.11 Value added multiplier effects for the EGSS and relevant subsectors



2.127 Finally, environmental multipliers may be calculated for the EGSS. For example, the greenhouse gas multiplier may indicate whether an overall increase in output of EGSS will produce more greenhouse gasses, than a similar increase of output of the economy on average. To explain the total environmental multipliers the different activities of the EGSS have to be analysed. For example, for sewage and refuse disposal services in the EGSS, the production of large amounts of carbon dioxide and methane are inherent in waste incineration and wastewater treatment. The direct emission effect clearly dominates, although the contribution of the indirect effects is also quite substantial. On the other hand, renewable energy production has a very low greenhouse gas multiplier effect when compared to electricity production using fossil energy.

Cost-recovery analysis

2.128 The SEEA Central Framework provides monetary information on a wide variety of environmental transactions in a consistent framework. As it covers both expenditures and revenues, it supports cost recovery analysis. Cost recovery can be defined as the ratio between the revenues paid for a specific service and the cost of providing that service. For example, the revenues from taxes ear-marked for wastewater treatment paid by households and industries may be directly compared to the relevant environmental expenditures by the government or specialised producers as recorded in the EPEA. Thus, it may be determined whether all of the costs (including operating and capital costs) are covered by revenues. It may also be possible to analyse the relative contribution of different sectors to the recovery of the costs of supplying the wastewater treatment service.

Micro analysis

2.129 In order to compile the various aggregates for the EGSS and EPEA it is useful to collect a range of information from individual enterprises. Such information would include data on employment, production, value added, exports, imports, innovation, R&D and fiscal schemes and subsidies. If this information can be collated into a micro database in consistent manner, it may be used to support analysis of industry effects relating to environmental activities such as those concerning research and development, innovation and environmental taxes and subsidies.

2.5 Analysis of environmental taxes and environmental subsidies and similar transfers

2.5.1 Introduction

2.130 Environmental taxes and environmental subsidies and similar transfers are important economic instruments used regularly by governments to achieve policy objectives. They receive a great deal of attention as they change the income of households and enterprises with the objective of encouraging and supporting desired behaviours.

2.131 The analysis of information on these flows may be of particular interest in the assessment of the relative size and burden of different policy options, the assessment of competitiveness between countries, and the assessment of the effectiveness of various environmental transfers in changing behaviours.

2.132 The SEEA Central Framework Chapter 4 sets out the appropriate definitions, classifications and measurement scope for environmental taxes and environmental subsidies and similar transfers. This information can be combined with information on physical flows (for example, changes in flows of solid waste or air emissions) to provide a broad information base for analysis.

2.133 This section presents the types of analysis that may be conducted on information compiled about environmental taxes and environmental subsidies and similar transfers consistent with the definitions outlined in the SEEA Central Framework.

2.134 There are a variety of other related analytical approaches, including the use of alternative definitions of environmental taxes (see the discussion in the SEEA Central Framework Chapter 4), the recognition of implicit subsidies (i.e. benefits obtained through reduced tax rates), analysis of producer subsidy equivalents (PSE) in agriculture, and analysis of the distinction between environmentally damaging and environmentally beneficial subsidies, but these types of analyses are not described here.

2.5.2 Indicators and aggregates for environmental taxes, subsidies and similar transfers

2.135 There is a range of countries around the world that have implemented environmental taxes. It is important to understand the use of the taxes, their social implications and their impact on the environment.

2.136 The SEEA Central Framework defines an environmental tax as a tax whose tax base is a physical unit (or a proxy of it) of something that has a proven, specific, negative impact on the environment (SEEA Central Framework 4.150). This includes taxes on production and imports, capital taxes and current taxes on income and wealth. Environmental taxes are classified according to their tax base in four broad categories: energy, transport, pollution and natural resources.

2.137 The most common indicator of environmental taxes is the total of environmental taxes as a percentage of GDP. This measure provides both an indicator of the tax burden and of the structure of taxation. Given that an environmental tax is generally levied on a physical unit, a tax-to-GDP ratio alone is not a sufficient measure of the size of the tax burden. For this purpose, it may be useful to compare particular environmental taxes, e.g. those on petrol/gasoline to volumes of petrol consumed and to total expenditure on petrol in monetary terms.

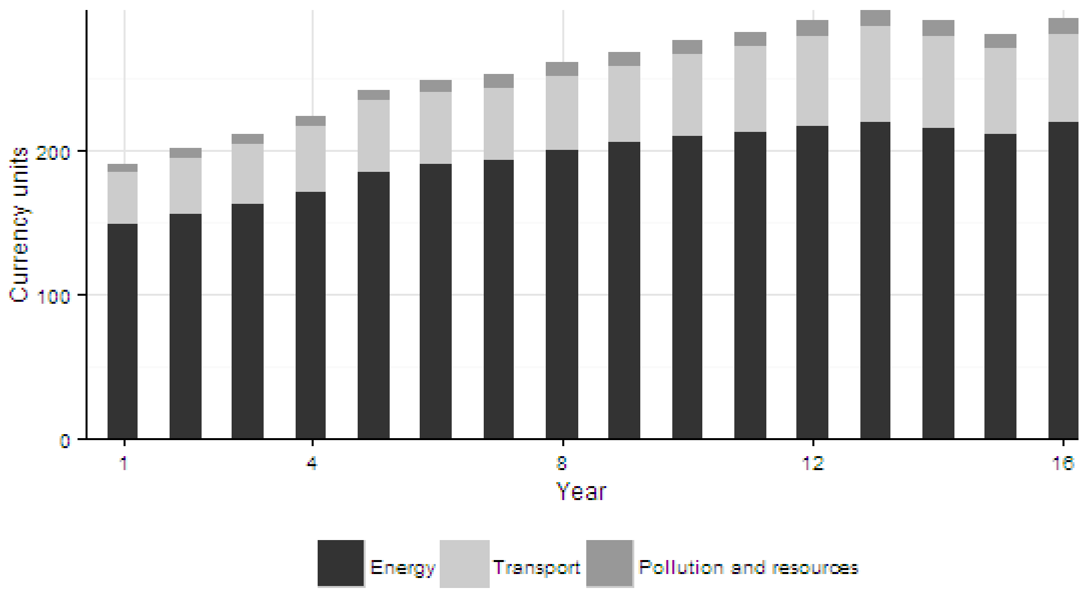
2.138 Another indicator is the ratio of environmental tax to total tax. However, a high ratio of this indicator does not necessarily mean that environmental protection is of a high priority; rather it can simply mean that the state has used this mechanism to obtain additional revenues but this in itself may give an indication of the relative dependence on environmental taxes as a source of government revenue. This may be further analysed by considering this ratio by type of tax (e.g. taxes on products, taxes on income).

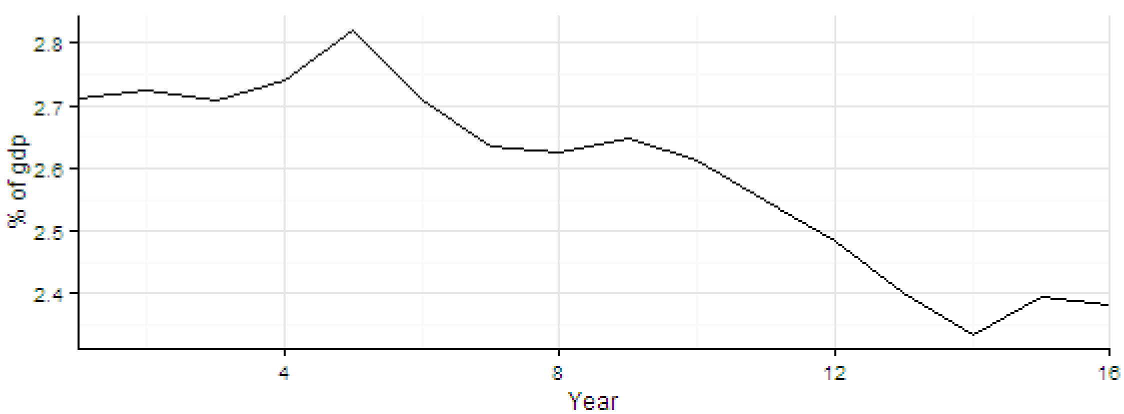
2.139 The key indicator for environmental subsidies and similar transfers is their share in total outlays by government.

2.5.3 Analysis of environmental taxes

2.140 For initial analysis of environmental taxes it may be useful to compare the relative proportions of the different types of environmental taxes - energy, transport, pollution and resources – and how these shares are changing over time. This type of analysis is shown in the figure below. This may be of particular interest in understanding the extent to which taxes drive changes in behaviour and, at the same time, the extent to which they lead to changes in environmental pressures. At the same time it should be recognised that movements in tax revenue will be impacted by changes in economic growth and broader business cycles.

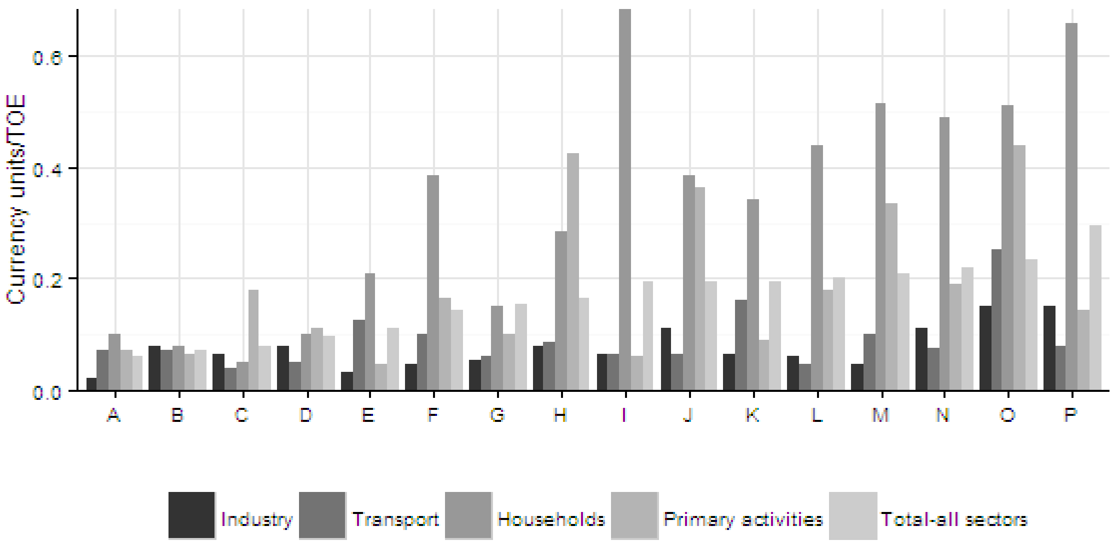
Figure 2.12 Environmental tax revenue by type





2.141 For environmental taxes there may be particular interest in constructing implicit tax rates although additional information is required. Implicit tax rates are the effective tax rate after the impact of all relevant government impositions, including regulation. These rates are less sensitive to reductions in tax revenue due to more efficient use of the taxed commodity. It involves the identification of an underlying measure of the tax base which corresponds to the tax revenue. In the case of environmental taxes there are often not one but many bases on which to construct an implicit tax rate. For energy taxes, an appropriate indicator for the potential tax base can be identified by creating a single aggregate reflecting all physical energy consumption as recorded in the energy flow accounts. Implicit energy tax rates are shown in the figure below for several countries.

Figure 2.13 Energy taxes divided by energy consumption by sector

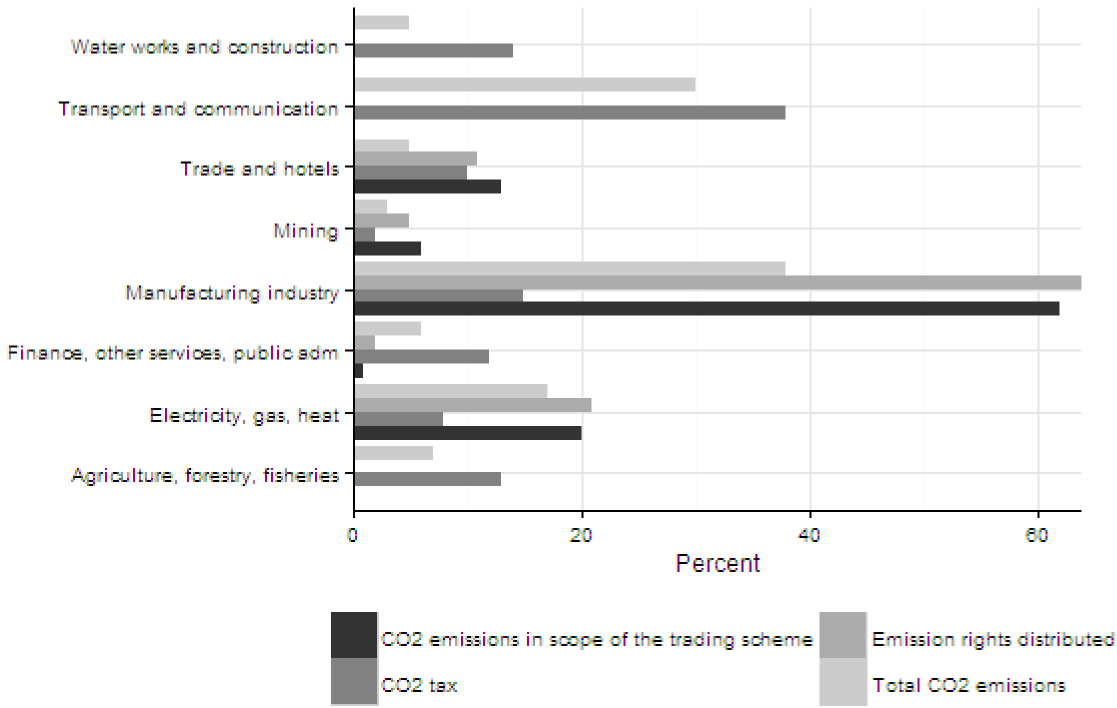


2.142 Analysis can also be undertaken to understand the environmental impact of a tax, for example the reduction in pollution resulting from the introduction of a pollution tax. To do this the physical data which relates to the tax (e.g. emissions, waste and energy products) are required. Figure 2.13 presents the share of CO_2 taxes, allocated emission trading permits, the CO_2 emissions occurring within the trading scheme[3] and total CO_2 emissions by industry. As shown, the CO_2 tax revenues to the government vary depending on the economic activity. The transport and communication industry paid the highest fraction of CO_2 taxes in the economy (36%), while the manufacturing industry (including energy intensive activities such as steel manufacturing and pulp and paper manufacturing) paid about 13% of total CO_2 taxes.

2.143 This type of analysis may be extended to consider the extent to which the polluter pays principle is in effect. That is, to what extent are the enterprises paying pollution taxes also responsible for the generation of the pollution being taxed.

[3] European Union Emissions Trading Scheme, launched in 2005 to combat emissions related to climate change. Aviation is included since 2012. Water works and construction, maritime transport and forestry are still excluded.

Figure 2.14 Distribution of CO_2 tax revenues, emissions rights, CO_2 emissions covered by the trading scheme and total CO_2 emissions by industry



2.144 Table 4.4.3 in the SEEA Central Framework presents an account for tradable emission permits showing the stock and changes in stock of permits measured in terms of tonnes of carbon dioxide. This information, which can be structured by institutional sector or by industry, can be used to analyse which economic units hold permits and the extent to which the holders are complying with relevant emission targets. It may also be relevant to assess the links between the industries holding permits and their contributions to GDP and employment.

2.145 Because of the common classifications used in the emission permit account and other accounts, such as the energy PSUT and the air emission accounts, it is possible for modellers to analyse energy input structures and relate these to the changes in demand for emission permits. Tables showing the monetary value of emission permits can be used to analyse the effect of changes in permit prices on energy use by industry.

2.5.4 Analysis of environmental subsidies and similar transfers

2.146 Analysis of environmental subsidies and similar transfers may be considered from a number of angles. In relation to the flows themselves the mix of different types of payments by government, particularly a distinctions between current and capital transfers may be of interest. Also a comparison of environmental and non-environmental subsidies and similar payments may highlight changes in policy focus over time.

2.147 Where information is available, measures of environmental subsidies and similar transfers by industry would be of interest and within the SEEA framework could be compared to measures of industry output, value added and operating surplus. Depending on the purpose of the payment, industry level flows might be compared to changes in physical flows of emissions, solid waste or other environmental pressures to assess the effectiveness of the subsidy or transfers.

2.148 The purpose of the environmental subsidy or similar transfer may be analysed by classifying the flows by type of environmental activity following the Classification of Environmental Activity (CEA). Although often the purpose of particular payments may be hard to assess, if this work can be done comparisons can then be made as to which activities are receiving support and whether there are links between the levels of environmental subsidy and similar transfers and the level of expenditure on environmental protection as recorded in Environmental Protection Expenditure Accounts (EPEA).

Further analysis

2.149 There may be interest in undertaking analysis of environmental taxes and subsidies using techniques that are applied in the analysis of taxes and subsidies more generally. For example, using the accounting structure of the SEEA it is possible to analyse the relative importance of environmental taxes and environmental subsidies and similar transfers in the context of the sequence of accounts (Table 6.2.3 in the SEEA Central Framework). Also, it would be possible to undertake an analysis of the incidence of environmental taxes and subsidies by using the structure of relevant supply and use tables and input-output tables in conjunction with general analytical approaches in this area.

2.6 Analysis of environmental assets, net wealth, income and depletion of resources

2.6.1 Introduction

2.150 There is a range of motivations for accounting for environmental assets. One motivation is to assess whether current patterns of economic activity are depleting and degrading the available environmental assets. Information from environmental asset accounts can also be used to assist in the management of environmental assets and valuations of natural resources and land can be combined with valuations of produced and financial assets to provide broader estimates of national wealth.

2.151 The SEEA Central Framework describes a comprehensive set of asset accounts for individual environmental assets covering mineral and energy resources, land, soil resources, timber resources, aquatic resources, other biological resources and water resources. The accounts presented are in both physical and monetary terms and hence contain a vast array of information on the stocks and changes in stocks of these various environmental assets.

2.152 The SEEA Central Framework does not describe the measurement of ecosystems since approaches to ecosystem accounting are less established than accounting for individual environmental assets. Approaches to ecosystem accounting are described in SEEA Experimental Ecosystem Accounting.

2.153 This section highlights the range of information that may be accessed from asset accounts and its combination with other information to provide comprehensive assessments of individual environmental assets. The types of question that may be answered with these information include:

- How has the stock of environmental assets changed over time
- What is the value of a country's environmental assets?
- How much income is generated from natural resources and to whom does it accrue?
- To what extent are environmental assets being depleted?

2.154 Discussion of sustainable development is often couched in terms of the use of different forms of capital, including environmental assets. The information in the asset accounts of the SEEA form part of the information needed to consider these types of questions but do not cover a comprehensive suite of capital including human and social capital. Nonetheless, for particular parts of the economy that are dependent on natural resources, information from the SEEA asset accounts may be able to provide useful indicators for assessing sustainable patterns of growth, or long-term viability of those industries that are dependent on natural resources.

2.155 The valuation of environmental assets in monetary terms in the SEEA Central Framework follows the same principles as the SNA. Consequently, the measures can be compared to the values of other assets within the SNA framework, for example, produced assets and financial assets. In this framework it may also be relevant to assess the extent to which the overall value of assets (including environmental and other economic assets) is changing in real, per capita terms.

2.156 However, it should be recognised that the approaches to valuing environmental assets in monetary terms often require the use of assumptions regarding future patterns of activity and assumptions regarding discount rates and, as a result, care should be taken in undertaking comparisons of values of different asset types. In this context, it is always relevant to consider both physical and monetary measures of environmental assets in considering questions of sustainable use of assets.

2.6.2 Analysis and indicators of individual environmental assets in physical terms

2.157 At the most basic level physical data can impart an appreciation of the lifetime or physical constraints in which the economy and society can operate. An important distinction in the analysis of data in physical terms is between land, natural resources, and cultivated biological resources.

2.158 Physical asset accounts for land generally focus on changes in land use and land cover within a country and can be particularly important in understanding changes in land management and potential environmental pressures arising from altered use of the environment. It is noted that, in physical terms, the scope of the SEEA Central Framework encompasses all land in a country, not only land considered to be "economic". Thus, land in physical terms is not restricted to land that is owned and can be used or held for monetary gain. This complete coverage in physical terms permits a full assessment of changes in land use and land cover – particularly in the change between economic and non-economic uses of land (e.g. in the analysis of desertification).

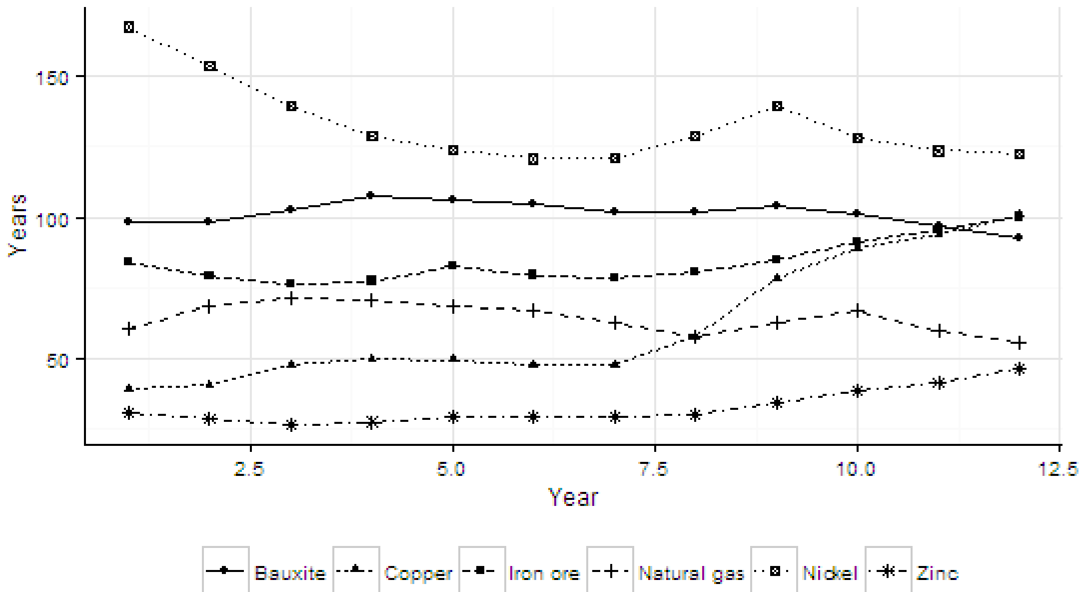
2.159 Biological resources, primarily timber resources and aquatic resources (e.g. fish), generally comprise both natural and cultivated resources. The scope of the SEEA Central Framework asset accounts covers both natural and cultivated resources, recognising the importance of clearly distinguishing between these two types of resources because the environmental pressures may be quite different. For example, the harvest of timber from mono-cultural plantation forests will have quite different effects compared to the harvest of timber from long-standing, native forest areas. As well, the production processes and effects involved in activities such as aquaculture are quite different from those in fishing in open waters. Data showing the relative changes in the share of cultivated and natural biological resources as part of the overall stock of timber and aquatic resources may be of significant policy interest. More broadly, analysis of rates of extraction, costs of extraction and available stock levels should be able to inform discussions on the sustainable use of resources.

2.160 Other environmental assets include mineral and energy resources, soil resources and water resources. Particularly for soil resources and water resources, the presentation of information on stocks by different spatial areas (e.g. rivers basins) possibly using maps, may provide a more useful set of data.

2.161 In physical terms, each set of information on different types of environmental assets will not be able to be readily compared since the measurement will be undertaken in different units of measure. Indeed, even within particular broad asset types the measurement units may vary (e.g. minerals and energy resources may be measured in tonnes, cubic metres, barrels, etc) and further, for biological resources it may me most relevant to assess the resources in terms of species. An exception to this approach is the measurement of energy related environmental assets which may be considered using joules as a common unit of measure. Thus for a range of different environmental assets – particularly mineral and energy resources, timber resources and water resources – the assessment of the physical stock in terms of a common unit of energy may be particularly useful. This approach is outlined in more detailed in SEEA Energy.

2.162 The SEEA Central Framework defines the depletion of natural resources as, in the first instance, a measure of physical change and hence there may be interest in comparing rates of depletion relative to the levels of the stock of certain natural resources. These comparisons give an insight into the extent to which extraction rates are likely to exceed rates of regeneration and hence can be used to assess remaining resource lives. For mineral and energy resources a particular interest may lie in analysis of rates of discovery of new resources. The chart below shows this type of analysis for selected mineral and energy resources over a twelve year period. For biological resources the analysis may be more complex due to the need to take into consideration various population dynamics and other ecosystem processes in assessing expected rates of regeneration of the resources.

Figure 2.15 Asset lives for selected mineral and energy resources



2.163 Other common indicators monitor the availability of a given asset and its changes over time, and relate the amounts extracted or harvested to the remaining stocks. They are particularly useful for the management of demand and supply of natural resources. Indicator examples include:

- The intensity of use of water resources, also called water stress, which relates water abstractions to the available natural stocks of renewable water resources. This indicator reflects the pressure exerted on natural resource stocks by water abstractions for human use. It can be sourced from physical asset accounts for water resources in combination with physical flow accounts for water, and is most relevant at territorial and at river basin level. Macro-level indicators of water stress often hide significant sub-national variations due to the concentration of human activities, the location of water stocks and local climatic and meteorological conditions.

- The intensity of use of forest resources (timber), which relates actual harvest (fellings) and natural losses to annual productive capacity. Annual productive capacity is either a calculated value, such as annual allowable cut, or an estimate of annual natural growth for the existing stock. The choice depends on forest characteristics and the availability of information. This indicator can be sourced from physical asset accounts for timber resources. It should be noted that indicators based on a national averages can conceal variations among forests. When used for environmental purposes, these indicators should be accompanied with information on forest quality (e.g. species diversity, including tree and non-tree species; forest degradation; forest fragmentation), and on forest management practices and protection measures. They can be used together with indicators on output of and trade in forest products.

2.164 For biological resources, such as timber and fish, it may also be of interest to distinguish between natural and cultivated resources, and between different types of management practices. Indicator examples include: the relative changes in the share of cultivated and natural biological resources as part of the overall stock of these resources or as part of the total production from these resources (e.g. the share of planted forests in total forest land; fish production from capture fisheries versus fish production from aquaculture); and the share of cultivated forest areas under sustainable management practices.

2.165 Other useful indicators inform about changes in land use and land cover and about conversions from one use category or cover type to another. Since land is an input into most economic activities, such indicators speak to competing uses of land. It has to be noted that land use and land cover are related, but not the same: land cover refers to the biophysical dimension of land while land use refers to the functional dimension of land for human and economic activities. Most land indicators can be sourced from physical asset accounts for land that contain data on both land use and land cover.

2.166 Indicator examples include:

- The share of built-up areas (or artificial surfaces) in total land area.
- Conversions of areas with a natural cover to crops, pastures for grazing or artificial surfaces.
- Conversions of agricultural (or forest land) land to built-up and related areas.
- The share of forest areas (cultivated and natural) in total land area, accompanied with a breakdown by type of forest land.

2.167 In terms of interpretation, indicators and aggregates of stocks and changes in stocks of natural resources, whether in physical or monetary terms, may not provide direction information on whether natural resource use is sustainable or whether there is a risk to future economic growth and well-being from unsustainable use and management practices. Further, the stocks of many natural resources are unevenly distributed among countries and within countries. This spatial component is important to consider when developing and interpreting natural resource indicators.

2.168 Physical measures of environmental assets may be particularly relevant in the assessment of access to resources, particularly for water resources and energy related resources. In this regard both the location of the resources and an understanding of who is able to access them, perhaps in terms of household income, may be needed for particular policy questions. This use of asset account data is considered further in Section 4.1.

2.6.3 Analysis of environmental assets in terms of wealth and incomes

2.169 The SEEA Central Framework follows the valuation approaches of the SNA in defining measures of environmental assets in monetary terms. This approach allows the formation of monetary estimates that can be readily compared with information contained in the standard national accounts. Relevant measures include flows of operating surplus from the extraction and use of environmental assets, flows of rent from natural resources and land, and balance sheets incorporating both economic and environmental assets.

2.170 Using this broader framework of assets and incomes, information may be organised to consider

- More comprehensive measures of wealth and the relative significance of different asset types
- Analysis of changes in wealth per capita and changes in the ownership of assets across different institutional sectors (e.g. corporations, government, households)
- Rates of return to natural resources through comparison of operating surplus to extracting industries to the stock of natural resources
- Depletion adjusted measures of income accruing to extracting industries and owners of natural resources
- Share of returns on extraction earned by government, commonly through rent and royalties, but also via quota schemes and taxation arrangements related to the extraction of natural resources
- Levels of investment and employment by extracting industries relative to the country as a whole.

2.171 At an aggregate, economy-wide level, adjustments to measures of economic activity such as depletion adjusted Net Domestic Product and depletion adjusted Net National Income may also be compiled following the guidelines in the SEEA Central Framework. These adjusted aggregates may be compared with non-adjusted aggregates to show, for example, the extent to which depletion contributes to the change in Net National Income over time.

2.172 Using the information required to estimate values of environmental assets it is also possible to derive volume measures or indexes reflecting changes in the values of environmental assets without the effect of price change. Volume measures are derived by weighting together changes in the stock of assets in physical terms using the relative value of each asset as a particular point in time. Aggregation may be completed within a type of asset (e.g. aggregating different types of mineral and energy resources) or across asset types (e.g. aggregating mineral and energy resources and timber resources).

2.173 The compilation of volume measures may usefully complement measures of changes in assets in physical terms which generally cannot be aggregated across asset type because the physical measures are in different units. Chapter 2 of the SEEA Central Framework provides a summary of the compilation of volume measures and a more detailed description is in the 2008 SNA, Chapter 15.

2.174 Aggregate measures of environmental assets, either in value or volume terms, should be interpreted cautiously since the process of valuation implies an assumption of substitutability between asset types that may, or may not, be considered appropriate. Further, it is noted that some measurement of the values of environmental assets and natural resources is undertaken using social valuations. Such valuation approaches are not endorsed within the SEEA Central

Framework and any estimates compiled using social valuations should not be compared with estimates of the value of other assets within scope of the SEEA or SNA.

2.7 Selection, interpretation and presentation of indicators

2.7.1 Introduction

2.175 Section 2.2 described the role and function of indicators and made some general points on the compilation of indicators in the context of the SEEA Central Framework. Sections 2.3-2.6 have provided examples of a range of aggregates and indicators across different topics to which environmental-economic information is relevant. Often, in the communication of information in complex and cross-cutting areas it is necessary to provide summary measures from a number of areas and in this regard the selection, interpretation and presentation of indicators are important tasks. Many agencies have considered the issues involved in selecting, interpreting and presenting indicators and the following paragraphs provide an overview of the key aspects.

2.7.2 Selection criteria

2.176 The number of potentially useful indicators is often large. It is therefore necessary to have a good understanding of the purpose for which they are to be used and to apply agreed criteria that guide and validate their choice. Some of the required judgements concern issues such as: What are the indicators supposed to measure? How and by whom will they be used? How solid is the information base on which the indicators rely? When used in international work, the indicators further require some consensus about their validity among the countries concerned.

2.177 Various criteria for selecting environmental and economic indicators have long been established. Relevant criteria include factors such as responsiveness, reliability, ease of interpretation, simplicity, scientific validity, data availability, comparability over time and space, structured around three basic criteria: policy relevance and utility for users, analytical soundness, and measurability.

2.178 It is relevant to recall that the use of common concepts, definitions, and classifications is central to the usefulness of the SEEA Central Framework for deriving indicators that monitor the interactions between the economy and the environment. Data in physical and monetary terms can thus be combined in a consistent format, for example for calculating intensity or productivity ratios. And macro-level indicators can be disaggregated by industry and institutional sector, to show structural changes over time, to analyse environmental pressures exerted by different economic activities, and distinguish government responses from those of the corporate sector or households.

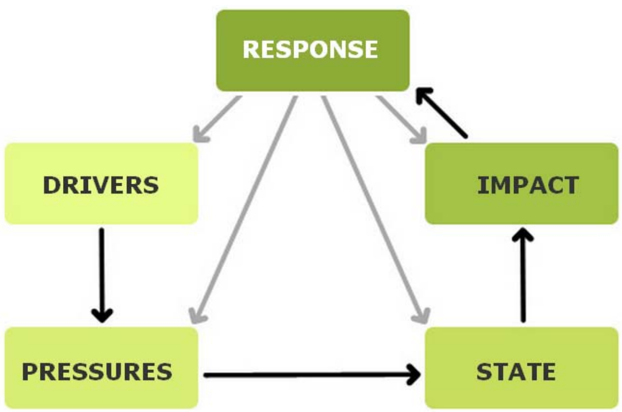
2.7.3 Interpretation and use of indicators

2.179 Indicators usually address policy questions at a general level by giving an overview of major issues and trends and by highlighting developments that require further analysis. Indicators are thus only one tool for evaluation and scientific and policy-oriented interpretation is required for them to acquire their full meaning. Often, indicators need to be supplemented by other qualitative and contextual information, particularly in explaining driving forces behind indicator changes which form the basis for an assessment. The information value of many indicators can also be enhanced when they are associated with policy objectives or targets.

2.180 Indicator sets are structured and communicated in different ways. Among the most frequently used frameworks are those based on the Pressure-State-Response (PSR) model and its variants that account for greater detail or for specific features, for example, the Driving force-Pressure-State-Impact-Response (DPSIR) model - see Figure 2.15. Such frameworks help ensure that important aspects are not overlooked when developing the indicators, and organise the indicators in a way understood by decision-makers and the public.

2.181 In the development of indicator sets the SEEA can play two roles. First, it can provide a basic structure for the set of relationships between the economy and the environment upon which policy and other interpretative frameworks may be built. Second, it can provide an underlying information set containing relevant information. In both roles, the SEEA can help to avoid the development of indicator sets that reflect only particular aspects or perspectives on particular topics.

Figure 2.16 DPSIR model



2.7.4 Presentation of indicators

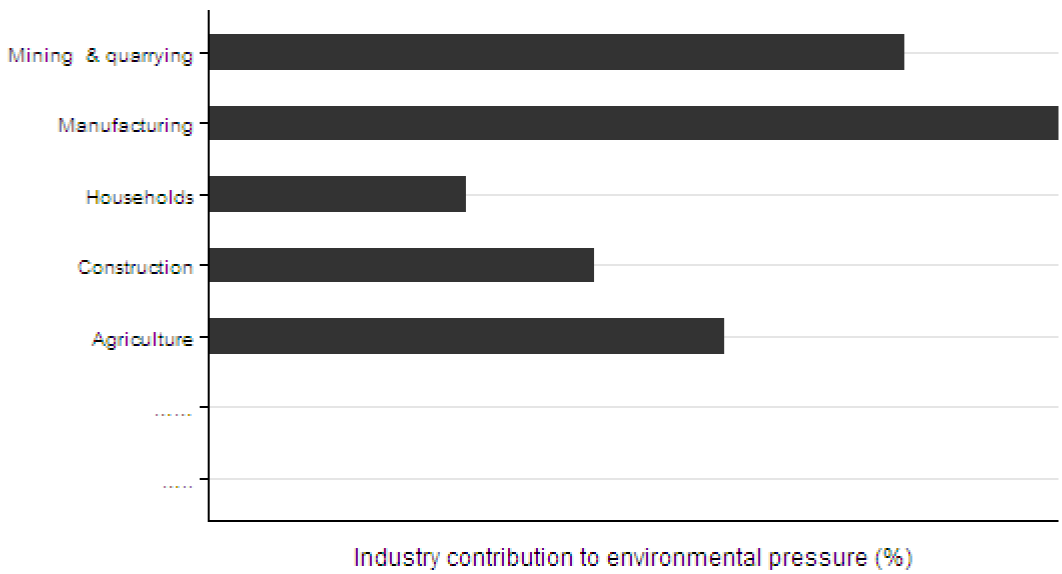
Level of detail and disaggregation

2.182 It is often necessary to disaggregate the indicators to focus on a particular topic of interest to better understand the macro-level trends. The extent to which the following disaggregations are possible will depend on the availability of information are finer levels of detail, either through the existence of more detailed data within the same data source used to compile aggregated information, or through the use of information from other data sets.

2.183 Industry disaggregation helps understand how structural changes in the economy affect environmental pressures and the use of environmental resources. It is also useful in understanding the contribution of different industries to a common environmental issue (e.g. CO_2 emissions) when reviewing the integration of environmental and industry specific policies. Macro-level indicators derived from SEEA accounts and from the associated analytical tools can generally be disaggregated at an industry level in accordance with industry classifications and the SNA. They can then be linked to data from economic accounts in monetary terms, to derive measures of intensity and productivity.

2.184 When macro-level indicators are broken down by industry in accordance with the SEEA, it is possible to present the indicators in the form of issue-profiles or environmental-economic profiles. An issue-profile consists of the contributions of relevant sectors and industries to a particular environmental pressure (e.g. greenhouse gas emissions) which in turn can be linked to a particular environmental issue (e.g. climate change). Issue profiles can also be used to show the contributions of the various industries to efforts aimed at preventing, controlling and mitigating a given environmental pressure (e.g. through environmental expenditure and transfers). Issue profiles can also be presented to show changes over time for different industries for a certain issue (with respect to a previous year or other reference year). A stylised issue profile is presented in Figure 2.17.

Figure 2.17 Issue profile by industry



2.185 Environmental-economic profiles provide a condensed and comparable review of environmental and economic performance for a certain economic activity (e.g. manufacturing, agriculture) or type of economic unit (e.g. households). These profiles may either show the development over time of the relevant indicators or their relative share with respect to other economic activities or units.

2.186 Institutional sector disaggregation helps distinguish government responses from those of the corporate sector or household sector. Disaggregation by sector is thus likely to be most relevant in understanding expenditure on environmental protection and resource management, the impacts of environmental taxes and subsidies, and the use of natural resources which are often publically owned but privately extracted under various institutional arrangements.

2.187 Disaggregation by type of environmental activity represents an extension beyond standard industry disaggregation. Here the purpose of activity undertaken by economic units (enterprises, governments and households) may be broken down into different types of environmental activity following the Classification of Environmental Activities (CEA) described in Chapter 4 of the SEEA Central Framework. Examples of relevant types of environmental activity include environmental protection activity and resource management activity.

2.188 Product and asset type disaggregation helps in understanding the most significant aspects within analysis of broad issues such as energy use or natural resource management. For example, disaggregation by type of energy product is likely to be useful in understanding the fuel mix and other compositional issues in the analysis of energy supply and demand. As well, disaggregation by type of environmental asset, (e.g. by type of mineral or energy resource or type of timber resource) may assist in understanding implications of changes in demand for different resources.

2.189 Spatial disaggregation (i.e. disaggregating data to smaller spatial scales) helps understand the relationships between the location of natural resource stocks (e.g. water and energy resources), settlement areas and economic activities. This is important when indicators are to support sub-national decision making, for example, when dealing with river basin or ecosystem management[4], or when using indicators describing drivers which are relevant at the local level or that distinguish between rural and non-rural areas. It is also important when national-level indicators hide important variations within countries.

2.190 Disaggregation by population groups, for example by age classes, gender and income levels, may be important in understanding the distributive aspects and social consequences of environmental policies and economic instruments. The combination of data required for disaggregation by population groups with SEEA based information is considered further in Chapter 4 as an extension of the SEEA Central Framework.

Indicator sets, dashboards and aggregated indices

2.191 Answering policy questions generally requires the use of more than one indicator. What is often needed is a set of indicators that cover to the greatest extent possible the various aspects of the topics covered and that collectively give the necessary insights. But a large set also carries the danger of losing a clear message that speaks to policy makers and helps communicating with the media and with citizens.

2.192 One way of addressing the issue is to construct aggregated indices. By combining the information contained in two or more indicators, aggregated indices make it possible to convey simple messages about complex issues.

2.193 However, reducing the number of indicators by condensing information also runs the risk of misinterpretation because users are not always aware of the scope and limitations of the index

[4] Neither environmental pressures nor ecological "carrying capacity" are evenly distributed across a country's surface area and local ecosystem collapses are likely to occur long before nationally-averaged pressures will approach critical values.

methodology, and because the message conveyed may be distorted by data gaps or differences in the quality of the data supporting the indexes. The advantages of ease of communication and concise presentation of a composite index must thus be balanced against the problem of choosing units and weights required for aggregation across different indicators.

2.194 In general, a balance needs to be struck between the wish to have as few indicators as possible and the need to keep each as intelligible, robust and transparent as possible. Many countries and institutions therefore identify small sets of "key indicators" or "headline indicators" that are representative of the topics covered and are able to track central elements of it. Others take an approach of visual aggregation in which the values of the constituent indicators or variables are displayed together, instead of consolidating the scores of all indicators or variables into an aggregated index. One example of such a visual aggregation are dashboards. These approaches, aggregated indices, headline indicators, dashboards need not be mutually exclusive.

Aggregation and the SEEA

2.195 Aggregation is generally considered straightforward when the relevant variables are expressed in a common metric (e.g. tonnes, joules); or when scientific evidence provides information about the relative "weights" of the various variables in a phenomenon that the index is intended to represent.[5] Aggregates based on an accounting framework such as the SEEA Central Framework are thus potentially attractive: they are based on a theoretically sound and widely accepted framework, and they are based on data expressed in common and familiar metrics. They also tend to be more transparent because their computation is straightforward, often involving only additions and deductions.

2.196 At the same time, care needs to be taken when undertaking some aggregations in common metrics since the relationships between variables and the relative significant of different variables may be hidden. This is particularly the case when considering measures of flows of different materials all measured in terms of mass units (e.g. tonnes). In this case, aggregates may be dominated by flows of materials that are abundant (e.g. soil) and not appropriately reflect flows of materials that represent more significant environmental pressures but be relative small in total quantity (e.g. mercury).

2.197 The standard metric in economic accounting is currency units. Aggregates may be formed by adding together relevant accounting entries expressed in common currency units to provide aggregates in monetary terms. There are a wide variety of aggregates that can be compiled in monetary terms, for example, the value of stocks of natural resources and the value of depletion of natural resources. Further, when a consistent basis for valuation is applied these aggregates can be directly incorporated with standard economic accounting aggregates such as net wealth and GDP. It is noted that in many cases there are a variety of assumptions required in order to assign monetary values to relevant accounting entries – Chapter 5 of the SEEA Central Framework discusses these measurement issues in detail.

[5] A prominent example is the global warming potential of various greenhouse gases that is used to aggregate GHG emissions into one index expressed in carbon or in CO_2 equivalents.

Chapter 3: Analytical techniques

3.1 Introduction

3.1 Analysis of the various topics and themes described in Chapter 2 may often be completed with straightforward consideration of data from SEEA tables or direct comparisons to similarly structured data from other sources. However, it is also possible to use the data from the SEEA for environmental-economic modelling using a variety of analytical techniques. This chapter describes a range of the most commonly used approaches.

3.2 Section 3.2 introduces the datasets at the core of these modelling and analytical techniques: environmentally extended input-output table (EE-IOT). The section will discuss the various types of EE-IOT, such as single region/multiregional input-output tables or input-output tables in hybrid units. Section 3.3 outlines a number of techniques that may be applied to data from these EE-IOT. Finally, Section 3.4 describes geo-spatial analysis. This is not done using EE-IOT data but is related to the land accounts described in the SEEA Central Framework. The annex to this chapter is reserved for some mathematical details related to the input-output model which underpins many of the analytical techniques described in Section 3.3.

3.2 Environmentally Extended Input-Output tables (EE-IOT)

3.2.1 Introduction

3.3 There are a variety of ways in which environmentally extended input-output tables (EE-IOT) can be constructed. The intent of this section is to introduce the main types of EE-IOT, to show key parts of their compilation, and to discuss some of the measurement issues associated with them. Section 3.2.2 shows the structure of the single region input-output (SRIO) table which is commonly compiled by statistical institutes. Sections 3.2.3 and 3.2.4 discuss EE-IOT in hybrid (physical and monetary) units and multiregional input-output (MRIO) tables respectively. Finally, section 3.2.5 concludes with a number of measurement issues which might arise when constructing the various EE-IOT. Overall, this section is intended to provide a basis for understanding the analytical techniques described in Section 3.3. It does not provide a complete description of requirements for the compilation of input-output tables.

3.4 Further, the presentations of the EE-IOT tables in this section are simplifications which do not include all the details which may be useful in environmental-economic modelling. For example, data on landfills or recycling (both in monetary and physical terms) may be introduced into the EE-IOT.[6] However, in this section the discussion of the EE-IOT has been kept as simple as

[6] For waste input-output modelling see Nakamura, 1999; 2000; Suh 2004; Nakamura and Nakajima 2005; Dietzenbacher 2005; Hoekstra and van den Bergh 2006; Weisz and Duchin 2006; Nakamura et al. 2007.

possible in order to be able to explain the basic premises of the analytical techniques described in section 3.3.[7] In each section, references to more detailed material are provided.

3.2.2 Single region input-output (SRIO) tables

3.5 In order to apply the analytical techniques environmental data are often combined with input-output tables (IOT). The compilation of IOT is described as an analytical extension in the System of National Accounts being derived through the combination of supply and use tables (SUT) which are core accounts of the SNA.[8] Various mathematical and analytical approaches are available to convert SUT to an IOT (SNA 2008; United Nations, 2008).

3.6 Table 3.1 shows a simplified version of a Single Region Input-Output (SRIO) table. It gives a detailed description of domestic production processes and transactions within a single country (or region). An IOT is usually structured as a product-by-product or industry-by-industry table. Table 3.1 shows an industry by industry table of *j* industries. The rows show the outputs of an industry while the columns provide information about the inputs required in the production process of an industry.

3.7 The output of the industries is the sum of intermediate consumption (Z_d) (which is a *j* by *j* matrix) and final demand categories such as final consumption (c_d), gross capital formation (f_d) and exports (e_d). The subscript *d* denotes the use of domestic inputs, since the imported goods and services are shown in the row "imports" (and are denoted by subscript *m*). On the input side of an industry there are the intermediate inputs (Z_d), value added categories (v) including compensation of employees (wages) and operating surplus (profit), and imports (m). Of course the inputs in an industry must equal the output, which is why the row and column sums (q) must be equal. All the variables with the subscript *tot* are scalars that show the totals for those respective row or columns.

Table 3.1. A single region input-output table (SRIO) with environmental data

		Industries	Final demand			Total
		1 … j	Final consumption	Gross capital formation	Exports	
Industries	*1* … *j*	Z_d	c_d	f_d	e_d	q
Value added		v				
Imports		m	c_m	f_m	e_m	m_{tot}
Total		q	c_{tot}	f_{tot}	e_{tot}	

Natural inputs/residuals	r				r_{tot}

[7] Note also that for the sake of simplicity, the direct emissions from consumers are also not included in the models. It is fairly straightforward to add these to the analytical techniques described in section 3.3.

[8] Note that it is also possible to model environmental-economic relationships using SUT systems (see for example Lenzen and Rueda-Cantuche (forthcoming)), but most applications use input-output tables.

3.8 The intermediate input matrix (Z) of an IOT is therefore square (it contains the same number of rows and columns) and symmetric (the items indicated by the rows and columns are the same: both are products or both are industries). The abbreviation SIOT is sometimes used to refer to a square and/or symmetric IOT.

3.9 The IOT can be augmented with environmental data by industry (denoted by the vector r) which may be taken from SEEA accounts. In most applications these data relate to flows of natural inputs and residuals (see SEEA Central Framework Chapter 3).

- Natural inputs are all physical inputs that are moved from their location in the environment as a part of economic production processes or are directly used in production. Natural inputs comprise natural resource inputs (such as, mineral and energy resources, water, soil and biological resources), inputs of energy from renewable sources (such as, solar, hydro and wind sources) and other natural inputs (such as, soil nutrients, and oxygen used in combustion). Natural inputs flow mainly from the national environment into the national economy.
- Residuals are flows of solid, liquid and gaseous materials and energy that are discarded, discharged or emitted by establishments and households through processes of production, consumption and accumulation. Residuals include flows of solid waste, wastewater, emissions to air, emissions to water, dissipative uses of products, dissipative losses and natural resource residuals (such as discard catch in fishing).

3.10 The sourcing and use of data on flows of natural inputs and residuals from SEEA accounts is advantageous for the compilation of EE-IOT since the information has already been organised in a manner consistent with the classifications (e.g. for products and industries) and measurement boundaries that are used in the compilation of the IOT itself.

3.2.3 Hybrid input-output tables

3.11 The input-output table shown in table 3.1 is in monetary units. However, it is possible to record the output of an industry, i.e. its products, in physical terms as well. For example, many studies have analysed energy using an IOT in which the output of the energy industries is measured in gigajoules or another energy unit. Table 3.2 shows such a hybrid unit IOT for which the industry j (shaded) is measured in physical terms. The input from this type of data could for example be from an energy account of the SEEA central framework.

3.12 For environmental analysis it remains relevant to extend the hybrid input-output table using information on flows of natural inputs and residuals as in the case of the SRIO above. The advantage of using physical units within the core IOT is that, in many cases, this provides a better description of the technological relationships. Hence, when applying the analytical techniques outlined in Section 3.3, there is likely to be a better estimation of the direct and indirect environmental pressures across the economy. In this regard it is important to note that the mathematical specifications of the input-output model work irrespective of the units of the rows of the hybrid input-output tables. The details of these types of models (for energy) are provided in Miller and Blair (2009, Chapter 9).

Table 3.2. A single region input-output table (SRIO) in hybrid units

		Industries	Final demand			Total
		1 ... *j*	Final consumption	Gross capital formation	Exports	
Industries	*1* ... *j*	Z_d	c_d	f_d	e_d	q
Value added		v				
Imports		m	c_m	f_m	e_m	m_{tot}
Total		q	c_{tot}	f_{tot}	e_{tot}	

3.2.4 Multiregional input-output (MRIO) tables

3.13 Input-output tables that are constructed by statistical institutes are mostly SRIO tables such as the one shown in table 3.1. Input-output models that are based on an SRIO have the limitation that they often need to use the "domestic technology assumption": i.e. it is assumed that imports are produced using the same production process that is used to produce the same product domestically (see Section 3.3.3). To the extent that the domestic technologies are not representative of the technology of the imported product, the effect of the assumption is that the EE-IOT model will produce estimates that do not reflect the likely environmental pressures.

3.14 Recently, there have been a number of large projects which have created multiregional input-output (MRIO) tables and made them available via databases[9]. These MRIO databases create input-output tables for the whole world, although the actual number of tables produced varies from around 40 to 190 depending on the regional breakdown used in each project.

3.15 Table 3.3 shows a simplified structure for an MRIO table in which there is a country A and B. The accounting structure remains the same: the rows signify the output (both to the domestic and export markets) and the columns represent the inputs (also domestic and imported). In this way imports and exports are fully accounted for. The superscripts indicate the country of the variable. If there are two superscripts the first indicates the source and the second the destination. E.g. c_{AB} is the final consumption in country B of the output of country A.

[9] GTAP (2012), EXIOPOL/CREEA (2012), WIOD (2012), EORA (2012), GRAM (2012) and GLIO (2012). A number of review articles have also been written by Wiedmann et al. 2007; Wiedmann 2009; Wiedmann et al. 2011). A special issue of *Economic Systems Research* and a book (Murray and Lenzen, forthcoming) about MRIO are to be published in 2013

Table 3.3. A multiregional input-output table (2 country) with environmental data

		Country A	Country B	Country A		Country B		Output
		Industries	Industries	Final demand		Final demand		
				Final consumption	Gross capital formation	Final consumption	Gross capital formation	
Country A	Industries	Z_{AA}	Z_{AB}	c_{AA}	f_{AA}	c_{AB}	f_{AB}	q_A
Country B	Industries	Z_{BA}	Z_{BB}	c_{BA}	f_{BA}	c_{BB}	f_{BB}	q_B
	Value added	v_A	v_B					
	Total input	q_A	q_B					
	Natural inputs/residuals	r_A	r_B					

3.16 The production of MRIO databases has enhanced the quality of the input-output models because it is no longer necessary to use the domestic technology assumption. In many cases the MRIO databases are linked to environmental and other socio-economic accounts, which makes it possible to analyse environmental and other sustainability issues. A number of these applications will be discussed in section 3.3.3.

3.17 At the same time, the integration of IOT across countries generally reduces the level of industry detail that can be analysed and requires adjustment to individual national IOT to ensure harmonisation of trade data and to account for currency conversion.

3.2.5 Measurement issues

3.18 Tables 3.1-3.3 provide simplified representations of the tables that may be used in the analytical techniques described in Section 3.3. However, there are a number of measurement issues that are important to recognise when compiling these accounts for use in environmental economic applications.

3.19 *Differences in the SEEA and SNA2008*. In the most recent revision of the system of national accounts (SNA2008) the definition of imports and exports are defined on the basis of ownership rather than physical flows. However, in physical terms a difference in the recording of some flows of products (e.g. goods sent abroad for processing) may need to be taken into account (see the SEEA Central Framework Chapter 3 for more details of the treatments in physical terms). Consequently, analysis seeking to utilise information in both monetary and physical terms may require adjustment to either data set to ensure an alignment in treatment of certain flows.

3.20 *Construction of MRIO tables*. An unavoidable consequence of the production of an MRIO is that it will not be consistent to the SRIO produced by national statistical offices. This is because SRIO are produced using data from that country only. On a national level, the supply and use accounting identity is used to balance the production and consumption statistics. In many cases the totals from source statistics (such as imports and exports) need to be adjusted to balance the system. In the MRIO the balancing needs to be done on a global scale. This also means that there may be conflicting source data which need to be resolved. The most important is the existence of "trade asymmetries" i.e. the phenomenon that the trade statistics on the import from country A from country B is not equal to the data about the export of country B to country A. In the resolution of these asymmetries, as well as through other construction procedures, it is most likely that differences between the MRIO and the SRIO of statistical institutes will emerge.

3.3 Analytical techniques

3.3.1 Introduction

3.21 The history of input–output tables and modelling dates back to 1936 when Wassily Leontief published his article on 'Quantitative input and output relations in the economic system of the United States' (Leontief, 1936). That article discussed the construction of an economic transactions table that Leontief based on the *Tableau Economique*, proposed by François Quesnay in 1758. Somewhat later, Leontief developed the first input-output model (Leontief, 1941), which was based on theories developed by Leon Walras. Wassily Leontief was awarded the Nobel Prize for Economics in 1972 for this work.

3.22 The first extensions of the input-output model to environmental concerns emerged at the end of the 1960s and early 1970s (Ayres and Kneese, 1969; Leontief, 1970; Leontief and Ford, 1972). In the 1970s/80s input-output models were used in a variety of academic publications and were also used widely for applied analysis. The mid to late 1990s provided a significant surge in interest in environmental input-output modelling. There was a large increase in the number of peer-reviewed journal articles starting at the end of the 1990s (Hoekstra, 2010). This increase coincided with the period in which there was also growing interest (and data) for environmental accounts. Given the recent proliferation of input-output data and environmental extensions (see for example the work done by Eurostat, OECD and the various initiatives to create multiregional input-output databases with environmental extensions), this development is likely to continue to strengthen.

3.23 In the array of work that has been completed in this area there are a range of different input-output models that have been developed. This section does not aim to explain all of the variations and instead explains a basic environmental input-output model to give a sense of the type of analysis that is possible. Equation 3.1 shows the environmental input-output model, which is based on the SRIO data:

$r_{tot} = n \cdot L_d \cdot y_d$ Where $\boldsymbol{n} = \boldsymbol{r} \cdot \hat{\boldsymbol{q}}^{-1}$ $L_d = (I - A_d)^{-1} = (I - (Z_d \cdot \hat{q}^{-1})^{-1}$ $\boldsymbol{y}_d = \boldsymbol{c}_d + \boldsymbol{f}_d + \boldsymbol{e}_d$	(3.1)

Definition of variables (see also Table 3.1)

$\boldsymbol{r}_{tot}$ Total environmental pressure (scalar)

$\boldsymbol{n}$ Intensity of environmental pressure (vector *1* by *j*)

$\boldsymbol{L}_d$ Leontief inverse of use of domestic output (matrix *j* by *j*)

$\boldsymbol{y}_d$ Final demand of domestic output (vector of *j* by *1*)

$\boldsymbol{r}$ Environmental pressure per industry (vector of *1* by *j*)

$\boldsymbol{q}$ Output per industry (vector of *1* by *j*)

$\boldsymbol{I}$ Identity matrix (matrix of zeros with values of 1 on the diagonal)

$\boldsymbol{A}_d$ Technical coefficients of use of domestic output (matrix *j* by *j*)

$\boldsymbol{Z}_d$ Intermediate use of domestic output (matrix *j* by *j*)

$\boldsymbol{c}_d$ Final consumption expenditures (vector *j* by *1*)

$\boldsymbol{f}_d$ Gross capital formation (vector *j* by *1*)

$\boldsymbol{e}_d$ Exports (vector of *j* by *1*)

The use of a "^" denotes that the relevant vector has been diagonalised, i.e. the vector has been transformed into a square matrix with the values of the vector on the diagonal.

3.24 The mathematical derivation of the Leontief inverse, which is the core concept in the input-output model, is described in the annex to this chapter. The interpretation of the coefficients in the Leontief inverse matrix model is important. This matrix provides information about the direct *and* indirect effects of an increase in final demand. This is one of the most important advantages of the input-output model, since it makes explicit the linkages and feedback loops in an economy.

3.25 A number of analytical techniques based on the input-output model are discussed in the remainder of this section. In the first sections two static applications will be discussed: multipliers (section 3.3.2) and the attribution of environmental pressures to final demand (section 3.3.3).

3.26 EE-IOT are also used for dynamic analysis such as decomposition analysis (section 3.3.4). When decomposition is applied using the input-output model it is known as structural decomposition analysis. However, other decomposition methods, which use EE-IO data but not the input-output model, also exist.

3.27 The input-output model has number of advantages, but it is also criticised for the rigid assumptions that underlie the model (constant technical coefficients, constant returns to scale). Computable general equilibrium (CGE) models, which use less restrictive assumptions, are therefore discussed in section 3.3.5.

3.3.2 Multiplier analysis

3.28 Multipliers provide a summary of I-O model results and typically provide a measure of direct and indirect economic impacts per unit of output by industry. Multipliers were traditionally compiled for economic variables such as output, value added, income, and employment (see Eurostat, 2008; Miller and Blair, 2009), but the approach has been readily extended to environmental variables (see Östblom, 1998; Lenzen 2001, Lenzen et al., 2004; Rueda-Cantuche and Amores, 2010). The most commonly used environmental variables are energy and carbon dioxide. Other environmental variables include greenhouse gas emissions, acidification, and emissions of heavy metals to water. Overall, knowledge of the magnitude of a wide range of multiplier effects of individual industries provides relevant information for the evaluation of trade-offs (Foran et al., 2005).

3.29 The basic formulation of the environmental multiplier is provided in the following equation. See the annex for more details.

$$\Pi = \hat{\boldsymbol{n}} \cdot \boldsymbol{L}_a \tag{3.2}$$

Where the variable which has not yet been defined previously is:

Π – Matrix of multipliers (matrix j by j)

3.30 There are several varieties of multipliers such as forward and backward linkages (Miller and Blair, 2009). The multipliers provide insight into the environmental pressures caused by the direct and indirect demand effects of a unit increase in output of a particular industry. Multipliers can therefore illustrate that an increase in one industry will also lead to increases in environmental pressures in other industries through the direct and/or indirect demand that is generated.

3.31 The challenge of aligning environmental data with the IO categories is often significantly remediated by use of the SUT framework and undertaking multiplier analysis in there, rather than converting to IO tables. This is because SUT often have many more products than industries and environmental data can often be allocated into additional vectors by product just as it can be allocated to vectors by industry. In such a way, multipliers for both industries and products can be calculated in one single elegant procedure. This technique is described in detail in Lenzen and Rueda-Cantuche (2012), and has been employed in case studies (Lenzen et al. 2004; Wachsmann et al. 2009).

Multipliers for the Environmental Goods and Services Sector

3.32 The relative importance of the Environmental Goods and Services Sector (EGSS) can be determined by calculating the indirect effects of its further growth. To obtain the appropriate multipliers for this sector, the data from the EGSS must be linked to data compiled in a national accounts based IOT.

3.33 The main challenge here is to adapt the standard IOT in order to determine the associated input coefficients and multipliers for the EGSS. Some activities of the EGSS, such as sewage and refuse disposal services or recycling, are already in the standard industry classification (ISIC) in the IO table. Their multipliers can be directly derived from the IO table used for this study. However, many activities of the EGSS are scattered across different industries. For example, companies producing environmental equipment are part of manufacturing of machinery and the producers of renewable energy are part of the energy supply sector. In the statistics for the EGSS these activities need to be allocated to the corresponding ISIC classes, i.e. using the same classification system that is used for the IOT.

3.34 For those EGSS activities that are spread across standard IOT industry classes it is necessary to create additional columns and rows within the IOT using a variety of data sources and assumptions. For those EGSS activities that cannot be separately identified it is necessary to assume that the activities have the same multipliers as the ISIC class into which they are classified.

3.35 Using the re-worked and more detailed IOT, the multipliers and multiplier effects for the total EGSS can be calculated by multiplying the output of the different activities by their multipliers and dividing this total by the total output of the EGSS.

3.3.3 Attribution of environmental pressures to final demand

3.36 Input-output analysis is regularly used to attribute environmental pressures to final demand categories. This type of analysis can identify the link between final demand and resource use, emissions and other environmentally related flows. It can thereby highlight ‘hot spots’ that may be subject for policy attention.

3.37 There are three research topics which are regularly tackled in the literature using this technique: footprints, consumption vs. production perspectives, and the global shifts in environmental pressures. The following paragraphs discuss each of these topics in turn, followed by a short description of the relevant mathematical details.

Footprint calculations

3.38 The calculation of a “footprint” is a technique in which environmental pressures are attributed to domestic demand. This line of work was popularized through the introduction of “ecological footprints” in the early 1990s (Rees, 1992, Wackernagel and Rees, 1996). The ecological footprint calculates the amount of land and water (surface area) that is necessary in the production of a certain consumption bundle. However, the initial work in this area did not use input-output techniques for its calculation.

3.39 Over the last decade or so, various other footprints have been introduced, and increasingly they are being calculated using input-output techniques, especially MRIO models.[10] Examples include the carbon footprints, water footprint and ecosystems pressure footprints.[11] Although the methodologies are currently quite varied, there are efforts to harmonize their calculation (Galli et al, 2011, Weinzettel et al., 2011).

Production versus consumption perspective

3.40 Footprint indicators make explicit the environmental pressures that are caused by consumer behaviour. However, their calculation is often used to highlight another point as well. It is a strand of the literature which is often referred to as the "production versus consumption perspective" (Peters, 2008; Peter and Hertwich, 2008; Barrett et al. 2012).

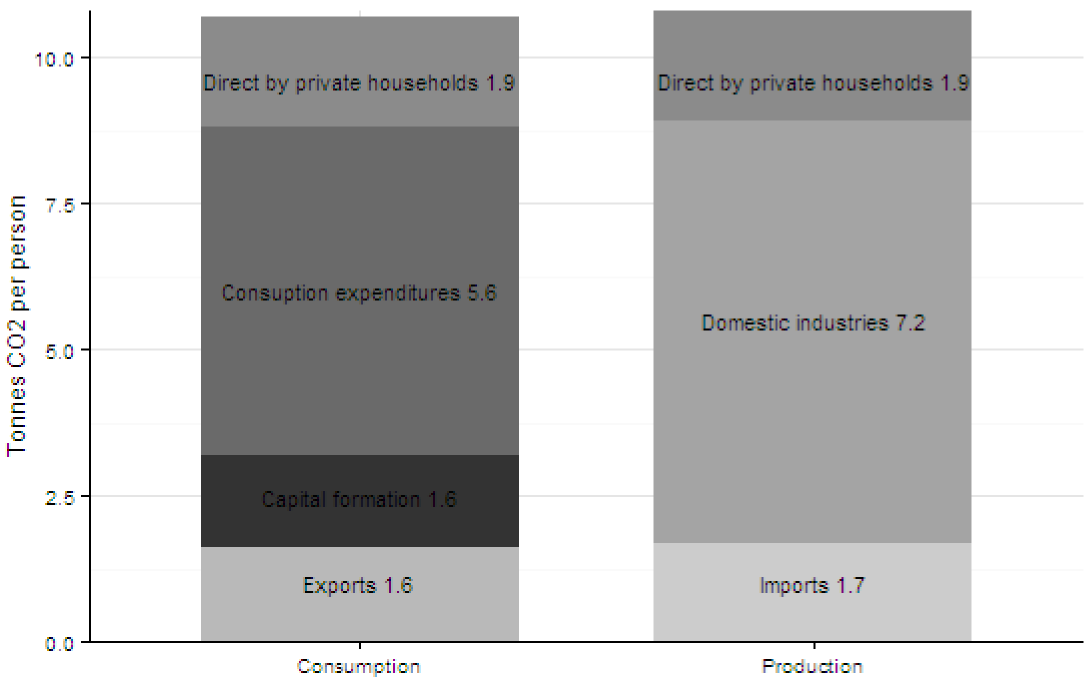
3.41 Underlying the discussion are the questions: Which environmental pressures is a country responsible for? In the polluter-pays-principle who is the polluter? On the one hand, it may be that industries (or producers), which are also responsible for most of the wealth creation in a country, are responsible. This is commonly referred to as the production perspective. Some international agreements, such as the Kyoto Protocol, follow this logic because they are based on all greenhouse gas emissions within the geographical boundaries of the country. On the other hand, the consumption perspective is based on the premise that the proverbial "polluter" is the consumer of the end product. The consumer perspective is captured by calculating environmental footprints which include all environmental pressures whether they are generated abroad or in the source country.

3.42 Figure 3.1 gives an example of an analysis of the production and consumption perspective for the EU27, showing the CO_2 emissions per capita in 2006 from both a consumption and a production perspective (EUROSTAT, 2011). At a more detailed level, it appears that around 70% of the CO_2 emissions are ultimately attributable to households via their demand for (i) energy used in and around the house, (ii) personal transport, and (iii) food. Such insights are important in understanding which product-related and consumption-related policies may help to limit carbon emissions.

[10] The increased use of input-output techniques is symbolized by the publication of a special issue on the carbon footprint in the *Economic Systems Research* (the journal of the international input-output association) in 2009 (ESR, 2009).

[11] Several national statistical offices and institutes such as the OECD and Eurostat have also explored the calculations of footprints(Statistics Canada, 2012; Rørmose et al, 2009; Eurostat, 2012; Lenglart, 2010; DESTATIS, 2010; Edens et al, 2011; Statistics Netherlands, 2010; 2011; Statistics Sweden 2003; Nijdam et al., 2005; Wilting and Vringer, 2009; Wilting, forthcoming; DEFRA, 2012; Wiedmann et al, 2008; Ahman and Wyckoff, 2003; Nakano et al, 2009.

Figure 3.1 Production and consumption based CO_2 emissions per capita



Global shifts in environmental pressures

3.43 In a closed economy, the total environmental pressures following the producer or consumer perspective would be the same. Differences occur because of trading relationships with other countries in the world. One can therefore observe that all countries have an "environmental trade balance". This environmental trade balance, which is the difference between the environmental pressures embodied in imports and exports, will change over time. This may be caused by economic developments as well as international agreements concerning the environment (e.g. the Montreal and Kyoto Protocols) or the economy (e.g. the Uruguay Round agreements on international trade).

3.44 A lot of research has analysed these shifts in environmental pressures. Various hypotheses have been proposed. For example, the term "carbon leakage" is often used to label studies that investigate whether countries' emissions under the Kyoto Protocol are being reduced by importing emission intensive products from countries that do not participate in the Protocol (Peters, 2008, Weber et al, 2008; Peters and Hertwich, 2006/2008; Babiker, 2005). A related field of research is the "pollution haven hypothesis" that investigates the same shifts from developed to developing countries resulting from differences in environmental regulation (Eskeland and Harisson, 2003;Cole, 2004).

3.45 It is possible to undertake consumption based modelling using a Life Cycle Analysis (LCA) approach whereby the "life cycles" for particular consumption items are traced and then the links to the use of various materials or emissions are drawn following the basic logic outlined above.

The difference in using an LCA approach is that the fully integrated industry and product information inherent in an IOT is not utilised, although LCA may use some input-output relationships as part of their calculations. LCA approaches are not further articulated here.

Mathematical attribution of environmental pressures to final demand

3.46 Environmental pressures can be attributed to consumption, gross capital formation and exports in the way that is shown in Equation 3.3. In this model, which uses SRIO data, domestic environmental pressures are attributed to final consumption, gross capital formation and export of domestic output:

$$\begin{aligned} \Phi_d &= \Phi_d^c + \Phi_d^f + \Phi_d^e \\ \Phi_d &= \boldsymbol{n} \cdot \boldsymbol{L}_d \cdot \boldsymbol{c}_d + \boldsymbol{n} \cdot \boldsymbol{L}_d \cdot \boldsymbol{f}_d + \boldsymbol{n} \cdot \boldsymbol{L}_d \cdot \boldsymbol{e}_d \end{aligned} \tag{3.3}$$

Where the variables which have not yet been previously defined (all scalars):

Φ_d Environmental pressures attributed to final demand of domestic output

Φ_d^c Environmental pressures attributed to final consumption expenditures of domestic output

Φ_d^f Environmental pressures attributed to gross capital formation of domestic output

Φ_d^e Environmental pressures attributed to exports of domestic output

3.47 The above model is based on data from the SRIO, which makes it possible to attribute the domestic emissions to final demand of domestic products. However, this is an incomplete picture because it does not show the emissions which are related to imported goods and services. A more complete picture of the total emission embodied in final demand can be arrived at by using the "domestic technology assumption" in the SRIO setting which is shown in equation 3.4.

$$\begin{aligned} \Phi &= \Phi^c + \Phi^f + \Phi^e \\ \Phi &= n \cdot L_d \cdot (c_d + c_m) + n \cdot L_d \cdot (f_d + f_m) + n \cdot L_d \cdot (e_d + e_m) \end{aligned} \tag{3.4}$$

Where the variables which have not yet been previously defined are:

Φ Environmental pressures attributed to final demand (scalar)

Φ^c Environmental pressures attributed to final consumption expenditures (scalar)

Φ^f Environmental pressures attributed to gross capital formation (scalar)

Φ^e Environmental pressures attributed to exports (scalar)

$\boldsymbol{c}_m$ Final consumption expenditures of imported products (vector *j* by *1*)

$\boldsymbol{f}_m$ Gross capital formation of imported products (vector *j* by *1*)

$\boldsymbol{e}_m$ Exports of imported products (re-exports)[12] (vector of *j* by *1*)

3.48 The domestic technology assumption is often criticised because it is not an accurate reflection of the environmental pressures created by goods and services produced in other countries. Where

[12] Note that many countries do not have re-exports and so this vector is 0.

possible it is therefore better to do the attribution using MRIO data because this makes it possible to calculate the environmental pressures embodied in imports more accurately. The model also includes the feedback loops in the world economy since the Leontief inverse includes all the inter-industry deliveries of all the countries. The formula for country A, which is based on the variables of table 3.3, is provided in equation 3.5.

$$\begin{aligned}\Phi_A &= \Phi_A^c + \Phi_A^f + \Phi_A^e \\ \Phi_A &= \begin{pmatrix} n_A & n_B \end{pmatrix} \cdot \begin{pmatrix} L_{AA} & L_{AB} \\ L_{BA} & L_{BB} \end{pmatrix} \cdot \begin{pmatrix} c_{AA} \\ c_{BA} \end{pmatrix} + \begin{pmatrix} n_A & n_B \end{pmatrix} \cdot \begin{pmatrix} L_{AA} & L_{AB} \\ L_{BA} & L_{BB} \end{pmatrix} \cdot \begin{pmatrix} f_{AA} \\ f_{BA} \end{pmatrix} \\ &+ \begin{pmatrix} n_A & n_B \end{pmatrix} \cdot \begin{pmatrix} L_{AA} & L_{AB} \\ L_{BA} & L_{BB} \end{pmatrix} \cdot \begin{pmatrix} e_{AA} \\ e_{BA} \end{pmatrix}\end{aligned} \quad (3.5)$$

Where the variables which have not yet been previously defined are:

Φ_A Environmental pressures attributed to final demand of country A

Φ_A^c Environmental pressures attributed to final consumption expenditures of country A

Φ_A^f Environmental pressures attributed to gross capital formation of country A

Φ_A^e Environmental pressures attributed to exports of country A

3.3.4 Decomposition analysis

3.49 Decomposition analysis can be used to analyse changes in environmental pressures and answer questions such as: which economic or technological changes have caused emissions of CO_2 to increase and, what economic factors have contributed to an increase in demand for raw materials? Decomposition analysis is a tool by which the particular driving forces influencing changes in environmental impacts are quantified separately.

3.50 The driving forces which are distinguished depend on the model that is used. When a decomposition model is specified using an input-output model, it is known as *structural decomposition analysis* (SDA).[13] The simplest specification, based on the SRIO model shown in equation 3.1, is provided in equation 3.6.

$$\Delta r_{tot} = \Delta n \cdot L_d \cdot y_d + n \cdot \Delta L_d \cdot y_d + n \cdot L_d \cdot \Delta y_d \quad (3.6)$$

3.51 In this equation, the changes in environmental pressures (Δr_{tot}) are determined by the changes in the intensity of environmental pressures ($\Delta n \cdot L_d \cdot y_d$), the changes in the industry structure of the economy ($n \cdot \Delta L_d \cdot y_d$) and the changes in final demand/economic growth ($n \cdot L_d \cdot \Delta y_d$). Note it is possible to provide more detailed decompositions by splitting final demand in subcomponents (Export, consumption and capital formation), or to analyse the changes in them (i.e. the mix and

[13] For overviews see Rose, 1999; Hoekstra and van den Bergh, 2002; and Hoekstra, 2005. For state of the art applications see de Haan, 2000; 2001; Lenzen, 2006; and Wood, 2009.

level effects of changes in final demand categories) so that it is possible to analyse the effect of changes in consumption patterns for example. Techniques also exist to decompose the technological aspects of changes. For example, the Leontief inverse may be broken down further, or the environmental pressures intensity may be broken down into a fuel mix and energy intensity effect.

3.52 To undertake an SDA it is necessary to have the monetary data in current prices and in prices of a base year (constant prices) in order to analyse the changes in the volume terms. Given that the decomposition is done using discrete data for a year *t* and *t-1* there are many ways in which the various effects can be weighted. In the SDA literature nearly all applications use the weighting method proposed by Dietzenbacher and Los (1998) which lead to equivalent results as Sun (1998).[14] In the related field of index decomposition analysis, which is discussed next, other methods are used.

3.53 Note that models which do not use an input-output model are more prevalent because the data requirements are less restrictive. These methods are often referred to as index decomposition analysis (IDA) or energy decomposition (Ang and Zhang, 2000; Ang, 2004).

3.54 The most simple IDA is provided in the following equation:

$$\Delta r_{tot} = \Delta n \cdot s \cdot q_{tot} + n \cdot \Delta s \cdot q_{tot} + n \cdot s \cdot \Delta q_{tot} \qquad (3.7)$$

Where s (q/q_{tot}) equal to the sector structure and q_{tot} is equal to the changes in the total output. This model only requires data on the output per industry and not an entire input-output table. It does however require data from environmental pressures by industry from the accounts of the SEEA Central Framework.

Example of structural decomposition analysis

3.55 Figure 3.2 shows the breakdown of CO_2 emissions into 4 effects (fuel mix, energy intensity, economic structure and economic growth).

3.56 The fuel mix effect quantifies possible shifts between different kinds of fossil energy product inputs. For example, substituting oil for gas may lead to lower CO_2 emissions per unit (joule) of energy consumption. In the example changes in the fuel mix are not very significant.

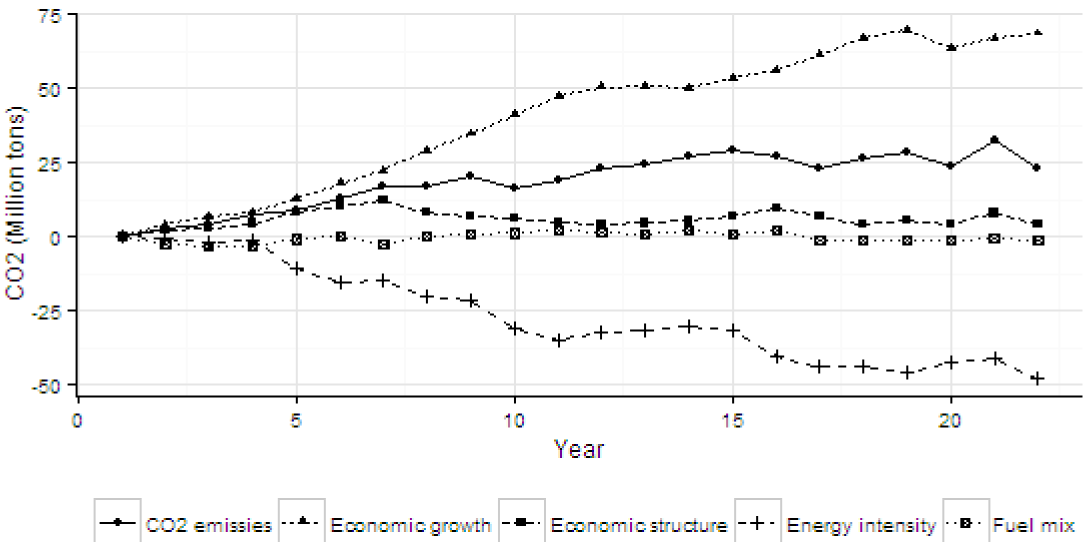
3.57 The second factor refers to energy consumption per unit of production. Adoption of energy saving measures will lead to diminishing energy intensities and this effect is clearly illustrated in the example.

[14] The Dietzenbacher and Los method relates to the removal of the residual term in the decomposition. The method involves averaging the possible alternative decomposition formulations, where the number of formulations is dependent on the number of variables in the decomposition. An overview of the various weighting schemes used in decomposition analysis can be found in Hoekstra and van den Bergh 2002, Hoekstra, 2005

3.58 The third component detects shifts in the economic structure. This component will show the effects of changes in the composition of production processes over time. In the example, the share of relatively polluting activities seems to have slightly increased.

3.59 The fourth factor indicates how much CO_2 emissions would have increased in case these emissions would have followed the same growth path as the volume growth of gross domestic product.

Figure 3.2 Example of a structural decomposition analysis of CO_2 emissions



3.60 Table 3.4 illustrates that the sum of the four components in the decomposition analysis equals the actual change in CO_2 emissions over time, the fifth line (×) in the diagram.

Table 3.4 Changes in CO_2 emissions

	Mton
Changes in CO2 emissions	34,1
1. Fuel mix	-3,7
2. Energy intensity	-37,2
3. Economic structure	8,5
4. Economic growth	66,5

3.3.5 Computable general equilibrium modelling

3.61 Computable general equilibrium (CGE) models are a class of economic models that use actual economic data to estimate how an economy might react to changes in policy, technology or other external factors. In the context of environmental-economic accounts CGE models may be developed using information contained in EE-IOT thus bringing together monetary and physical data. It should be recognised that the incorporation of physical data within CGE models may require particular assumptions regarding the relationships between environmental and economic variables that are different from the standard assumptions that are used in relation to economic variables measured in monetary terms. For example, all variables expressed in monetary terms will reflect relationships between prices and volumes of products. However, for some environmental flows, such as emissions and waste, similar types of relationships may not by present.

3.62 The use of CGE models can help to understand what dynamic impacts may be expected in case of policy interventions, or other developments. For example, it is possible to analyse the dynamic effects of the introduction of a carbon tax, that results in increased production costs for the industry, or of some shifts in final demand that impact the production of goods and services overall in the economy. While EE-IOT and time series of EE-IOT are excellent for understanding the current situation, or the causes related to historical changes, they are not well suited to analyse the future effects of policies.

3.63 One of the limitations of EE-IOT is that they have fixed technological coefficients. For example, it is assumed that in a specific year, the steel industry needs a specific, fixed set of inputs from various suppliers (the iron ore industry, the coal industry, etc) in order to produce $1000 of output. As well, the EE-IOT framework does not allow the calculation of changes in prices of different goods and services produced/consumed in the economy and the respective changes in intermediate and final consumption. Both of these features are not realistic in the medium and long-run and restrict the capacity of EE-IOT to fully assess the impacts of, for example, autonomous macro-economic and technological trends, or specific policy measures (e.g. shifting taxes from labour to pollution). To some extent this problem is overcome by the regular, ideally annual, update of EE-IOT and the accounts of the SEEA which help to track the change in prices and in patterns of intermediate and final consumption of goods and services.

3.64 CGE models use EE-IOT as their core database, hence preserving the details of this framework, and at the same time allow for the representation of gradual economic adjustments to defined policy changes. Where the price of a particular input increases in response to a new tax measure, industries will seek alternative inputs. The substitution possibilities for each industry depend on its technology and the effects are captured in CGE models by elasticities of substitution. If no substitution is possible then the output price will increase which will result in lower demand for the industry’s output and hence reduce its production.

3.65 CGE models consist of a system of non-linear demand, supply and market equilibrium equations. The main model equations are based on neo-classical principles. Producers are assumed to be cost optimizers functioning under the conditions of perfect competition and full information, and households are assumed to be fully rational utility optimizers functioning who make their decisions in the conditions of full information.

3.66 EE-IOT databases are used in order to calibrate main parameters of CGE models such that in the initial reference year the model reproduces the EE-IOT data. It is usually the case that not all of the model parameters can be calibrated on the basis of EE-IOT database and hence are taken from relevant literature or estimated econometrically. Such parameters include, among others, the elasticities of substitution and elasticities of demand with respect to income.

3.67 The core structure of CGE models is quite similar to the structure of EE-IOT. However, these models may also include other elements related to more realistic and detailed the representation of economy, energy and environmental systems that are not directly included into EE-IOT. Inclusion of these elements depends on the purpose of the particular CGE models and varies significantly between the existing models.

3.68 One of the elements that is widely included in CGE modelling is the representation of the government sector which collects taxes and pays subsidies and social transfers to households and enterprises. Another common feature is the modelling of unemployment that may be differentiated between different types of labour according to their education and/or profession. Some of the existing CGE models include the representation of technological progress. This can vary from some exogenous assumptions about technological growth rate to detailed modelling of endogenous and semi-endogenous technological progress as a function of availability of human capital, investments in R&D and technological frontiers. Some of the existing CGE models relax the assumption of perfect competition at least on some markets (for example, for oil and gas) and use instead oligopolistic frameworks such as those by Cournot or Bertrand.

3.69 Building Computable General Equilibrium (CGE) models and deriving related elasticities is a specialist job falling outside the scope of this document. In particular, in the context of environmental-economic analysis both economic and scientific modelling is likely to be required. Well known CGE models include:

- the GTAP model (build around the GTAP database) (e.g. Hertel et al. 2007)
- the OECD Env-linkages model, used for a.o. the OECD Environmental Outlook to 2050 (OECD, 2012)
- GEM-E3 model used by DG ENV and DG ENERGY (GEM-E3 model manual http://ipts.jrc.ec.europa.eu/activities/energy-and-transport/gem-e3/)
- WorldScan model used y DG ENV and DG TRADE (Lejour et. al , 2006)
- EPPA model of MIT (Paltsev et. al. 2005)

3.4 Geo-spatial analysis

3.70 The data described in the SEEA Central Framework largely relate to specific materials, substances and resources, and the various stocks and flows are accounted for without regard to the precise location of the materials, substances or assets, aside from the country about which the accounts are compiled.

3.71 In reality, all materials, substances and resources are found in particular locations and, from a policy perspective, knowledge of the location of various stocks and flows may be of particular relevance. Thus, knowledge of the locations of depleted fish stocks, or places of high emissions to water bodies, may be of more power than knowledge of the total stocks or flows for the country as a whole. Indeed, national averages may hide important local variations. In short, knowing the locations can help to better identify environmental pressure points.

3.72 Increasingly it is possible to use mapping and information technologies (i.e. geographic information systems (GIS)) to re-present standard national level information according to the location of the underlying observation. Thus, water resources can be mapped to particular river basins and emissions mapped to particular urban areas. Geo-spatial analysis refers to the capacity to re-organise existing information according to standard geographical classifications. Most commonly, the power of this approach is seen in the creation of maps that can highlight particular areas of interest or concern.

3.73 A particular challenge in geo-spatial analysis is combining information from various sources according to a common geographical classification.[15] For this purpose it is necessary to delineate (or mark out) a set of relatively small spatial areas (essentially building blocks). Information is then attributed to these spatial areas. A common difficulty is that observations for different types of data may not all be able to be easily attributed to the same level of spatial area.

3.74 Where multiple sets of information can be attributed the power of geo-spatial analysis increases. Also, where information can be organised to the same spatial areas in a time series, geo-spatial analysis allows powerful analysis of change over time in a way that is not possible through analysis of standard accounts and tables.

3.75 To point to the potential of geo-spatial analysis and the use of SEEA data, two examples are provided. These examples work within the general framework provided by land accounts as described in the SEEA Central Framework. The SEEA land accounts show measures of stocks and changes of stocks of land in terms of areas of land use and land cover. They may also be structured to consider land in terms of ownership by economic units, for example by industry or institutional sector. It should be recognised that the completion of geo-spatial analysis requires strong underlying information systems. A description of such systems and the relevant methodologies and best practices is not contained in the SEEA Central Framework.

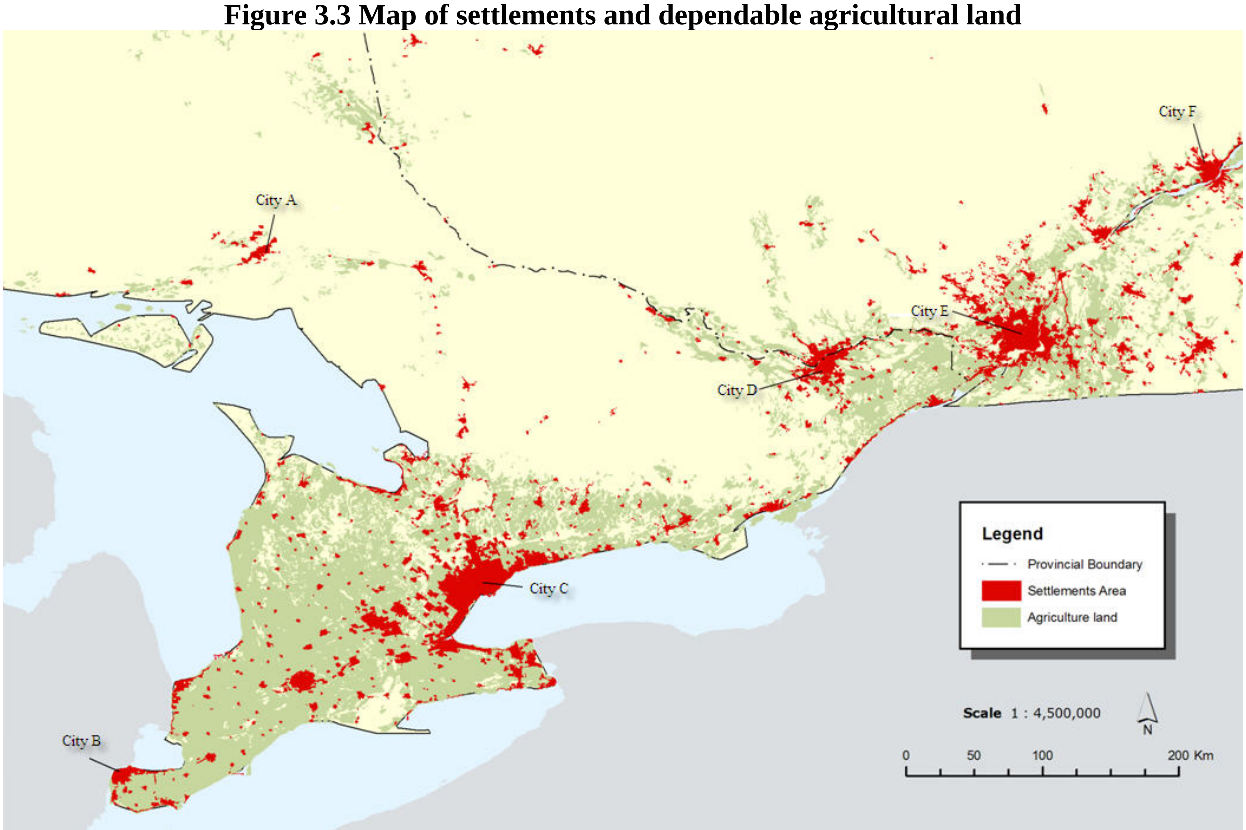
3.76 The two examples point to the usefulness of spatially attributed information for policy purposes. A focus on the use of specific spatial areas enables a stronger, joint consideration of social, economic and environmental implications of various policy choices and options. The expansion in the use of land for housing, for example, requires in turn infrastructure such as roads, sewers, and water supply lines and at the same time can lead to encroachment into high quality agricultural land. Potential environmental impacts include loss of wildlife habitat, increased air pollution and greenhouse gas emissions, and the contamination of rivers, lakes and aquifers. The type or form of expansion may also be significant, e.g. is the expansion relatively high or low density in terms of changes in human population.

3.77 The first example involves analysis of settlements over time. Settlements were defined as tracts of land where humans have altered the physical environment. The methodology was based on

[15] A specific geographic classification is not described in the SEEA Central Framework. However, related classifications on land use and land cover are discussed in Chapter 5 and SEEA Experimental Ecosystem Accounting discusses the measurement issues in more detail.

Geographical Information System (GIS) technology. At its heart, the method is statistical through combining remote sensing technology and imagery with the most detailed data from the population census. Application of the methodology provided detailed, harmonised and comparable datasets enabling a more complete national analysis of settlements and formed the basis for the development of indicators that can be used to track land cover and land use change. As a brief indication of the types of maps that may be generated, the map in Figure 3.3 shows some results for settlements in relation to dependable agricultural land (i.e. land free of severe constraints to crop production).

Figure 3.3 Map of settlements and dependable agricultural land



3.78 The second example concerns the integration of environmental and economic information over a large coastal area. As a result of carefully defining the spatial areas, and through attribution of various data sources to the spatial areas; a rich dataset was constructed. The types of information included population, land use, land ownership, land values, vegetation cover, forest extent and change, water consumption, agricultural production (physical and monetary terms), land management practices (such as use of fertiliser, irrigation) and topographical features (e.g. elevation and slope). The integration of socio-economic data and environmental data is a particular feature of this dataset and enables the investigation of a broad range of issues. These data can be presented in tables and maps[16]. Figure 3.4 shows a map to which a selection of data have been overlaid for each spatially defined area.

3.79 The development of geo-spatial information sets is particularly relevant in the development of ecosystem accounts as described in SEEA Experimental Ecosystem Accounting. Since ecosystem accounts can utilise much information described in the SEEA Central Framework, integrated approaches to the development of spatially referenced information sets are likely to provide very rich sources of information for analysis of many issues concerning the link between the economy and the environment.

Figure 3.4 Map of Statistical Local Area

2.1 Land use and rateable land value

Data item	Value	Unit
Area of this SA1 region	246.3	Ha
Rateable Value	12.9	$m
Agriculture	-	%
Retail/Wholesale	-	%
Transport Storage	-	%
Industrial	-	%
Sport, Recreation, Accommodation	4.8	%
Community Services	-	%
Residential	17.4	%
Vacant Land - Urban	27.5	%
Vacant Land - Rural	-	%
Other	31.7	%
Total rateable area	81.4	%

2.2 Land use

Data item	Value	Unit
Area of this SA1 region	246.3	HA
Conservation and Natural Environments	35.6	%
Production from Relatively Natural Environments	14.3	%
Production from Dryland Agriculture and Plantations	0	%
Production from Irrigated Agriculture and Plantations	0.2	%
Intensive uses	43.0	%
Water	7.0	%

[16] ABS 2011. Land Account: Great Barrier Reef Region, Experimental Estimates, cat. No. 4609.0.55.001:

Chapter 4: Extensions of the SEEA

4.1 Introduction

4.1 The focus in this chapter is the potential of data from the accounts of the SEEA Central Framework to be extended and integrated with other information. The potential to connect SEEA accounts to a range of existing information sources can be of direct assistance in better understanding multi-faceted issues such as sustainable development. It also recognises that responses to environmental pressures will usually rely on understanding connections between the environment, the economy and individuals. In this context the SEEA accounts cannot provide the complete information set but can provide an important part of the information and is a framework that supports and encourages integration of data.

4.2 There are two main approaches to considering extensions of the SEEA. The first approach involves a decomposition of existing SEEA accounts using additional information, for instance through further breakdown of the household sector or through a focus on certain themes where there is an interaction between human activity and the environment such as tourism or health. The second approach involves using the environmental-economic data of the SEEA as an input to development of broader information sets for analysis of topics such as sustainable development. This will usually require linking the SEEA with data on social conditions. The focus of this chapter is on the first approach.

4.3 In regard to the second approach, there have been discussions and some research on the potential of developing holistic accounting models that link the SEEA with so-called Social Accounting Matrices (SAMS). SAMS provide a connection between the SNA and social datasets – in particular information on household income and expenditure (see 2008 SNA Chapter 28). The discussion here does not attempt to build these broader models but at the same time it should be recognised that the SEEA, given its strong connections to the SNA, may play an important role in the development of such integrated frameworks and datasets.

4.4 A particular feature of the extensions to the SEEA described in this chapter is that information concerning households and household activity is prevalent. This reflects both the focus on the industry dimension in the earlier chapters (where households are often considered as simply one single dimension) and also the important role that consumer behaviour plays in relation to environmental pressures. Thus, the capacity to further analyse the behaviour of different types of households or households in different locations in relation to access to natural resources and environmental pressures, is an important extension of the SEEA. Extensions to household sector data are described in Section 4.2.

4.5 The other extension described in this chapter involves re-organisation (and disaggregation) of existing industry and product information to focus on particular themes. The example highlighted here is tourism activity but the same type of approach may be applied in other cross cutting activities and specific themes such as transport, forest and food industries. This type of extension is in Section 4.3.

4.6 The extensions described in this chapter are likely to require the integration of additional data beyond the data required for compiling accounts in the SEEA Central Framework. These data may already exist but it may also require additional primary data collection activity. For example, surveys of household income and consumption showing the location and distribution of household incomes and household types are required in order to allocate information at these levels of detail. At the same time it may be possible to model the relationships between physical flows of natural inputs and residuals and specific products using the structure of data from the SEEA Central Framework.

4.2 Extensions of SEEA to the household sector

4.2.1 Introduction

4.7 Integrated data, including social, economic and environmental accounts based on agreed classifications and methods, are important in efforts to help countries design effective sustainable development and other cross-cutting policies. Comparable data over time and across countries are needed to track performance across a range of sustainable development related goals and objectives, including, for example the Millennium Development Goals.

4.8 It is important that these common data are used to inform policymaking and implementation as part of integrated planning at all levels. Such data is also integral to the systems used to define, track and achieve future national and international development objectives. Extensions into these areas are encouraged by the Rio+20 Conference Outcome Document, and are supported by several development programmes linking the collection and analysis of data to integrated policymaking.

4.9 The SEEA Central Framework provides the basis for integrating environmental-economic data. This section considers how the SEEA Central Framework can be expanded to include household and social information and thus provide information for a broader analysis of relevant tradeoffs. A general caveat to this expansion is that there may be significant data requirements beyond the scope of the SEEA Central Framework, and even where data are available, work is likely to be required to ensure and alignment between this additional data and the SEEA based information.

4.10 In relation to the connection between households, society and the environment, it is increasingly recognised that there are a range of non-marketed benefits that are received by societies and individuals from the environment such as air filtration, carbon sequestration, water regulation and various opportunities for recreation. There are also often strong cultural, including religious, connections to environmental locations. Measurement of various non-marketed benefits is not covered in this chapter but relevant developments in measurement in this area are presented in the SEEA Experimental Ecosystem Accounts.

4.11 Some examples of key social indicators are already included in the SEEA-Water and SEEA-Energy accounts, including data on access to water with respect to supply, sanitation, infrastructure, and cost recovery, as well as energy fees and subsidies for households and industries. This section highlights some of the key aspects of these potential extensions to the

SEEA Central Framework with a focus on information that relates to the question of environmental sustainability.

4.2.2 Household access to natural resources

4.12 Expanded SEEA indicators should help capture and inform the multi-dimensional poverty and environment nexus. Poverty may be linked to environmental conditions and often the poor and vulnerable groups rely on the environment for their livelihoods and well-being. For these reasons they can also contribute to and be affected by policies designed to manage natural resources and respond to related environmental issues.

4.13 Given the many different factors influencing well-being, livelihoods, and sustainable development, no single indicator, such as income or other financial data, can reflect the multiple aspects of poverty, deprivation, and links to the environment. The multiple dimensions of poverty link to the environment and the economy in many ways. These links include empowerment, inclusion, health, education, living standards, environmental degradation, ecosystem services, income, employment, food, water, sanitation, energy, safety, and access to basic services and infrastructure.

4.14 The main areas in which SEEA might be extended to capture relevant information relate to data on stocks and flows of water resources and energy resources. These two types of resources are central to the operation of well-functioning households and communities in all parts of the world. The extension of most direct relevance is likely to be a breakdown of household consumption of water and energy by household income. This involves the analysis of data on this consumption and integrating it within the Physical Supply and Use Tables (PSUT) for water and energy (see SEEA Central Framework Chapter 3) through the incorporation of additional columns in the use table. This may for example be done by income decile or quintile.

4.15 Also in relation to flows of these resources it may be relevant to understand the extent to which households are dependent on finding their own water and energy resources as distinct from using relevant distribution systems. In this regard additional columns can be added to the supply tables within the PSUT for water and energy to record explicitly household production of water and energy (i.e. through collection of water, fuelwood, installation of solar energy panels, etc). Again, the addition of columns reflecting household production by household income would be of assistance and it would be useful to ensure that the rows of the table are designed to capture the various types of resources being sourced.

4.16 The focus in the discussion to date has been on household final consumption but there may also be interest in understanding the use of natural inputs into the economic production undertaken by households such as agriculture, fishing, forestry, construction, or in small businesses. For analysis of this aspect of household activity, additional columns may be introduced into the industry section of the use table within the PSUT to distinguish household activity from activity by other enterprises in the same industry.

4.17 In terms of sustainability of access to these resources an important factor will be the stocks and changes in stocks of the relevant resources. In this context, the development of asset accounts for water resources and energy resources (particularly timber resources) may be particularly relevant with a focus on distinguishing those resources available for use by households for their own collection and consumption. Asset accounts are described in the SEEA Central Framework Chapter 5. Depending on the economic structure of a country, land, soil resources and aquatic resources may be of particular relevance to lower income households. Asset accounts for these resources may therefore be of particular relevance although attributing the resources to specific households may not be straightforward. One alternative may be to consider the availability of resources by spatial area (e.g. via land accounts) and then link this information to the location of households of various income types.

4.18 The applicability of extended analysis of access to water and energy resources through the SEEA can be seen in the context of the Millennium Development Goals (MDGs). Table 4.1 presents 8 MDGs and their environmental links. Goals 1 and 7 relate most directly to the type of information and extensions just described. However, it is also clear that progress towards other goals may also be supported by progress in relation to access to water and energy resources. For example, reducing the time taken to collect water and fuelwood by children may allow more time for school attendance. Although the extended SEEA datasets cannot directly answer these questions, SEEA based data may provide part of a broader set of information (e.g. sustainable development indicator sets) relevant for consideration of them.

4.19 Linking to the discussion in Chapter 3, extensions in terms of spatial disaggregation may be of particular importance both in relation to distinguishing between rural and non-rural areas and in terms of understanding the spatial relationships between the location of resources (particularly water and energy) and the relevant settlement areas. Land accounts are a starting point for this type of analysis.

Table 4.1 Links between selected Millennium Development Goals and the environment

MDG	Environment link
1. Eradicate extreme poverty and hunger	✓livelihoods and food security depend on functioning ecosystems ✓the poor often have no entitlements to environmental resources and inadequate access to environmental information, markets and decision-making ✓lack of energy services limits productive opportunities for the poorest
2. Achieve universal primary education	✓time spent collecting water and fuel wood can reduce time available for schooling ✓lack of energy, water and sanitation discourage teachers to live in rural areas
3. Promote gender equality and empower women	✓water and fuel collection reduce the time that women and girls might have available for education, literacy and income-generating activities ✓women do not benefit from equal entitlements to land and other natural resources
4. Reduce child mortality	✓water and sanitation-related diseases (e.g. diarrhoea) and respiratory infections are the two most important causes of under-five child mortality ✓lack of clean water and fuels for boiling water contribute to preventable water-borne diseases
5. Improve maternal health	✓indoor air pollution and carrying heavy loads of water and fuel wood affect women's health, increasing risks of complication during pregnancy ✓lack of energy (light, refrigeration) and sanitation limit the quality of health services in rural areas
6. Combat major diseases	✓environmental health hazards are associated with risk factors (e.g. malaria, parasitic infections)

7. Ensure environmental sustainability	✓keeping the resource base (land area covered by forests, biodiversity, water sources) and regulating energy, carbon dioxide emissions and recycling provides the foundation for the links described in this table
8. Global partnership for development	✓global environmental problems need the participation of rich countries (that consume more resources) ✓external debt, unfair terms of trade and predatory investment can increase pressure to overexploit ✓environmental assets in developing countries

Source: From Table 3, UNDP, UNEP, IIED, IUCN and WRI (2005: 17), based on DFID et al (2002). http://unpeilac.org/documentos/Poverty_&_Environment_Indicators-eng.pdf

4.2.3 Linking household activity and environmental pressures

4.20 Another SEEA extension relating to households concerns linking household activity to measures of residual flows related to that activity. This may consider the direct effects of household activity on the environment such as via flows of solid waste, wastewater (e.g. sewerage), air emissions and emissions to water. Or it may also consider the indirect effects of household activity by considering the residual flows that occur in the process of producing and distributing goods and services that households consume. The indirect effects include the flows of residuals embedded in goods and services that are exported and imported.

4.21 In the first instance, the extension of the SEEA in relation to these environmental pressures involves extending the Physical Supply and Use Tables (PSUT) for the residual flows of interest. The PSUT for air emissions, emissions to water and solid waste are described in the SEEA Central Framework Chapter 3. In these tables, the household sector is generally shown as a single column that "supplies" residuals either for collection and treatment by other economic units or direct to the environment. The first extension is therefore to introduce additional columns. Alternatives for the disaggregation include household income, household structure (e.g. number of people, single person, couple with children, etc), the size and type of dwelling (e.g. number of bedrooms, floor area, apartment or detached house, etc), or location (e.g. city or rural). The variable chosen to characterise households will depend on the data available and the policy or analytical research question. In turn, this question may depend on what aspects of household behaviour are of most interest or places where household behaviour may have the greatest impact on the environment.

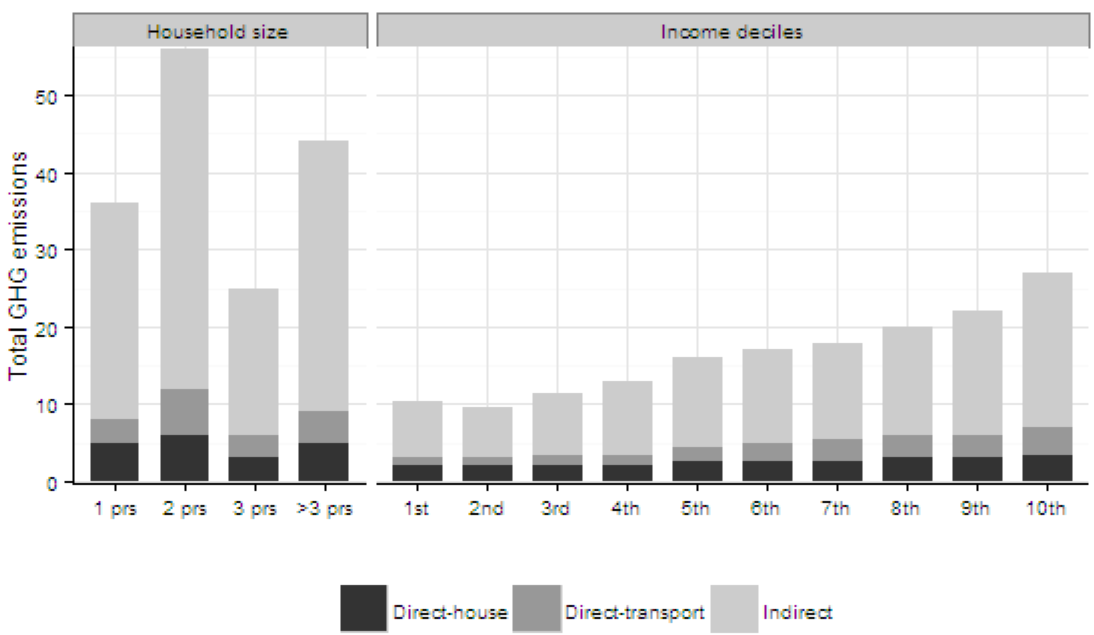
4.22 Using the connection between the SEEA and the SNA it is then possible to relate the physical measures of residuals flowing from households to estimates of consumption and income in monetary terms. The connection to income is particularly relevant if information is to be structured using income by decile or quintile. For this purpose data from household surveys or other data sources (e.g. administrative sources for housing construction, energy efficiency rating schemes, income tax, etc) containing information on household size, income and consumption patterns is likely to be required. Work may be needed to align the data with the concepts and classifications of the SEEA.

4.23 The measurement of indirect effects requires modelling of residual flows via EE-IOT that have been extended to incorporate information by type of household. Through EE-IOT it is possible to link residual flows with particular products (goods and services) and in turn link these products to their source – i.e. domestic industry or imports. A longer discussion of the relevant modelling is described in Chapter 3.

4.24 Much of the focus of household activity and residual flows is on household consumption (e.g. air emissions from driving cars or heating houses, generation of solid waste, etc). However, it may also be relevant to incorporate aspects of household investment, particularly in dwellings. Although there are likely to be few direct residual flows associated with household investment in dwellings, there may well be significant indirect flows in terms of the choice of building materials, for example.

4.25 Figure 4.1 and 4.2 give examples of possible extensions in this area through a combination of air emissions data from the SEEA Central Framework and a range of data from household income and expenditures surveys. Figure 4.1 shows total greenhouse gas emissions for direct and indirect emissions by both number of persons in a household and by decile of household income. Extensions of this figure include showing measurements on a per household basis or in terms of equivalised income (i.e. where the household income is adjusted to account for differences in the number of people supported per household).

Figure 4.1 GHG by household characteristics of size (persons) and income (deciles)



4.26 Table 4.2 shows the links between the types of consumption expenditure by purpose (COICOP) and the associated levels of greenhouse gas emissions. The message here is that the proportion of total expenditure on a particular consumption item may not correspond directly to the proportion of GHG emissions attributable to that item. Analysis of this type of information can be extended by considering the mix of consumption items purchased by different households.

Table 4.2 Household final consumption expenditure and GHG emissions by COICOP category

COICOP category	Consumption (%)	Emissions (%)
Food and non-alcoholic beverages	13	18
Alcoholic beverages, tobacco and narcotics	2	1
Clothing and footwear	2	2
Housing, water, electricity, gas and other fuels	20	32
Furnishings, household equipment and routine household maintenance	2	2
Health	12	5
Transport	13	21
Communication	3	1
Recreation and culture	8	7
Education	1	0
Restaurants and hotels	3	4
Miscellaneous goods and services	21	7

4.3 Extensions to present environmental-economic accounts data by theme

4.3.1 Introduction

4.27 There are a number of perspectives on economic activity that may not be easily reflected in the structure of information on economic activity following standard international industry classifications. This may occur for two reasons. First, a particular activity may involve enterprises from a range of different parts of the economy each having different production functions and principle outputs. Consequently while the enterprises are classified to different industries they may have relationships that could be analysed jointly. The most commonly considered activity in this regard is tourism activity. Another example would be activities around health (e.g. hospitals, pharmaceuticals, medical equipment, education, policy development, etc).

4.28 Second, there may be a particular activity that is undertaken by many enterprises in different industries but which may be difficult to identify in standard industry statistics since it is often not the principal activity of the enterprise. The most relevant example of this for environmental-economic accounting is transport activity which is a significant user of natural resources and a significant contributor to air emissions. The own-production of energy is another activity that may fit this type of analysis. It is noted that for analysis of these specific activity an important aspect may be the own-account production of households in addition to production by enterprises.

4.29 This section presents an example of an extension of the SEEA Central Framework in relation to tourism activity. In general, the same considerations as described in relation to tourism will apply to other activities. That is, it will generally be necessary to start with a standard monetary PSUT or IOT, then determine the key products and industries of relevance to measurement of the activity (this may require disaggregation of some of the standard rows and columns), and finally extend the modified table with relevant physical flow information (e.g. on flows of emissions or solid waste).

4.3.2 Presentation of environmental-economic accounts data for tourism

Introduction

4.30 The importance of good information on the tourism sector has been recognised within the presentation of principles and objectives in the Lanzarote Charter developed at the 1995 World Conference on Sustainable Tourism. Significantly, it was observed in that charter that tourism can contribute positively to socio-economic and cultural development, while at the same time it can cause degradation of the natural environment and loss of local identity. Integrated environmental, economic and social information is essential, then, for defining policies in the tourism field.

4.31 In the context of the SEEA it is relevant to consider links between the accounting approach that has been developed for analysis of tourism, the Tourism Satellite Account (TSA), and the SEEA since both are based on the accounting principles of the SNA. A combining of TSA and SEEA would enable consideration, within an integrated dataset of both the contribution of tourism to the economy and the environmental uses and pressures of tourism activities.

4.32 The expansion of the SEEA suggested here is along the lines of an approach explained in the *International Recommendations for Tourism Statistics 2008* (IRTS2008) whereby tourism is incorporated as a specific set of industries and of consumers within environmental combined physical and monetary flow accounts of the SEEA Central Framework (see SEEA Central Framework Chapter 6). This section provides a summary of the approach and uses information from Italy where this approach has been trialled to give an insight to the potential in this area.

4.33 The coverage of the information concerning tourism and the environment in this section is not limited to consideration of what may be referred to as “eco-tourism”, i.e. tourism activities designed to enhance the connection between the tourist and the environment. Rather the coverage here is all tourism activity and its use of natural inputs and generation of residuals. In principle, the approaches described here may be applied more narrowly as data permit.

4.34 It is noted that TSA fall within the general family of satellite accounts described in the SNA (2008 SNA, Chapter 29) of functionally oriented accounts. More specifically, tourism is a concept that must be defined from the perspective of the consumer rather than the producer and hence the following description should be applicable to the combination of the SEEA with other functionally oriented satellite accounts defined from the demand side, such as health.

Key aspects of integrating tourism and environmental information

4.35 In general terms, the focus for measurement should be on regular monitoring of tourism activity and allowing analysis of the pressures emerging from tourism activities. Within this scope aspects to be considered particularly important include: current levels of tourism, number of enterprises, employment supported, visitor facilities and services, environmental conditions (air, water), relative contribution of tourism to the economy. All these elements are of interest for making assessments concerning the tourism sector inspired by a holistic approach.

4.36 Satellite accounting, within official statistics, is a specific tool that in principle best allows the integration of information on the environmental, the economic and the social systems, by focusing on the interrelationships between these three distinct spheres. One specific advantage of accounting approaches is linking data on tourism and on the environment, to the economic aggregates of the core system of national accounts (e.g. GDP), by making use of common concepts, definitions and classifications.

4.37 From a methodological point of view, compiling a TSA requires definition of the boundary of the tourism sector. This is done through a focus on the qualitative and quantitative elements observed on the demand side, i.e. to the acquisition of goods and services (products) by visitors[17]. Tourism consumption is then a key concept for a correct identification of tourism-related activities and consumption products. From the supply perspective, the aim is to describe the productive activities that provide the tourism products that visitors acquire.

4.38 The link to the SEEA can then be made by focusing on (i) the residuals generated as a result of tourism consumption (either by the visitors themselves or by the enterprises supplying goods and services to visitors; and (ii) the natural inputs used in the production of tourism products.

4.39 The following tourism products are distinguished:

- *tourism characteristic consumption products*: those that satisfy one or both of the following criteria:
    i. tourism expenditure on the product should represent a significant share of total tourism expenditure (share-of-expenditure/demand condition);
    ii. tourism expenditure on the product should represent a significant share of the supply of the product in the economy (share-of-supply condition). This criterion implies that the supply of a tourism characteristic product would cease to exist in meaningful quantity in the absence of visitors."
- *tourism connected products*: those of lower significance to tourism analysis.

4.40 Examples of characteristic products are transportation, hotel and accommodation expenditure, restaurant meals, payments for tourist attractions. An example of tourism connected products are products purchased in supermarkets by visitors.

4.41 Once the relevant set of tourism products is identified, connections to relevant producing industries can be made using standard supply-use and input-output relationships. These relationships form the core of the TSA model. Tourism expenditures are usually estimated on the basis of surveys of visitors and these data form the basis to distinguish between visitor and non-visitor expenditure.

4.42 Using the defined set of economic activities and products of relevance, the connection can be made to relevant environmental flows noting that some disaggregation of industry level data normally recorded in the SEEA accounts is likely to be required. Thus, the core of the approach consists of establishing a more complex type of input/output matrix in which not only the 'usual'

[17] "A visitor is a traveler taking a trip to a main destination outside his/her usual environment for less than a year and for any main purpose (business, leisure or other personal purpose) other than to be employed by a resident entity in the country or place visited." (TSARMF2008, par 1.1).

inputs are considered, but also environment inputs established in quantity, and output also includes waste, greenhouse gas emissions and other environmentally significant by-products.

4.43 Table 4.3 shows the type of information that may organised using the type of matrix just described based on research undertaken in Italy. The main value added of the framework proposed stems from the fact that it organises statistical information on economic and environmental aspects in a way that best enables a detailed assessment of the environmental pressures of the economic development of tourism. By making it possible to identify trade-offs between economic development and environmental pressures as far as tourism is concerned, the statistical information organised according to the framework is best suited for providing a valuable support to decision-making for sustainable tourism.

4.44 Once time series are made available, these tourism-environment accounts allow to assess, for example, whether or not *decoupling* is occurring and, in this perspective, they can be used as a key tool for assessing the sustainability of actions taken or policies proposed for adoption in the tourism sector.

4.45 Using the sequence of economic accounts outlined in SEEA Central Framework Chapter 6, it is also possible to consider the integration of information on relevant taxes, subsidies and similar transfer and also the connection to information on environmental protection expenditure.

4.46 Table 4.4 shows a simple way of depicting tourism related economic activity and environmental flows in contrast to other economic activities. As with the SEEA more generally, it is clear that the organisation of information following integrated use of classifications and accounting principles can help to provide readily accessible and relevant information.

Table 4.3 -Stylised tourism-environment accounts – specifying tourism industries and tourism characteristic consumption products

		Tourism Satellite Account (TSA)					Environmental accounts (SEEA)						
		Economic aggregates				Other	Environmental pressures						
							Residual flows			Natural inputs			
		Production	Intermediate Consumption	Valued Added	Tourism consumption	Employment	Air emissions	Water emissions	Solid waste	Energy resources	Minerals	Biological resources	Water
Supply (tourism industries)	Accommodation for visitors												
	Food and beverage serving activities												
	Railway passenger transport												
	Road passenger transport												
	Water passenger transport												
	Air passenger transport												
	Transport equipment rental												
	Travel agencies and other reservation services activities												
	Cultural activities												
	Sports and recreational activities												
	Retail trade of country-specific tourism characteristic goods												
	Country-specific tourism characteristic activities												
Use (tourism characteristic consumption products)	Accommodation services for visitors												
	Food and beverage serving services												
	Railway passenger transport services												
	Road passenger transport services												
	Water passenger transport services												
	Air passenger transport services												
	Transport equipment rental services												
	Travel agencies and other reservation services												
	Cultural services												
	Sports and recreational services												
	Country-specific tourism characteristic goods												
	Country-specific tourism characteristic services												

Not applicable

Table 4.4 Flows from tourism-environment accounts (as percent of total economy)

	Tourism industries (%)	Other industries (%)		Tourism industries (%)	Other industries (%)
Production	5	95	Hg	0	100
Intermediate consumption	5	95	N2O	0.2	99.8
			NH3	0	100
Value added	7	93	Ni	5	95
Employment	9.5	90.5	NMVOC	1.5	98.5
As	0	100	Nox	16	84
Cd	0.3	99.7	Pb	2	98
CH4	0	100	PM10	8	92
CO	2.5	97.5	PM2.5	10	90
CO2	4.5	95.5	Se	3.5	96.5
Cr	0.5	99.5	Sox	15	85
CU	6	94	Zn	0	100

Annex A1: Derivation of examples and links to the SEEA Central Framework

(To be developed)

Note by the Editor: This annex (to be developed) will provide explanations of the methods and data sources underlying the examples presented in the document (particularly those depicted in the figures in Chapter 2). These explanations are intended to give additional guidance to compilers who may wish to replicate or extend the applications and extensions that have been presented. The explanations will provide details of links to sources of data within the SEEA Central Framework.

Annex A2: Mathematical derivation of the Leontief inverse

A.1 Calculation of the Leontief inverse is a standard operation in input-output analysis (e.g. Miller and Blair, 2009). At the core of the IO model is the Leontief matrix, which will be derived in this annex.

A.2 Equation A.3.1. shows the technical coefficients matrix A for the SRIO model.

$\boldsymbol{A_d} = \boldsymbol{Z_d} \cdot (\hat{\boldsymbol{q}})^{-1}$	(A.3.1)

A.3 Here, Z_d denotes the intermediate input matrix, while q is the output vector. A 'hat' (^) indicates that the vector has been diagonalized, that is the vector is transformed into a square matrix with the values of the vector on the diagonal. The IO coefficient matrix A_d gives a technological description of the intermediate input–output structure: the quantity of intermediate input that are required to produce one unit of output. IO models assume that the elements of A are constant. This fixed coefficient assumption implies that IO coefficients are independent of the level of output. In other words, the production relations exhibit constant returns to scale.

A.4 The Leontief production function of the IO model, which results from the fixed coefficient assumption, exhibits complementarity between inputs: output cannot be increased by substituting one input for another. This assumption deviates from most neoclassical production functions, which allow for substitution between inputs.

A.5 By rearranging Equation A.3.1 and using the identities implicit in Table 3.1 Equation A.3.2 is derived:

$\boldsymbol{A_d} \cdot \boldsymbol{q} + \boldsymbol{y_d} = \boldsymbol{q}$	(A.3.2)

A.6 Rearranging this identity gives:

$\boldsymbol{q} = (\boldsymbol{I} - \boldsymbol{A_d})^{-1} \cdot \boldsymbol{y_d}$	(A.3.3)

A.7 This equation is the best-known formulation of the IO model, where matrix $(I - A)^{-1}$ is usually referred to as the 'Leontief inverse'. Mathematically, the Leontief inverse can only be found if $(I - A)$ is square and non-singular. An element of the Leontief inverse matrix assesses the direct and indirect effects of a change in final demand. When the final demand matrix is y_d, then the production units produce y_d to meet the demand. This is the direct demand. However, to produce this output, the production unit requires inputs of magnitude $A \cdot y_d$. This constitutes an increase in the demand for all production units that provide inputs. This extra demand will, in turn, have to be satisfied by more inputs: $A(A \cdot y_d) = A^2 \cdot y_d$, and so on. The IO model can therefore also be represented by Equation A3.4 (Miller and Blair, 2009):

$\boldsymbol{q} = \left(\boldsymbol{I} + \boldsymbol{A_d} + \boldsymbol{A_d^2} + \boldsymbol{A_d^3} + \ldots\right) \cdot \boldsymbol{y_d}$	(A.3.4)

A.8 Mathematically, equations A3.3 and A.3.4 are equivalent. Therefore, elements on the diagonal of the Leontief inverse are always equal to 1 plus the indirect requirements per unit output. The off-diagonal elements constitute indirect demand only.

Annex A3: Additional material on multipliers

Output multipliers

A.9 Output multipliers[18] are commonly used to determine the impact of changes in final demand on output (e.g. Eurostat, 2008; Miller and Blair, 2009). An output multiplier for industry j is defined as the total value of production in all sectors of the economy that is necessary at all stages of production in order to produce one unit of product j for final demand. In other words, output multipliers relate the changes in sales to final demand by one industry to total changes in output (gross sales) by all industries. For example, an industry output multiplier of 1.75 would indicate that a change in sales to final demand of 1 euro by the industry in question would result in a total change in domestic output of 1.75 euro. The output multipliers correspond to the column sums of the Leontief inverse. This can be expressed formally as:

$$m_j = \sum_i [I - A_D]_{ij}^{-1} \qquad [1]$$

where m_j denotes the outcome multiplier for each industry j; A_D is the technical coefficients matrix and I the identity matrix.

Multiplier effects

A.10 The multiplier effects on other economic variables such as value added, income, employment as well as environmental multipliers in terms of GHGs, energy or water use can easily be calculated. These resource inputs are always net uses in order to avoid double counting. Mathematically this is done by pre-multiplying the Leontief inverse with a vector of coefficients of the variable of interest. These coefficients could be energy intensities or employment intensities per industry j. Mathematically, this can be expressed as:

$$f^z{}_j = \sum_i e^z{}_i [I - A_D]_{ij}^{-1} \qquad [2]$$

where f_j denotes the multiplier effect for industry j; e_i represents the vector of intensities for the effect of study; the superscript z denotes the subject of our effect (energy, employment etc.).

A.11 For example, the energy multiplier effect for industry j provides an estimate of the direct and indirect increase in energy use that would result from an additional unit of output of industry j.

[18] Sometimes called revenue multipliers.

Multipliers

A.12 Multipliers can be derived by normalizing the multiplier effects and dividing them by intensities. In formula this is represented as:

$$m^z{}_j = f^z{}_j / e^z{}_j \qquad [3]$$

where $m^z{}_j$ denotes the z-multiplier for each industry j; the superscript z again denotes the subject of our multiplier (energy, employment etc.).

A.13 For example, the employment multiplier for industry j expresses the number of jobs that would be created in the whole domestic economy due to the creation of one additional job at industry j. As a result of the normalisation, the direct effect is by definition equal to 1. The use of multipliers therefore facilitates the analysis of direct and indirect effects. It should be noted as well that due to the nature of the IO model, the output multiplier effect and the output multiplier are by definition equal.

Average multipliers and effects

A.14 In order to compare multipliers across industries, average multipliers are calculated by weighting the industry specific multipliers with their respective output.

$$\hat{m}^z = \sum_j m^z{}_j * x_j / \sum_i x_i \qquad [4]$$

where $\hat{m}^z$ denotes the average z-multiplier effect; x_j the output of industry j.

A.15 Likewise, average multiplier effects can be calculated by weighting the industry specific multiplier effects with their respective output and dividing by the total output, using the formula:

$$\hat{f}^z = \sum_j f^z{}_j * x_j / \sum_i x_i \qquad [5]$$

where $\hat{f}^z$ the average z-multiplier effect for the domestic economy.

Annex A4: Additional material on decomposition analysis

A.16 A range of decomposition techniques is available to transform this relationship into a linear additive function.

$$\Delta e = \alpha\Delta\left(\frac{e}{c}\right) + \beta\Delta\left(\frac{c}{p}\right) + \delta\Delta p + \varepsilon \tag{3}$$

A.17 Each term in this equation quantifies the contribution of a particular factor to the overall change in environmental impacts. The coefficients, α, β and δ in this equation represent the weighting factors expressing how changes in individual factors contribute to the overall change in environmental impacts. The last coefficient ε is needed when using so-called open decomposition forms that lead to a rest term. A rest term will not show up when using a closed decomposition form.

Numerical example

	e	*c*	*p*	*e/c*	*c/p*
t = 0	100	80	10	1,25	8
t = 1	110	85	11	1,29	7,7
Δ	10	5	1	0,04	-0,27

A.18 How decomposition works can be explained with the help of a simple example exposed in the table. Values for environmental impacts (e), consumption levels (c) and population size are presented in this table for two periods (0) and (1). Environmental impacts per unit consumption and per capita consumption ratios are derived and also presented in the table. Further the last row in the table presents the changes in variables from one period to another.

A.19 The decomposition could be conducted by using either begin period or end period weights. A decomposition form with begin period weights looks as follows.

$$\Delta e = \boldsymbol{\Delta}\left(\frac{\boldsymbol{e}}{\boldsymbol{c}}\right) \times \left(\frac{c}{p}\right)_0 \times p_0 + \left(\frac{e}{c}\right)_0 \times \boldsymbol{\Delta}\left(\frac{\boldsymbol{c}}{\boldsymbol{p}}\right) \times p_0 + \left(\frac{e}{c}\right)_0 \times \left(\frac{c}{p}\right)_0 \times \boldsymbol{\Delta p_0} \tag{4}$$

A.20 In each term the changes are shown in bold. The corresponding weights are printed in regular (non bold) characters. In each term the ordering of elements is kept the same as shown in equation 1. For scalars this ordering is not an issue. However, when introducing vectors or matrices in the decomposition analysis the ordering of elements is predetermined.

A.21 This formula can be filled in with data from the table which leads to the following result.

$$\Delta e = 10 = (0.04 \times 8 \times 10) + (1.25 \times -0.27 \times 10) + (1.25 \times 8 \times 1) - 0.12$$

In other words, based on period (0) weights the decomposition gives the following three factor values:

$$\alpha \Delta \left(\frac{e}{c} \right) = 0.04 \times 8 \times 10 = 3.53$$

$$\beta \Delta \left(\frac{c}{p} \right) = 1.25 \times -0.27 \times 10 = -3.41$$

$$\delta \Delta p = 1.25 \times 8 \times 1 = 10$$

$$\varepsilon = -0.12$$

A.22 Using period (0) weights implies in this case that the sum of the three distinguished factors leads to a small overestimation (0.12) of the overall change in energy use from period (0) to (1). Using period (1) weights would lead to a small underestimation. Taking the average of the two forms is sometimes proposed to downscale the residual ε. Again, one could also use closed decomposition forms which do not have residual terms.

References

Note by the Editor: Currently the references in the consultation draft are limited to those relating to environmentally extended input-output tables and analysis (see below). It is anticipated that additional references will be incorporated in the final document.

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