# System of Environmental-Economic Accounting 2012

## Applications and Extensions

**White cover publication, pre-edited text subject to official editing**

European Commission • Food and Agriculture Organization of the United Nations
Organisation for Economic Co-operation and Development • United Nations • World Bank

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**The World Bank**

**2014**

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# Preface

In response to growing calls for information on the relationship between the economy and the environment to aid in the understanding of numerous policy issues including those related to sustainable development, the international statistical community finalised the international statistical standard for environmental-economic accounting the System of Environmental-Economic Accounting 2012 – Central Framework (SEEA Central Framework). This standard was adopted by the Statistical Commission in 2012.

To support the implementation of the various components of the SEEA Central Framework and to highlight the potential uses of data organised following the conceptual framework it describes, the Statistical Commission endorsed the preparation of SEEA 2012 – Applications and Extensions and welcomed its development at its forty-fourth session in 2013 recognizing it "as a useful contribution to illustrating possible applications of the SEEA Central Framework".

SEEA Applications and Extensions provides potential compilers and users of SEEA based environmental-economic accounts with material to show how this information can be used in decision making, policy review and formulation, analysis and research. SEEA Applications and Extensions is intended to provide a bridge between compilers and analysts allowing each to recognise the potential uses and the related measurement considerations.

SEEA Applications and Extensions is a summary of the most common applications and extensions and does not provide complete coverage of all materials that may be relevant in the communication and dissemination of information on environmental-economic accounts. Since it is a summary guide to the use of SEEA based data, SEEA Applications and Extensions is not a statistical standard. The choice of topics and examples is intended to provide an indication of the possibilities and does not represent a basis for standardised reporting at national or international level.

It is recognised that implementation of the SEEA Central Framework itself, and the subsequent analysis and extensions, requires ongoing efforts at the integration of information across various disciplines and usually from a number of agencies. To support implementation of the SEEA, various training and technical materials are under development as part of the SEEA implementation strategy. These materials will provide additional information relevant to the completion of the types of analysis and extensions described here.

SEEA Applications and Extensions was prepared under the auspices of the Committee of Experts on Environmental-Economic Accounting (UNCEEA), as mandated by the Statistical Commission at its thirty-either session in 2007. The UNCEEA is a governing body comprising senior representatives from national statistical offices and international organizations. It is chaired by one of the country members of the Committee. The United Nations Statistical Division serves as Secretariat for UNCEEA. Regular oversight of the project was provided by the Bureau of the UNCEEA.

The determination of the content of SEEA Applications and Extensions occurred through a series of discussions within the London Group on Environmental-Economic Accounting and through discussions of a subgroup of UNCEEA which was formed to determine the appropriate purpose, audience and scope of the document.

Based on the outcomes of these deliberations, the content was prepared in a two stage process under the direction of an Editorial Board. The first stage, undertaken through the first half of 2012, involved the gathering of contributions on specific topics from nominated authors. The second stage, from mid 2012 onwards, involved the Editor bringing these materials together for ongoing review by the Editorial Board. Preliminary draft chapters were discussed by the London Group (in October 2012), and a broad consultation process involving the international statistical community and other interested parties was undertaken from December 2012 to January 2013. The consultation draft was presented to the forty-fourth session of the Statistical Commission in 2013 and a final draft taking on board all feedback was endorsed by the UNCEEA at its meeting in June 2013.

## Acknowledgements

*Background*

SEEA Applications and Extensions is the result of a process that was notable for its transparency and the wide involvement of the international statistical community, economists and modellers, policy makers and others. The process comprised six steps.

a. identifying and obtaining agreement on the topics and issues to be considered in the drafting of SEEA Applications and Extensions, including via a subgroup of UNCEEA members convened for this purpose:

b. gathering technical material and examples on the various topics, including via submissions from nominated contributors;

c. drafting and editing of provisional chapters;

d. consulting with countries and experts on specific issues as well as on complete chapters;

e. presenting an interim draft to the Statistical Commission in 2013 who in its commission report "[w]elcomed the SEEA Applications and Extensions as a useful contribution to illustrating possible applications of the SEEA Central Framework, and agreed with its process of finalization".

f. incorporating comments received though the consultation and preparation of a final draft of SEEA Applications and Extensions which was endorsed by the Committee of Experts on Environmental-Economic Accounting at its meeting in June 2013.

*The Committee of Experts on Environmental-Economic Accounting (UNCEEA) and its Bureau*

The process of drafting SEEA Applications and Extensions involved the UNCEEA; other international, regional and nongovernmental organizations; project staff; agencies responsible for compiling official statistics in many countries; city groups; other expert groups; and individual experts in economics, policy and related fields from multiple regions of the world. As could be expected of a product of such a complex and sustained process, SEEA Applications and Extensions reflects many diverse contributions.

The Statistical Commission established the UNCEEA at its thirty-sixth session in March 2005 with the mandate, among others, to oversee and manage the revision of the SEEA. The UNCEEA comprises senior representatives from national statistical offices and international agencies.

The Bureau of the UNCEEA, comprised of representatives elected among its members and acting under delegated authority from the UNCEEA, managed and coordinated the preparation of SEEA Applications and Extensions.

The UNCEEA and its Bureau, which was formed in 2008, were chaired by Peter Harper (Australia, 2009-2013).

The following served as members of the Bureau of the UNCEEA: Peter Harper (Australia, 2009-2013), Karen Wilson (Canada, 2009-2011), Art Ridgeway (Canada, 2012-2013), Peter van de Ven (the

Netherlands, 2009-2011), Geert Bruinooge (the Netherlands, 2012-2013), Olav Ljones (Norway and Chair, Oslo Group on Energy Statistics, 2009-2013), Joe de Beer (South Africa, 2010-2013), Pietro Gennari (FAO, 2011-2013), Paul Cheung, Ivo Havinga, Alessandra Alfieri, Eszter Horvath (UNSD, 2009-2013), Mark de Haan (Chair, London Group on Environmental Accounting, 2009-2012), Pedro Diaz (Eurostat, 2009-2013), Glenn-Marie Lange (The World Bank, 2010-2013), Peter van de Ven (OECD, 2013) and Joe St Lawrence (Chair, London Group on Environmental Accounting, 2013).

The staff of the Economic Statistics Branch of the United Nations Statistics Division under the overall supervision of Ivo Havinga (UNSD) and the assistance of Alessandra Alfieri (UNSD) provided secretariat services to the Bureau of the UNCEEA.

The following representatives from countries served as members of the UNCEEA: Peter Harper, Gemma van Halderen (Australia), Luiz Paulo Souto Fortes, Wadih Joao Scandar Neto, Eduardo Nũnes (Brazil), Martin Lemire, Art Ridgeway, Robert Smith (Canada), Huaju Li, Yixuan Wang (China), Luz Amparo Castro, Monica Rodriguez Diaz, Carlos Eduarte Sepulveda Rico, Luz Dary Yepes Rubiano (Colombia), Ole Gravgård Pedersen, Bent Thage, Kirsten Wismer (Denmark), Miguel Jimenez Cornielle, Roberto Blondet Hernandez, Olga Luciano Lopez, Olga Diaz Mora (Dominican Republic), Leo Kolttola (Finland), Walter Radermacher, Michael Kuhn, Karl Schoer (Germany), Ramesh Chand Aggarwal, Jogeswar Dash, Shri V. Parameswaran (India), Kecuk Suhariyanito, Slamet Sutomo (Indonesia), Cesare Costantino (Italy), Geert Bruinooge, Mark de Haan, Peter van de Ven (Netherlands), Torstein Bye, Olav Ljones (Norway), Khalaf Al-Sulaimani (Oman), Estrella Domingo, Raymundo Talento (Philippines), Sergey Egorenko, Igor Kharito, Andrey Tatarinov (Russia), Joe de Beer, Anemé Malan (South Africa), Inger Eklund, Viveka Palm (Sweden), Rocky Harris (United Kingdom) and Dennis Fixler (USA).

The following representatives from international organizations served as members of the UNCEEA: Salvador Marconi, Kristina Taboulchanas (ECLAC), Joel Jere (ESCAP), Wafa Aboul Hosn (ESCWA), Jean-Louis Weber (European Environment Agency), Pedro Díaz Muñoz, Pieter Everaers (Eurostat), Pietro Gennari (FAO), Manik Shrestha (IMF), Myriam Linster, Peter van de Ven (OECD), Kirk Hamilton, Barbro Elise Hexeberg, Glenn-Marie Lange, Marian S. delos Angeles (The World Bank), Linda Ghanimé, Maria Netto, Veerle van de Weerd (UNDP), Kathleen Abdalla, Tariq Banuri, Matthias Bruckner, Jean-Michel Chéné, Manuel Dengo, Liisa-Maija Harju, David O'Connor, Mary Pat Silveira (UNDSD), Lidia Bratanova (UNECE), Hussein Abaza, Derek Eaton, Maaike Jansen, Fulai Sheng, Guido Sonnemann, Jaap van Woerden (UNEP), Alessandra Alfieri, Ivo Havinga, and Eszter Horvath (UNSD).

A subgroup of UNCEEA members was established to develop proposals on the scope, purpose, structure and content of the SEEA Applications and Extensions as well as the relationship of the document with other promotional and communication materials. The following members served in the subgroup: Shri V. Parameswaran (India), Mark de Haan (Netherlands), Inger Eklund and Viveka Palm (Sweden), Rocky Harris (United Kingdom), Dennis Fixler (USA), Myriam Linster (OECD), Alessandra Alfieri (UNSD), and Carl Obst (Editor SEEA)

Other staff members of international organizations who contributed substantively were:

> Julian Chow, Daniel Clarke, Magdolna Csizmadia, Anthony Dvarskas, Ricardo Martinez-Lagunes, and Sokol Vako (United Nations Statistics Division)

The United Nations Statistics Division developed and maintained the Project website, which provides more information on the contributions summarized in this section (http://unstats.un.org/unsd/envaccounting/default.asp).

*The Editorial Board*

The SEEA Applications and Extension Editorial Board provided technical guidance and expert advice to the Editor, Carl Obst, in the drafting and co-ordination of material and the resolution of technical issues. The Editorial Board comprised: Peter van de Ven (Chair, OECD,): Michael Vardon (Australia), Sjoerd Schenau (Netherlands), Rocky Harris (United Kingdom), Dennis Fixler (USA), Brian Newson (Eurostat), Myriam Linster (OECD), Alessandra Alfieri (UNSD) and Carl Obst (Editor SEEA).

*The London Group on Environmental Accounting*

The London Group on Environmental Accounting discussed issues related to SEEA Applications and Extensions at a number of its meetings. At its 18th meeting held in Ottawa, Canada and hosted by Statistics Canada the London Group discussed a preliminary draft of SEEA Applications and Extensions. The 18th meeting of the London Group was chaired by Sjoerd Schenau on behalf of Mark de Haan (Statistics Netherlands).

The following people participated in the 18th meeting of the London Group: Alessandra Alfieri, Michael Bordt, Julian Chow, Raúl Figueroa Díaz, Bram Edens, Mark Eigenraam, Per Arild Garnåsjordet, Kyle Gracey, Ryan Greenaway-McGrevy, Rocky Harris, Julie Hass, Gary Jones, Jawed Khan, Suresh Kumar Sukumarapillai, Glenn-Marie Lange, Warwick McDonald., Richard Mount, Jukka Muukkonen, Urvashi Narain, Frédéric Nauroy, Carl Obst, Thomas Olsen, Viveka Palm, Masahiro Sato, Sjoerd Schenau, Joe St. Lawrence, Anton Steurer, Stéphanie Uhde, Michael Vardon and Jean-Louis Weber.

*Other experts*

The following experts and practitioners from national statistical offices, international organizations and non-government organizations contributed short papers to the Editorial Board on specific sections of SEEA Applications and Extensions: Lilina Feng, Mark Lound, Nancy Steinbach and Michael Vardon (Australia); Pat Adams and Michael Bordt (Canada); Massimo Anzalone, Cesare Costantino and Angelica Tudini (Italy); Roel Delahaye, Mark de Haan, Rutger Hoekstra, Maarten van Rossum and Sjoerd Schenau (Netherlands); Viveka Palm (Sweden); Rocky Harris (United Kingdom); Myriam Linster (OECD); Brad Ewing (University of Alaska); Tim Scott (UNDP); Alessandro Galli, Katsunori Iha, Mathis Wackernagel (Global Footprint Network) and Arnold Tukker and Olga Ivanova (TNO, Netherlands).

Other consultations also informed the process. These included consultations with a number of experts on input-output analysis who included Manfred Lenzen (University of Sydney), Tommy Weidman (University of New South Wales), Glyn Wittwer (Monash University), Rutger Hoekstra and Bram Edens (Statistics Netherlands)

*Country contributions*

National statistical offices, ministries responsible for the environment and other national agencies made significant in-kind contributions to the drafting of SEEA Applications and Extensions. Over 30 countries and international organizations submitted comments during the broad consultation on the draft of the document held from December 2012 to January 2013. Heads of the national statistical offices were involved through their participation in the Statistical Commission.

Last but not least, a number of national and international agencies supported the project through financial contributions. Major financial contributors to the project were Australia and Eurostat.

## List of abbreviations and acronyms

| | |
|---|---|
| ABS | Australian Bureau of Statistics |
| As | arsenic |
| Cd | cadmium |
| CEA | Classifications of Environmental Activities |
| CFC | chloro-fluoro carbon |
| CGE | computable general equilibrium models |
| $CH_4$ | methane |
| COICOP | Classification of Individual Consumption According to Purpose |
| CO | carbon monoxide |
| $CO_2$ | carbon dioxide |
| Cr | chromium |
| Cu | copper |
| DF | driving force |
| DFID | UK Department for International Development |
| DPSIR | driving force-pressure-state-impact-response |
| EE-IOT | environmentally extended input-output tables |
| EGSS | environmental goods and services sector |
| EPEA | environmental protection expenditure accounts |
| EIPRO | environmental impacts of products |
| EP | environmental pressure |
| EP | environmental protection |
| EU | European Union |
| Eurostat | Statistical Office of the European Union |
| EW-MFA | economy wide – material flow accounts |
| FDES | Framework for the Development of Environment Statistics |
| GDP | gross domestic product |
| GHG | greenhouse gas |
| GIS | geo-spatial information systems |

| | |
|---|---|
| GVA | gross value added |
| Hg | mercury |
| IDA | index decomposition analysis |
| IIED | International Institute for Environment and Development |
| I-O | input-output |
| IOT | input-output tables |
| IRTS2008 | International Recommendations for Tourism Statistics 2008 |
| ISIC | International Standard Industrial Classifications of All Economic Activities |
| IUCN | International Union for the Conservation of Nature |
| JRC | European Commission Joint Research Council |
| kWh | kilowatt hour |
| LCA | life cycle analysis |
| MDG | millennium development goals |
| MRIO | multi-regional input-output tables |
| MSA | material systems analysis |
| N | nitrogen |
| $N_2O$ | nitrogen dioxide |
| $NH_3$ | ammonia |
| Ni | nickel |
| NMVOC | non-methane volatile organic compounds |
| NNI | net national income |
| NOx | mono-nitrogen oxides |
| OECD | Organisation for Economic Cooperation and Development |
| P | potassium |
| Pb | lead |
| PM2.5 | particulate matter of size 2.5 microns or smaller |
| PM10 | particulate matter of size 10 microns or smaller |
| PPP | purchasing power parities |
| PRTR | pollutant release and transfer registers |
| PSE | producer subsidy equivalents |

| | |
|---|---|
| PSUT | physical supply and use tables |
| PWT | Penn world tables |
| SAMS | social accounting matrices |
| SDA | structural decomposition analysis |
| Se | selenium |
| SEEA | System of Environmental-Economic Accounting |
| SEEA-Energy | System of Environmental-Economic Accounting for Energy |
| SEEA-Water | System of Environmental-Economic Accounting for Water |
| SEEA-2003 | Integrated Environmental and Economic Accounting 2003 |
| SNA | System of National Accounts |
| SOx | sulphur oxides |
| SRIO | single region input-output table |
| SUT | supply and use table |
| TOE | tonnes of oil equivalent |
| TSA | tourism satellite account |
| UK | United Kingdom of Great Britain and Northern Ireland |
| UNDP | United Nations Development Programme |
| UNEP | United Nations Environment Programme |
| UNFCCC | United Nations Framework Convention on Climate Change |
| UNSD | United Nations Statistics Division |
| WRI | World Resources Institute |
| Zn | zinc |
| 2008 SNA | System of National Accounts 2008 |

# I: Introduction

1.1 The System of Environmental-Economic Accounting 2012 - Applications and Extensions (SEEA Applications and Extensions) provides potential compilers and users of SEEA based environmental-economic accounts with material to show how this information can be used in decision-making, policy review and formulation, analysis and research. The SEEA Applications and Extensions provides a bridge between compilers and analysts allowing each to recognise both the potential uses and the related measurement considerations.

1.2 The SEEA Applications and Extensions is a companion document to the SEEA Central Framework. 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 It is envisaged that through the course of implementing the standards of the SEEA Central Framework in a modular fashion – for example, through compilation of accounts for water, energy, land, or air emissions – various applications and extensions might be adopted as appropriate to the topic of interest. Beyond a modular focus, 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.

1.4 SEEA Applications and Extensions is a summary of the most common applications and extensions. It does not intend to be exhaustive in its coverage nor does it describe all of the relevant data sources and methods in depth. Since it is a summary guide to the use of SEEA based data, SEEA Applications and Extensions is not a statistical standard and the choice of topics and examples does not represent a basis for standardised reporting at national or international level.

1.5 Consistent with the advice that the SEEA Central Framework should be implemented in a flexible and modular way in line with available resources and national information demands, it is not required that countries seek to implement all of the applications and extensions described here. Indeed, completion of some of the analysis and extensions outlined here will require the use of information that is not described in the SEEA Central Framework – such as detailed information on the household sector. Further, 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.

1.6 It is recognised that implementation of the SEEA Central Framework itself, and the subsequent analysis and extensions, requires ongoing efforts at the integration of information across various disciplines and usually from a number of agencies. To support implementation of the SEEA, various training and technical materials are under development as part of the SEEA implementation strategy. These materials will provide additional information for the completion of the types of analysis and extensions described here.

1.7 SEEA Applications and Extensions does not provide a complete coverage of all materials that may be relevant in the communication and dissemination 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 that houses a broad ranging knowledge base of environmental-economic accounting resources.

*Analytical and policy focus*

1.8 The focus in SEEA Applications and Extensions is on describing measurement and analysis at a broad, national level on topics such as resource use, environmental intensity, environmental protection activity and the production of environmental goods and services, environmental assets and natural resources, and household and other sector's behaviour with respect to the environment. SEEA Applications and Extensions also highlights the potential for analysis and extension at sub-national scales and in this context there are strong areas of synergy with the developments in geo-spatial information systems (GIS) and related datasets.

1.9 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, sustainable production and consumption, resource management and productivity, and land management. The applications and extensions described here may be relevant for the development of policy, the articulation of policy targets, and the monitoring and evaluation of policies, in particular assessment of the effectiveness of specific policy instruments.

1.10 Information from the SEEA alone, does not generally provide direct statements regarding sustainability, either of individual activities or of countries and regions as a whole. Assessments of sustainability require consideration of, or assumptions regarding, societal choices and the appropriate balance between economic, social and environmental objectives. At the same time, the integrated and coherent nature of the SEEA is well-suited to providing an information base that can support discussions on sustainability, in particular concerning the relationship between economic activity and the use of environmental assets.

1.11 For the compiler of environmental-economic accounts, SEEA Applications and Extensions provides 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.

1.12 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.

*Relationship to the SEEA Central Framework and related documents*

1.13 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.

1.14 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.

1.15 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.

1.16 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.

1.17 SEEA Applications and Extensions does not provide details of applications and extensions related to ecosystem accounting although reference is made to analysis and extensions related to land accounting which may serve as a starting point for ecosystem accounting. The lack of coverage of ecosystem accounting does not reflect on its relative importance. 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.

1.18 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.

1.19 Ultimately, the analyses and extensions outlined here rely on the development of appropriate basic information and data. Many relevant economic data may be collected through the national accounts framework (System of National Accounts (SNA)). For environmental data, the recent revision of the Framework for the Development of Environment Statistics (FDES) may provide a basis for the collection and organisation of data to compile SEEA accounts.

*Structure of the SEEA Applications and Extensions*

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

1.21 Chapter 2 "Applications of SEEA data" describes range of commonly analysed topics using environmental-economic data. The four broad topics covered are (i) resource use and environmental intensity; (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.

1.22 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 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 computable general equilibrium (CGE) modelling.

1.23 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 integrated information for analysis of the household sector in relation to the environment. Another example is the use of geo-spatial techniques to consider the connections between environmental, economic and social data for particular area or regions within a country. A final 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.

1.24 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 II: 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 In addition, it is commonly the case that SEEA data can be combined with a range of other economic, environmental and social data to form indicators or to undertake analysis. This is particularly the case in linking SEEA data with standard national accounting aggregates such as GDP or industry value added.

2.4 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 resource use and environmental intensity; 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.

2.5 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

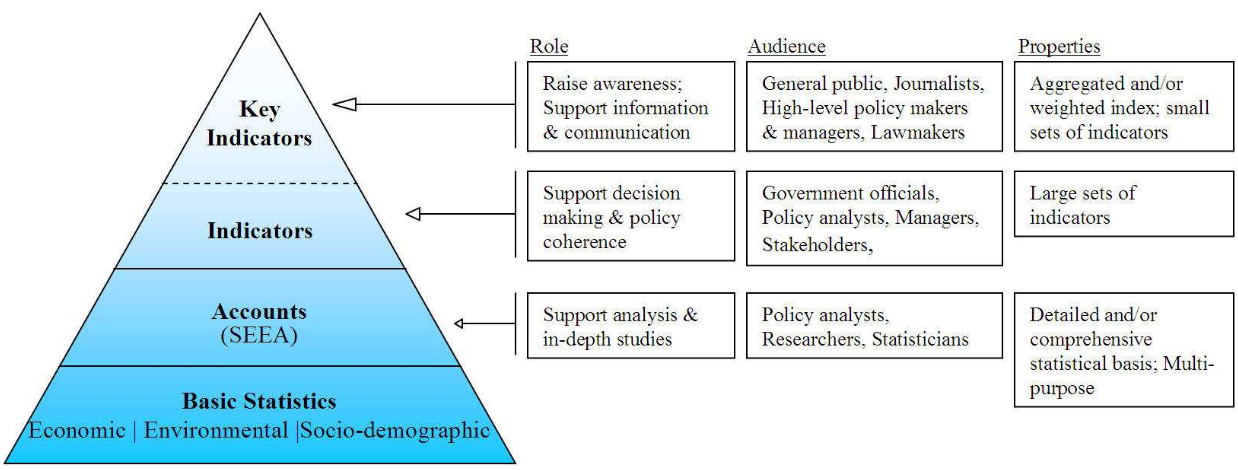
2.6 Indicators, aggregates and totals (collectively referred to here as indicators) may serve many purposes depending on the scale at which they are applied, on the audience to be reached, and on the quality of the underlying data. Indicators are useful tools for tracking progress with respect to the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

2.7 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.

2.8 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 a balance between their relevance for users and policies, their statistical accuracy, 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).

2.9 The relationships between different types of information in the context of the SEEA are shown in Figure 2.1. The figure highlights that basic statistics and data are organised using accounting frameworks and that indicators can be sourced from accounts. While it is the case that indicators can be sourced directly from basic statistics, the filter of an accounting framework lends significantly to the coherence of the indicators. Further, in the case of the SEEA, its alignment with the SNA provides a consistency between economic and environmental information that provides a robustness to indicators that are sourced from accounts.

**Figure 2.1 Information pyramid**




### 2.2.2 Compiling indicators

2.10 The SEEA Central Framework lends itself to the derivation of important aggregates and indicators in the same way as the national accounts is best known by the important aggregates and indicators that are derived from the SNA's accounting structure, particularly GDP and NNI. The range of aggregates and indicators is described in Section 6.4 of the SEEA Central Framework. The range includes descriptive statistics (such as aggregates, total, structural statistics); environmental asset aggregates and indicators; aggregates related to the financing and cost recovery of economic activity related to the environment (such as the provision of water); and environmental ratio indicators including productivity and intensity indicators, decoupling indicators and polluter pays indicators.

2.11 Given this broad range, it is recognised that some indicators are directly embedded in individual SEEA Central Framework accounts in the form of aggregates (e.g. total air emissions for the economy). Other indicators are 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).

2.12 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.

2.13 Indicators that benefit most from being founded in the SEEA Central Framework include those that relate to:

- resource use and environmental intensity 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).

2.14 The suitability of a data source as the basis for indicators 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.

2.15 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. For example, an economy-wide indicator reflecting average energy intensity may not be useful for analysis of industry specific policy options. The use of data quality assessment frameworks and the application of general principles of “fitness for purpose” are relevant considerations, and, when appropriate, assumptions about the relationship between the scope of the indicator and the analytical question of interest should be made explicit.

2.16 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 to 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 more 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.

### 2.2.3 Indicators in SEEA Applications and Extensions

2.17 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. The coverage includes:

i. *Indicators of resource use and environmental intensity* (sect. 2.3) These indicators include aggregates such as gross energy input, net domestic energy use, and final water use, and environmental ratio indicators such as intensity, productivity and decoupling indicators for various environmental flows such as water, energy, carbon dioxide emissions, nutrient balances, and solid waste. Also included are indicators of environmental flows from a consumption- or demand-based perspective.

ii. *Indicators of production, employment and expenditure relating to environmental activities* (sect. 2.4) These indicators cover those relating to environmental protection and resource management activities. The indicators are generally in the form of relationships between these environmental activities to broad measures of economic activity such as the share of GDP, share of employment and share of exports. Important aggregates such as total national expenditure on environmental protection are also covered.

iii. *Indicators of environmental taxes and environmental subsidies and similar transfers* (section 2.5) These include measures relating to the share of environmental taxes in total taxes, indicators by type of environmental tax (energy taxes, pollution taxes, etc.), implicit tax rates, indicators relating to emission permit schemes, and indicators of the level and purpose of environmental subsidies and similar transfers.

iv. *Indicators of environmental assets, net wealth, income and depletion of resources* (section 2.6) The indicators in this section cover physical measures of levels and changes in the stocks (e.g. depletion) of different environmental assets (including mineral and energy resources, timber resources, aquatic resources, etc), indicators of asset or resource life, patterns of change in land use and land cover, indicators of intensity of use of resources, and measures of income and changes in wealth associated with natural resources.

2.18 Through the chapter some examples of indicators and analyses are presented. Annex 1 provides an explanation of the underlying types of data and methods used in these examples and the structured list of references provides information on relevant studies and publications in these various topics. 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 different topics. For all indicators and analysis it is important to consider the surrounding context, for example the economic structure and environmental circumstance, as part of the interpretation.

## 2.3 Analysis of resource use and environmental intensity[1]

### 2.3.1 Introduction

2.19 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.

2.20 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.

2.21 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.

2.22 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.

[1] Environmental intensity generally refers to the way in which economic activity uses the environment as a sink. Thus, increasing the rates at which pollutants and other residuals are released will generally correspond to increases in environmental intensity.

2.23 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.

2.24 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.

2.25 In recent decades, economic development has been 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 significant materials 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.

2.26 At the same time, prices for energy and other material resources have also tended to rise along with 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 intensity in the use of materials have become important issues, adding to long standing concerns about the availability of resources.

2.27 The concepts of resource use and environmental intensity build on an integrated and long-term approach to resource management. They encompass 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, the concepts aim 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 depletion.

iv. Maintaining non-market ecosystem services and restricting ecosystem degradation.

2.28 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.

2.29 Data for the analysis of resource use and environmental intensity 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.

2.30 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 intensity

2.31 Resource use and environmental intensity may be analysed at a broad, economy-wide level through consideration of relevant aggregates and a variety of indicators, generically referred to as intensity 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.

2.32 Intensity 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. These indicators are expressed as either intensity or productivity ratios, where intensity indicators are calculated as the ratio of the environmental flow to the measure of economic activity, and productivity indicators are the inverse of this ratio. When monitoring trends over a given period, these indicators can also be expressed as decoupling ratios or as decoupling factors. (Decoupling analysis is discussed in sect. 2.3.3).

2.33 Intensity indicators are often grouped into two broad types:

- Environmental intensity indicators characterise the environmental and economic intensity with which pollutants and other residuals generated in production and consumption are mitigated, controlled and prevented. They are ratios of 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 intensity indicators can be disaggregated by institutional sector and by industry, as well as by emission source.

- Resource intensity indicators characterise the intensity with which natural resources, including water, energy and other materials are used in production and consumption. They are ratios of 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]

2.34 All environmental and resource intensity 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.

2.35 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.

2.36 Measurement in volume terms is most relevant when considering analysis over time within a single country. For cross-country comparison different approaches should be considered. The most appropriate method of adjusting economic data from different countries to a comparable basis is the use of purchasing power parities (PPPs) that allow economic data to be compared through reference baskets of goods and services.[3]

2.37 Indicators that show a country's production include gross output, industry value added and GDP. 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.

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[2] Note that depending on the context and the selected input, increasing intensity ratios (declining productivity ratios) may not reflect increasing (declining) environmental pressures.

[3] For detail on the calculation of PPPs see Eurostat-OECD (2012) Methodological manual on purchasing power parities (PPPs). PPP data may be accessed from a range of sources including OECD, World Bank and as part of the Penn World Tables (PWT 7.1, 2012).

2.38 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 that may commonly be found within the underlying accounts.

2.39 International comparisons of environmental and resource intensity 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 intensity indicators (e.g. information about economic structures, stage of economic development, and natural resource endowments).

*Examples of environmental intensity indicators*

2.40 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.

2.41 Air pollutant emission intensities, which relate emissions of greenhouse gases or air pollutants to economic activity, expressed in tonnes per unit of GDP. Depending on the air pollutant of interest, indicators may benefit from a spatial breakdown, for example, to provide indicators of air quality for specific urban areas or airsheds.

2.42 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. As for air pollutants, indicators compiled for specific locations may be of particular interest.

2.43 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.).

2.44 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 intensity indicators*

2.45 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.

2.46 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.

2.47 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.

2.48 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.

2.49 Other useful water related indicators include: the ratio of final water use (often referred to as water consumption) to net domestic water use reflecting 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 proportion of water sourced from outside a territory (i.e. imported). 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.

2.50 Land use intensity 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*

2.51 Most environmental and resource intensity 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.

2.52 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 environmental flows 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.

2.53 Consumption-based indicators should be based on data and relationships contained in input-output tables, and ideally given the globalised nature of many environmental flows, multi-regional input-output tables should be used. Consumption-based indicators have similarities with footprint indicators (e.g. carbon and water footprints). Two distinct types of footprint indicators should be recognised. Some footprint indicators are compiled using industry-product relationships embodied in input-output tables and hence are closely related methodologically to the consumption–based indicators just described. Other footprint indicators are based on life-cycle analysis which tracks particular products through supply chains. Section 3.3 discusses relevant measurement issues in more detail.

2.54 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 intensity 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 intensity

*Decoupling analysis*

2.55 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. real 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).

2.56 Decoupling can be either absolute or relative. Absolute decoupling is said to occur when the growth in the environmental pressure 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.

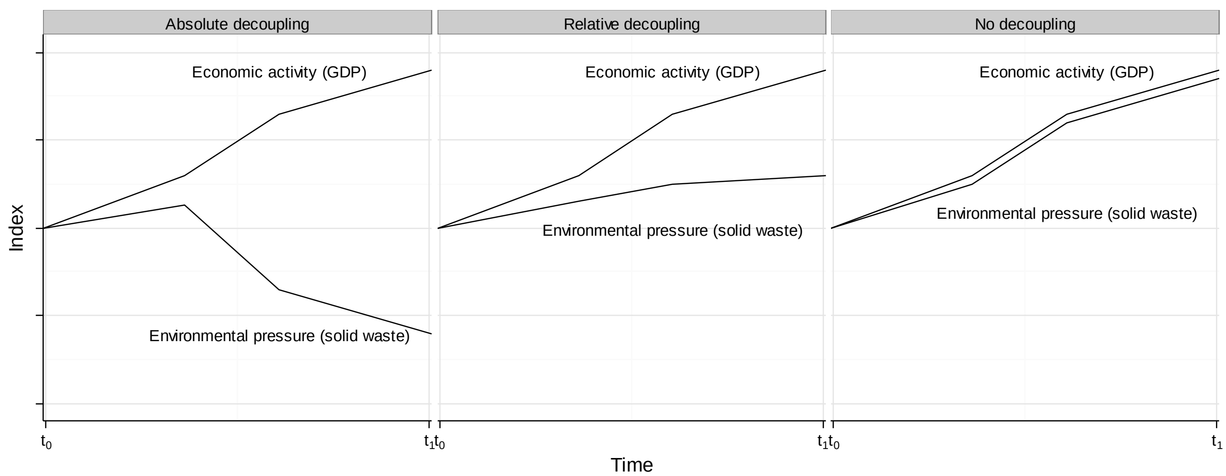
2.57 Many of the variables that feature in decoupling indicators also appear in the concepts of environmental and resource intensity. Decoupling is usually conceived as an elasticity focusing on changes in volumes, whereas intensity and productivity are more concerned with the actual values of these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

2.58 Decoupling can be measured by intensity 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.

2.59 When decoupling is presented as a single line in the form of intensity ratios (i.e. a time series of the ratio of the environmental variable to the economic driving force), the idea of a decrease in intensity 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, as a result of structural economic change towards service industries, production across the economy is becoming, on average, relatively less resource intensive.

2.60 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 economic activity (e.g., real GDP) is growing or shrinking and whether decoupling – absolute or relative – is occurring, when it started and whether it continues. The three charts below (Figure 2.2) use stylised data on economic activity and an indicator of environmental pressure (e.g. generation of solid waste) to show the various types of decoupling that might be exhibited.

**Figure 2.2 Stylised examples of decoupling trends**




2.61 To compare decoupling among countries, a decoupling ratio can be derived following the formula below which reflects the rate of change in decoupling over an accounting period.

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

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 in any country was absolute or relative, or whether one country's decoupling is larger or smaller than another country's in absolute terms. To avoid displaying (e.g., on a bar graph), small values when the rate of decoupling is significant, a decoupling factor can be calculated as follows:

$$\textit{Decoupling factor} = 1 - \textit{decoupling ratio}$$

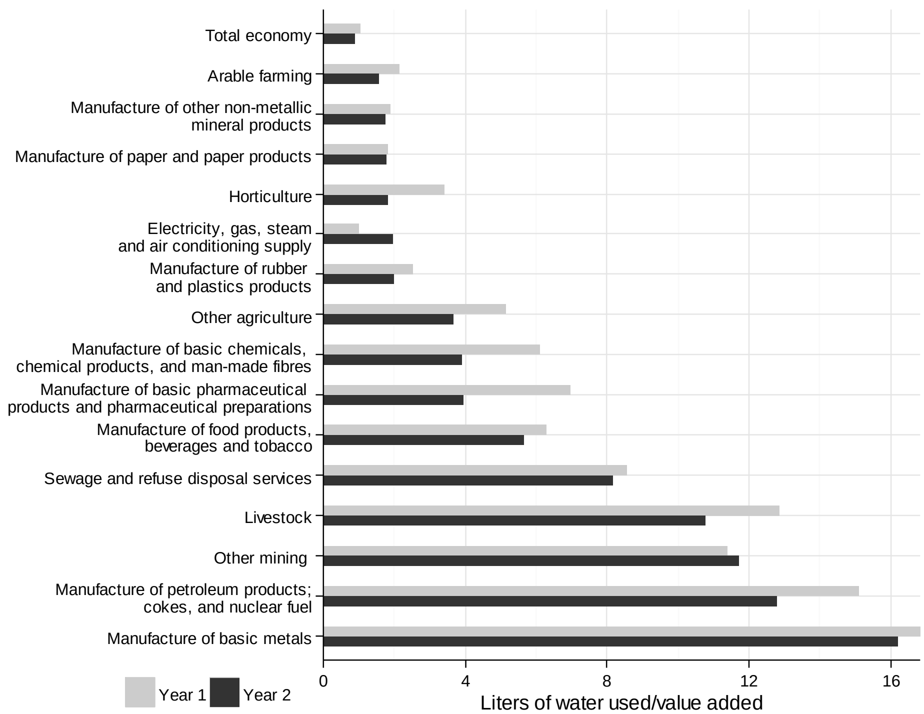
The decoupling factor is zero or negative in the absence of decoupling and has a maximum value of 1 when the environmental pressure reaches zero

*Analysis by economic industry*

2.62 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.

2.63 The following example in Figure 2.3 highlights use of water (measured in terms of intermediate consumption) by selected 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 ***




* Water use refers to intermediate consumption of water. Details and relevant measurement considerations are described in Annex I.

2.64 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 intensity of production with respect to residual flows and the effectiveness of policy instruments.

2.65 The monetary supply and use tables, 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 monetary supply and use tables are structured following the same classifications additional industry analysis may be completed considering resource use per unit of production or value added.

2.66 Comparing PSUT and monetary supply and use tables 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 monetary supply and use tables. 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*

2.67 Using both PSUT and monetary supply and use tables, 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 (including as inputs to own-account production by households) to the point of final consumption 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 section 3.3.3 entitled “Attribution if environmental flows to final demand”.

2.68 Where information is available these measures may be further developed to consider resource use and environmental intensity 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 (e.g., rural and urban households) may also be conducted if information is available. Chapter 4 provides additional detail on the analytical possibilities with respect to the household sector.

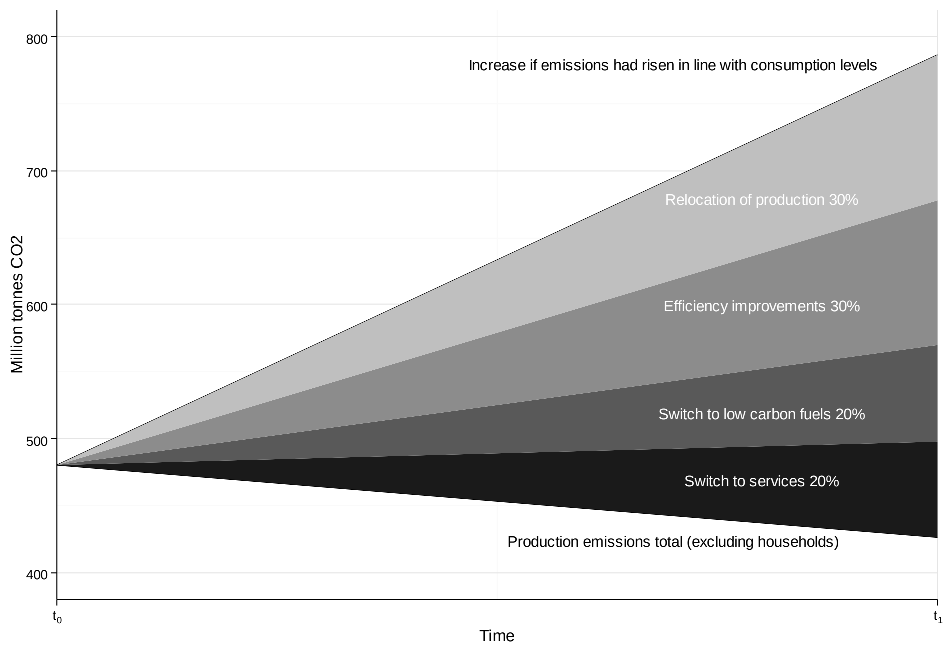
*Decomposition analysis*

2.69 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 intensity have actually contributed to changes in the levels of these pressures.

2.70 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, changes in the structure of the supply chain and the structure of demand, changes in the energy intensity of production, and improvements in the production process.

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

**Figure 2.4 Decomposition of changes in $CO_2$ emissions**



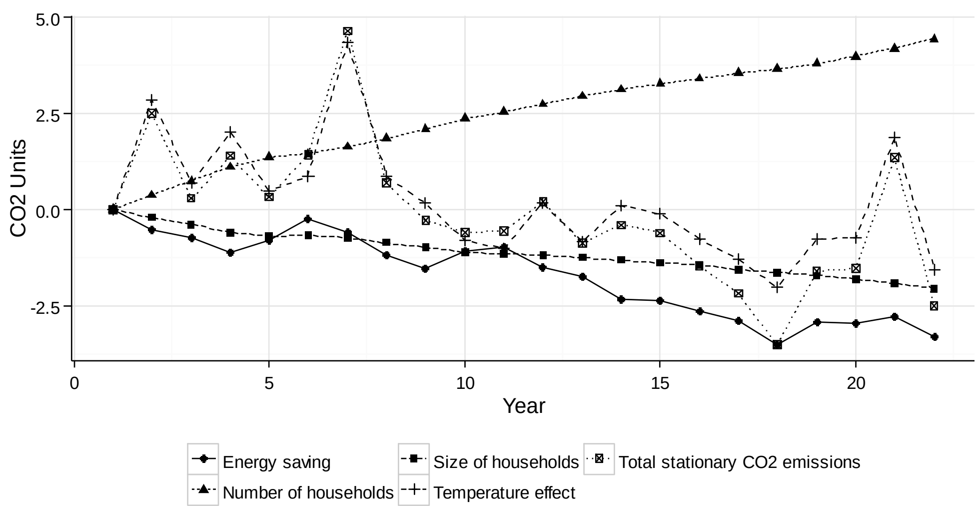

2.72 The figure shows that carbon dioxide emissions would have increased by 306 million tonnes if they had grown in line with consumption levels. This estimate may be obtained by using the relationship between consumption and emissions in $t_0$, and then estimating emissions in each subsequent year based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

2.73 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; gains in energy use (i.e. reduced energy intensity) - 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.

2.74 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.

2.75 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 $CO_2$ intensity effects (emissions per kilometre travelled).

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




2.76 Section 3.3 provides a summary of the mechanics of decomposition analysis, including on the distinction between structural decomposition and index decomposition, and Annex I provides some additional details on the examples shown in Figures 2.4 and 2.5.

*Input-output analysis – multipliers and footprints*

2.77 Beyond the types of approaches described above, more detailed analytical approaches can be applied 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.

2.78 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 intensity. 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*

2.79 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.

2.80 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.

2.81 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*

2.82 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).

2.83 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.

2.84 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 may therefore provide an indication of the potential overall environmental pressure. However, this should not be interpreted as reflecting either the precise environmental pressure associated with a given activity or the related potential environmental impacts.

2.85 This is because aggregate input measures do not consider any characteristic of materials other than mass. 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, and the way the materials are managed across their life-cycle, including methods of production and treatment of wastes and other residual flows.

2.86 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.

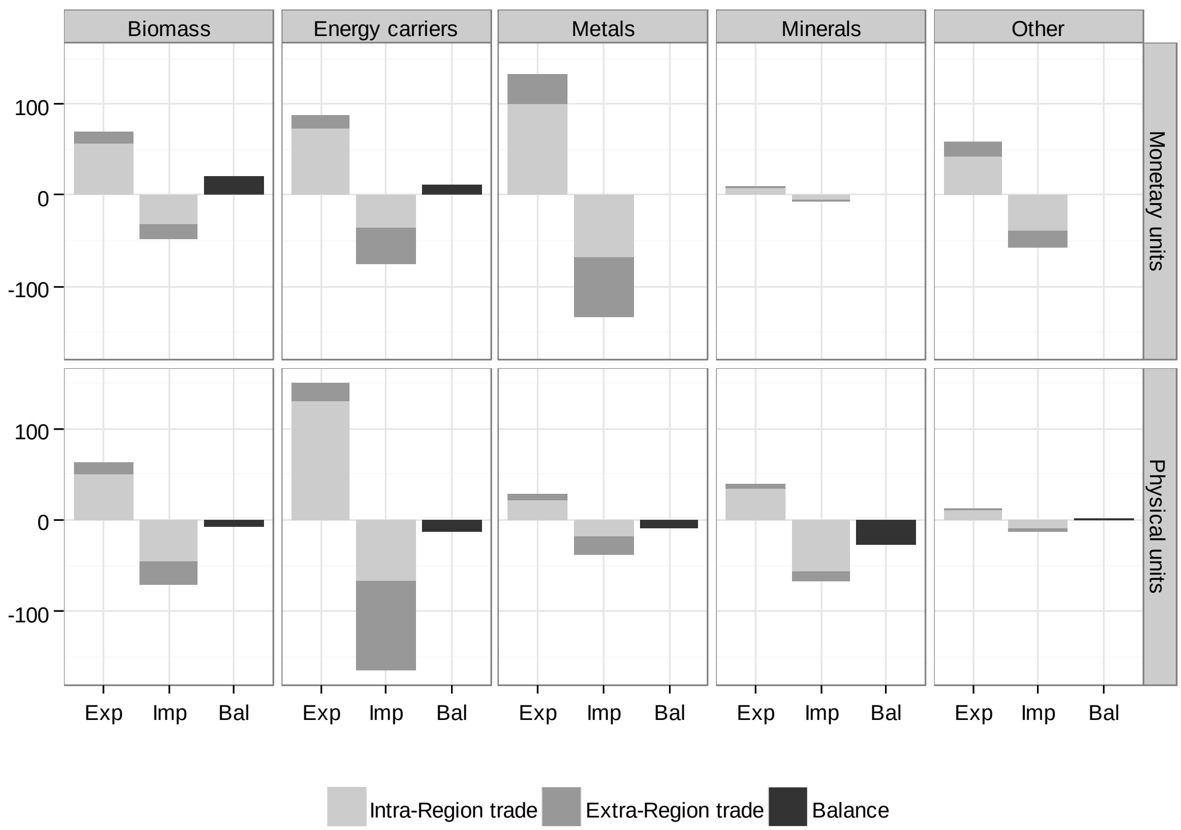
2.87 Proper interpretation of EW-MFA indicators therefore requires, wherever possible, a breakdown of the indicators into their constituent variables. EW-MFA indicators broken down by type of material inform about the mix of materials and help see the weights of different types of materials in the overall 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 may 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) or according to their relative toxicity.

*Analysis by product / material groups*

2.88 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) intensity of the use of different materials to produce a similar product can be assessed and the substitution of materials can be monitored.

2.89 By combining data from the PSUT and monetary supply and use tables 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 (top section) and physical (bottom section) measures of exports (+) and imports (-) for five groups of materials.

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




2.90 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, $CO_2$, 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 goods (e.g. batteries, cars, computers, textiles), and analyse the material requirements and potential environmental pressures along the full life cycle of the goods. LCA can equally be applied to services through consideration of the different physical inputs that are required for their production.

2.91 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*

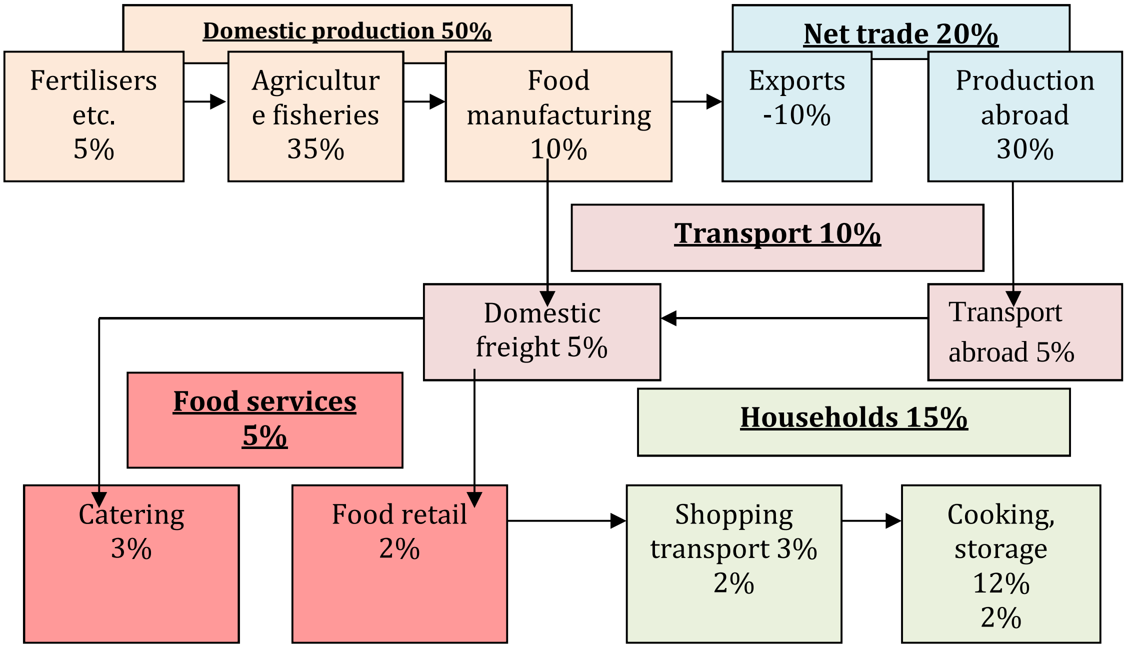
2.92 A complete PSUT also contains information on the supply and use of solid waste. Analysis of flows of solid waste with all other natural input, product and residual flows can provide resource intensity indicators such as the solid waste generated per primary product or the share of secondary materials (products produced from solid waste) relative to primary (natural) resource inputs.

2.93 A wide number of studies (e.g. EIPRO[4]) 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.

2.94 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 (both direct and embodied 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 and fisheries production are a major source of food chain emissions (contributing 35% of all emissions related to food), transport and trade are also important contributors.

[4] Environmental Impact of Products (EIPRO) (2006) Institute of Prospective Technological Studies, European Science and Technology Observatory and European Commission Joint Research Centre.

**Figure 2.7 Food chain greenhouse gas emissions**




2.95 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 are allocated to the relevant parts of the supply chain. Emissions relating to households are based on household travel surveys and energy use in the home. Emissions relating to international trade are derived 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*

2.96 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*

2.97 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.

2.98 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 intensity of different transport modes can be assessed.

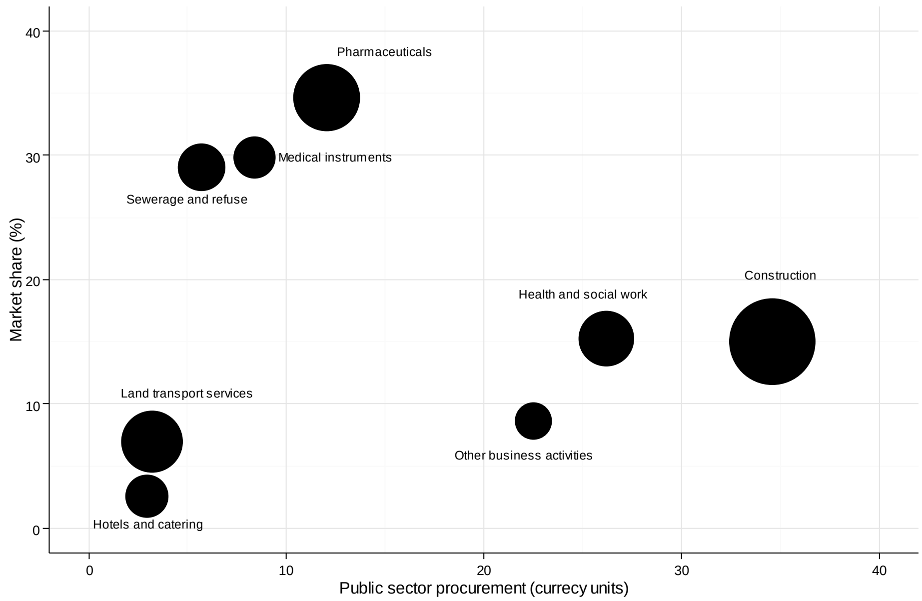
*Linking residual flows and expenditures*

2.99 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.

2.100 The example below shows a few selected activities where the emissions associated with general government sector procurement are significant. (The size of the circle reflects the extent of direct emissions relating to that activity.) For some activities, such as pharmaceuticals, general government procurement accounts for up to 35 per cent of the total output of that industry. Although government procurement in this activity is only just over 10 local currency units, emissions from this activity are larger than those from a number of other sectors, such as land transport, or sewerage and refuse.

2.101 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

2.102 The economic consequences of environmental measures and environmental concerns are of great interest to policymakers. They approach these topics from various perspectives. For example, their interest may focus on the financial burden that is placed on the polluting industries, as they have to invest in pollution prevention, abatement and control in order to comply with environmental regulations. Alternatively, 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.

2.103 The SEEA Central Framework presents two measurement approaches relevant to these information needs: statistics on the Environmental Goods and Services Sector (EGSS) and Environmental Protection 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.

2.104 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.

2.105 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 to include resource management activities. 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).

2.106 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.

2.107 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.

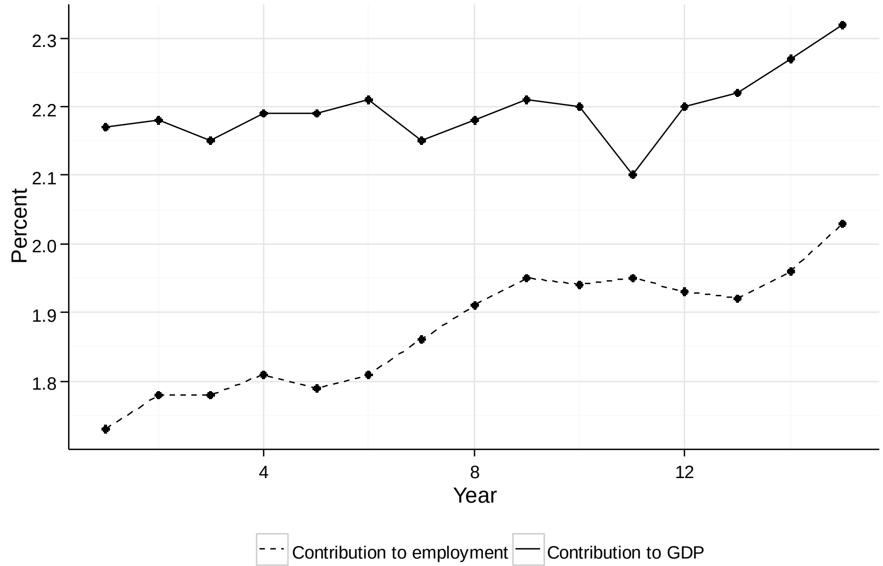
### 2.4.2 Indicators and aggregates for environmentally related production and employment

*Key EGSS indicators and aggregates*

2.108 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 EGSS expressed as a percentage of GDP (see Figure 2.9).
- Employment in the EGSS expressed as a percentage of total employment (see Figure 2.9).
- Exports of environmental goods and services as a percentage of the production of environmental goods and services
- Trade (exports, imports) in environmental goods and services as a percentage of total trade
- The proportion of enterprises that produce environmental goods and services in the economy
- The level of investment in the EGSS and its development over time.

**Figure 2.9 EGSS contributions to GDP and employment**




2.109 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. reduced energy intensity 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.

2.110 Green jobs has been an area of recent interest to policy makers. Several approaches have been taken to the definition of green jobs including approaches based on employment in relevant economic activities, in the production of relevant products, in relevant processes, or in jobs with specific descriptions and roles. Each of these approaches will lead to the derivation of different measures of green jobs and will vary depending on the chosen scope of activities, products, processes or job descriptions. International work on the definition of green jobs is conducted under the auspices of the International Labour Organization.

2.111 The SEEA Central Framework does not define a measure of green jobs. However, the measure of employment in the EGSS may prove a useful indicator of changes in environmentally related employment. The indicator's usefulness may be strengthened through its coherence with other economic information that is structured following the EGSS as defined in the SEEA Central Framework.

2.112 Indicators and aggregates on the EGSS 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 research and development 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.

2.113 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 using information classified at finer levels of the Classification of Environmental Activities, like the growth of enterprises involved in the prevention of pollution through in-process modifications or research and development activities.

*Key EPEA indicators*

2.114 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.

2.115 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. At the same time, these indicators do not provide a measure of the change in environmental condition in response to any expenditure.

2.116 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, including the relative share of activity by private and public sectors.

2.117 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[5] 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).

[5] See SEEA Central Framework Chapter 4 and Annex 1.

ii. The relative importance of investment expenditure compared to operating expenditure. In general, the investment-related share of EP expenditure 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).

2.118 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.

2.119 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.

2.120 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*

2.121 For the EGSS indicators noted above, it may be relevant to compare 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.

2.122 For EPEA data, analysis 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 noting that care in needed in differentiating between direct expenditure by government and activities by the private sector that are financed by government. Comparison of levels of environmental protection expenditure to industry estimates of value added and operating surplus may also be relevant.

*Analysis by environmental activity domain*

2.123 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[6]) 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.

2.124 One area of particular interest may be those enterprises within the EGSS that produce renewable energy (exploitation phase), as well as enterprises active in pre-exploitation phases (e.g., the design and production of energy saving activities and products).

2.125 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*

2.126 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 integrated (pollution preventing) technologies compared to end-of-pipe technologies. This is very important in the case of raising the awareness on the type of environmental output, in particular adapted goods[7] 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.

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

[7] 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)

2.127 More specifically, in addition to the standard economic indicators (value added, production, employment, exports, imports, capital formation), data related to renewable energy activities may be further broken down into various product profiles and process profiles.[8]

*Regional analysis*

2.128 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*

2.129 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.

2.130 For EPEA comparison of expenditure data to physical flows of emissions and waste may be particularly relevant and would enable the derivation of polluter pays indicators (see SEEA Central Framework 6.111) and 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. A commonly derived indicator in this regard is implicit tax rates (see sect. 2.5.3 Analysis of environmental taxes).

2.131 It should be noted that the comparison of monetary data from EGSS and EPEA with relevant physical data requires consideration of the extent to which the data are classified and recorded on a comparable basis (for example, in terms of industry and product scopes, accounting period, etc). Any differences in classification and recording approaches must be taken into account.

*Multiplier analyses*

2.132 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

[8] Product profiles include items such as ‘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’. Process profiles include items such as ‘research and development’, ‘consultancy’, ‘transport’, ‘preparation/raw material production’, ‘supply, assembly and construction’, ‘production of energy carriers’, ‘installation and maintenance’.

the rest of the economy. These indirect effects can be determined by calculating multipliers derived from input-output (IO) tables - 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.

*Cost-recovery analysis*

2.133 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*

2.134 Depending on the methods used to collect source data, as part of organising data for use in compiling accounts it may be possible to construct a database holding information on various economic flows at the level of individual businesses, including on the location of businesses. Such information may include data on employment, production, value added, exports, imports, innovation, research and development activity, fiscal schemes and subsidies. If this information can be collated in consistent manner, it may be used to support micro-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

2.135 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.

2.136 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, the assessment of the effectiveness of various environmental transfers in changing behaviours, and the assessment of the distributive effects of different taxes, subsidies and other transfers.

2.137 The SEEA Central Framework Chapter 4 sets out the 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.

2.138 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.

2.139 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 (e.g., benefits obtained through lower relative tax rates for certain activities), 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

2.140 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.

2.141 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 products, other taxes on production, 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.[9]

2.142 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.

2.143 Another indicator is the ratio of environmental taxes to total taxes. However, interpretation of this ratio needs to take into account a range of contextual factors, including environmental circumstance and the nature of the tax base, and the use of regulation as distinct from taxation to implement environmental policy.

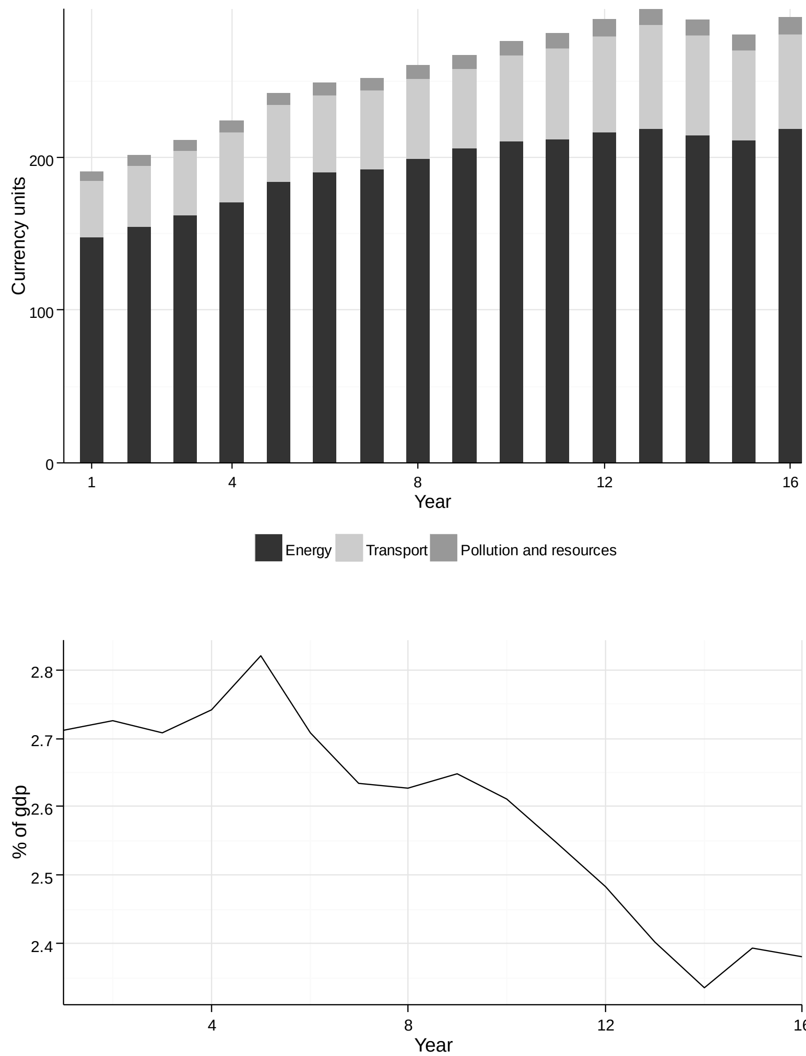
[9] Payments for tradable emission permits relating to emissions of carbon dioxide are treated as environmental taxes, specifically energy taxes. See SEEA Central Framework 4.185-4.187 for a summary of the treatment.

2.144 A key indicator for environmental subsidies and similar transfers is their share in total outlays by government. The mix of different types of payments by government, particularly a distinction between current and capital transfers may be of interest, and a comparison of environmental and non-environmental subsidies and similar transfers may highlight changes in policy focus over time. Payments of environmental subsidies and similar transfers may also be compared to relevant environmental protection and resource management expenditure. In addition, classification of these flows by purpose or by receiving industry and sector may highlight developing trends and inform on the structure of the payments.

### 2.5.3 Analysis of environmental taxes

2.145 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 influence changes in behaviour (through changes in relative prices) 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.

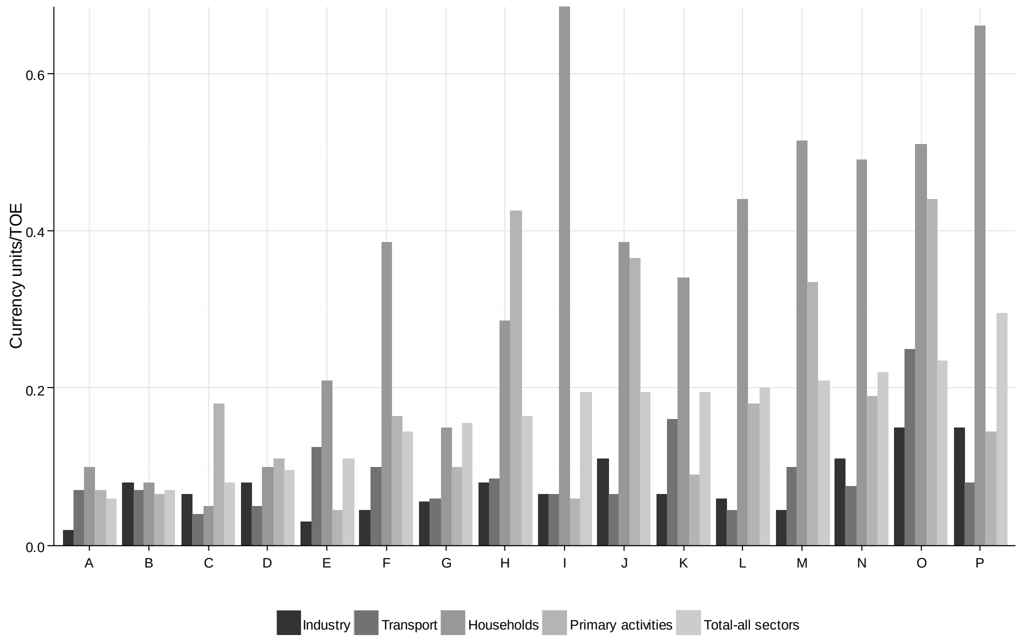
**Figure 2.10 Environmental tax revenue by type**




2.146 For environmental taxes there may be interest in constructing implicit (or effective) tax rates. Implicit tax rates are derived as the ratio between environmental tax revenues (measured in currency units) and an indicator of consumption of environmental flows (e.g. unit of energy or carbon dioxide emissions). Thus, an implicit tax rate for energy may be defined as the ratio of energy tax revenues to final energy consumption measured in tonnes of oil equivalent (TOE). Such rates may be compared across industries, sectors, products and countries. In the figure below implicit tax rates for energy are shown for several countries.[10]

[10] Within the EU Sustainable Development Strategy, the implicit tax rate for energy (measured in Euro/TOE) is a sustainable development indicator see http://epp.eurostat.ec.europa.eu/portal/page/portal/sdi/indicators/all_indicators. Effective tax rates on energy are also measured by the OECD – see http://www.oecd.org/tax/tax-policy/taxinenergyuse.htm

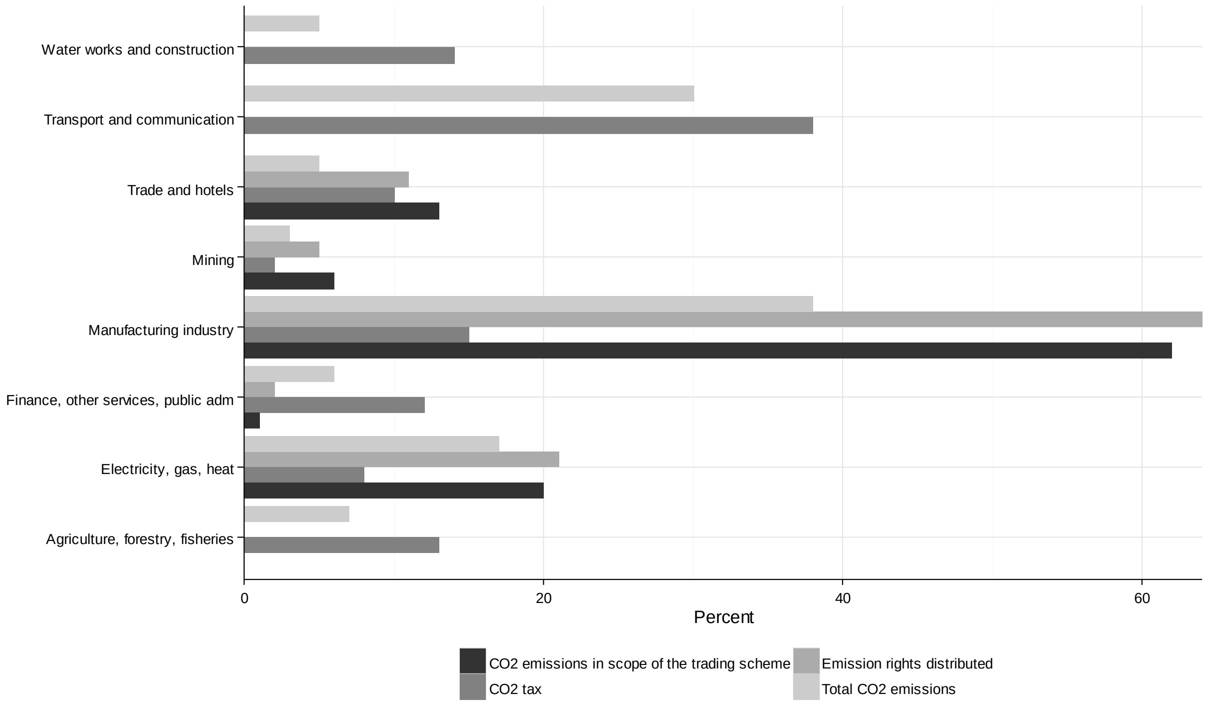
**Figure 2.11 Energy taxes divided by energy consumption by sector**




2.147 Using SEEA data, analysis can also be undertaken to understand the environmental effect of a tax, for example, the change in pollution resulting from the introduction of a pollution tax. To do this, physical data relating to the tax (e.g. emissions, waste and energy products) are required. Figure 2.12 presents the share of $CO_2$ taxes, allocated emission trading permits, the $CO_2$ emissions occurring within the trading scheme[11] 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. This type of analysis may be extended using additional data and assumptions to consider the extent to which the polluter pays principle is in effect.

[11] 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 2.12 Distribution of $CO_2$ tax revenues, emissions rights, $CO_2$ emissions covered by the trading scheme and total $CO_2$ emissions by industry**




2.148 Table 4.10 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.

2.149 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

2.150 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.

2.151 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*

2.152 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 6.3 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

2.153 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.

2.154 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.

2.155 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.

2.156 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?

2.157 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 forms part of the information needed to consider these types of questions but does not cover a comprehensive suite of capital that will generally also include 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.

2.158 The valuation of environmental assets in monetary terms in the SEEA Central Framework follows the same principles as the SNA.[12] 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. Undertaking valuation for individual natural resources can also help in understanding the relationship between physical stocks of resources and changing likelihoods of extraction since the likelihood of extraction will be based on the extent to which expected extraction costs using available technologies are less than expected prices for the extracted resources.

2.159 In this context, it is likely to be beneficial to consider monetary and physical measures of resources as being complementary while also recognising that the approaches to valuing environmental assets in monetary terms often require the use of assumptions regarding future patterns of activity and discount rates and, as a result, care should be taken in undertaking comparisons of values of different asset types.

### 2.6.2 Analysis and indicators of individual environmental assets in physical terms

2.160 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. From the perspective of the SEEA Central Framework assessments of these constraints are based on consideration of each different type of environmental asset within the broad categories of land, natural resources, and cultivated biological resources.

2.161 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

[12] While the principles are aligned the valuation of environmental assets often requires the use of alternative valuation approaches (e.g. net present value approaches) when market prices are not observable.

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).

2.162 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.

2.163 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.

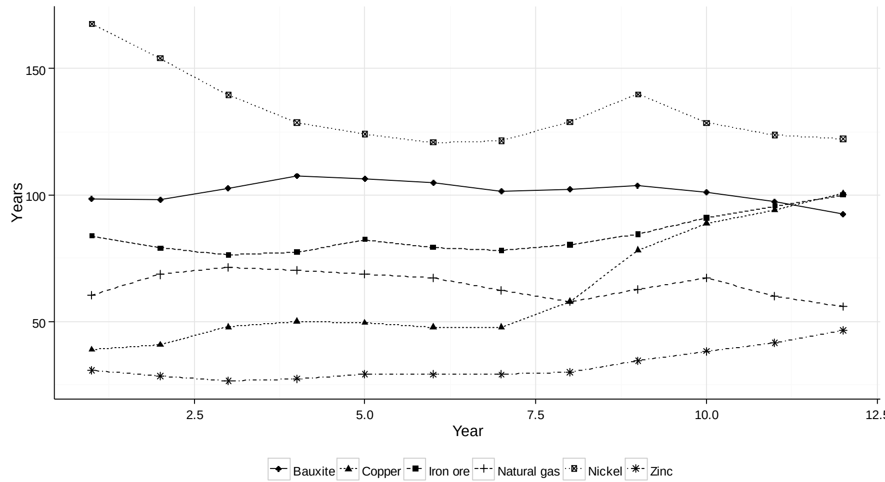
2.164 In physical terms, each set of information on different types of environmental assets will not be able to be readily compared since the measurement will be undertaken in different units of measure. Indeed, even within particular broad asset types the measurement units may vary (e.g. different mineral 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.

2.165 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 asset lives.[13]

[13] Ideally, asset lives would be determined on the basis of expected extraction rates (rather than based on recent trends). However, expected extraction rates may be difficult to determine given various future uncertainties particularly concerning changes in prices and technology that will impact on extraction rates.

2.166 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 2.13 Asset lives for selected mineral and energy resources**




2.167 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.

2.168 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.

2.169 Other useful indicators inform about changes in land use and land cover and about conversions from one use category or cover type to another. For these types of analysis it is possible to use the interim classifications on land use and land cover as presented in Annex 1 of the SEEA Central Framework. 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.

2.170 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.

2.171 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 a complete picture 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 and this spatial component is important to consider when developing and interpreting natural resource indicators. While it may not provide a complete picture, this information maybe very useful in providing a sense of the scale and scope of changes and thus help to form an information base for the assessment of sustainability with regard to environmental assets.

2.172 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 Chapter 4.

### 2.6.3 Analysis of environmental assets in terms of wealth and incomes

2.173 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.

2.174 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.

2.175 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.

2.176 Using the information required to estimate values of environmental assets it is also possible to derive volume measures or indexes[14] 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).

2.177 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

[14] In this context volume measures do not relate to measures of physical changes, for example cubic metres of water. See SEEA Central Framework section 2.7.4 for an introduction to volume measures.

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.

2.178 Aggregate measures of environmental assets, either in value or volume terms, should be interpreted cautiously since when presented in a common unit of measure, such as in monetary terms, it may be implied that there is substitutability between asset types. Such an interpretation 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

2.179 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

2.180 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 is the environmental and economic context about which the indicators are intended to inform? How and by whom will they be used? How solid is the information base on which the indicators rely? In addition, when used in international contexts, indicators will require some consensus about their validity among the countries concerned.

2.181 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.

2.182 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.

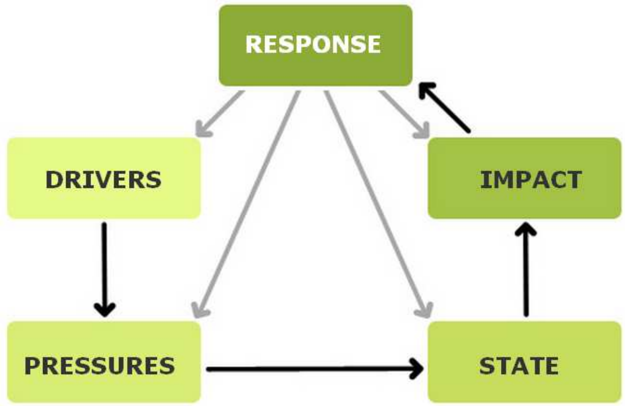
### 2.7.3 Interpretation and use of indicators

2.183 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. Examples of contextual information include population change and economic structure. The information value of many indicators may also be enhanced when they are associated with policy objectives or targets.

2.184 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 2.14. 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.

2.185 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 2.14 DPSIR model**




### 2.7.4 Presentation of indicators

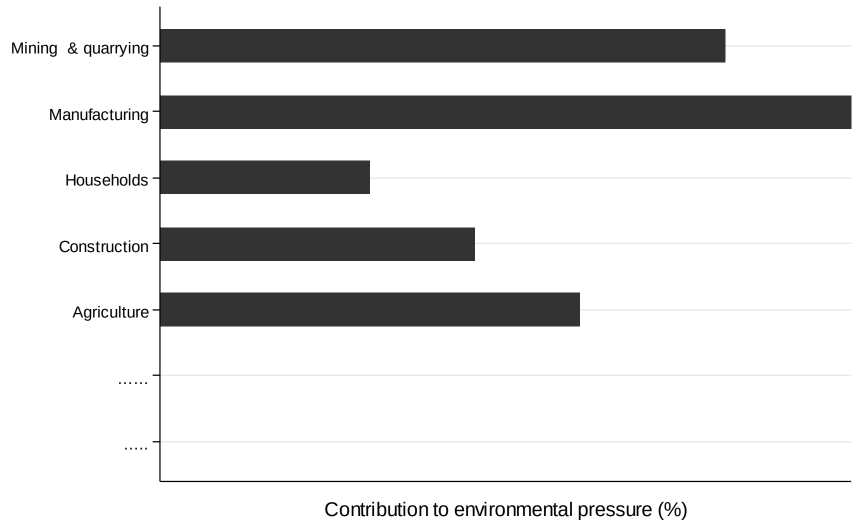
*Level of detail and disaggregation*

2.186 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.

2.187 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.

2.188 When macro-level indicators are classified by industry and by institutional sector, 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 and sectors to efforts aimed at preventing, controlling and mitigating a given environmental pressure (e.g. through environmental expenditure and transfers) or 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 covering industries and the household sector for a generic environmental pressure is presented in Figure 2.15.

**Figure 2.15 Stylised issue profile**




2.189 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.

2.190 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.

2.191 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.

2.192 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.

2.193 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[15], 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. Methods and data requirements related to spatial disaggregation are considered further in Chapter 4 as an extension of the SEEA Central Framework.

2.194 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*

2.195 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.

2.196 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.

2.197 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 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.

2.198 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. For particular topics it may be relevant to present an aggregate indicator and relevant component indicators. 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

[15] 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.

approaches - aggregated indices, headline indicators, dashboards, etc - need not be mutually exclusive.

*Aggregation and the SEEA*

2.199 Aggregation is generally considered straightforward when the relevant variables are expressed in a common metric (e.g. currency units, 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.[16] 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.

2.200 At the same time, care needs to be taken when undertaking some aggregations in common metrics since the relationships between variables and the relative significance of different variables may be complex. 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). The OECD/JRC handbook on constructing composite indicators provides additional description and explanation of aggregation issues.[17]

2.201 The standard metric in economic accounting is currency units (money). 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.

[16] 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.

[17] OECD, European Commission Joint Research Council (2008), *Handbook on Constructing Composite Indicators: Methodology and User Guide*.

# Chapter III: 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 tables (EE-IOT). The section discusses the various types of EE-IOT, such as single region and multiregional input-output tables, and input-output tables in hybrid units. Section 3.3 outlines a number of analytical and modelling techniques that may be applied to data from these EE-IOT, including multiplier analysis, the attribution of environmental flows to final demand (including footprints), decomposition analysis and computable general equilibrium (CGE) modelling.

3.3 The chapter aims to provide a summary of the technical aspects concerning the construction of relevant datasets and the related analytical techniques. A summary is relevant since often there are important implications in the choice of approach that have a material impact on the interpretations and conclusions that can be made. These implications can be lost amid the technical complexity of input-output tables and the associated models. An extensive list of references is provided on the various topics that are introduced to allow further consideration of the critical elements.

3.4 A key message of the chapter is that the construction of detailed EE-IOT datasets, that reflect industry and product detail in physical and monetary terms and encompass economic and environmental information, can be powerful tools in analysis and research. Models based on EE-IOT have been used to study the impact of changes in carbon emissions on economic activity, the links between water use and industry performance and the connections between economic activity and the location of environmental pressures. Since the SEEA Central Framework provides an articulation of precise measurement boundaries, it is possible to have a coherent integration of environmental data into standard input-output datasets that are compiled in accordance with the SNA. While there may be ongoing discussion about the appropriate choice of analytical or modelling technique, there should be recognition that the establishment of detailed, accounting based, input-output datasets is an important aspect of advancing understanding of environmental and economic issues.

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

### 3.2.1 Introduction

3.5 Environmentally extended input-output tables (EE-IOT) are integrated datasets that combine information from standard economic input-output tables in monetary units and information on environmental flows, such as flows of natural inputs and residuals, that are measured in physical units. There are a number of ways in which 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 EE-IOT.

3.6 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.[18] Thus, the discussion of the EE-IOT has been kept as simple as possible in order to be able to explain the basic premises of the analytical techniques described in section 3.3.[19] In each section, references to more detailed material are provided.

### 3.2.2 Single region input-output (SRIO) tables

3.7 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.[20] Various mathematical and analytical approaches are available to convert SUT to an IOT (see United Nations, 2009).

3.8 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 by industry while the columns provide information about the inputs required in the production process of an industry.

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

[19] 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.

[20] Note that it is also possible to model environmental-economic relationships using SUT systems (see for example Lenzen and Rueda-Cantuche (2012)), but most applications use input-output tables.

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

| ***Data in monetary terms*** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Industries | | | Final demand | | | Total output |
| | | *1* | … | *j* | Final consumption | Gross capital formation | Exports | |
| Industries | *1* | | | | | | | |
| | … | | *Z* | | *c* | *f* | *e* | *q+m* |
| | *j* | | | | | | | |
| Value added | | | *v* | | | | | |
| Total inputs | | | *q* | | $c_{tot}$ | $f_{tot}$ | $e_{tot}$ | |

| ***Data in physical (non-monetary) terms*** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Natural inputs / residuals | | *r* | | | | | | $r_{tot}$ |

3.9 The output of the industries is the sum of intermediate consumption ($Z$) (which is a $j$ by $j$ matrix) and final demand categories such as final consumption ($c$), gross capital formation ($f$) (including changes in inventories), and exports ($e$). Note that for all these categories this is the sum of domestically produced goods and services and imported products. i.e. $Z=Z_d+Z_m$, $c=c_d+c_m$, $f=f_d+f_m$, $e=e_d+e_m$ (subscript $d$ denotes the use of domestically produced inputs and $m$ the use of imported goods and services). The inputs for each domestic industry comprise the intermediate inputs ($Z$) and value added categories ($v$) - including compensation of employees (wages) and gross operating surplus (profit). Since the inputs into an industry must equal the outputs, the column sums are thus equal to the outputs ($q$) of domestic industries while the row sums are equal to domestic output plus the imported products ($q+m$). All the variables with the subscript *tot* are scalars that show the totals for those respective row or columns.

3.10 The intermediate input matrix ($Z$) of an IOT is therefore a square matrix (i.e., it contains the same number of rows and columns) and a symmetric matrix (i.e., the items indicated by the rows and columns are the same: both are products or both are industries).

3.11 The IOT is then augmented using data on environmental flows by industry (denoted by the vector $r$) which may be taken from relevant SEEA accounts. In most applications these data relate to flows of natural inputs and/or 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).

3.12 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.

3.13 It was noted above that the core IOT may be structured using an industry by industry or a product by product matrix for intermediate consumption. Where a product by product based structure is used it is likely to be necessary to adjust data on environmental flows which is most commonly collected and classified by industry. The adjustment of environmental flow data in terms of industries and products will also arise when supply and use tables (SUT) form the basis for the representation of flows within the economy. SUT are generally structured with columns representing industries and rows representing products with substantially more products than industries. Examples of environmentally extended SUT are emerging in the literature and may be beneficial for some analysis since they provide additional detail by product.

### 3.2.3 Hybrid input-output tables

3.14 The entries in the input-output table shown in table 3.1 are 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. Note that because the columns contain a mix of entries in different units (some monetary and some physical) it is not possible to aggregate entries within a column. However, summation across each row is possible.

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

| | | Industries | Final demand | | | Total output |
|---|---|---|---|---|---|---|
| | | *1 … j* | Final consumption | Gross capital formation | Exports | |
| Industries | *1* | | | | | |
| | … | $Z$ | $c$ | $f$ | $e$ | $q+m$ |
| | *J (physical units)* | | | | | |
| Value added | | $v$ | | | | |

3.15 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 for industries that have a reasonably large share of physical rather than service-based flows. 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. It is important to note that the mathematical specifications of the input-output model apply 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).

3.16 This type of EE-IOT incorporates elements of life cycle analysis and process analysis since it is possible to reflect the chain of flows between economic units in physical terms in the context of an economy wide set of flows.

### 3.2.4 Multiregional input-output (MRIO) tables

3.17 Input-output tables that are constructed by statistical offices are mostly SRIO tables such as the one shown in table 3.1. Subsequent, input-output modelling that is based on an SRIO has the limitation that they often need to use the "domestic technology assumption": i.e. it is assumed that imported products 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 used to produce the imported product, the effect of the assumption is that the input-output modelling will produce estimates that do not reflect the likely environmental pressures.

3.18 Given the significant and ongoing globalisation of production processes there is thus strong interest in the construction of EE-IOT datasets that take these international flows into account. Recently, there have been a number of large projects that have created multiregional input-output (MRIO) tables and made them available via databases[21]. The number of countries covered can vary significantly (from 2 to around 190) depending on the regional breakdown used in each project. As well there is variety in the number of industry classes used, types of aggregation procedures used, and in the inclusion of time series of information.[22] [23]

[21] GTAP (2012), EXIOPOL/CREEA (2012), WIOD (2012), EORA (2012), GRAM (2012) and GLIO (2012). A number of review articles have also been written see for example Wiedmann et al. 2007; Wiedmann 2009; Wiedmann et al. 2011). A special issue of *Economic Systems Research* (Volume 25, Issue 1) and a book (Murray and Lenzen, forthcoming) provide additional detail on MRIO.

[22] There are also datasets that cover only trade between two countries (Bilateral Trade Input-Output BTIO tables) and associated input-output models such as Emissions Embodied in Bilateral Trade (EEBT). With developments in data availability and computing power a focus on bilateral datasets and models is becoming less frequent. A comparison of different approaches can be found in Peters & Solli (2010).

[23] In general MRIO are compiled using data on international trade flows between countries and production relationships for individual products are modelled into each relevant country. An alternative approach is to directly survey the production processes associated with international flows of products at an industry level. Such datasets, generally referred to as Inter-Regional Input-Output (IRIO) tables are challenging to compile given the high data requirements.

3.19 Table 3.3 shows a simplified structure for an MRIO table in which there is a country A and country B.[24] The accounting structure follows that of the SRIO: 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 subscripts indicate the region of the variable. If there are two subscripts the first indicates the source and the second the destination. E.g. $c_{AB}$ is the output of country A that is used as final consumption in country B.

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

| | | Country A | Country B | Country A | | Country B | | Total 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 | $r_A$ | $r_B$ | | | | | |

3.20 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 then makes it possible to analyse both environmental and other sustainability issues. A number of these applications are discussed in section 3.3.3.

3.21 At the same time, the integration of input-output data across countries generally reduces the level of industry detail that can be analysed and generally requires adjustment to individual national IOT to, among other matters, ensure harmonisation of trade data and account for currency conversion. These and other measurement issues are described in the following sub-section.

[24] All MRIO aim to include economic activity for all countries. In practice, there is usually a small residual reflecting a "rest of the world" region that would generally account for less that 1% of world GDP. This "rest of the world" region has been omitted here for the purposes of exposition.

### 3.2.5 Measurement issues

3.22 Tables 3.1-3.3 provide simplified representations of the tables that may be used as underlying datasets for the application of 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.

3.23 *Differences in the SEEA and the 2008 SNA*. In the most recent revision of the system of national accounts (2008 SNA) 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 treatment 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 the treatment of certain flows.

3.24 *Utilisation of data on environmental flows*. Commonly information on environmental flows will not be strictly aligned to the measurement boundaries of the SEEA. Care should therefore be taken to appropriately record, with adjustment as necessary, entries for purchases abroad by tourists, re-exports and the general issue of recording data on a residence basis rather than on territory. (See SEEA Central Framework section 3.3 for details)

3.25 *Construction of MRIO tables*. A range of measurement issues arise in the construction of MRIO. First, an unavoidable consequence of the production of an MRIO is that it is unlikely to be consistent with the individual SRIO produced by national statistical offices. This is because SRIO are produced using data from that country only, whereas generally compilation of MRIO requires all countries' data to be amended to ensure an overall balance in the I-O tables. On a national level, the supply and use accounting identity is used to balance the production and consumption statistics.

3.26 A common area of adjustment relates to the existence of "trade asymmetries" i.e. the phenomenon that the trade statistics on the imports of country A from country B are not equal to the data about the exports 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.

3.27 Second, it is necessary to convert all SRIO based data into a common currency to permit aggregation and analysis of the resulting MRIO. Ideally, purchasing power parities (PPP) for different products and industries would be applied but such information is generally unavailable at the required level of detail. The use of aggregate PPP information or exchange rates is likely to affect the quality of the resulting MRIO.

3.28 Third, compilation of MRIO requires the use of a single reference year at which all cross-country relationships are compared. However, most countries do not compile their input-output tables on an annual basis and hence it is likely to be necessary to adjust available data to a common reference year using assumptions concerning the links between industry and product structures and broad measures of economic activity.

3.29 Given these compilation issues it is reasonable to consider whether the benefits of adopting an MRIO approach, most notably the capacity to remove the domestic technology assumption, are sufficiently large. Decisions to opt for an MRIO or SRIO approach may, for example, depend on the extent of differences in production processes between trading partners, or between their environmental and resource use profiles. The greater the differences the greater the error in treating trading partners as though they have the production processes and technologies.

3.30 Another factor to be considered in making the choice is that the significance of the compilation issues in terms of quality of the estimates can be assessed in terms of stochastic errors on the estimates, whereas the use of the domestic technology assumption using an SRIO may introduce systematic errors to subsequent analysis.[25]

3.31 It is noted that for some purposes it may be reasonable to construct multi-region input-output databases by holding some country information constant rather than allowing all countries' data to vary in the modelling process.

## 3.3 Techniques for the analysis of input-output data

### 3.3.1 Introduction

3.32 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.

3.33 The first extensions of input-output tables and modelling 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 and 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.

3.34 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

[25] For example, see Lenzen et al (2013) "Building Eora: A global multi-region input-output database at high country and sector resolution", *Economic Systems Research*, 25, 20-49. See also Lenzen, Pade & Munksgaard (2004) for an analysis of aggregation errors in an MRIO for Scandinavia.

instead explains a basic environmentally-extended input-output model to give a sense of the type of analysis that is possible.

3.35 Equation 3.1 shows an input-output model based on a single region EE-IOT. The model estimates the total environmental pressure ($r_{tot}$) (e.g. emissions) as a function of the intensity of the environmental pressure in each industry ($\delta$), the domestic output of each industry ($L_d$) and the various sources of final demand ($y_d$) including household consumption, capital formation and exports.

$$r_{tot} = n \cdot L_d \cdot y_d \tag{3.1}$$

where

$$\boldsymbol{n} = \boldsymbol{r} \cdot \hat{\boldsymbol{q}}^{-1}$$

$$L_d = (I - A_d)^{-1} = (I - (Z_d \cdot \hat{q}^{-1})^{-1}$$

$$\boldsymbol{y}_d = \boldsymbol{c}_d + \boldsymbol{f}_d + \boldsymbol{e}_d$$

Definition of variables (see also Table 3.1)

| | |
|---|---|
| $r_{tot}$ | Total environmental pressure (scalar) |
| $\delta$ | Intensity of environmental pressure (vector *1* by *j*) |
| $L_d$ | Leontief inverse of use of domestic output (matrix *j* by *j*) |
| $y_d$ | Final demand of domestic output (vector of *j* by *1*) |
| $r$ | Environmental pressure per industry (vector of *1* by *j*) |
| $q$ | Output per industry (vector of *1* by *j*) |
| $I$ | Identity matrix (matrix of zeros with values of 1 on the diagonal) |
| $A_d$ | Technical coefficients of use of domestic output (matrix *j* by *j*) |
| $Z_d$ | Intermediate use of domestic output (matrix *j* by *j*) |
| $c_d$ | Final consumption expenditures (vector *j* by *1*) |
| $f_d$ | Gross capital formation (vector *j* by *1*) |
| $e_d$ | 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.

3.36 The mathematical derivation of the Leontief inverse, which is the core concept in the input-output model, is described in Annex II. 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.

3.37 A number of analytical techniques based on this 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).

3.38 Input-output models 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 input-output models, also exist.

3.39 The input-output model has a number of advantages, but it is also criticised for the assumptions that underlie the model, especially when used for scenario or future modelling. The most notable of these is the assumption of perfectly elastic supply (i.e. of inputs of labour, capital and materials). Another issue is that substitution between inputs is not possible. Computable general equilibrium (CGE) models, which use less restrictive assumptions while still being based on EE-IOT, are therefore an important analytical technique. CGE models are discussed in section 3.3.5.

### 3.3.2 Multiplier analysis

3.40 Multipliers provide a summary of input-output 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 flows (see Östblom, 1998; Lenzen 2001, Lenzen et al., 2004; Rueda-Cantuche and Amores, 2010). The most commonly used environmental flows relate to energy and carbon dioxide. Other environmental flows 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).

3.41 The basic formulation of the environmental multiplier (sometimes referred to as eco-efficiencies) is provided in the following equation. The derivation of the multipliers ($\alpha$) involves multiplying the intensity of the environmental flow for each industry ($\delta$) by the structure of output by industry ($L$).

$$\alpha = \delta \cdot L \tag{3.2}$$

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

$\alpha$ – multipliers (vector *1* by *j*)

3.42 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. At the same time, interpretation of multipliers should take into account the validity of the assumptions underlying the input-output model, most notably, as described above, the assumption of perfectly elastic supply of inputs, i.e. that there are no resource constraints.

3.43 The practical challenge of aligning environmental data with the input-output categories may be remediated by use of a supply and use table (SUT) framework and undertaking multiplier analysis in there, rather than converting to IO tables. Since SUT often have many more products than industries, 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 procedure. This more recently developed 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). The appropriateness of an SUT approach is likely to depend on the availability of data, the relative ease with which data on the relevant environmental flows can be attributed to products and industries, and the strength of any required assumptions.

3.44 A wide variety of multipliers covering different environmental themes have been compiled. The range includes multipliers relating to energy, emissions, land, water, biodiversity, pollutants, phosphorous, nitrogen, and the environmental goods and services sector.

### 3.3.3 Attribution of environmental flows to final demand

3.45 Input-output analysis is regularly used to attribute environmental flows 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' or 'pressure points' that may be subject for policy attention.

3.46 There are three research topics which are regularly tackled in the literature using this technique: footprints, consumption versus 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. It is noted that analysis for each of these three topics is based on the same input-output approach and hence the analyses present complementary rather than competing perspectives.

3.47 It is possible to undertake analysis concerning the links to final demand by using Life Cycle Analysis (LCA). Under LCA based approaches the "life cycles" for particular consumption items are traced through their production processes (creating supply or value chains) and then the links to the use of various materials or emissions can be determined. The difference in using an LCA approach rather than an input-output based approach is that the fully integrated industry and product information inherent in an IOT is not utilised and consequently the full effects may not be captured.[26] At the same time LCA approaches may be able to provide a more detailed "bottom-up" type of assessment in contrast to the broader level or "top-down" perspective inherent in I-O approaches. Thus there are hybrid LCA approaches that utilise EE-IOT data together with specific data on certain production processes. The combination of physical and monetary relationships present in these hybrid datasets can be used to conduct process analysis and structural path analysis.

[26] These are referred to as truncation errors.

*Footprint calculations*

3.48 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 used an LCA based approach rather than input-output techniques for its calculation.

3.49 From an input-output perspective the analysis of links between environmental flows and final demand is relatively long-standing. Over the last decade or so, a variety of footprints have been derived using input-output techniques, especially from MRIO models.[27] Examples include carbon footprints, land footprints, water footprints and ecosystems pressure footprints.[28] As noted in Chapter 2, footprints may also be derived using LCA based datasets and these should be considered a distinct, albeit related, family of footprint indicators. Although the methodologies are currently quite varied, there are efforts to harmonize their calculation (Galli et al, 2011, Weinzettel et al., 2011).

3.50 Footprints derived based on data in the SEEA Central Framework will be limited to a focus on environmental flows that are separable, such as flows of water or carbon. The derivation of ecological and ecosystem pressure type footprints requires consideration of more systemic changes in environmental and ecosystem condition. Potential approaches to the measurement of such changes is presented in SEEA Experimental Ecosystem Accounting.

*Production versus consumption perspective*

3.51 Footprint indicators make explicit the environmental pressures that are driven by consumer behaviour. However, their calculation may also be used to highlight the "production versus consumption perspective" (see Peters, 2008; Peters and Hertwich, 2008; Barrett and Scott, 2012).

3.52 Underlying this discussion are the questions: which environmental pressures is a country responsible for, and in the polluter-pays-principle who is the polluter? On the one hand, the polluter may be the industries (or producers). This view 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. (It should be noted that this view of production is based on the territory principle of attributing economic activity whereas in the SNA and the SEEA production is attributed to countries on the

[27] 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).

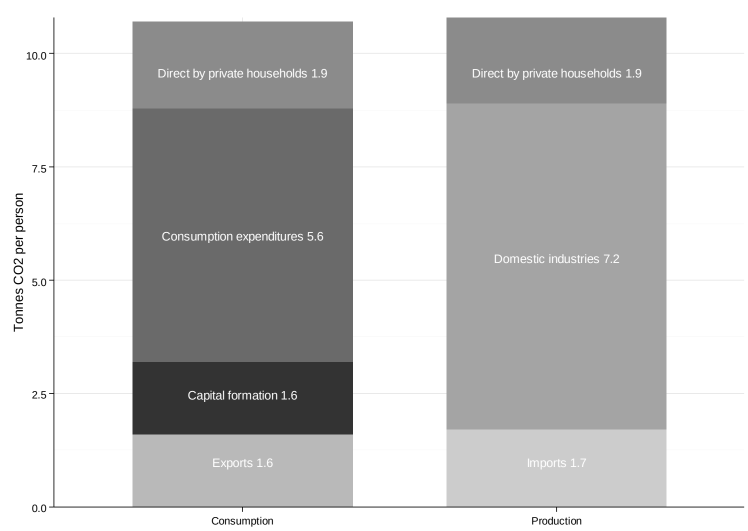
[28] Several national statistical offices and institutes such as the OECD and Eurostat have also explored the calculations of footprints (Eurostat, 2006; Lenglart, 2010; DESTATIS, 2012; Statistics Netherlands, 2013; Nijdam et al., 2005; Wilting and Vringer, 2009; DEFRA, 2013; Ahmad and Wyckoff, 2003; Nakano et al, 2009.

basis of the residence of the producing units. There is likely to be significant overlap in these attribution methods but there are notable differences, for example in relation to international transport. SEEA Central Framework section 3.3 provides more details.)

3.53 On the other hand, the consumption perspective is based on the premise that the ultimate "polluter" is the consumer of the end product. The consumption perspective is captured by calculating environmental footprints that include all environmental pressures attributable to consumption by residents of a country whether they are generated by producing units located abroad or in the reference country.

3.54 Figure 3.1 gives an example of an analysis of production and consumption perspectives for the 27 countries of the European Union, showing the carbon dioxide emissions per capita in 2006 from both a consumption and a production perspective (Eurostat, 2011). The starting point for this analysis is the total emissions related to final use or demand including demand from the rest of the world. The consumption perspective attributes these emissions to exports, capital formation, and consumption (both in expenditures and in terms of transport and heating activity undertaken by households). The production perspective attributes the same emissions but with a focus on those industries and activities that supply the relevant goods and services. It can be seen 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. Further, it is apparent that there is a relative balance in the import and export of emissions reflecting that the products that are imported include raw materials that generate few emissions in extraction whereas exports comprise finished products that embody a significant amount of emissions. Such insights are important in understanding which product-related and consumption-related policies may help to limit carbon emissions.

**Figure 3.1 Production and consumption based $CO_2$ emissions per capita**




*Global shifts in environmental pressures*

3.55 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" for specific environmental pressures such as carbon dioxide emissions. 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).

3.56 A lot of research has analysed these shifts in environmental pressures. Various hypotheses have been proposed. For example, estimates of "carbon leakage" have been made in 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 and Matthews, 2008; Peters and Hertwich, 2006 & 2008; Babiker, 2005).[29] 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).

*Mathematical attribution of environmental pressures to final demand*

3.57 Environmental pressures can be attributed to final demand categories in the way that is shown in Equation 3.3. In this model, which uses SRIO data, environmental pressures are attributed to final consumption, gross capital formation and exports of domestic output. It can be seen that the second row of equation 3.3 is an expansion of equation 3.1 where the variable for final demand $y_d$, is separated into its constituent parts – consumption ($c_d$), capital formation ($f_d$) and exports ($e_d$).

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

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

| | |
|---|---|
| $\Phi_d$ | Environmental pressures attributed to final demand of domestic output |
| $\Phi_d^c$ | Environmental pressures attributed to final consumption expenditures of domestic output |
| $\Phi_d^f$ | Environmental pressures attributed to gross capital formation of domestic output |
| $\Phi_d^e$ | Environmental pressures attributed to exports of domestic output |

3.58 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

[29] Estimates of "carbon leakage" depend in part on the choice of model used to analyse the environmental pressure. In general the use of input-output models will generate higher estimates of carbon leakage than the use of CGE models since the latter takes into account adjustments in production and consumption patterns that arise due to changing relative prices and other substitution effects.

possible, and taking into account the measurement challenges outlined in section 3.2.5, it is likely to be therefore appropriate 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.

3.59 The formula for country A is provided in equation 3.4. It uses the variables of table 3.3 for countries A and B to reflect the multi-regional dimension to the model, and follows the general structure of the expression for multipliers shown in equation 3.3.

$$\Phi_A = \Phi_A^c + \Phi_A^f + \Phi_A^e$$
$$\Phi_A = \begin{pmatrix} n_A & n_B \end{pmatrix} \begin{pmatrix} L_{AA} & L_{AB} \\ L_{BA} & L_{BB} \end{pmatrix} \cdot \begin{pmatrix} c_{AA} \\ c_{BA} \end{pmatrix} + \begin{pmatrix} n_A & n_B \end{pmatrix} \begin{pmatrix} L_{AA} & L_{AB} \\ L_{BA} & L_{BB} \end{pmatrix} \cdot \begin{pmatrix} f_{AA} \\ f_{BA} \end{pmatrix}$$
$$+ \begin{pmatrix} n_A & n_B \end{pmatrix} \begin{pmatrix} L_{AA} & L_{AB} \\ L_{BA} & L_{BB} \end{pmatrix} \cdot \begin{pmatrix} e_{AA} \\ e_{BA} \end{pmatrix} \quad (3.4)$$

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

| | |
|---|---|
| $\Phi_A$ | Environmental pressures attributed to final demand of country A |
| $\Phi_A^c$ | Environmental pressures attributed to final consumption expenditures of country A |
| $\Phi_A^f$ | Environmental pressures attributed to gross capital formation of country A |
| $\Phi_A^e$ | Environmental pressures attributed to exports of country A |

### 3.3.4 Decomposition analysis

3.60 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 estimated separately. Examples of decomposition analysis are presented in section 2.3.3.

3.61 The driving forces that 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).[30] The simplest specification, based on the SRIO model shown in equation 3.1, is provided in equation 3.5.

$$\Delta r_{tot} = \Delta\delta \cdot L_d \cdot y_d + \delta \cdot \Delta L_d \cdot y_d + \delta \cdot L_d \cdot \Delta y_d \quad (3.5)$$

3.62 In this equation, the changes in environmental pressures ($\Delta r_{tot}$) 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

[30] For overviews see 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.

economy ($n \cdot \Delta L_d \cdot y_d$) and the changes in final demand/economic growth ($n \cdot L_d \cdot \Delta y_d$).[31] 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 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.

3.63 To undertake an SDA it is necessary to have data that permits analysis in volume terms, i.e. through the removal of price effects. This may be done by using input-output data in the current prices of a given reference year and in prices of a base year (constant prices). Given that the decomposition is done using discrete data for a year *t* and *t-1* each variable in equation 3.5 has to be weighted using a relative importance of the variable at time t and t-1. There are many ways in which this weighting can be undertaken and this explains the lack of a time notation in the equation. In the SDA literature most recent studies use the weighting method proposed by Dietzenbacher and Los (1998) which lead to equivalent results as Sun (1998).[32] In the related field of index decomposition analysis other weighting methods are used.

3.64 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).

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

$$\Delta r_{tot} = \Delta n \cdot s \cdot q_{tot} + n \cdot \Delta s \cdot q_{tot} + n \cdot s \cdot \Delta q_{tot} \quad (3.6)$$

Where $s$ ($q/q_{tot}$) equal to the sector structure and $q_{tot}$ is equal to the changes in the total output.

3.66 As for the decomposition shown in equation 3.5 this model still decomposes the change in environmental pressure into the effects of changes in intensity, changes in industry structure and changes in economic activity. However, this model only requires data on the output by industry and not an entire input-output table – hence, compared to equation 3.5 the matrix *L* is replaced with the sector structure, *s*. Note also that here the focus is on decomposing total output, *q*, rather than final demand *y*. An IDA approach still requires data from environmental flows by industry from the accounts of the SEEA Central Framework.

[31] Note that the model is slightly different from the ones of section 3.3.2 and 3.3.3 in that the Leontief inverse and final demand only include the domestically produced goods and services (denoted by subscript *d*). This is because SDA is usually applied to explain changes in domestic emissions (which are only generated by the demand for domestic products). Also use of the model which includes imported intermediate inputs has been criticised in a related input-output technique called "impact analysis" (Dietzenbacher and Los, 1998).

[32] 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

3.67 Note that in equations 3.5 and 3.6 no residual term is included and hence these decompositions should not be considered to be exact. In effect exogenous and mixed effects are not separately analysed and are distributed across the components that are included in the model.

### 3.3.5 Computable general equilibrium modelling

3.68 Computable general equilibrium (CGE) models are a class of economic models that combine input-output data with micro-economic theory. 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. The connection to the SEEA Central Framework lies in the use of data on environmental flows in the compilation of EE-IOT that in turn underpin CGE models.

3.69 CGE models consist of a system of non-linear demand, supply and market equilibrium equations. The main model equations are based on neo-classical economic principles. Each industry in a CGE model selects inputs of labour, capital and materials to minimise costs of production. Demand within a CGE model reflects prices and incomes. Market clearing equations ensure that supply for each good or service produced equals demand and industry investment reflects rates of return on capital. Finally it is assumed that there are markets for all possible goods and services and that there are no externalities.

3.70 The key distinction between analysis using CGE models and analysis using input-output models as described in the previous sections, is that CGE models allow resource constraints to be taken into account. In addition, depending on the type of CGE model used various short run and long run assumptions may be used concerning constraints on capital and labour. CGE models also allow for price induced substitutions and do not require the assumption of fixed production technologies.

3.71 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, in the case of the introduction of a tax on carbon emissions, there will be substitution away from relatively carbon-intensive inputs, and CGE models can assist in understanding these dynamics. Overall, while input-output models 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.

3.72 The incorporation of physical data within CGE models requires the addition of equations that link environmental quantities to economic quantities. This may be particularly relevant in cases where the monetary value of flows, for example water, does not bear a close relationship to the underlying physical flows. Further, for some environmental flows, such as emissions and waste, relationships in monetary terms to industry activity measures may not be present.

3.73 EE-IOT databases are used in order to calibrate the main parameters of CGE models such that in the initial reference year the model reproduces the EE-IOT data. Overall, the core structure of CGE models is quite similar to the structure of EE-IOT. However, 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. Inclusion of these additional elements and parameters depends on the purpose of the particular CGE models and varies significantly between the existing models.

3.74 Building Computable General Equilibrium (CGE) models 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 ORANI model (see Dixon, et al., 1982)
- the MONASH model (see Dixon and Rimmer, 2002)
- the GTAP model (built around the GTAP database adapting the ORANI model to a multi-country application) (see Hertel, 2012)
- the OECD Env-linkages model, used for the OECD Environmental Outlook to 2050 (see Burniaux and Chateau, 2010)
- GEM-E3 model used by DG ENV and DG ENERGY (see Capros et. al., 2013)
- WorldScan model used by DG ENV and DG TRADE (see Lejour et. al, 2006)
- EPPA model of MIT (see Babiker et. Al., 2008)

# Chapter IV: 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 do not provide a complete information set but can provide an important part of the information and SEEA is a framework that supports and encourages the 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 linking to specific spatial areas, 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 Following the first approach to extending the SEEA, Section 4.2 provides an introduction to the potential for spatially disaggregating SEEA based data to provide information sets that are more amenable to the consideration of specific issues. Approaches to generating spatially disaggregated information have advanced significantly in recent years with the increasing adoption of geo-spatial information systems (GIS) in many areas and the increasing capability to organise and analyse large datasets.

4.5 Section 4.3 provides a description of extensions to the SEEA concerning households and household activity. The importance of this extension reflects both the focus on the industry dimension in the earlier chapters (whereas households are often considered as simply one single vector), 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.

4.6 The final extension described in this chapter involves re-organisation (and disaggregation) of existing industry and product information to focus on particular themes. The example highlighted concerns tourism activity but the same type of approach may be applied in the analysis of other cross cutting activities and specific themes such as transport, forest products and food industries. This type of extension is in Section 4.4.

4.7 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 Spatial disaggregation of SEEA data

4.8 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.

4.9 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 often hide important local variations. In short, knowing the locations can help to better identify environmental pressure points.

4.10 In some cases, the basic source data may be collected and compiled so that the location is accurately known (e.g. using geographic coordinates) or in reference to relatively detailed administrative areas. Often however, there will remain a requirement to integrate data that has been compiled at different spatial scales through aggregation and disaggregation as appropriate. In this regard, the structured framework of the SEEA provides a strong basis for the harmonisation of data at desired levels of detail.

4.11 Increasingly it is possible to use mapping and information technologies (i.e. 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.

4.12 A particular challenge in geo-spatial analysis is combining information from various sources according to a common geographical classification.[33] 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.

4.13 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.

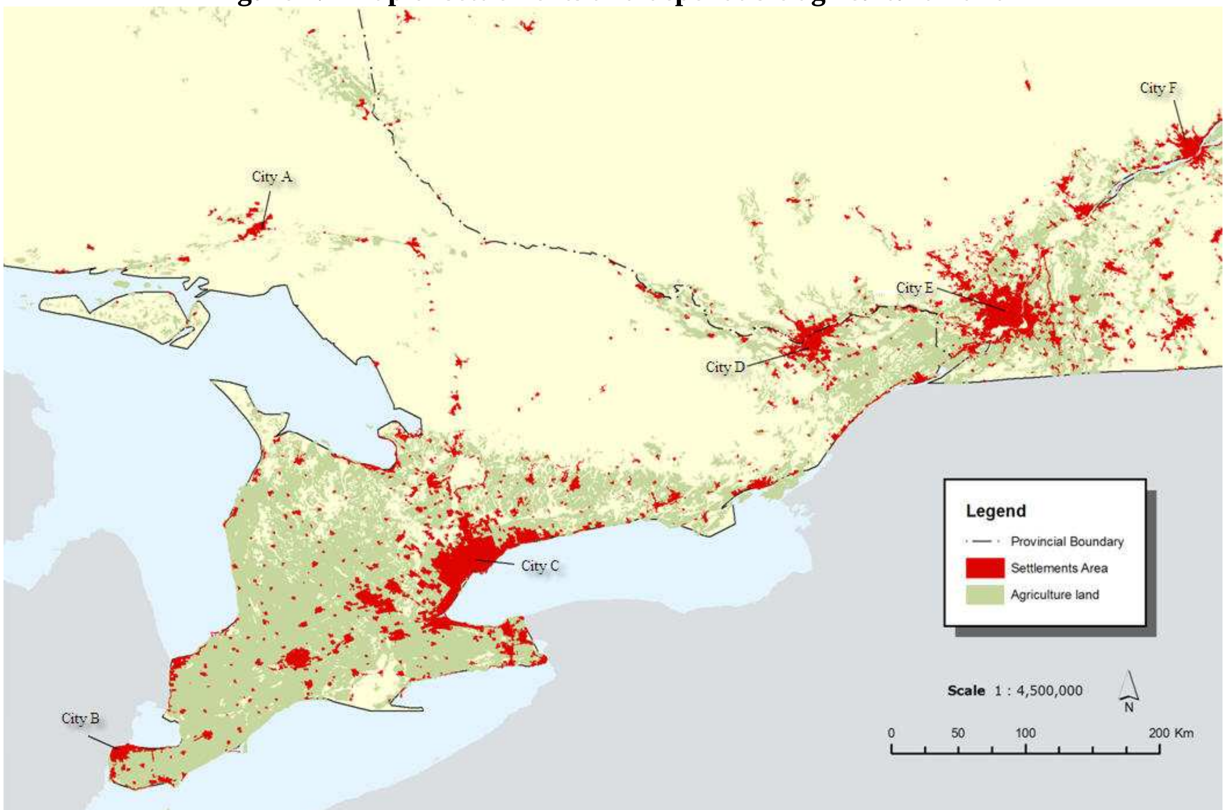
4.14 To point to the potential of geo-spatial analysis and the use of SEEA data, two examples are provided. These examples work within the general framework provided by land accounts as described in the SEEA Central Framework. The SEEA land accounts show measures of stocks and changes of stocks of land 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.

4.15 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.

4.16 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 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 4.1 shows some results for settlements in relation to dependable agricultural land (i.e. land free of severe constraints to crop production).

[33] 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. In particular, SEEA Experimental Ecosystem Accounting describes a units model for spatial areas involving basic spatial units, land cover/ecosystem functional units and ecosystem accounting units, and such a units model may be relevant in the development of a whole range of extensions of the type described in this chapter.

**Figure 4.1 Map of settlements and dependable agricultural land**

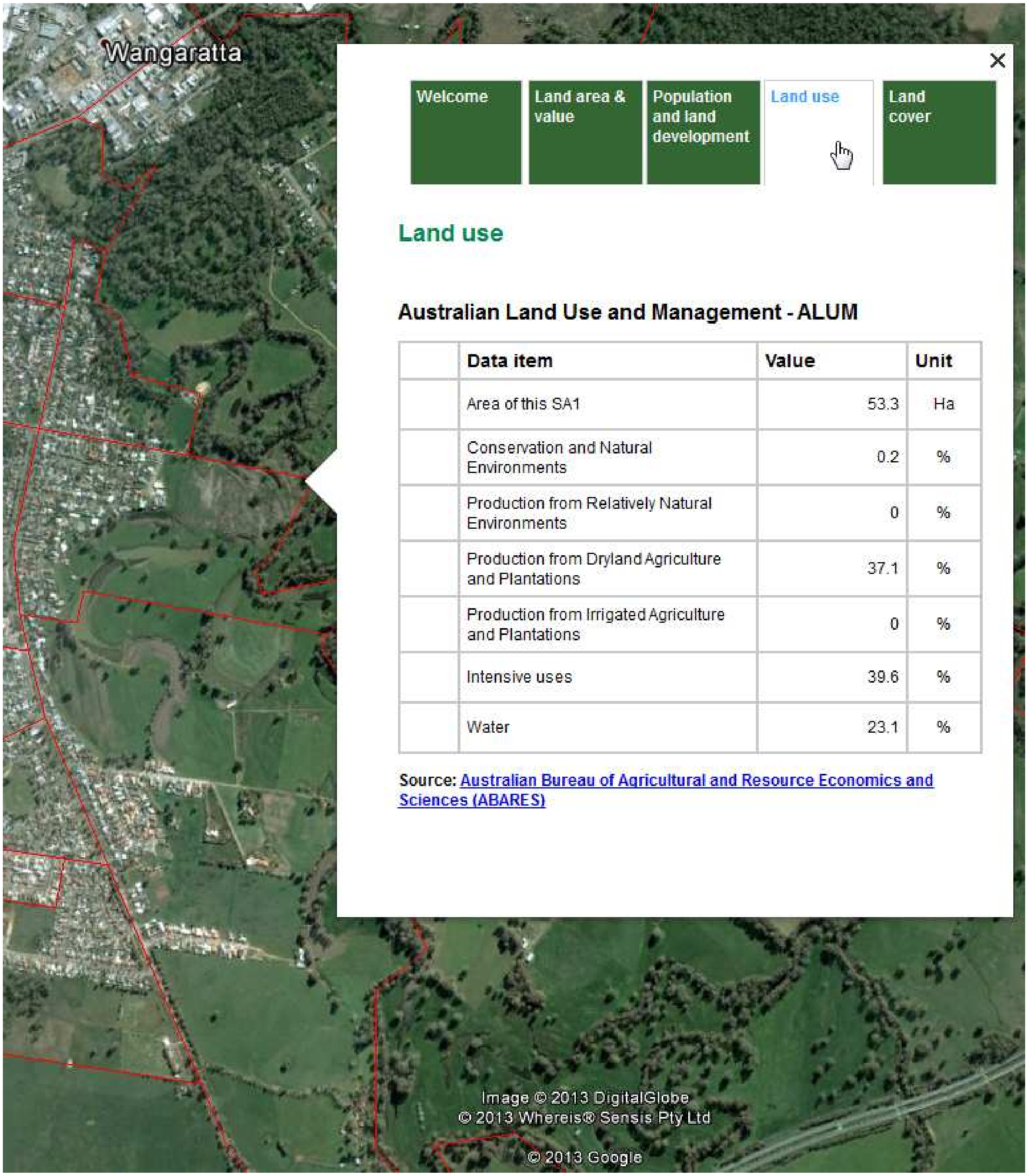



4.17 The second example concerns the integration of environmental and economic information over a large coastal area. As a result of carefully defining the spatial areas, and through attribution of various data sources to the spatial areas; a rich dataset was constructed. The types of information included 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[34]. Figure 4.2 shows a map to which a selection of data have been overlaid for each spatially defined area.

4.18 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.

[34] Australian Bureau of Statistics (2012), Land Account: Victoria, Experimental Estimates, 2012; and Australian Bureau of Statistics (2011), Land Account: Great Barrier Reef Region, Experimental Estimates

**Figure 4.2 Map of Statistical Area, Level 1**



## 4.3 Extensions of SEEA to the household sector

### 4.3.1 Introduction

4.19 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.

4.20 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.

4.21 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.

4.22 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 SEEA Experimental Ecosystem Accounting.

4.23 Some examples of key social indicators are already included in the SEEA-Water Chapter 7 and SEEA-Energy Chapter 7, 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.

### 4.3.2 Household access to natural resources

4.24 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.

4.25 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.

4.26 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.

4.27 The types of breakdown that are applied will depend on the analytical interest and data availability. There may be interest in decomposing information on household consumption of energy and water use by purpose, i.e. differentiating energy used for heating, cooking, transportation or water used for washing, cooking, bathing, etc. Alternatively, there may be interest in decompositions that aid in the study of equality and development. In this case data that differentiates urban and regional areas, special population groups (e.g., the elderly, families with young children, specific ethnic groups) or household consumption and activity by income decile or quintile, may be relevant.

4.28 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.

4.29 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.

4.30 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.

4.31 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.

4.32 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<br>✓the poor often have no entitlements to environmental resources and inadequate access to environmental information, markets and decision-making<br>✓lack of energy services limits productive opportunities for the poorest<br>✓ improvement in the management of natural resources will improve livelihoods for rural households whose incomes are largely dependent on these resources<br>✓ improved access to clean water and basic sanitation will help to reduce malnutrition |
| 2. Achieve universal primary education | ✓time spent collecting water and fuel wood can reduce time available for schooling<br>✓lack of energy, water and sanitation discourage teachers to live in rural areas<br>✓ a lack of water, sanitation and hygiene is a major cause of malnutrition which in turn lowers educational attainment |
| 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<br>✓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<br>✓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<br>✓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)<br>✓external debt, unfair terms of trade and predatory investment can increase pressure to overexploit<br>✓environmental assets in developing countries |

Source: From Table 3, UNDP and UNEP (2008) Poverty and Environment Indicators. Based on DFID et al (2002). http://unpeilac.org/documentos/Poverty_&_Environment_Indicators-eng.pdf

### 4.3.3 Linking household activity and environmental pressures

4.33 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. It should be recognised that there are likely to be considerable data challenges involved in establishing these types of data sets and the quality of the analysis will be dependent upon the quality of the data set that can be formed.

4.34 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.

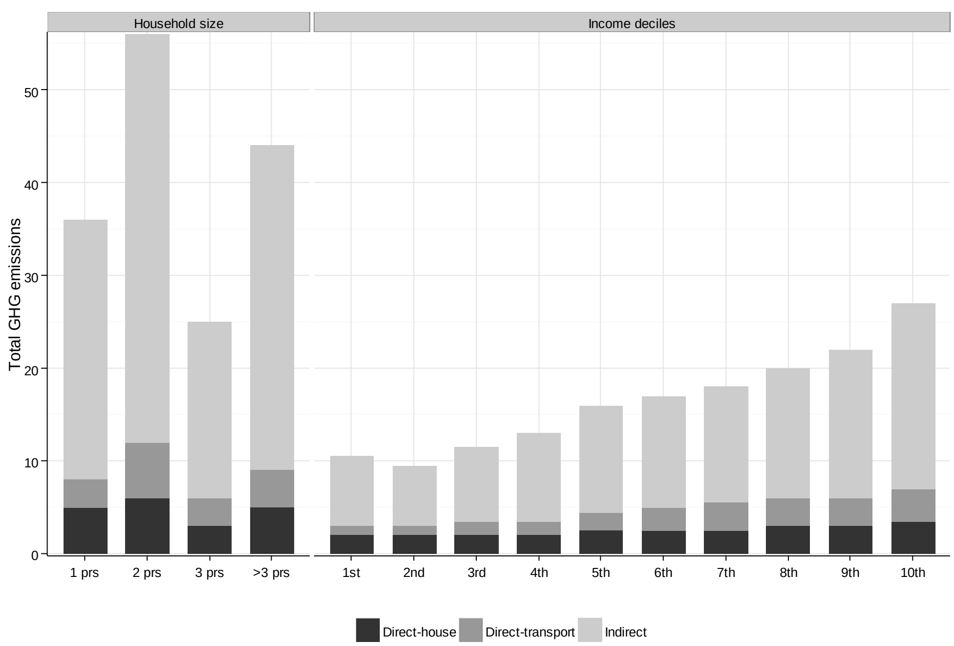
4.35 Using the connection between the SEEA and the SNA it is then possible to relate the physical measures of residuals flowing from households to estimates of consumption and income in monetary terms. The connection to income is particularly relevant if information is to be structured using income by decile or quintile. For this purpose data from household surveys or other data sources (e.g. administrative sources for housing construction, energy efficient 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.

4.36 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.

4.37 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.

4.38 Figure 4.3 gives an 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 4.3 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 4.3 GHG emissions by household characteristics of size (persons) and income (deciles)**




4.39 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 |

## 4.4 Extensions to present environmental-economic accounts data by theme

### 4.4.1 Introduction

4.40 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).

4.41 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.

4.42 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).

### 4.4.2 Presentation of environmental-economic accounts data for tourism

*Introduction*

4.43 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.

4.44 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.

4.45 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.

4.46 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.

4.47 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*

4.48 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 measures of tourism activity (e.g. value added, output, consumption), 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.

4.49 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.

4.50 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[35]. 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.

4.51 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. Important connections may also be possible by linking measures of tourism activity to measures of ecosystem condition and extent. For example, activity to improve the attractiveness of an area to tourists may lead to improvements in ecosystem condition. Alternatively, increasing tourism activity may increase environmental pressures and reduce ecosystem condition. Measures of ecosystem condition and extent are not well developed. Initial efforts in this area are summarised in SEEA Experimental Ecosystem Accounting.

4.52 In line with the International Recommendations for Tourism Statistics, 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.

[35] "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).

4.53 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.[36]

4.54 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.

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

4.56 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 proposed framework 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.

4.57 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.

4.58 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.

4.59 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.

[36] Note that the International Recommendations for Tourism Statistics also contains a set of internationally comparable tourism products that forms a core list for the purposes of international comparisons of data within tourism satellite accounts.

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

| | | Tourism Satellite Account (TSA) – Monetary units | | | | | Environmental accounts (SEEA) Physical units | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 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 a percentage 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 I: Derivation of examples and links to the SEEA Central Framework

## Background

1. This annex provides an explanation of each of the examples presented through chapters 2, 3 and 4. The explanation includes a description of the data series used, relevant methods, and the connection to the tables and accounts in the SEEA Central Framework. The data used are generally based on work undertaken in the specific analytical topics at a country level, however, for the purposes of SEEA Applications and Extensions, the examples have been stylised to provide an indication of the potential outputs and analysis since the intent is not to describe research pertaining to individual countries.

2. At the same time, it is recognised that readers may be interested in understanding further the specific research projects at a country level. To this end SEEA Applications and Extensions provides references to individual country level projects as part of the structured list of references. In addition, the United Nations Statistics Division maintains an on-line Knowledge Library with up-to-date references to a wide range of country studies, reports by international agencies, and other material on environmental-economic accounting.

3. Interested users are also encouraged to consider the practical work on environmental-economic accounting that has been presented to, and discussed by the London Group of Expert on Environmental-Economic Accounting since its first meeting in 1994. Papers and other relevant material can be found via the London Group website.

## Explanation of examples

*a. Industry level water use intensity indicators (Figure 2.3)*

4. The preparation of this figure involved use of information on the intermediate consumption of water distributed by ISIC Class 36 and used by detailed industry class and estimates of gross value added for the same industries. The figure presents a comparison of the ratio of the litres of water to the value of gross value added in monetary terms (litres per value added in currency units) at two different points in time.

5. In broad terms this information may be considered to emerge from a table similar to that presented in the SEEA Central Framework Table 6.6 “Combined presentation for water data”, noting that the industry classes shown in that table would need to be more detailed to provide the information of the type shown in Figure 2.3.

6. Information to form estimates of water use by industry should be sourced from a physical supply and use table for water as shown in the SEEA Central Framework Table 3.6. The data in Figure 2.3 relate to the intermediate consumption of distributed water by industries. Alternative measurement scopes for the general concept of water use may also be used (also sourced from SEEA Central Framework Table 3.6) depending on data availability and the analytical requirements. The SEEA Central

Framework defines some alternative indicators that may be used (see paragraphs 3.219-223). Data on value added by industry should be sourced from the national accounts.

*b. Decomposition of changes in $CO_2$ emissions (Figure 2.4)*

7. The preparation of this figure required time series information on (i) the generation of carbon dioxide emissions by industries (i.e. non-household $CO_2$ emissions), (ii) changes in household consumption, and (iii) the various factors driving changes in emissions by industry. Estimates of emissions by industry may be organized following the “Air emissions account” (SEEA Central Framework, Table 3.7). Measures of household consumption should be sourced from the national accounts. Indicators of drivers of changes in emissions are based on information on (i) the location of production by product type from international trade data reflected in input-output tables; (ii) the product composition of consumption reflected in input-output tables; (iii) changes in the composition of industries as reflected in input-output tables; and (iv) carbon dioxide emissions by industry by type of fuel used and by non-fuel sources of emissions that may be reflected as an extension to SEEA Central Framework Table 3.7.

8. The top line in the figure reflects an estimate of the time series of carbon dioxide emissions that would have occurred if there had been no changes in the pattern of consumption over the time period. This estimate is obtained by determining the ratio of emissions to total consumption in period 1 and multiplying this ratio by subsequent estimates of consumption to form a time series of projected carbon dioxide emissions.

9. With this alternative scenario estimated then, using the data noted above, it is possible to apply decomposition techniques (see Chapter 3) to assess the differing impacts of “reduced energy intensity”, “switches to low carbon fuels”, “relocation of production” and “switch to services”.

10. The decomposition in this example was based on analysis using a Multi-Regional Input-Output (MRIO) table and hence is considered a structural decomposition analysis. Similar types of analysis may be undertaken using index decomposition analysis.

*c. Decomposition analysis for CO2 emissions by households from stationary sources (Figure 2.5)*

11. The preparation of this figure required information on (i) the generation of CO2 emissions by households from stationary sources (i.e. excluding emissions related to transportation activity) – compiled consistently with the “Air emissions account” (SEEA Central Framework, Table 3.7); (ii) demographic information on the number and size of households (i.e. number of people in a household), likely to be obtained from a population census or similar data source; (iii) energy use by households by purpose (compiled consistently with the “Physical supply and use table for energy” (SEEA Central Framework, Table 3.5)); and (iii) changing external temperatures (from national meteorological agencies) which will influence the extent to which heating and air-conditioning is required by households to regulate internal temperatures.

12. Using index decomposition analysis techniques (see sect. 3.3) the different contributions of each of these factors can be determined.

*d. Analysis of imports and exports in physical and monetary terms (Figure 2.6)*

13. The preparation of this figure is based on international trade data on flows of imports and exports of goods between European countries and external to Europe in both physical terms (kilogrammes) and monetary terms (currency units) and adjusted to align with Balance of Payments and SNA measurement boundaries. A specific account for organizing information on trade flows is not shown in the SEEA Central Framework but, in general terms, the organization of this information reflects the consistency in structure between monetary supply and use tables and physical supply and use tables (SEEA Central Framework Tables 2.1 and 2.2).

14. The classification of goods used in the figure follows the highest level of aggregation used for material flow accounting but this classification can be aligned with the central product classification (CPC) which is the classification recommended for use in the SEEA Central Framework (see paragraph 3.72).

15. Consideration should be given to ensuring the alignment of the conceptual scope of data in physical and monetary terms based on the discussion in the SEEA Central Framework sect. 3.3.

*e. Food chain greenhouse gas emissions (Figure 2.7)*

16. The preparation of this figure requires information on greenhouse gas emissions by industry and by type of household consumption activity following the general structure of "Air emissions accounts" SEEA Central Framework Table 3.7. The level of detail required will depend on how precisely flows related to the production and consumption of food can be traced within an economy.

17. A food chain (i.e. an articulation of all economic activity involved in the production, distribution and consumption of food) is determined from analysis of standard national accounts based, input-output tables. Emissions from the relevant activities – sourced from the "Air emission accounts" (SEEA Central Framework Table 3.7) are summed to provide an estimate of total emissions of green house gases related to food. From the supply side, there is consideration of (i) the domestic production of food and a listing of the relevant industries and (ii) the importation of food. Emissions generated for each relevant industry and for imports are added and emissions related to food that is exported are deducted. The relevant industries on the supply side include the distribution of food via transport, retailers and restaurant and catering activities. On the demand side, the consumption of food requires activities such as shopping (including associated transport), cooking and storage (e.g. refrigeration), each of which will generate some greenhouse gas emissions (with emissions data also sourced from the Air Emissions Account). Measurement of the economic size of these activities is likely to require additional data through combining information on household final consumption expenditure by purposes (from the national accounts) with data from household surveys (e.g. time-use surveys) that measure food related activity (e.g. cooking).

18. The total emissions reflect the sum of the supply and the demand side emissions for each relevant activity. The proportions of the total for each activity can then be directly determined. In this example, both direct and embodied emissions for each supply and demand activity are included.

19. Relevant measurement considerations include determining the boundary of food production in reference to industry output (i.e. there might be non-food production by agricultural units), and determining the treatment of agricultural outputs used for non-food purposes (e.g. for bio-fuels).

*f. Carbon dioxide emissions and public sector expenditure (Figure 2.8)*

20. The preparation of this figure requires information on carbon dioxide emissions for various industries whose outputs are commonly purchased by public sector agencies. Similar to the articulation of the food chain (Figure 2.7), it is necessary to use relationships in standard national accounts input-output tables to identify those products that are purchased by public sector agencies and, from there, determine the industries which supply those products. The figure includes those industries where either the purchases by the public sector represent a significant proportion of total industry output (e.g., purchases of pharmaceuticals) or the purchases are a significant proportion of total public sector expenditure (e.g., construction). In this case the scope of the public sector is limited to general government agencies. The cross-tabulation of each relevant industry in terms of market share and level of public sector expenditure provides the centre point of each "dot" in figure 2.8.

21. Once the relevant set of industries has been selected, the relevant emissions information may be organized following the structure of the "Air emissions accounts" (SEEA Central Framework, Table 3.7). In this figure the scope of emissions is limited to those arising from the use of energy products and in this context it may be relevant to model the flows of emissions using data on the end use of energy products (particularly electricity) by industry from the PSUT for energy (SEEA Central Framework, Table 3.5). The larger the flow of emissions the larger the "dot" in figure 2.8.

*g. EGSS contributions to GDP and employment (Figure 2.9)*

22. This figure presents information that may be sourced from the "Environmental Goods and Services Sector" table in the SEEA Central Framework (Table 4.6). This table includes information on the gross value added, compensation of employees, exports, gross fixed capital formation and employment of various producers in the EGSS. Information on all of these variables can be compared to economy wide aggregates for the same variables sourced from standard national accounts tables and labour force survey data sets to provide ratios of the type shown in Figure 2.9.

23. The figure shows the gross value added (GVA) of the EGSS in basic prices to GDP. Strictly, the most appropriate comparison would be between EGSS GVA in basic prices to economy wide GVA in basic prices. The use of GDP reflects a choice to utilize a more commonly known indicator of economic size.

24. All types of EGSS producers are included in the figures, i.e. specialist, non-specialist and own-account producers.

*h. Environmental tax revenue by type (Figure 2.10)*

25. The preparation of information for this figure requires time series data on different categories of environmental taxes following the definition of environmental taxes (SEEA Central Framework para. 4.150). The categories of environmental taxes are energy taxes, transport taxes, pollution taxes and resource taxes (SEEA Central Framework para. 4.155). SEEA Central Framework Table 4.9 is an organization of this type of information for a single accounting period. Also in Figure 2.12 is a comparison of total environmental taxes to GDP.

*i. Energy taxes divided by energy consumption by sector (Figure 2.11)*

26. The preparation of this figure requires information on energy taxes paid by various economic activities and sectors – in this case energy taxes paid by industries (excluding taxes related to transport activity and excluding primary activities), energy taxes paid in relation to transport activity, energy taxes paid by households and energy taxes paid by primary activities (agriculture, forestry, fishing and mining). Data on energy taxes are not organized in this way in the SEEA Central Framework but the definition of an energy tax does follow the definition in the SEEA Central Framework, para. 4.155. Data to compile estimates of energy taxes by industry and activity may be available in detailed tax revenue statistics or may be modeled based on information on energy use by these activities and sectors combined with information on relevant tax rates.

27. This figure also requires information on energy consumption across all sources of energy measured in a common unit of measure such as joules or TOE, and classified by the relevant economic activities and sectors. An appropriately structured "Physical supply and use table for energy" (SEEA Central Framework Table 3.5) could provide such information.

28. The ratio of energy taxes to energy consumption provides an implicit tax rate for energy.

*j. Distribution of carbon dioxide tax revenues, emission rights, carbon dioxide emissions covered by the trading scheme and total carbon dioxide emissions by industry (Figure 2.12)*

29. The preparation of this figure requires a range of information from different sources pertaining to carbon dioxide emissions. The key to the figure is that all relevant information has been classified following the same industrial classification.

30. Carbon dioxide taxes relate to specific types of taxes within scope of the definition of environmental taxes (see SEEA Central Framework sect. 4.4.3). Carbon dioxide taxes include payments for tradable emission permits (of carbon dioxide) following the treatment summarized in the SEEA Central Framework paras. 4.185-4.187. Analysis of government finance statistics by type of tax is likely to be the best source of information on these flows.

31. Information on emission rights distributed and carbon dioxide emissions within the trading scheme may be structured along the lines of SEEA Central Framework Table 4.10 “Account for tradable emission permits”, using an industrial classification rather than an institutional sector classification. Information on total carbon dioxide emissions may be structured as per the “Air emissions account” (SEEA Central Framework Table 3.7).

*k. Asset lives for selected mineral and energy resources (Figure 2.13)*

32. The information in this figure may be sourced from the “Physical asset account for mineral and energy resources” (SEEA Central Framework, Table 5.8) compiled for the relevant resource types. Expected patterns of extraction and associated annual rates of extraction may be determined either on the basis of historical or recent average rates of extraction or based on discussion with relevant experts and taking into account a range of factors affecting rates of extraction (such as technology, output prices and discoveries). Asset lives for each resource type are then derived by dividing the closing stock of the resource by the expected extractions per year for that resource. (For more details on asset lives see SEEA Central Framework paras 5.137-5.140 and 5.210-5.213.)

*l. Production and consumption based carbon dioxide emissions per capita (Figure 3.1)*

33. The data that underlies this figure reflect a combination of data on carbon dioxide emissions classified by industry and sector (following standard structures of supply and use and input-output tables and following the “air emissions account, SEEA Central Framework Table 3.7); and economic data contained in supply and use and input-output tables. Together these data are used to form an environmentally extended input-output table (EE-IOT) following the descriptions in Chapter 3.

34. Using the data and relationships within the EE-IOT it is possible to estimate the carbon dioxide emissions that are (i) induced by the final use of products in EU countries; and (ii) embodied in the production of EU countries including their exports. Since the study covers the 27 countries of the EU it is also possible to determine the extent to which emissions are embodied in the imports of products traded within the EU.

*m. Geo-spatial analysis (Figures 4.1 & 4.2)*

35. The data in the maps shown in figures 4.1 and 4.2 are from a variety of sources including population censuses, agricultural and land use surveys, remote sensing imagery, and administrative data from government agencies (e.g. land planning authorities). It is then necessary to select a particular scale or region of analysis – figure 4.1 covers a large area of roughly 600km$^2$ while the area in figure 4.2 is 245 hectares. Using GIS methods the data are attributed to the relevant areas. There is a range of tools that are available for undertaking this step.

36. The particular challenge in developing figures such as these is aligning the desired information to a common scale that is appropriate for analysis of the different variables. The scale used is likely to vary depending on the available data and the analysis being undertaken.

*n. Greenhouse gas emissions by household characteristics and household expenditure (Figure 4.3)*

37. To develop the extension shown in this figure it is necessary in the first instance to have estimates of greenhouse gas emissions consistent with those in the “Air emissions account” (SEEA Central Framework Table 3.7). This should cover estimates of emissions embodied in products consumed by households (classified by the industries producing the products) and direct emissions of households in undertaking various activities, particularly heating/cooling and transportation.

38. In addition it is necessary to have detailed data on household characteristics, such as the number of people per household, the income per household, etc. Finally, it is necessary to have information on the types of expenditure and activities that are undertaken by different household types. Most commonly, these latter two pieces of information may be obtained from household budget or expenditure surveys.

39. For SEEA purposes it is necessary to integrate these data from household surveys with estimates of household expenditure from the national accounts such that a coherent and comprehensive perspective on household activity can be produced.

40. Using input-output table relationships and including assumptions regarding the emissions embodied in imports, it is possible to attribute emissions to the products consumed by different households. There are a number of ways in which this series of steps may be undertaken. (The relevant methods are summarized in Chapter 3). The key from a SEEA perspective is that there is an alignment made between the aggregate economy wide emissions and household expenditure measures and the detailed information on household characteristics and emissions for specific products.

*o. Flows from tourism-environment accounts (Table 4.4)*

41. The data in this table require information on emissions for the range of substances classified by industry following the general structure of the “Air emissions account” (SEEA Central Framework Table 3.7). However, the level of industry detail required is greater than in the standard air emissions account because it is necessary to distinguish between those industries that are considered tourism industries and all other industries. The definition of tourism industries should follow the International Recommendations for Tourism Statistics and, while fairly common across countries, the set of industries will vary by country depending on the nature of the tourism industry. Depending on the level of industry detail generally used to collect air emissions information, additional data collection may be required to generate emissions data for tourism industries.

42. Information on the production, intermediate consumption, value added and employment of tourism industries is generally compiled within the framework of a tourism satellite account (TSA). It is possible to combine the air emissions information and standard TSA data into an environmentally extended TSA – this is the logic presented in Table 4.3.

# Annex II: 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):

| | |
|---|---|
| $\boldsymbol{q} = (\boldsymbol{I} + \boldsymbol{A_d} + \boldsymbol{A_d^2} + \boldsymbol{A_d^3} + \ldots) \cdot \boldsymbol{y_d}$ | (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.

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