System of Environmental-Economic Accounting 2012

Applications and Extensions

United Nations

European Commission

Food and Agriculture Organization of the United Nations

Organisation for Economic Co-operation and Development

World Bank Group

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Foreword

Comparable and reliable data supporting coherent analytical and policy frameworks are essential elements to inform debates and guide policy related to the relationship between the economy and the environment.

The System of Environmental-Economic Accounting 2012—Applications and Extensions (SEEA Applications and Extensions) provides examples of potential uses of environmental-economic accounts for policy and research. SEEA Applications and Extensions supplements the conceptual framework presented in the System of Environmental-Economic Accounting 2012—Central Framework (SEEA Central Framework). It has been produced and is released under the auspices of the United Nations, the European Commission, the Food and Agriculture Organization of the United Nations, the Organisation for Economic Co-operation and Development, and the World Bank Group.

The United Nations Committee of Experts on Environmental-Economic Accounting (UNCEEA) managed and coordinated the work as mandated by the Statistical Commission at its thirty-eighth session in 2007. Representatives of national statistical offices and international organizations made valuable contributions. The draft chapters of the document were posted on the website of the United Nations Statistics Division for worldwide review, thereby achieving full transparency during the drafting process.

At its forty-fourth session in 2013, the United Nations Statistical Commission welcomed the SEEA Applications and Extensions as a useful contribution to illustrating possible applications of the SEEA Central Framework.

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Preface

In 2012 the international statistical community adopted the international statistical standard for environmental-economic accounting and the *System of Environmental-Economic Accounting 2012—Central Framework* (SEEA Central Framework) was finalized by the Statistical Commission.[1] The adoption of the SEEA Central Framework responded to the growing number of 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.

[1] See Official Records of the Economic and Social Council, 2012, Supplement No. 4 (E/2012/24), chap. I.B decision 43/105, para. (c).

To support the implementation of the various components of the SEEA Central Framework and to highlight the potential uses of data organized in accordance with the framework's conceptual basis, the Statistical Commission endorsed the preparation of the *System of Environmental Economic Accounting 2012—Applications and Extensions* (SEEA Applications and Extensions) and welcomed its development at the forty-fourth session in 2013, where the Commission recognized it "as a useful contribution to illustrating possible applications of the SEEA Central Framework".[2]

[2] Ibid., 2013, *Supplement No. 4* (E/2013/24), chap. I.C, decision 44/104, para. (g).

SEEA Applications and Extensions provides compilers and users of SEEA-based environmental-economic accounts with material aimed at demonstrating how this information can be used in decision-making, policy formulation and review, analysis and research. SEEA Applications and Extensions is intended to bridge the divide between compilers and analysts, allowing members of both groups to recognize potential uses and related measurement considerations.

SEEA Applications and Extensions offers a summary of the most common applications and extensions rather than complete coverage of all the materials that may be relevant to the communication and dissemination of information on environmental-economic accounts. As a summary guide to the use of SEEA-based data, SEEA Applications and Extensions cannot be regarded as a statistical standard. Thus, the topics and examples chosen are intended to illustrate possible applications but are not to be taken as constituting a basis for standardized reporting at the national or the international level.

It is recognized that the implementation of the SEEA Central Framework itself, and the various types of analyses and extensions that follow, require ongoing efforts to integrate information across various disciplines and from a number of agencies. In support of the SEEA implementation strategy, various training and technical materials are under development, and these will provide additional information relevant to the completion of analyses and extensions described here.

SEEA Applications and Extensions was prepared as mandated by the Statistical Commission at its thirty-eighth session in 2007, under the auspices of the Committee of Experts on Environmental-Economic Accounting (UNCEEA).[3] The Committee of Experts functions as a governing body and comprises senior representatives of national statistical offices and international organizations. It is chaired by one of the country members of the Committee. The United Nations Statistics Division (UNSD) serves as the secretariat of the Committee, and project oversight is regularly provided by the Committee's Bureau.

[3] Ibid., 2007, *Supplement No. 4* (E/2007/24), chap. I.B, decision 38/107).

The content of SEEA Applications and Extensions was determined through a series of discussions within both the London Group on Environmental Accounting and a subgroup of the Committee of Experts, which was formed to establish the purpose and scope of the publication.

Based on the outcomes of these deliberations, the content was prepared in a two-stage process under the direction of an editorial board. During the first stage, extending through the first half of 2012, contributions on specific topics were gathered from nominated authors. During the second stage, beginning in mid-2012, the Editor presented these materials to the editorial board for ongoing review. A discussion of the preliminary draft chapters by the London Group was held in October 2012. This was followed by a broad consultation process between December 2012 and January 2013 involving the international statistical community and other interested parties. The draft emerging from the consultation was presented to the Statistical Commission at its forty-fourth session in 2013 and a final draft incorporating all feedback was endorsed by the Committee of Experts on Environmental-Economic-Accounting at its seventh meeting in June 2013.

Acknowledgements

Background

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

(*a*) Identifying and reaching agreement on the topics and issues to be considered in the drafting of SEEA Applications and Extensions, including through the convening of members of the United Nations Committee of Experts on Environmental Economic Accounting for this purpose;

(*b*) Gathering technical material and examples for the various topics, including from the submissions of nominated contributors;

(*c*) Drafting and editing of provisional chapters;

(*d*) Consulting with countries and experts on specific issues, as well as on completed chapters;

(*e*) Submitting an interim draft to the Statistical Commission at its forty-fourth session in 2013. In its report on that session, the Commission "welcomed 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*) A final draft of SEEA Applications and Extensions incorporating comments received though the consultation was prepared. That was endorsed by the Committee of Experts on Environmental-Economic Accounting at its seventh meeting in June 2013.

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

The process of drafting SEEA Applications and Extensions involved the United Nations Committee of Experts on Environmental-Economic Accounting; other international, regional and non-governmental organizations; project staff; agencies responsible for compiling official statistics in many countries; city groups; other expert groups; and individual experts in economics, environment and related fields from many 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 Committee of Experts at its thirty-sixth session in March 2005 with the mandate, among others, to oversee and manage the revision of the SEEA. The Committee of Experts comprises senior representatives of national statistical offices and international agencies.

The Bureau of the Committee of Experts, whose representatives are elected from among its members, acts under the authority delegated by the Committee. The Bureau managed and coordinated the preparation of SEEA Applications and Extensions. The Committee of Experts and its Bureau, which was formed in 2008, were chaired by Peter Harper (Australia), 2009-2013.

The following persons served as members of the Bureau of the Committee of Experts: Peter Harper (Australia), 2009-2013; Karen Wilson (Canada), 2009-2011; Art Ridgeway (Canada), 2012-2013; Peter van de Ven (Netherlands), 2009-2011; Geert Bruinooge (Netherlands), 2012-2013; Olav Ljones (Norway), Chair, Oslo Group on Energy Statistics, 2009-2013; Joe de Beer (South Africa), 2010-2013; Pietro Gennari (Food and Agriculture Organization of the United Nations), 2011-2013; Paul Cheung, Ivo Havinga, Alessandra Alfieri and Eszter Horvath (UNSD), 2009-2013; Mark de Haan (Netherlands), Chair, London Group on Environmental Accounting, 2009-2012; Pedro Diaz (Eurostat), 2009-2013; Glenn-Marie Lange (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 (UNSD), under the overall supervision of Ivo Havinga (UNSD) and the assistance of Alessandra Alfieri (UNSD), provided secretariat services to the Bureau of the Committee of Experts.

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

The following representatives of international organizations served as members of the Committee of Experts: Salvador Marconi and Kristina Taboulchanas (Economic Commission for Latin America and the Caribbean), Joel Jere (Economic and Social Commission for Asia and the Pacific), Wafa Aboul Hosn (Economic and Social Commission for Western Asia), Lidia Bratanova (Economic Commission in Europe), Jean-Louis Weber (European Environment Agency), Pedro Díaz Muñoz and Pieter Everaers (Eurostat), Pietro Gennari (Food and Agriculture Organization of the United Nations), Manik Shrestha (International Monetary Fund), Myriam Linster and Peter van de Ven (OECD), Linda Ghanimé, Maria Netto and Veerle van de Weerd (United Nations Development Programme), Kathleen Abdalla, Tariq Banuri, Matthias Bruckner, Jean-Michel Chéné, Manuel Dengo, Liisa-Maija Harju, David O'Connor and Mary Pat Silveira (United Nations Division for Sustainable Development, Department of Economic and Social Affairs of the United Nations), Hussein Abaza, Derek Eaton, Maaike Jansen, Fulai Sheng, Guido Sonnemann and Jaap van Woerden (United

Nations Environment Programme), Alessandra Alfieri, Ivo Havinga, and Eszter Horvath (UNSD), Kirk Hamilton, Barbro Elise Hexeberg, Glenn-Marie Lange and Marian S. de los Angeles (World Bank).

A subgroup of members of the Committee of Experts was established to develop proposals on the scope, purpose, structure and content of SEEA Applications and Extensions, as well as the relationship of the publication 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 (United States of America), 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, Leila Rohd-Thomsen and Sokol Vako (UNSD).

The United Nations Statistics Division developed and maintains the project website, (http://unstats.un.org/unsd/envaccounting/default.asp), which provides more information on the contributions summarized here.

Editorial Board

The SEEA Applications and Extension Editorial Board, which provided technical guidance and expert advice to the Editor, Carl Obst, in the drafting and coordination of material and the resolution of technical issues, comprised: Peter van de Ven, Chair (Organisation for Economic Co-operation and Development), Michael Vardon (Australia), Sjoerd Schenau (Netherlands), Rocky Harris (United Kingdom), Dennis Fixler (United States of America), Brian Newson (Eurostat), Myriam Linster (Organisation for Economic Co-operation and Development), Alessandra Alfieri (UNSD) and Carl Obst (Editor, SEEA).

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 eighteenth meeting, held in Ottawa and hosted by Statistics Canada, the London Group discussed a preliminary draft of SEEA Applications and Extensions. That meeting of the London Group was chaired by Sjoerd Schenau (Netherlands) on behalf of Mark de Haan (Netherlands).

The following persons participated in the eighteenth 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, and international organizations and non-governmental organizations submitted 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); Mark de Haan, Roel Delahaye, Rutger Hoekstra, Maarten van Rossum and Sjoerd Schenau (Netherlands); Viveka Palm (Sweden); Rocky Harris (United Kingdom); Myriam Linster (OECD); Tim Scott (UNDP); Brad Ewing (University of Alaska); Alessandro Galli, Katsunori Iha and Mathis Wackernagel (Global Footprint Network) and Olga Ivanova and Arnold Tukker (TNO, Netherlands).

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

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

List of abbreviations and acronyms

ABS	Australian Bureau of Statistics
As	arsenic
BTIO	bilateral trade input-output
Cd	cadmium
CEA	classifications of environmental activities
CFC	chlorofluoro carbon
CGE	computable general equilibrium (modelling)
CH_4	methane
CO	carbon monoxide
CO_2	carbon dioxide
COICOP	classification of individual consumption according to purpose
Cr	chromium
Cu	copper
DF	driving force
DFID	United Kingdom Department for International Development
DPSIR	driving force-pressure-state-impact-response (model)
EEBT	emissions embodied in bilateral trade (model)
EE-IOT	environmentally extended input-output table(s)
EGSS	environmental goods and services sector
EIPRO	Environmental Impacts of Products (project)
EPEA	environmental protection expenditure account
EU	European Union
EW-MFA	economy-wide material flow account(s)
FAO	Food and Agriculture Organization of the United Nations
FDES	Framework for the Development of Environment Statistics
GDP	gross domestic product
GHG	greenhouse gas
GIS	geographic 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 table(s)
IRIO	interregional input-output (table(s))
IRTS 2008	International Recommendations for Tourism Statistics 2008
ISIC	international standard industrial classifications of all economic activities
IUCN	International Union for Conservation of Nature
JRC	European Commission Joint Research Council
kWh	kilowatt-hour
LCA	life-cycle assessment
MRIO	multi-regional input-output (table(s))
MSA	material system analysis
N	nitrogen
N_2O	nitrous oxide
NH_3	ammonia
Ni	nickel
NMVOC	non-methane volatile organic compounds
NNI	net national income
NO_2	nitrogen dioxide
NOx	mono-nitrogen oxides
OECD	Organisation for Economic Co-operation 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 parity
PRTR	pollutant release and transfer register
PSE	producer subsidy equivalent(s)
PSR	pressure state response (model)
PSUT	physical supply and use tables
PWT	Penn World Tables
RMW	raw material equivalent(s)
SAM	social accounting matrix

SDA	structural decomposition analysis
SDG	Sustainable Development Goals
Se	selenium
SEEA	System of Environmental-Economic Accounting
SEEA-2003	*Handbook of National Accounting: Integrated Environmental and Economic Accounting 2003*
SEEA-AFF	System of Environmental-Economic Accounting for Agriculture, Forestry and Fisheries
SEEA-Energy	System of Environmental-Economic Accounting for Energy
SEEA-Water	System of Environmental-Economic Accounting for Water
SNA	System of National Accounts
SOx	sulphur oxides
SRIO	single region input-output (table(s))
SUT	supply and use table(s)
TOE	tons 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

Chapter I

Introduction

1.1 The System of Environmental-Economic Accounting 2012–Applications and Extensions (SEEA Applications and Extensions) shows compilers and users of SEEA-based environmental-economic accounts how the information gathered can be applied to decision-making, policy review and formulation, analysis and research. SEEA Applications and Extensions bridges the divide between compilers and analysts, allowing members of both groups to recognize the potential uses and the related measurement considerations.

1.2 The present publication is meant to serve as a companion to the System of Environmental-Economic Accounting 2012–Central Framework (SEEA Central Framework) (United Nations and others, 2014a), which was adopted as the initial international statistical standard for environmental–economic accounting in 2012. SEEA Central Framework is a multipurpose conceptual framework which focuses on the interactions between the economy and the environment, and the stocks and changes in stocks of environmental assets.

1.3 It is envisaged that in 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 and air emissions—various applications and extensions might be adopted, as appropriate, to the topic of interest. Many of the applications and extensions would benefit not only from a modular focus but also 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 organization using the SEEA accounting framework is likely to be of long-term benefit.

1.4 SEEA Applications and Extensions offers 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. As a summary guide to the use of SEEA-based data, SEEA Applications and Extensions cannot be regarded as a statistical standard. Thus, the presented topics and examples are not to be taken as constituting a basis for standardized reporting at the national or international level.

1.5 Consistent with the recommendation that the implementation of the SEEA Central Framework be flexible and modular, in line with available resources and national information demands, countries need not seek to implement all of the applications and extensions described here.[4] Indeed, carrying out some of the analyses and extensions outlined here will require information that is not provided 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. SEEA Applications and Extensions does not set forth prescriptions with respect to assumptions, modelling approaches or the collection of the information required for analysis. It intends only to indicate the common requirements and considerations.

1.6 It is recognized that implementation of the SEEA Central Framework itself, and the analyses and extensions that follow, require ongoing efforts to integrate information across

4 See Official Records of the Economic and Social Council, 2012, Supplement no. 4 (E/2012/24), chap. I.B decision 43/105, para. (e).

various disciplines, usually from a number of agencies. In support of the SEEA implementation strategy, various training and technical materials are under development. These will provide additional information relevant to the completion of analyses and extensions.

1.7 SEEA Applications and Extensions does not provide complete coverage of all materials that may be relevant to the communication and dissemination of information on environmental-economic accounts, nor does it cater to every possible audience. An audience of particular relevance in this regard comprises those persons who are generally thought of as policymakers, i.e., politicians and senior government officials. For them, it is likely that summaries of environmental-economic data are required. This publication provides information that may be pertinent in the preparation of those summaries, including relevant charts and figures. Further examples of material that may best meet the requirements of such an audience are on the UNSD website, which houses a knowledge base encompassing a broad range of of environmental-economic accounting resources.

1.1 Analytical and policy focus

1.8 The focus in SEEA Applications and Extensions is on measurement and analysis at the broad national level for topics such as resource use, environmental intensity, environmental protection activity, the production of environmental goods and services, environmental assets and natural resources, and household and other sectors' behaviour with respect to the environment. SEEA Applications and Extensions also highlights the potential for analysis and extension at subnational scales, a context where there is a strong degree of synergy with developments in geographic information systems (GIS) and related data sets.

1.9 Analysis in these areas may feed into discussions in 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, natural 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, however, does not generally include directives regarding sustainability, of either individual activities or those of countries and regions as a whole. Assessments of sustainability require consideration of, or assumptions regarding, societal choices and the appropriate balance among 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 integrated environmental-economic accounts, SEEA Applications and Extensions provides an introduction to the types of analysis that may be conducted using them. SEEA Applications and Extensions also indicates what types of accounts may be required to undertake such analyses.

1.12 For the analyst of environmental-economic issues, SEEA Applications and Extensions provides insights into the benefits that may be derived from utilizing a common, integrated framework, as reflected in the compilation of accounts, for the organization of environmental and economic data. It is anticipated that this publication will stimulate thinking about the analysis and presentation of data which should emerge from an examination of concepts and accounts considered in the SEEA Central Framework.

1.2 Relationship to the SEEA Central Framework and related publications

1.13 Like the SEEA Central Framework, 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), (United Nations and others, 2003).

1.14 In this regard, SEEA Applications and Extensions builds on chapter XI of SEEA-2003 entitled "Applications and policy uses of the SEEA", as well as on the many examples provided in the other chapters of that publication. In the revision of SEEA-2003 a different approach has been adopted. The focus of the SEEA Central Framework is on the description of accounting principles and relevant concepts and definitions. Consequently, it includes no examples.

1.15 There are close links between a number of the applications discussed in this publication and the material presented in chapter VI of the SEEA Central Framework, entitled "Integrating and presenting the accounts". Chapter VI discusses the important characteristics of the integration of environmental and economic data which is the hallmark of the SEEA. Of particular note are the combined presentations of data in physical and monetary terms and the development of aggregates and indicators. Discussion of these features is expanded in SEEA Applications and Extensions through a more complete discussion of indicators and aggregates for specific topics, the description of possible analytical approaches and the provision of relevant examples.

1.16 The discussion of indicators and aggregates is particularly noteworthy. The SEEA Central Framework describes a number of indicators and key aggregates but does not recommend the measurement of any specific indicators, observing instead that the relevant indicator should be defined based on the particular issue under consideration. While following this approach, SEEA Applications and Extensions also discusses the role and function of indicators and their selection, interpretation and presentation. This discussion is relevant to the consideration of how information from SEEA accounts may best be applied to developing and populating the range of indicator sets that utilize environmental and economic information.

1.17 SEEA Applications and Extensions does not include a detailed presentation of applications and extensions related to ecosystem accounting, although reference is made to analysis and extensions related to land accounts, which may serve as a starting point for ecosystem accounting. That there is a lack of coverage of ecosystem accounting does not reflect on its relative importance but rather highlights the fact that the coverage of the SEEA Central Framework in terms of physical flows of materials, energy and water, expenditure and production related to environmental activities, and asset accounts for individual resources, is much more well established than approaches to ecosystem accounting. The body of knowledge on ecosystem accounting is expanding along with the main work in the generally accepted areas summarized in SEEA Experimental Ecosystem Accounting (United Nations and others, 2014b). It is anticipated that, in time, publications focused on applications and extensions as related to ecosystem accounting will be produced.

1.18 More generally, the SEEA comprises a number of other publications including SEEA-Water (United Nations, 2012b), SEEA-Energy (United Nations, forthcoming), SEEA-Agriculture, Forestry and Fisheries (United Nations and and Food and Agriculture Organization of the United Nations, forthcoming), SEEA-Fisheries (*Handbook of National Accounting: Integrated Environmental and Economic Accounting for Fisheries*, United Nations and Food and Agriculture Organization of the United Nations, 2004). Each of these publications highlights applications and extensions relevant to its subject matter. Compilers and analysts are encouraged to consult them for further suggestions in the areas of 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), United Nations and others, 2009). For environmental data, the recent revision of the Framework for the Development of Environment Statistics (FDES) (United Nations, 2013) offers a basis for the collection and organization of the data required to compile SEEA accounts.

1.3 Structure of SEEA Applications and Extensions

1.20 Chapter I of this publication outlines the rationale for SEEA Applications and Extensions and places it within the broader context of related SEEA publications.

1.21 Chapter II, entitled "Applications of SEEA data", describes the range of topics commonly analysed using integrated environmental-economic data. The four broad topics covered are (*a*) resource use and environmental intensity; (*b*) production, employment and expenditure related to environmental activities; (*c*) environmental taxes and environmental subsidies and similar transfers; and (*d*) environmental assets, wealth, income and depletion of resources. For each topic, the material covers both the most commonly used indicators and aggregates and the most common types of analysis. Chapter II 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 III, entitled "Analytical techniques", considers the use of SEEA data to support the application of techniques in the analysis of various topics. A significant portion of the chapter is devoted to the subject of environmentally extended-input-output tables (EE-IOT), which provide a statistical basis for a wide variety of analyses, from more straightforward structural analysis to more complex modelling. The chapter describes a range of techniques including multiplier analysis, consumption-based modelling, decomposition analysis and computable general equilibrium (CGE) modelling.

1.23 Chapter IV, entitled "Extensions of the SEEA", highlights examples of augmentation, disaggregation or reclassification of data from the SEEA Central Framework with a view to creating integrated data sets for different areas of policy concern. Three examples are described. In the first, a wide range of SEEA data are utilized to provide integrated information for analysis of the household sector in relation to the environment. In the second example, geo-spatial techniques are used to establish the connections among environmental, economic and social data for particular areas or regions within a country. In the third example, SEEA data and data on tourism, compiled within a tourism satellite account, are connected. The extensions described do not, however, entail alternative definitions of SEEA concepts.

1.24 Annex I provides additional detail on the derivation of various indicators and data presented in this publication and includes an explanation of the links to the relevant parts of tables within the SEEA Central Framework. Annex II provides additional details related to the analytical techniques described in chapter III. Lastly, Annex III provides more information on the Sustainable Development Goals (SDGs) and the SEEA.

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 of application is attributable to the range of accounts that make up the SEEA Central Framework and the linkages between those accounts. These linkages enable 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, leading to the derivation of key indicators and aggregates. Since the indicators emerge from the accounts, they 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 produce indicators or to enable analysis. This is particularly the case in linking SEEA data with standard national accounting aggregates such as GDP or industry value added.

2.4 This present chapter begins with a general introduction to indicators, followed by an examination of some of the most common topics of analysis to which SEEA data are applied and for which indicators are derived. Those 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 outlined above and the development of relevant indicators may require both additional, more detailed data than those considered in the SEEA Central Framework and the use of various assumptions and modelling. This chapter examines the relevant considerations and measurement issues in this regard.

2.2 Use of indicators in environmental analysis

2.2.1 Roles and functions of indicators

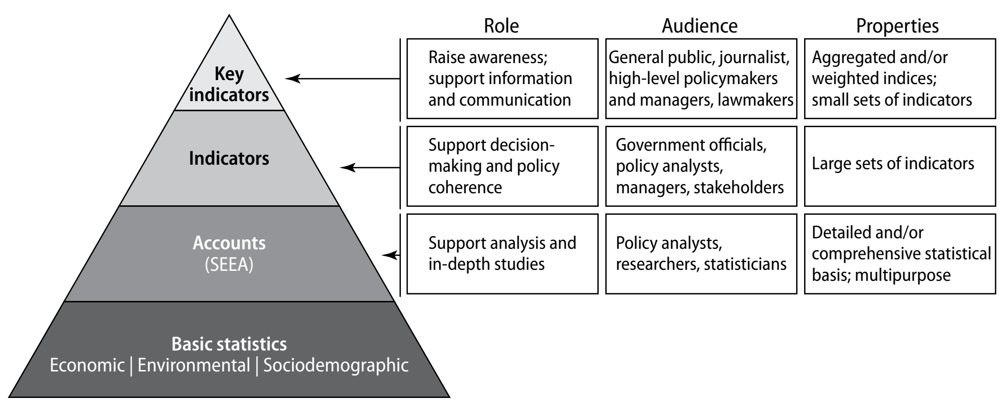
2.6 Indicators, aggregates and totals (collectively referred to here as indicators) may serve many purposes, depending on the scale at which they are applied, the audience to be reached, and the quality of the underlying data. Indicators are useful tools for tracking progress with respect to the environment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

2.7 Among the main audiences are the general public, journalists, managers and decision makers in business and government, policymakers including parliamentarians, and stakeholders from non-governmental organizations. Most of these audiences are not made up of statistical experts. It is therefore important that the indicators presented be understandable and meaningful, and reflect a synthesis of the complexity and level of detail of the original data.

2.8 A key function of indicators is to simplify the process of communication through which the results of analysis and accounting are provided to users, and to adapt the information provided to users' needs. Owing to such simplification and adaptation, indicators may not always meet strict scientific requirements with respect to demonstrating causal chains. Instead, they reflect a balance between relevance for users and policies, statistical accuracy, and analytical soundness and scientific coherence. Indicators should therefore be regarded as summary measures which aim at being fit for purpose and should be embedded within larger information systems (e.g., databases, accounting frameworks, monitoring systems and models).

2.9 The relationships between different types of information within the context of the SEEA are portrayed in figure 2.1. The figure highlights the organization of basic statistics and data using accounting frameworks and the sourcing of indicators from accounts. While it is the case that indicators can be sourced directly from basic statistics, the filter provided by an accounting framework adds significantly to the coherence of the indicators. Further, the alignment of the SEEA with the SNA facilitates a consistency between economic and environmental information which ensures the robustness of the indicators 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 are best known for the important aggregates and indicators that are derived from the accounting structure of the SNA, particularly GDP and net national income (NNI). The range of aggregates and indicators is described in section 6.4 of the SEEA Central Framework. They include descriptive statistics (such as aggregates, totals and structural statistics); environmental asset aggregates and indicators; aggregates related to the financing and cost recovery of economic activity associated with 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 As regards this broad range, it is recognized 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., the population census).

2.12 The connectivity and coherence of information sourced from the accounts of the SEEA Central Framework are particularly important when the indicators are designed to provide information about both the environmental effectiveness and the economic efficiency of policies, or are established to support structural policy analyses. Relevant functions include measuring progress towards sustainable development and monitoring the integration of economic and environmental policies.

2.13 Indicators that benefit most from having their foundation 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., contribution of 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 must be the information, and the more detailed must be the underlying accounts and databases. Often a combination of several sources is necessary to calculate indicators and support in-depth analysis.

2.15 Consequently, the quality and usefulness of an indicator depend 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. Therefore, the use of data quality assessment frameworks and the application of general principles of "fitness for purpose" are relevant considerations. When appropriate, assumptions about the relationship between the scope of the indicator and the analytical question of interest should be made explicit.

2.16 As noted above, section 6.4 of the SEEA Central Framework introduces a range of indicators. Others are described throughout this chapter or may be derived using the analytical techniques described in chapter III. The data underlying the indicators may also be obtained from other statistical sources (e.g., environmental monitoring systems, emissions inventories, pollutant release and transfer registers (PRTRs), opinion polls and business surveys). These other statistical sources are often needed to populate SEEA accounts, but their data 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. For example, it enables comparisons between industry valued added and water use of particular industries (e.g., agriculture or mining) to be made with confidence.

2.2.3 Indicators in SEEA Applications and Extensions

2.17 In the following sections a number of indicators for analysis of various topics are described within the general context of using data from the SEEA Central Framework. The coverage includes:

(*a*) *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, CO_2 emissions, nutrient balances, and solid waste. Also included are indicators of environmental flows from a consumption- or demand-based perspective;

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

(*c*) *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 related to emission permit schemes, and indicators of the level and purpose of environmental subsidies and similar transfers;

(*d*) *Indicators of environmental assets, 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 and aquatic resources), 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 Some examples of indicators and analyses are presented throughout the chapter. Annex I provides an explanation of the underlying types of data and methods used in these examples, and the references section provides a structured list of relevant studies and publications on the various topics. Section 2.7 discusses a number of issues relevant to the selection, interpretation and presentation of indicators across the range of 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[5]

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, which often extend beyond the borders of individual countries or regions. This has a bearing on decisions cutting across many policy areas, ranging from economic development, trade and technology 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 emerge at different stages of the resource cycle and affect the quantity and

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

quality of natural resource stocks and the quality of ecosystems and environmental media (i.e., land, water, air). Those consequences encompass:

(*a*) The rate of extraction and depletion of renewable and non-renewable resources;

(*b*) The extent of the harvest, reproductive capacity and natural productivity of renewable resources;

(*c*) 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 nature and intensity of these consequences depend on the kind and amounts of natural resources and materials used, the manner of their use and management and the type and location of the environment from which 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 for employment and human health and implications for leisure habits associated with the presence and accessibility of particular resources, landscapes and ecosystems. There may also be cultural implications in cases where natural resources constitute a basic element of the cultural heritage of people. How revenues and other financial flows related to resource production and supply are managed, particularly in resource-rich countries, may also have a bearing on relative income levels.

2.23 From an economic point of view, how natural resources and residual flows are managed has consequences for among others:

(*a*) Short-term costs and long-term economic sustainability;

(*b*) The supply of strategically important materials;

(*c*) The costs associated with the downstream management of materials;

(*d*) 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, which in turn will have economic effects.

2.25 In recent decades, economic development has been generally accompanied by a growing demand for raw materials, energy and other natural resources with consequences for market prices and trade flows of those resources. Worldwide, use of significant materials has been rising, and concerns about shortages of stocks of natural resources and the security of the supply of water, energy and materials have been recurrent. Growing economic and trade integration has shifted many policy issues from local and national to global scales. It has enlarged the size of markets, allowed greater specialization and mobility in production, increased the role of multinational 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 materials 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 and also has 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 issues 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 phenomena. The concepts aim at generating optimization of the net benefits from resource use within the context of economic development through:

(*a*) Ensuring adequate supplies of renewable and non-renewable resources to support economic activities and economic growth;

(*b*) Managing the environmental pressures associated with the extraction, processing, use and end-of-life disposal of materials so as to minimize the adverse effects on environmental quality and human health;

(*c*) Preventing natural resource depletion;

(*d*) Maintaining non-market ecosystem services and restricting ecosystem degradation.

2.28 The concept of sustainable resource use may be applied to analysis along two main streams (*a*) sustainable production and consumption and resource productivity, and (*b*) residual flows. The various types of indicators and analysis related to these two streams are described below.

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 (i.e., 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 chapter VI of the SEEA Central Framework. 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 to environmental pressures 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); and total flows of air emissions, releases of substances to water and generation of solid waste. All of these aggregates are derived within the various PSUT described in chapter III of the SEEA Central Framework.

2.32 Intensity indicators compare trends in economic activity including in value added, income and consumption, with trends in specific environmental flows such as emissions, energy and water use and solid 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 trends are monitored over a given period, these indicators can also be expressed as decoupling ratios or decoupling factors. (Decoupling analysis is discussed in section 2.3.3).

2.33 Intensity indicators are often grouped into two broad types:

(*a*) *Environmental intensity indicators,* which characterize the environmental and economic intensity with which pollutants and other residuals generated in production and consumption are prevented, controlled or mitigated. They are expressed as the ratio of an environmental variable, such as emissions of pollutants and other residuals, to an economic variable 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.

(*b*) *Resource intensity indicators,* which characterize the intensity with which natural resources, including water, energy and other materials, are used in production and consumption. They are expressed as the ratio of an environmental variable, such as the extraction, supply and consumption of natural resources and materials, to an economic variable, such as output, income and value added.[6]

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 be further decomposed to reflect the extent to which underlying drivers (e.g., technological factors) and structural changes have contributed to the reduction in, or increase of, environmental pressures over the period considered.

2.35 Economic activity used in the calculation of the indicators should be measured in volume terms for time-series purposes. That is to say, the measures should be adjusted for the effect of price change (inflation). If the measures used are not adjusted 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 if the GDP measure used is not adjusted 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 for adjusting economic data from different countries so as to establish a basis for comparison entails the use of purchasing power parities (PPPs). PPPs allow economic data to be compared through use of reference baskets of goods and services.[7]

2.37 Indicators that measure a country's economic activity include gross output, industry value added and GDP. Care should be exercised in the choice of measure utilized to represent economic activity. For example, output and value added are significantly different national accounting concepts. In essence, value added is gross output less intermediate consumption of goods and services. Thus, depending on the scope of the environmental flow measure that is part of the intensity or productivity indicator, significantly different levels and growth rates in the indicators will be obtained using different measures of economic activity. For indicators concerning a country's domestic final demand for environmental flows (natural resources and residual flows), household consumption or real net income measures are generally preferred.

2.38 While intensity and productivity indicators can provide a good summary of overall change, they give no direct indication of whether environmental pressures are changing 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 entailing a shift towards the service industries. Consequently, the interpretation of indicators is likely to require additional contextual information which may commonly be found within the underlying accounts.

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

7 For detail on the calculation of PPPs see Eurostat-OECD (2012) *Methodological Manual on Purchasing Power Parities.* 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).

2.39 Comparisons of environmental and resource intensity between countries must also be interpreted carefully. Differences in industry and location structure may account for some of the cross-country differences. Hence, intensity indicators should be accompanied by complementary information on, for example, economic structures, the stage of economic development, and natural resource endowments.

Examples of environmental intensity indicators

2.40 *Greenhouse gas (GHG) or CO2 productivity indicators* relate economic activity to emissions of greenhouse gases (from energy use or from all sources), expressed in national currency per ton of CO_2 or CO_2 equivalent emitted.

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

2.42 *Water pollution intensities* relate the volume of wastewater generated or the quantities of pollutants released in wastewater to economic activity, expressed in tons per unit of GDP. As for air pollutants, indicators compiled for specific locations may be of particular interest.

2.43 *Nutrient surplus intensities* (nitrogen, phosphorus) relate nutrient surpluses (or deficits) to economic activity. The most common indicators concern nutrients in agriculture. They are usually expressed in kilograms of nutrient surplus (or deficit) per hectare of agricultural land, and can also be related to agricultural output in physical or monetary terms. Levels and changes in the physical quantities of nutrient surpluses (or deficits) can be used to indicate trends in and levels of potential physical pressure of nutrient surpluses (or deficits) on the environment, including risks of declining soil fertility in the case of a nutrient deficit, and risks of polluting soil, water and air in the case of a nutrient surplus. Owing to regional differences in climate, soil, crop types, farming systems and topography, such indicators benefit from a spatial breakdown into:

(*a*) *Agricultural nutrient balances,* which are calculated as the difference between the total quantity of nutrient inputs entering an agricultural system (mainly fertilizers and livestock manure, but also natural inputs, e.g.,nitrogen fixation by lightning strike) and the quantity of nutrient outputs leaving the system (mainly through uptake of nutrients by crops and grassland).

(*b*) *Economy-wide nutrient balance indicators* (e.g., for reactive nitrogen) covering all major sources (agricultural, industrial, traffic, households, etc.). These can be calculated at the macrolevel using the same approach applied for agricultural nutrient balances.

2.44 *Waste generation intensities* relate the amounts of waste generated to economic activity. A distinction can be made between types of waste or waste materials (mineral or non-mineral, hazardous or non-hazardous, industrial or municipal). In cases where municipal or household waste is being monitored, the amounts of waste generated can be related to household final consumption expenditure. When monitoring industrial waste, the amounts of waste generated can be related to value added by industry. Quantities of waste can also be compared with the amounts of primary resource inputs as shown in from material flow accounts. Other useful indicators include waste recovery ratios, which relate the amounts of waste recovered (through material recycling, biological recovery or 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 corresponding economic activity. Such indicators can be calculated both at an aggregate, economy-wide level, by industry and for 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 imports of certain groups of materials within total gross material input.

2.46 *Energy productivity* or *intensity indicators* relate net domestic energy use to the corresponding economic activity. Such indicators can be calculated at the economy-wide level, 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, which compare the energy produced in a country or territory with the energy imported; and indicators linking energy production and consumption to resource use and air emissions, expressed in tons of oil equivalent (TOE) or kilowatt-hours (kWh) per unit (e.g., per ton) of greenhouse gas or air pollutant emitted.

2.48 *Water-use productivity* or *intensity indicators,* which relate the use of water to the corresponding economic activity. Such indicators can be calculated at the economy-wide level, by industry and by water source. Examples of indicators include:

- *Water abstraction intensity indicators,* which relate the amounts of water abstracted (i.e., total abstracted water in the water PSUT) to economic activity or population. Abstraction intensities can be broken down by source (surface water, groundwater, desalinated water and reused water) and by abstracting industries.
- *Water-use intensity or productivity ratios,* which relate the amounts of water used (i.e., net domestic water use in the water PSUT) to economic activity. These intensity ratios can be compiled for both individual industries and households. They can also be broken down by water source (e.g., surface water, 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 water used in an economic activity that is evaporated or incorporated into products and hence no longer available for use; water recycling rates which indicate the share of reused or recycled water in water supply; and water dependency ratios which exhibit the proportion of water sourced from outside a territory. Dependency ratios can be calculated at country level or for regions within a country 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 (e.g., in dollars per hectare) or of the value of land used to economic activity. The ratios can be calculated for industries, institutional sectors and the country, as well as for particular regions.

Production and consumption-based indicators

2.51 Most environmental and resource intensity indicators are production-based. Thus, they account for the environmental flows (extraction of natural resources and residual flows) directly "produced" or "used" in domestic production. However, it is also of interest to calculate indicators that encompass a consumption-based perspective on environmental flows, i.e., those environmental 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 into production processes in other countries. 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 provide information on 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 those concerning carbon and greenhouse gas emissions. Consumption-based indicators should be based on data and relationships contained in input-output tables; ideally, given the globalized nature of many environmental flows, multiregional input-output tables should be used.

2.53 Consumption-based indicators share similarities with footprint indicators (e.g., carbon and water footprints). However, two distinct types of footprint indicators should be recognized. 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 relationships from life-cycle assessment which track particular products through supply chains. Section 3.3 discusses relevant measurement issues in more detail.

2.54 Concerning the development and use of consumption-based indicators, the following points are highlighted:

(*a*) The appeal of consumption-based methods 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, which provides a justification for considering direct and indirect flows together.

(*b*) Indicators that reflect the direct and indirect environmental flows in final demand are more difficult to link to policy responces 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 replaced by imports, policy responses are likely to be more complex, multidimensional and difficult to assess in terms of their effects since they involve trade issues, issues of international investment, and consumer and industry concerns.

2.3.3 General analytical approaches to resource use and environmental intensity

Decoupling analysis

2.55 A common analysis entails examining 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 demonstrate the extent to which growth in income and consumption is occurring with a decreasing use of environmental flows (e.g., of greenhouse gas emissions, energy and water use or waste generation).

2.56 Decoupling can be either absolute or relative. Absolute decoupling occurs when the growth in the environmental pressure is flat or decreasing while economic activity is increasing. Relative decoupling occurs when the growth rate of the environmental pressure is positive but less than the growth rate of the economic variable.

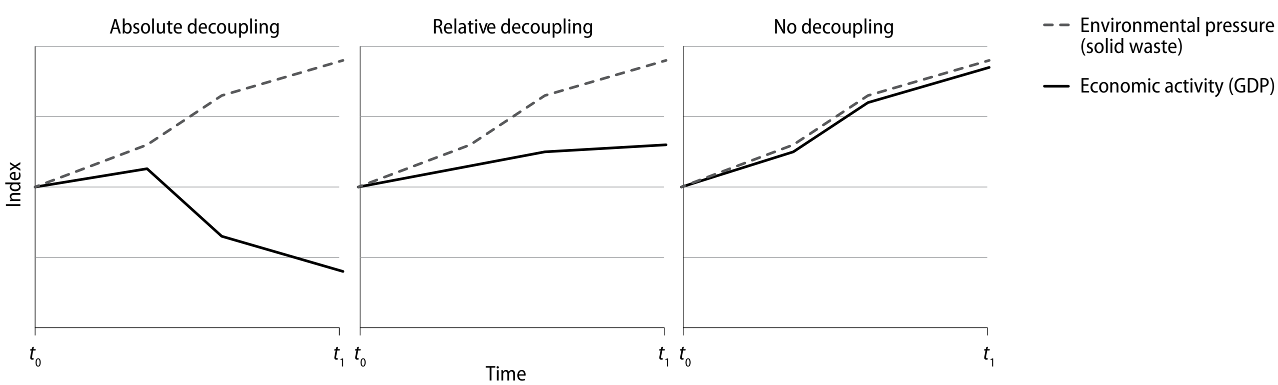
2.57 Many of the variables that feature in decoupling indicators also appear in the context of the concepts of environmental and resource intensity. Decoupling, which is usually conceived of in terms of elasticity, focuses on changes in volumes, whereas intensity and productivity are more concerned with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

2.58 Decoupling can be measured by intensity indicators, for which an environmental pressure variable is the numerator and an economic variable is the denominator. Sometimes the denominator (or driving force) may be population growth or some other variable.

2.59 When decoupling is presented graphically as a single line in the form of intensity ratios (i.e., as a time series of the ratio of the environmental variable to the economic driving force), the concept of a decrease in intensity is well communicated. However, this gives no indication of whether environmental pressures are decreasing in absolute terms or 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 specify the environmental and economic components of indicators, which can be done in terms of decoupling trends, that is, by displaying two commonly indexed time series, (e.g., base year=100) on the same graph. From such a graph, it immediately becomes clear whether economic activity (e.g., real GDP) is growing or shrinking and whether decoupling—absolute or relative—is occurring, including when it started and whether it is continuing. Figure 2.2 uses stylized data on economic activity (GDP) and an indicator of environmental pressure (generation of solid waste) to exhibit the three types of decoupling that might occur.

Figure 2.2
Stylized 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:

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

where EP = environmental pressure

and DF = economic driving force

If the decoupling ratio is less than 1, decoupling has occurred during the period, although the ratio does not indicate whether decoupling in any country was absolute or relative, or whether one country's decoupling is larger or smaller in absolute terms than another's. 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:

$$\text{decoupling factor} = 1 - \text{decoupling ratio}$$

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

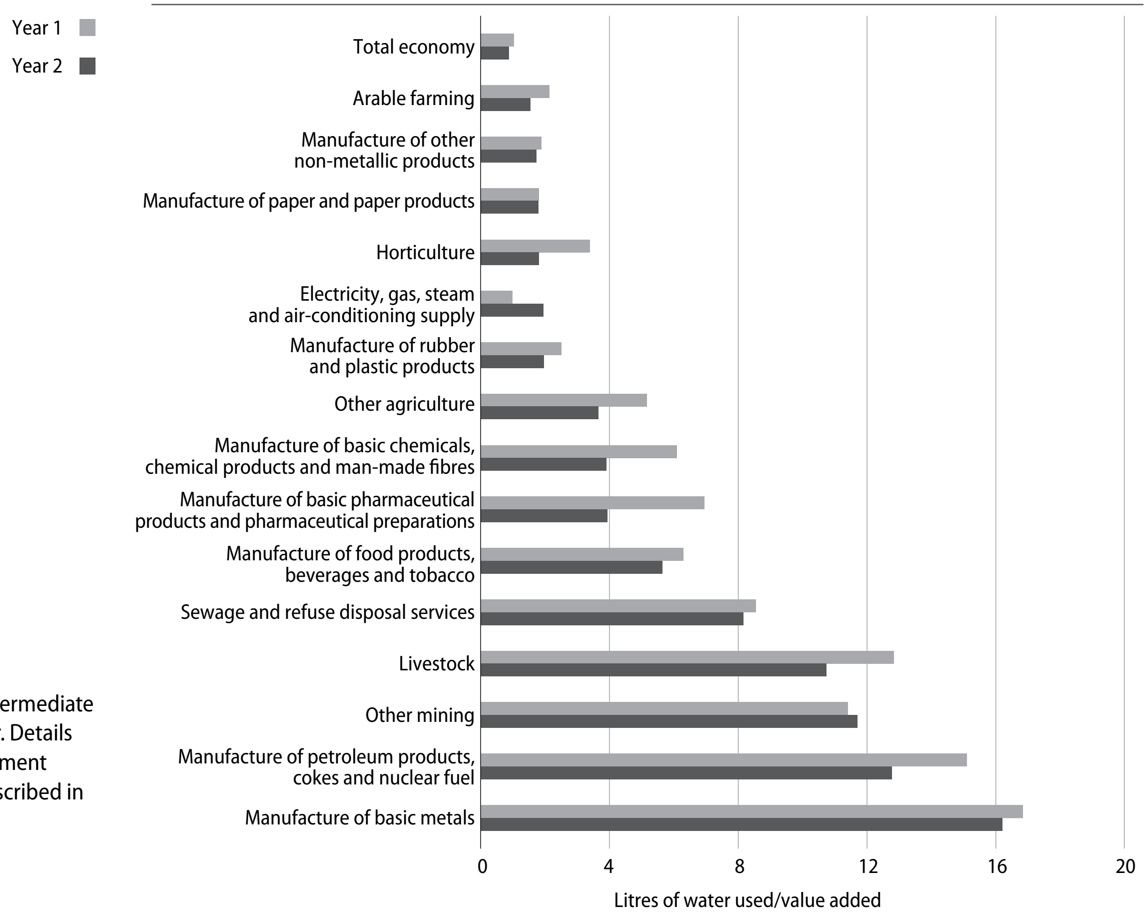
2.62 In PSUT, flows between the economy and the environment and flows within the economy are presented together and are structured following standard classifications for economic statistics. Using information on individual material inputs for industries within the PSUT, measures of resource intensity and productivity can be estimated using the quantity of raw materials that are needed to produce a unit of 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. As in economy-wide analysis, decoupling graphs may be constructed for individual industries.

2.63 Figure 2.3 highlights the use of water (measured in terms of intermediate consumption) by selected industries in relation to their value added, i.e., industry-level intensity indicators. The presentation may be considered an issue profile, as described in section 2.7.

2.64 The same basic approach can be used to track flows of emissions (e.g., greenhouse gas emissions, emissions to water) and flows of waste by industry in order to assess changes in the intensity of production with respect to residual flows and the effectiveness of policy responses.

2.65 Monetary supply and use tables, with estimates obtained using standard national accounts data, provide economic information by industry on production and value added. They 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 conducted based on resource use per unit of production or value added.

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.

2.66 Comparing PSUT and monetary supply and use tables offers the possibility of analysing implicit prices at an aggregated level. For example, the average energy prices for different industries may be assessed by examining 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. Note, however, that such implicit prices should be taken as indicative rather than definitive, since they will often be based on a comparison of data from different sources. Further, they will represent unit values and, as such, may not take into account important compositional and 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 produced. Since these data are integrated with those for industries, it is possible to trace flows of individual materials from the point of entry into 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 associated with 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 of environmental flows to final demand".

2.68 Where information is available, these measures may be further developed to encompass resource use and environmental intensity for different household types. This can be achieved by using information from the SEEA in combination with data from the SNA and household budget surveys. Accordingly, several household characteristics can be analysed, such household size, gender and age composition and income levels. This kind of information may help policymakers and researchers better understand present and future developments with respect to greenhouse gas emissions, for example, and facilitate building responses that influence associated consumption patterns. Spatial analysis based on the location of households (e.g., rural or urban) may also be conducted if information is available. Chapter IV 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 occur within dynamic systems of interactions where, for example, the size and structure of the economy vary in response to changes in demand and global trade. It is therefore often difficult to identify the extent to which specific consumption and production activities and measures aimed at improving resource and environmental intensity have actually contributed to changes in the levels of those 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 used in the calculations include changes in the size of the economy, changes in the structure of the supply chain and 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 CO_2 emissions from economic production may be attributed to a number of changes in the nature of the economy.

2.72 Figure 2.4 shows that CO_2 emissions would have increased by 306 million tons if they had grown in line with consumption levels. This estimate may be obtained by starting from 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 a SEEA-based data set using certain assumptions.

2.73 However, rather than increasing, measured emissions decreased by 54 million tons. The difference between potential emissions and actual emissions can be decomposed and shown to be a result of a combination of reduced CO_2 emission intensity (a switch to low carbon fuels), accounting for 20 per cent of the overall saving; the structural change in the supply chain, accounting for 30 per cent of the saving; gains in energy use (i.e., reduced energy intensity), accounting for 30 per cent of the saving; and a structural change in demand (e.g., a change in the pattern of consumption of different products), accounting for 20 per cent 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 emissions 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 (figure 2.5). Likewise, the change in emission levels for mobile sources of emissions can be decomposed into factors that include population growth, car ownership, traffic intensity (kilometres travelled per vehicle) and CO_2 intensity effects (emissions per kilometre travelled).

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 related to the content of figures 2.4 and 2.5.

Figure 2.4

Decomposition of changes in CO_2 emissions

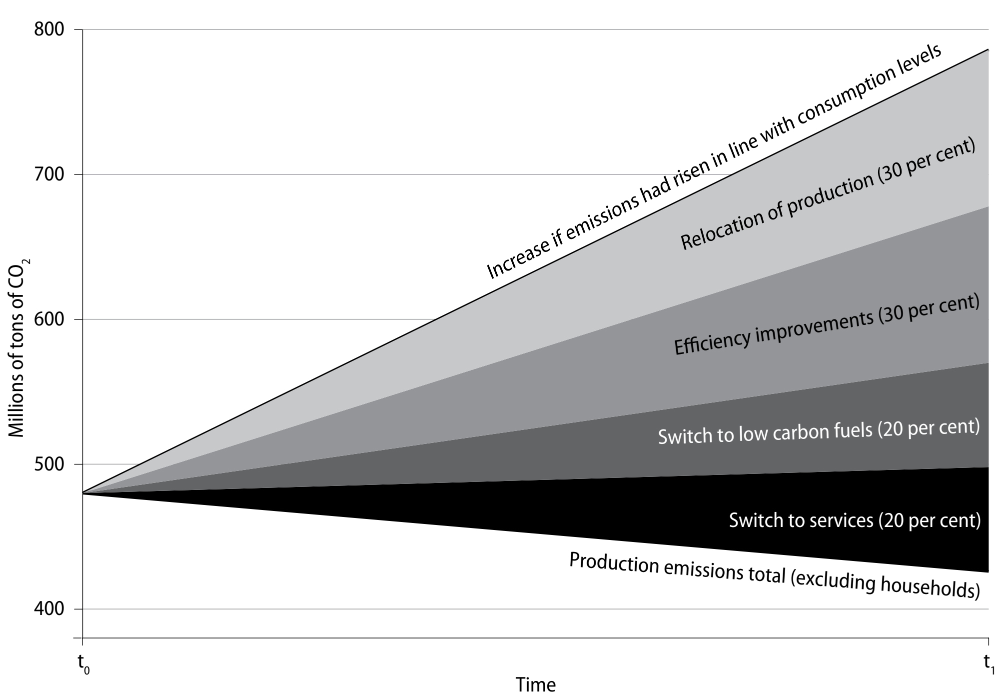
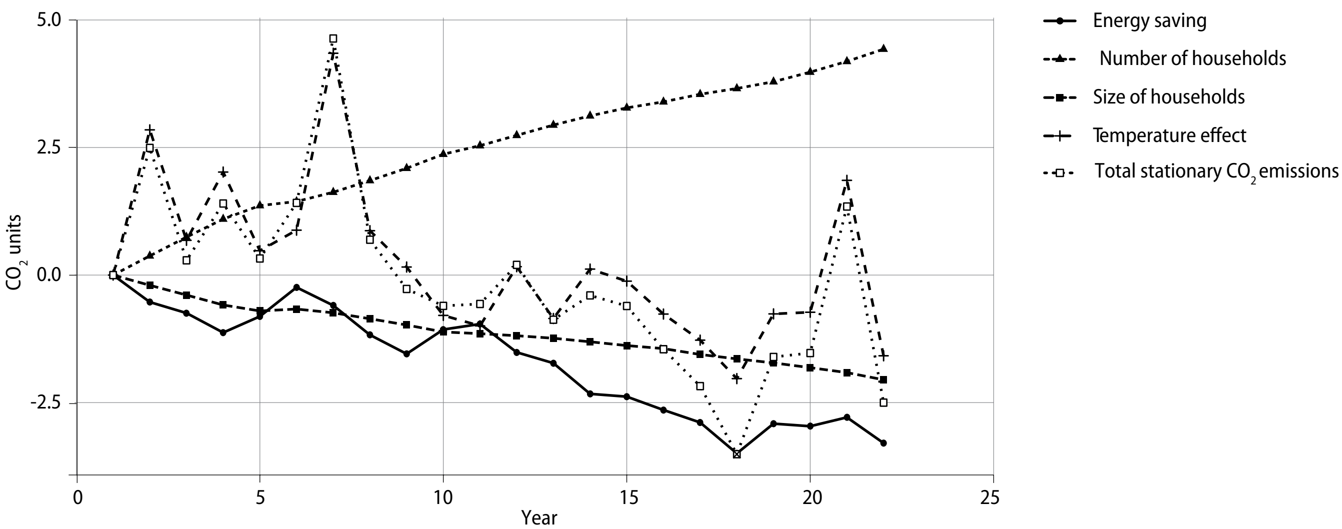


Figure 2.5
Decomposition analyses for CO_2 emissions by households from stationary sources



Input-output analysis: Multipliers and footprints

2.77 Besides the types of approaches described above, more detailed analytical approaches can be utilized, including approaches that take advantage of the integrated nature of data sets incorporating both economic and environmental flows. The development and use of EE-IOT constitute the key starting point. 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 flows through the economy and potentially linking to other economies using multiregional input-output models. Some common outputs from modelling processes are multipliers and footprints which can be defined in relation to particular aspects of resource use and environmental intensity. Section 3.3 discusses the measurement of such 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 III). These resource-specific PSUT enable a complete mapping to be made of relevant flows through an economy and, given the structure of the PSUT, direct links can be established with associated monetary flows relating to the resource.

2.80 The types of analysis that are possible using these PSUT are broad-ranging. In relation to water, chapter IX of SEEA-Water (United Nations, 2012b) 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, and water intensity by product. Using the same framework, distinctions may also be made between the use of resources for intermediate consumption of enterprises and their use for final household consumption.

2.81 Certain issues are associated with 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. It may also be relevant in this area 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, understanding the issue of availability of resources within the country will be relevant. For this purpose, data compiled in asset accounts (as described in the SEEA Central Framework, chapter V) are required. Analysis of the stock of resource's is discussed in section 2.6.

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 flows of all materials, energy and residuals from the environment, through the economy and back into the environment. A common adjunct to SEEA-based PSUT are economy wide material flow accounts (EW-MFA). These accounts are introduced briefly in chapter III of the SEEA Central Framework. EW-MFA focus on physical flows into and out of the economy, i.e., they ignore intra-economy physical flows. With this in mind they are commonly compiled with some differences in the treatment of certain flows compared to the SEEA (see SEEA Central Framework para. 3.282-3.286). A variety of indicators reflecting aggregate material input, output and consumption can be derived (see OECD, 2008a; 2008b).

2.83 One of the limitations with respect to EW-MFA indicators is that materials in different states of production (raw materials, semi-finished products and final products) are added together. Accordingly, some indicators of material consumption fall short in terms of encompassing the total mass of raw materials consumed by a country, as the indicators account only for the mass of the final goods imported, not the raw materials used to produce them. A more genuine indication of the resource productivity of a country can be provided if the material flows are expressed in terms of the amounts of raw materials (raw material equivalents (RME)) that were needed throughout the entire production chain of a product.

2.84 Material input and consumption indicators are sometimes used as proxies for an aggregate 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 these aggregate flow measures do not consider any characteristics 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 (e.g., their toxicity); the location at which ores, for example, are mined or pollutants released; and how the materials are managed across their lifecycle, including methods of production and treatment of wastes and other residual flows.

2.86 Like other highly aggregated indicators, EW-MFA indicators can hide flows of important variations in their constituent variables. For example, quantities of individual materials may 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 which masks developments in other material groups. This is why flows of water are generally excluded from the scope of EW-MFA.

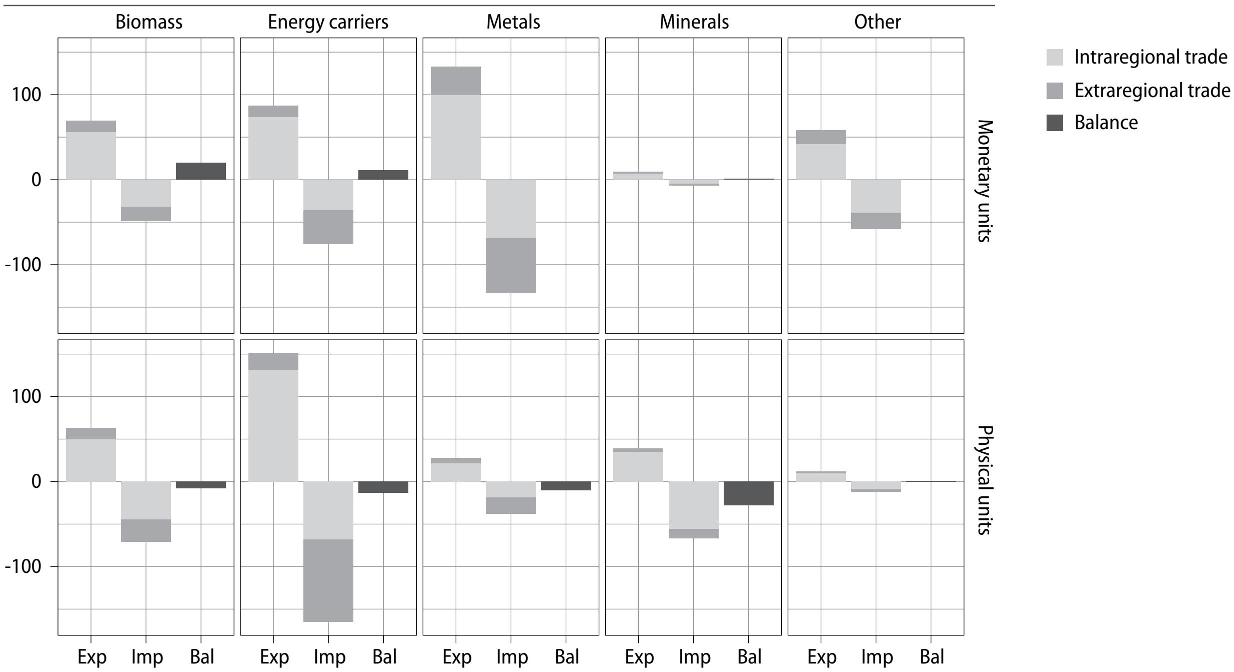
2.87 Proper interpretation of EW-MFA indicators therefore requires, wherever possible, a breakdown of the indicators into their constituent variables. The breakdown of EW-MFA indicators by type of material provides information about the mix of materials and helps display the contributions of different types of materials in the overall material basis of the economy and the shifts in those contributions over time. The most common material groups are: metals (metallic ores and metal-based products), non-metallic industrial minerals, construction minerals, fossil energy carriers (e.g., oil, coal, gas and peat), and biomass (e.g., food crops, fodder crops, timber and wild animals). Materials may also be grouped according to the type of natural resource from which they are extracted (e.g., renewable and non-renewable natural resource stocks) or 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. This information enables the resource productivity of particular types of materials and energy for different industries to be estimated. From this information it is possible to determine the types of industries for which a particular material yields the most value added. Further, 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 examine flows of imports and exports in more detail and analyse trade deficits and surpluses in monetary and physical terms. Figure 2.6 presents the monetary and physical 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 There are three main types of analyses that focus on specific concerns related to the environmental impacts, supply security and technology development associated to certain substances, materials and manufactured goods. They are:

- *Substance flow analysis* which monitors flows of specific substances (e.g., Cd, Pb, Zn, Hg, N, P, CO_2 and CFC) that are known for raising particular concerns about the environmental and health risks associated with their production and consumption.

- *Material system analysis* (*MSA*), which 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 is applied to materials that raise particular concerns regarding the sustainability of their use, the security with respect to their supply to the economy and/or the environmental consequences of their production and consumption.
- *Life cycle analysis* (*LCA*), which is based on life cycle inventories. It focuses on materials connected to the production and use of specific goods (e.g., batteries, cars, computers, textiles), and entails analysing the material requirements and potential environmental pressures along the full life cycle of the goods. A life cycle analysis can be applied equally 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 organized within a PSUT structure. However, it is likely that populating an appropriate PSUT structure would require detailed technical discussions related to the individual elements and substances. No details pertaining to compiling such tables are provided in the SEEA Central Framework.

2.3.5 Specific analysis for residual flows

Describing residual flows in the supply chain

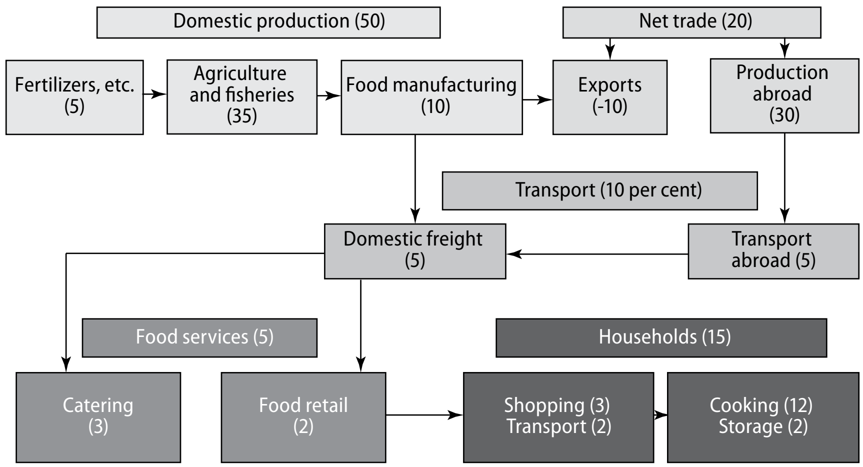
2.92 A complete PSUT also contains information on the supply and use of solid waste. Analysis of flows of solid waste together with all other natural input, product and residual flows can provide resource intensity indicators such as the solid waste generated per primary product or the share of secondary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

2.93 A wide number of studies (e.g., the Environmental Impact of Products (EIPRO) project) 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 points.

2.94 Figure 2.7 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 per cent of all emissions related to food), transport and trade activities are also important contributors.

2.95 Data for this type of analysis needs to be derived from a wide range of sources. The main source is the PSUT for emissions of CO_2 (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; those relating to households are based on household travel surveys and surveys on energy use in the home; and those relating to international trade are derived based on input-output analyses. This type of analysis highlights the potential for data organized using PSUT and input-output table structures to be applied to tracing residual flows through the economy since all of the information is classified to common industry and product classifications.

Figure 2.7
Food chain greenhouse gas emissions (*percentage*)



Analysis of emissions a ccording to different frameworks

2.96 Emissions may be accounted for in different frameworks yielding different results for some types of analysis. Well known in this regard are the emissions reported under the (United Nations Framework Convention on Climate Change (UNFCCC)[8] measured) and other frameworks, including general environmental statistics and the air emissions accounts of the SEEA Central Framework. Bridge tables can be developed which both describe the differences between the various concepts and boundaries 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.

[8] United Nations, Treaty Series; vol. 1771, No. 30822.

Emissions with respect to transport and energy

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

2.98 Emissions 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 SEEA data opens up many kinds of analytical possibilities. For example, the emissions intensity of different transport modes can be assessed.

Linking residual flows and expenditures

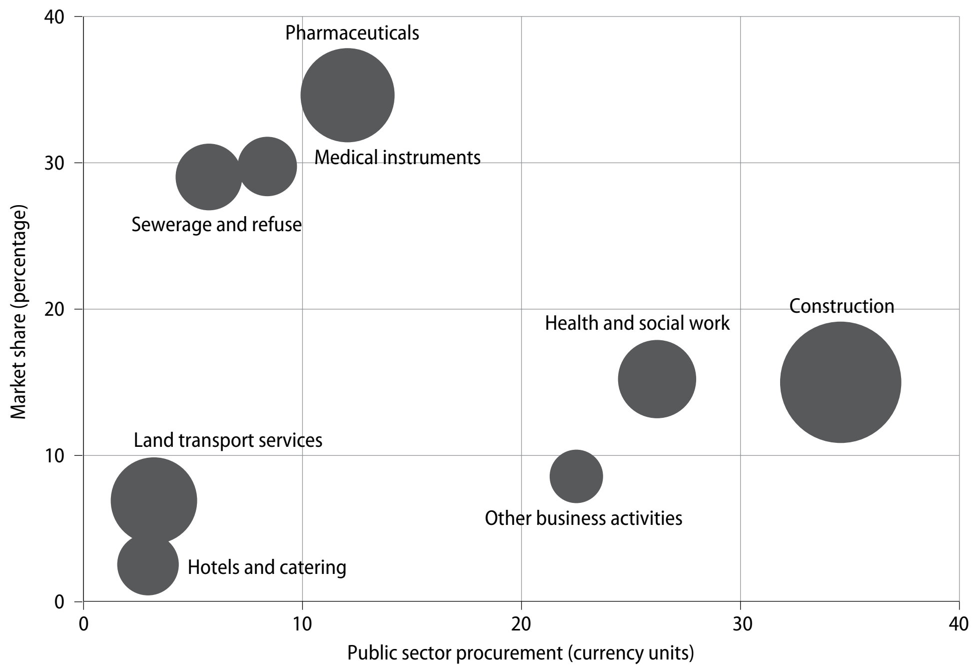
2.99 Public sector agencies are significant purchasers of certain industries' output; hence public sector procurement practices and choices can serve as a policy lever for improving sustainable resource use in those industries.

2.100 Figure 2.8 presents a few activities where the emissions associated with general government sector procurement are significant. (The size of the circle reflects the magnitude of direct emissions relating to that activity.) For some activities, such as those of the pharmaceuticals industry, general government procurement accounts for up to 35 per cent of the total output.

Although government procurement for 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, and sewage and refuse disposal.

2.101 The data used in this analysis are derived from a PSUT for emissions of CO_2 by industry, based on the air emissions account in the SEEA Central Framework section 3.6. The emissions related to use of energy, particularly electricity, are then attributed 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, who approach these topics from various perspectives. For example, their interest may focus on the financial burden that is placed on polluting industries through their having to invest in pollution prevention, abatement and control in order to comply with environmental regulations. Alternatively, environmental concerns will bring about new economic activities which may create jobs and stimulate economic growth. Policymakers therefore need information both on enterprises and institutions that produce environmental goods and services and on the levels of expenditure on those goods and services by enterprises, governments and households.

2.103 The SEEA Central Framework presents two measurement approaches relevant to these information needs. One approach entails using statistics on the environmental goods and services sector (EGSS) and the other uses environmental protection expenditure accounts (EPEA). EGSS statistics and EPEA are described in chapter IV of the SEEA Central Framework. These are related but distinct sets of economic data which may be compiled for the purposes of analysing environmental activities.

2.104 As defined in the SEEA, environmental activities comprise environmental protection activities and resource management activities and are related to economic activities aimed at reducing environmental degradation and safeguarding against the depletion of natural resources. Environmental activities lead to the production of environmental goods and services.

2.105 The EGSS consists of a heterogeneous set of enterprises which produce environmental goods and services. Historically, the production of environmental goods and services focused on the demand for basic services, such as wastewater treatment and 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 expanded to also 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 those involved in renewable a nd 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 the wish to identify and measure 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. On the one hand, the EPEA has a somewhat narrower scope than EGSS in as much as it covers only environmental protection activity. On the other hand, its coverage is broader than that of the EGSS to the extent that the EPEA 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, the EPEA will include vehicles purchased to undertake environmental restoration work even though the vehicles themselves were not designed for this specific purpose.

2.107 The following sections present various types of indicators together with analysis of issues of environmentally related production and employment, which may be undertaken using data derived from the EGSS, and analysis of demand related to environmental activities from the EPEA.

2.4.2 Indicators and aggregates for environmentally related production and employment

Key EGSS indicators and aggregates

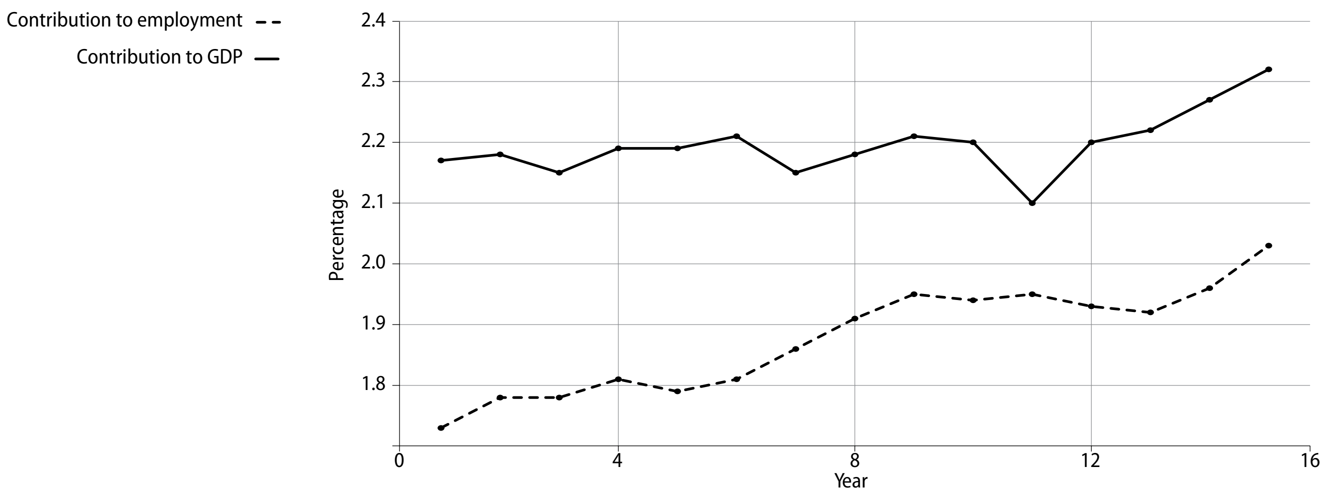
2.108 The most common indicators and aggregates show the importance of environmentally related activities in the economy and characterize those activities through their contribution to employment, to the economy as a whole and to trade (exports and imports). Examples of indicators include:

- 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

Contributions of the environmental goods and servcie sector to GDP and employment



2.109 The production of environmental goods and services and employment in the EGSS make an important, albeit partial, contribution to the shift towards a more resource-efficient and less waste-intensive economy. At the same time, actions in "traditional" industries (e.g., reduction of energy intensity in steel production) can also move an economy towards a low-carbon, resource-efficient growth path. These changes, often driven by cost or competitiveness-related considerations rather than environmental concerns, can have a significant impact.

2.110 The area of green jobs has been of growing interest to policymakers. There have been several approaches to defining green jobs, including focusing, inter alia, on employment in relevant economic activities, in the production of relevant products, in relevant processes, or on specific job descriptions and roles. Each of these approaches will lead to the derivation of a different measure of green jobs, varying with 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 (ILO).

2.111 The SEEA Central Framework does not establish 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 which is structured in accordance with the EGSS, as defined in the SEEA Central Framework.

2.112 EGSS indicators and aggregates 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. They can also be supported by information on technology development and innovation, including research and development expenditure, patents in the areas of pollution abatement and waste management technologies, and energy and climate change mitigation technologies. Information on the framework conditions in place for doing business and accessing financing is also important.

2.113 The EGSS encompasses a broad set of activities, including not only "traditional" ones like waste and wastewater treatment, but also innovative activities like the development of new environmentally friendly technologies. Further, EGSS activities often replace other environmentally harmful activities, for example through the production of renewable energy to replace the burning of fossil fuels. The effort to provide useful indicators for policy purposes for new economic activities may benefit from an examination of certain aspects of the EGSS by utilizing information classified at more detailed levels of the Classification of Environmental Activities, such as information on the growth of enterprises involved in the prevention of pollution through in-process modifications or research and development activities.[9]

[9] See the SEEA Central Framework, chap. IV and annex I.

Key EPEA indicators

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

(*a*) Finance environmental protection activities;

(*b*) Finance resource management and preservation;

(*c*) 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 industry spends on preventing, controlling and reducing pressures from pollution and resource use and on managing natural resources and materials efficiently. This information may be helpful in determining the extent to which an economy is transitioning towards less resource and waste intensiveness. On the other hand, these indicators do not provide a measure of the change, positive or negative, in environmental condition arising from any expenditure.

2.116 The most common indicators show trends in expenditure on pollution prevention, pollution abatement and biodiversity conservation; the shift to pollution preventing technologies; and how expenditure on environmental protection compares with other types of expenditure. Such indicators provide useful information about the financial efforts undertaken by society to prevent, mitigate or abate environmental concerns, including the relative shares of activity by the private and public sectors.

2.117 Key indicators and aggregates include:

(*a*) The level of national expenditure on environmental protection, disaggregated by environmental activity domains (i.e., the classes of the Classification of Environmental Activities, such as air and climate, soil and water, and biodiversity and landscape), by the institutional sector undertaking the measures (government, corporations, households) and by industry according to the International Standard Industrial Classification of All economic Activities (ISIC), (United Nations, 2008);

(*b*) The relative importance of investment expenditure compared with operating expenditure. In general, the investment-related share of environmental protection expenditure decreases as investment programmes progress, while the share of operating expenditure grows;

(*c*) The share of environmental protection expenditure in GDP and its relative importance compared with other types of expenditure such as expenditure on health or education;

(*d*) 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 information exists on experiences with indicators on resource management expenditure, for which internationally agreed definitions and classifications have been elaborated only recently.

2.119 Environmental protection expenditure is sometimes used as a proxy for measuring the implementation and costs of complying with environmental regulations and the level of integration of environmental considerations in a country or an industry. However, information on environmental protection expenditure does not by itself provide any information on the quality of the environment or on the effects of environmental protection activities on the environment, and hence requires careful interpretation in this regard.

2.120 Indicators and aggregates for environmental protection expenditure can usefully be complemented by 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 of 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 privatization. Analysis of corporate and government activities can also be conducted at a more detailed level so as to provide information on the magnitude of the environmental activities carried out by the different ISIC subsectors for corporations and administrative levels for general government, including through comparison with levels of value added. Data on corporations can also be analysed to measure the importance of ancillary activities (i.e., activities that are commonly undertaken within enterprises instead of being purchased from other enterprises), the evolution of outsourcing and the relative magnitude of market and non-market activities.

2.122 Analysis of EPEA data by industry and sector can highlight those areas in which expenditure is most prevalent and the results can in turn be compared with measures of other environmental flows such as emissions or solid waste. The relative significance of environmental protection expenditure within the 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; however care must be exercised in differentiating between direct expenditure by government and activities of the private sector that are financed by government. Comparison of levels of environmental protection expenditure with industry estimates of value added and operating surplus may also be relevant.

Analysis by environmental activity domain

2.123 Analysing 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[10]) reveals the most important domains of specialization for environmental producers in a country. This analysis is important because a large majority of environmental enterprises focus on only one of the environmental domains while the competitive conditions in each of the domains can vary significantly. When combined with

[10] For details see the SEEA Central Framework, annex I.

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 that may be of particular interest encompasses those enterprises within the EGSS that produce renewable energy (the 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. It may be useful to compare such information with information on aspects of environmental change and on policies designed to promote expenditure in particular domains (e.g., through the granting 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 environment-specific services, sole-purpose products, adapted goods,[11] end-of-pipe technologies and integrated technologies. An analysis of the different types of environmental goods, technologies and services can highlight, for example, the importance of integrated (pollution preventing) technologies compared with that of end-of-pipe technologies. This is highly important in raising awareness of the type of environmental output, in particular adapted goods and integrated technologies, whose development represents one of the most important goals of policies directed towards sustainable development. Given the peculiarities of adapted goods, particular attention should be paid to the producers of this class of environmental goods and services.

2.127 More specifically, in addition to being measured in terms of the standard economic indicators (value added, production, employment, exports, imports, capital formation), data related to renewable energy activities may also be presented in terms of various product and process profiles.[12]

Regional analysis

2.128 Where the requisite information can be obtained, the activities of the EGSS may also the analysed at the regional (i.e., subnational) level. It may then be determined whether EGSS activities are concentrated in certain areas and whether this indicates a direct linkage with other economic activities or particular environmental characteristics of these areas. For example, the presence of electrical engineering at a technical university may play a key role in the growth of companies specializing in the development of certain environmental equipment, such as solar panels. Similarly, the presence of significant natural features like coral reefs may spur the concentration 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 compared directly with physical data from the physical supply and use tables. For example, the physical data on the production of renewable energy can be a highly valuable supplement of the data derived from the sustainable energy sector and vice versa.

2.130 For EPEA, comparison of expenditure data with data on physical flows of emissions and waste may be particularly relevant and would enable the derivation of polluter pays

11 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).

12 Product profiles include items such as solar photovoltaic cells, concentrating solar power, solar thermal energy, biogas, biomass (solid) and waste, biofuels, biorefining, wind on land, wind at sea, heat and 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, raw material preparation and production, supply, assembly and construction, production of energy carriers and installation and maintenance.

indicators (see SEEA Central Framework para. 6.111) and an assessment of compliance with polluter pays principles, i.e., the extent to which the economic unit responsible for the residual flows incurs the cost of remediating any environmental degradation or limiting the residual flows. A commonly derived indicator in this regard is the implicit tax rate (see sect. 2.5.3 on the analysis of environmental taxes).

2.131 The comparison of monetary data from the 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 designed to stimulate particular industries often goes well beyond their direct impact on output, employment or emissions. The growing interconnectedness of economic activities also leads to significant indirect or spillover effects in the rest of the economy, which may be analysed by calculating multipliers derived from input-output (I-O) tables (see section 3.3 for details). Multipliers rely on assumptions regarding the relationships between economic and environmental variables. The multipliers discussed here assume linear relationships which, while they may be applicable to economic variables, may be less appropriate for environmental variables.

Cost-recovery analysis

2.133 The SEEA Central Framework provides monetary information on a wide variety of environmental transactions within a consistent framework. As the Central Framework covers both expenditures and revenues, it thereby supports cost-recovery analysis. Cost recovery can be defined as the ratio of the revenues paid for a specific service to the cost of providing that service. For example, the revenues from taxes earmarked for wastewater treatment paid by households and industries may be compared directly with the relevant environmental expenditures by the government or specialized producers, as recorded in the EPEA. Thus, it may be determined whether all of the cost, 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.

Microanalysis

2.134 Depending on the methods used to collect source data, 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 as a part of the process of organizing data for use in compiling accounts. 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 a consistent manner, it may be used to support microanalysis of industry effects related to environmental activities encompassing, inter alia, research and development, innovation and environmental taxes and environmental 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 effect changes in 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: (*a*) the relative size and burden of different policy options, (*b*) competitiveness between countries, (*c*) the effectiveness of various environmental transfers in changing behaviours, and (*d*) the distributive effects of different taxes, subsidies and other transfers.

2.137 Chapter IV of the SEEA Central Framework 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 Presented below are the types of analysis that may be conducted on information compiled on 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 use of alternative definitions of environmental taxes (see the discussion in the SEEA Central Framework, chapter IV), consideration 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. However, these types of analysis are not described here.

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

2.140 A number of countries 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 one whose tax base is a physical unit (or a proxy thereof) of something that has a proven, specific and negative impact on the environment (SEEA Central Framework para. 4.150). These may include 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.[13]

2.142 The most common indicator for environmental taxes is their total as a percentage of GDP. This measure provides an indicator of both the tax burden and the structure of taxation. However, 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 levied on petrol/gasoline, to volumes of petrol consumed or to total expenditure on petrol in monetary terms.

2.143 Another indicator is the ratio of environmental taxes to total taxes. Interpretation of this ratio needs to take into account a range of contextual factors, including environmental

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

circumstances, the nature of the tax base and the use of regulation as distinct from taxation to implement environmental policy.

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 the distinction between current and capital transfers, may be of interest. 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 with 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 describe the structure of the payments.

2.5.3 Analysis of environmental taxes

2.145 For the initial analysis of environmental taxes, it may be useful to compare the relative proportions of the different types of environmental taxes—on energy, transport, pollution and natural resources—and how these shares are changing over time. This type of analysis is illustrated in figure 2.10. It may be of particular interest to those seeking to understand the extent to which taxes influence changes in behaviour through changes in relative prices and how they lead to changes in environmental pressures. At the same time, it should be recognized that movements in tax revenue will also be impacted by changes in economic activity and broader business cycles.

Figure 2.10
Environmental tax revenue by type

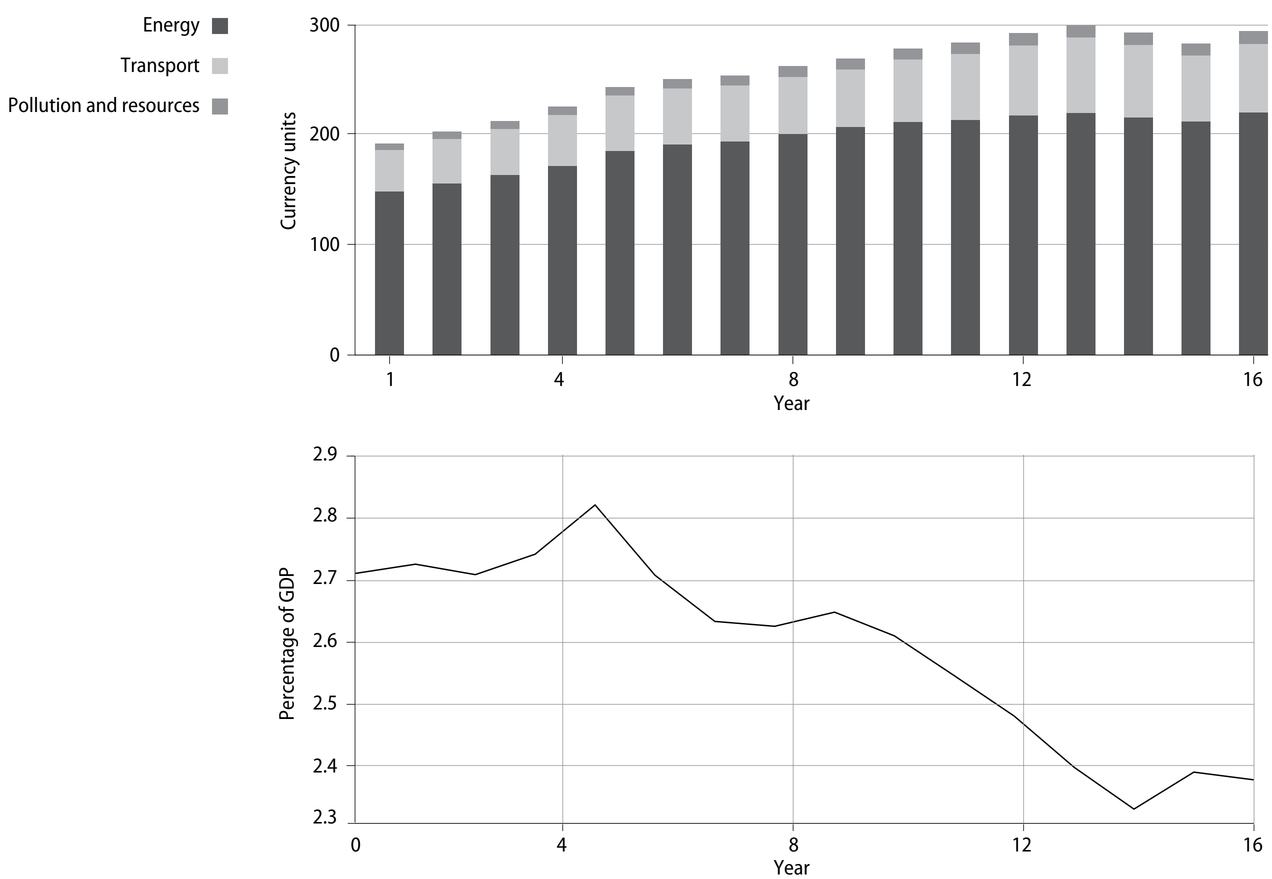
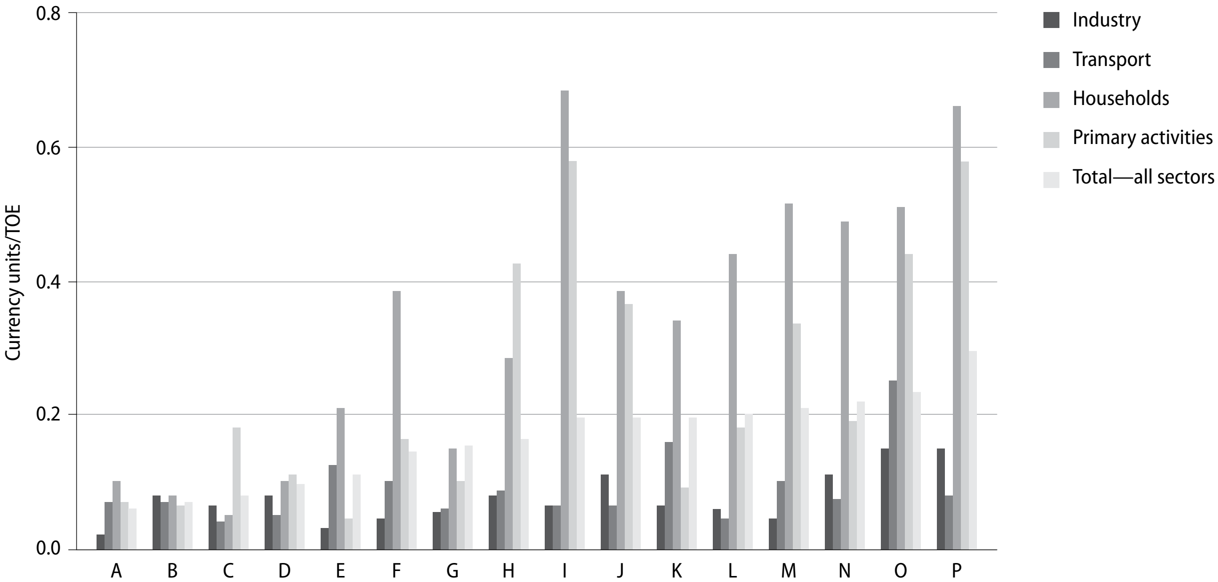


Figure 2.11
Energy taxes divided by energy consumption by sector



2.146 It may be of interest to construct implicit, or effective, tax rates for environmental taxes. Implicit tax rates are derived as the ratio of environmental tax revenues (measured in currency units) to an indicator of the consumption of environmental flows, e.g., units of energy or CO_2 emissions. Thus, an implicit tax rate for energy could be defined as the ratio of energy tax revenues to final energy consumption measured in tons of oil equivalent (TOE). Such rates may be compared across industries, sectors, products and countries. In figure 2.11 above, implicit energy tax rates are presented for several countries.[14]

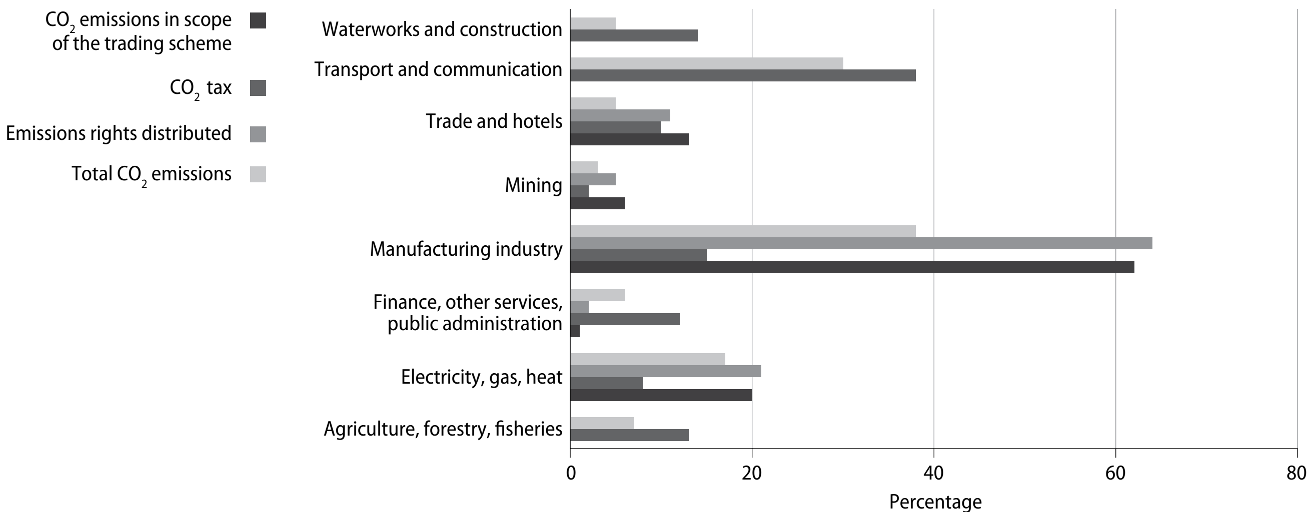
2.147 Analysis using SEEA data can also be undertaken to achieve an understanding of the environmental effect of a tax. For example, the change in pollution resulting from the introduction of a pollution tax. In addition to the data on tax revenue, this requires physical data on the related environmental flow (e.g., emissions, waste and energy products). Figure 2.12 presents the share of CO_2 taxes, allocated emissions trading permits, CO_2 emissions occurring within the trading scheme and total CO_2 emissions by industry. As shown, the CO_2 tax revenue accruing to the government varies depending on the economic activity. The transport and communication industry paid the highest share of CO_2 taxes in the economy (36 per cent), while the manufacturing industry, including energy-intensive activities such as steel manufacturing and pulp and paper manufacturing, paid about 15 per cent of total CO_2 taxes. This type of analysis may be extended, using additional data and assumptions, to determine the extent to which the polluter pays principle may be considered to be in effect.

2.148 Table 4.10 in the SEEA Central Framework presents an account for tradable emissions permits showing the stock and changes in stock of permits measured in terms of tons of CO_2. This information, which can be structured by institutional sector or by industry, can be used to determine which economic units hold permits and the extent to which the holders are complying with relevant emissions targets. It may also be relevant to assess the relationships between the industries holding permits and their contributions to GDP and employment.

2.149 Because common classifications are used in the emissions 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 them to the changes in demand for emissions permits. Tables illustrating the monetary value of emission permits can be used to analyse the effect of changes in permit prices on energy use by industry.

[14] Within the European Union Sustainable Development Strategy, the implicit tax rate on energy (measured in euros per ton (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/taxinenergy-use.htm).

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



2.5.4 Analysis of environmental subsidies and similar transfers

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

2.151 The purpose of an environmental subsidy or similar transfer may be analysed by classifying the flows by type of environmental activity, in accordance with the Classification of Environmental Activities (CEA). Although the purpose of particular payments may often be hard to assess, if this work is successful, then comparisons can be made on the basis of which activities are receiving support and whether there are links between the levels of environmental subsidies and similar transfers and the level of expenditure on environmental protection as recorded in 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 (see table 6.3 of the SEEA Central Framework). Also, it would be possible to undertake an analysis of the incidence of environmental taxes and subsidies by utilizing 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, wealth, income and depletion of resources

2.6.1 Introduction

2.153 There are a range of motivations for undertaking accounting for environmental assets. One motivation is the need to assess whether current patterns of economic activity are degrading or depleting the available environmental assets. Information from environmental asset accounts can also 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. As the accounts are presented in both physical and monetary terms, they contain a vast array of information on the stocks and changes in stocks of those assets.

2.155 The SEEA Central Framework does not describe the measurement of ecosystems, as approaches to ecosystem accounting are less well established than approaches to accounting for individual environmental assets. Approaches to ecosystem accounting are described in SEEA Experimental Ecosystem Accounting (United Nations, and others, 2014).

2.156 The present section highlights the range of information that may be accessed from asset accounts and combined with other kinds of information to provide comprehensive assessments of individual environmental assets. The types of question that may be answered with this 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 Sustainable development is often discussed in terms of the use of different forms of capital, including environmental assets. The information in the asset accounts of the SEEA constitutes part of the information needed to consider these types of questions but does not cover a comprehensive suite of capital which 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 might provide useful indicators for assessing sustainable patterns of growth, and the 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 used in the SNA.[15] Consequently, the measures can be compared with the values of other assets within the SNA framework, for example, with 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 values of individual natural resources can also help foster an understanding of the relationship between physical stocks of resources and the changing likelihood of extraction since that likelihood will be based on the extent to which expected extraction costs using available technologies are less than the expected prices for the resources extracted.

[15] 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.

2.159 In this context, it is beneficial to regard monetary and physical measures of resources as complementary. At the same time, it is important to recognize that the approaches to valuing environmental assets in monetary terms often require the use of assumptions regarding future patterns of activity and discount rates. 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 of resources or the physical constraints under 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 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 potential environmental pressures arising from altered use of the environment. It is to be noted that, in physical terms, the scope of the SEEA Central Framework encompasses all of the land in a country, not only the land that is considered to be "economic" in SNA terms. 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 terms of 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 SEEA Central Framework asset accounts cover both natural and cultivated resources, reflecting the importance of distinguishing between these two types of resources since the environmental pressures involved may be quite different. For example, the harvest of timber from monocultural plantation forests will have quite different effects compared with the harvest of timber from long-standing, native forest areas. Further, the production processes and effects associated with activities such as aquaculture are quite different from those associated with fishing in open waters. Thus, data showing the relative changes in the share of cultivated and natural biological resources in the overall stock of timber and aquatic resources may be of significant policy interest. More broadly, it should be possible to analyze the rates of extraction, costs of extraction and available stock levels and hence provide information relevant to 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, it will not be possible for each set of information on different types of environmental assets to be readily compared since measurement will be undertaken in different units. Indeed, even within particular broad asset types, the measurement units may vary (e.g., different mineral and energy resources may be measured in tons, cubic metres or barrels). Further, it may be most relevant to assess biological resources in terms of species. An exception in this regard is energy-related environmental assets, which may be measured using joules as a common unit. In this case, 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 the System of Environmental-Economic Accounting for Energy (SEEA-Energy) (United Nations, forthcoming).

2.165 The SEEA Central Framework defines the depletion of natural resources, in the first instance, as a measure of physical change, and hence, it may be of interest to compare rates of depletion relative to the levels of the stock of certain natural resources. For renewable resources, these comparisons provide insight regarding the extent to which extraction rates are likely to exceed rates of regeneration and hence can be used to assess the amount of time remaining in the life of an asset.[16] For mineral and energy resources there may be an interest in analysing the rates of discovery of new resources.

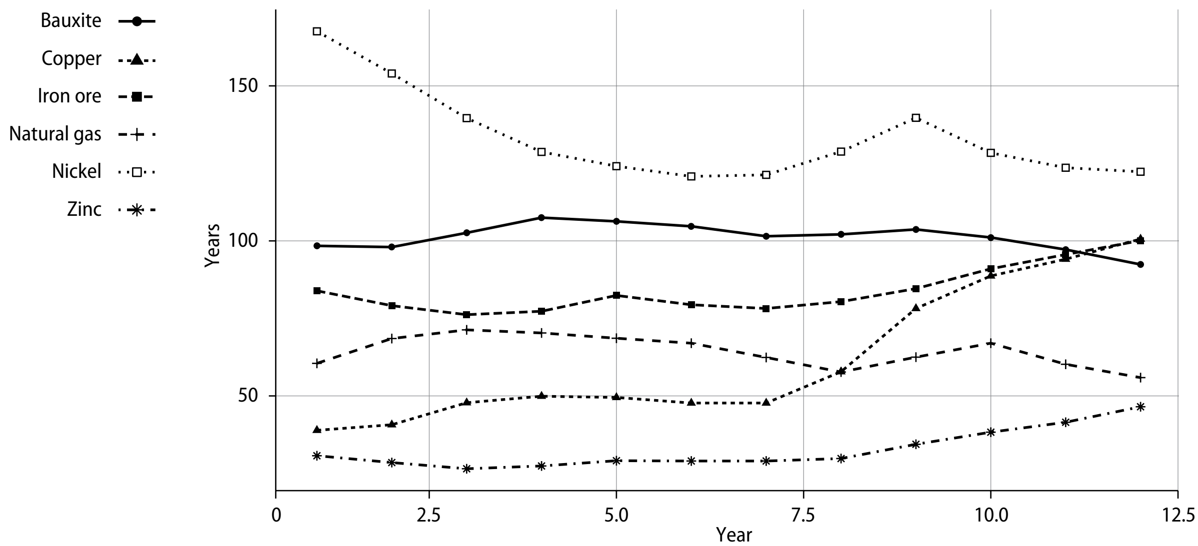
2.166 Figure 2.13 illustrates the analysis of asset lives for selected mineral and energy resources over a 12-year period. For biological resources, the analysis may be more complex owing to the need to consider population dynamics and other ecosystem processes when assessing expected rates of resource regeneration.

2.167 Other indicators also 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. Examples of such indicators 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 the territorial and river basin levels. Macrolevel indicators of water stress often hide significant subnational variations due to the concentration of human activities, the location of water stocks and local climatic and meteorological conditions.
- The intensity of use of timber resources, which relates actual harvest (fellings) and natural losses to annual productive capacity. Annual productive capacity is either a defined value, such as the annual allowable cut, or an estimate of annual natural growth for the existing stock. The choice depends on forest characteristics, forest management practice and the availability of information. This indicator can be derived from physical asset accounts for timber resources. It should be noted that indicators based on a national average can conceal variations among forests. When used for environmental purposes, these indicators should be accompanied by information on forest condition (e.g., species diversity, including tree and non-tree species; forest degradation and forest fragmentation) and forest management practices and protection measures. They can be used together with indicators on output of and trade in forest products.

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

Figure 2.13
Asset lives for selected mineral and energy resources



2.168 For biological resources such as timber resources and fish, it may be of interest to distinguish between natural and cultivated resources and between different types of management practices. Examples of indicators 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 arising 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 indicators provide information on changes in land use and land cover and on 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 I of the SEEA Central Framework. Since land is an input into most economic activities, such indicators speak to competing uses of land. However, it must be noted that land use and land cover are related but not identical: land cover refers to the biophysical aspects 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, either in terms of land use or land cover

2.170 Examples of indicators include:

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

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 of 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, as the stocks of many natural resources are unevenly distributed among and within countries, it is important to consider spatial aspects when developing and interpreting natural resource indicators. While it may not offer a complete picture, the information may still be highly useful in providing a sense of the scale and scope of changes and contributing to 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 water resources and energy related-resources. In this regard, knowing where the resources are located and who can access them, perhaps in the context of household incomes, may be required in order to deal with particular policy questions. This use of asset account data is considered further in chapter IV.

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 allows the formation of monetary estimates that can be readily integrated with information contained in the standard national accounts. Relevant measures include flows of operating surpluses 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 a framework of assets and incomes, information may be organized to cover:

- 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 surpluses accruing to extracting industries that use 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 through quota schemes and taxation arrangements related to the extraction of natural resources
- Levels of investment and employment in extracting industries relative to the country as a whole.

2.175 At an economy-wide level, adjustments to measures of economic activity such as depletion-adjusted net domestic product (NDP) and depletion adjusted net national income (NNI) may also be compiled following the guidelines contained in the SEEA Central Framework. These adjusted aggregates may be compared with non-adjusted aggregates to exhibit, for example, the extent to which depletion contributes to the change in net national income over time.

2.176 Through use of the information required to estimate values of environmental assets, it is also possible to derive volume measures or indices[17] reflecting changes in the values of environmental assets after removing the effect of price change. Volume measures are derived by weighting together changes in the stocks of assets in physical terms using the relative value of each asset type at a particular point in time. Aggregation may be completed for a type of asset (e.g., for types of mineral and energy resource) or across asset types (e.g., 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 types because the physical measures are expressed in different units (e.g., ton, cubic metres). Chapter II of

[17] 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.

the SEEA Central Framework provides a summary of the compilation of volume measures. A more detailed description is contained in chapter 15 of the 2008 SNA.

2.178 Further, it is to be noted that some measurements of the values of environmental assets and natural resources are undertaken using social valuations. Such valuation approaches are not directly discussed in the SEEA Central Framework, and any estimates compiled using social valuations should not be compared with estimates of the value of other assets that use different methodology.

2.7 Selection, interpretation and presentation of indicators

2.7.1 Introduction

2.179 Section 2.2 describes the role and function of indicators and makes some general points concerning the compilation of indicators in the context of the SEEA Central Framework. Sections 2.3-2.6 provide examples of a range of aggregates and indicators in the context of different topics to which integrated environmental-economic information is relevant. Often in the communication of information in complex and cross-cutting areas, it is necessary to introduce summary measures from a number of areas. In this regard, the selection, interpretation and presentation of indicators are important tasks and many agencies have considered the issues involved. An overview of key considerations is provided below.

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 to guide and validate their choice. Some of the required judgments concern questions such as: What is the environmental and economic context about which the indicators are intended to provide information? 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 degree of consensus about their validity among the countries concerned.

2.181 There exists various long-established criteria for selecting environmental and economic indicators. Relevant factors include responsiveness, reliability, ease of interpretation, simplicity, scientific validity, data availability and comparability over time and space. These factors should be considered 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 in 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. Further, macrolevel indicators can be disaggregated by industry and institutional sector to illustrate structural changes over time, support integrated analysis of environmental pressures exerted by different economic activities, and distinguish government responses from those of the corporate sector or households.

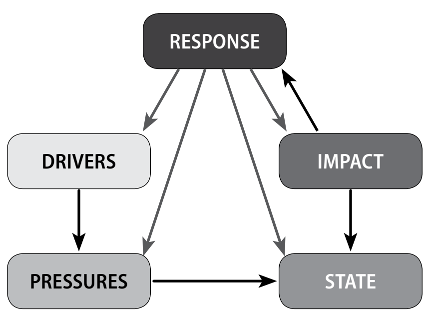
2.7.3 Interpretation and use of indicators

2.183 Indicators usually address policy questions at a general level by providing an overview of major issues and trends and by highlighting developments that require further analysis. Indicators thus represent only one tool for evaluation, and hence a scientific and policy-oriented interpretation will be required if they are to acquire their full meaning. Often indicators need to be supplemented by other qualitative and contextual information (for example, on population change and economic structure), particularly as regards explaining the driving forces behind indicator changes which form the basis of an assessment. The information value of many indicators may also be enhanced through association with policy objectives or targets.

2.184 Indicator sets are structured and presented in different ways. Among the most frequently used frameworks are those based on the pressure-state-response (PSR) model and those of its variants which 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 not only help ensure that important features are not overlooked when the indicators are being developed, but also organise the indicators in such a way as to make them understandable to 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. In both roles, the SEEA can help to prevent the development of indicator sets that reflect only particular aspects of or particular perspectives on topics.

Figure 2.14
Driving force-pressure-state-impact-response (DPSIR) model



2.7.4 Presentation of indicators

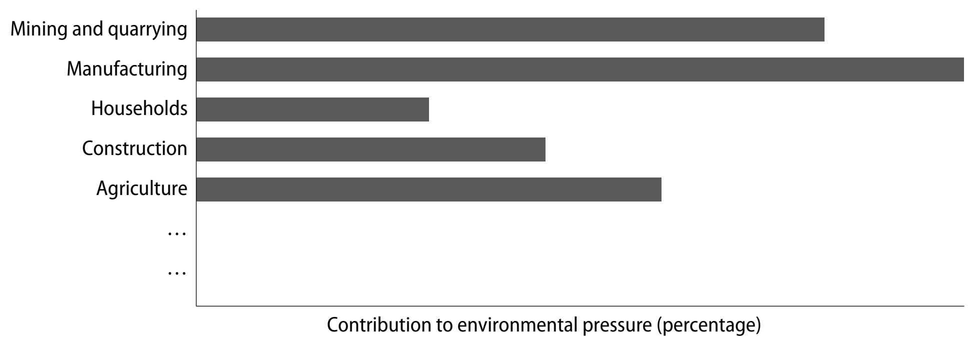
Level of detail and disaggregation

2.186 It is often necessary to disaggregate indicators to focus on a particular topic of interest so as to better understand the macrolevel trends. The extent to which the following disaggregations are possible will depend on the availability of information at finer levels of detail, either from the same data source used to compile the aggregate information, or from other data sets.

2.187 Industry disaggregation enables an understanding of how structural changes in the economy affect environmental pressures and the use of environmental resources. It is also useful for an understanding of the contribution of different industries to a common environmental phenomenon (e.g., CO_2 emissions) in the integration of environmental and industry-specific policies. Macrolevel 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, for the purpose of deriving measures of intensity and productivity.

2.188 When macrolevel 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 comprises 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 exhibit 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 or transfers) or to show changes in different industries over time regarding a certain issue (with respect to a previous or other reference year). A stylized issue profile covering industries and the household sector for a generic environmental pressure is presented in figure 2.15.

Figure 2.15
Stylized issue profile



2.189 Issue profiles provide a condensed and comparable summary of environmental and economic performance for a certain economic activity (e.g., manufacturing or agriculture) or type of economic unit (e.g., households). These profiles may show either 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 in distinguishing government responses from those of the corporate or household sector. Disaggregation by sector is thus likely to be most relevant for an understanding of expenditure on environmental protection and resource management, the impacts of environmental taxes and subsidies, and the use of natural resources that are often publicly owned but privately extracted under various institutional arrangements.

2.191 Disaggregation by type of environmental activity constitutes 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 IV of the SEEA Central Framework. Examples of relevant types of environmental activity include environmental protection and resource management activity.

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

2.193 Spatial disaggregation (i.e. disaggregation of data to smaller spatial scales) helps in understanding the relationships between the location of natural resources (e.g., water resources), settlement areas and economic activities. This is important when using indicators that support subnational decision-making, for example, with respect to river-basin or ecosystem management. Spatial disaggregation is also important when national-level indicators hide important variations within countries.[18] Methods and data requirements related to spatial disaggregation are considered further in chapter IV as an extension of the SEEA Central Framework.

2.194 Disaggregation in terms of population groups, for example, by age classes, gender or income levels may be important for 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 IV as an extension of the SEEA Central Framework.

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

Indicator sets, dashboards and aggregated indices

2.195 Generally, answering policy questions requires the use of more than one indicator. Often what is needed is a set of indicators that cover to the greatest extent possible the various aspects of the topics under consideration and that collectively offer the necessary insights. However, with a large set of indicators comes the danger of failing to provide a clear message that speaks to policymakers and facilitates communication with citizens and the media.

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

2.197 However, reducing the number of indicators by condensing information introduces 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 indices. The advantages of ease of communication and concise presentation offered by a composite index must thus be measured against the challenges associated with selecting the important indicators and choosing the 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 of them as intelligible, robust and transparent as possible. Many countries and institutions therefore identify small sets of "key indicators" or "headline indicators" which are representative of the topics covered and are able to track the central elements. For particular topics, it may be relevant to present an aggregate indicator and relevant component indicators. Another approach is visual aggregation where the values of the constituent indicators or variables are displayed together, as opposed to consolidation of the scores of all indicators or variables into an aggregated index. One example of such a visual aggregation is the dashboard. These different approaches—aggregated indices, headline indicators and dashboards—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, tons, joules) or when scientific evidence provides information about the relative "weights" of the various variables in the concept that the index is intended to represent.[19] Aggregates based on a theoretically sound and widely accepted accounting framework like the SEEA Central Framework and on data expressed

[19] A prominent example in this regard is the global warming potential of various greenhouse gases, which is used to aggregate greenhouse gas emissions into one index expressed in carbon units or in CO_2 equivalents.

in common and familiar metrics are thus potentially attractive. They also tend to be more transparent because their computation is commonly 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 that are all measured in terms of mass units (e.g., tons). In this case, aggregates may be dominated by flows of materials that are abundant (e.g., soil) but may not appropriately reflect flows of materials that contribute more significant environmental pressures but are relative small in total quantity (e.g., mercury). The *Handbook on Constructing Composite Indicators* (Organisation for Economic Co-operation and Development and European Commission Joint Research Centre, 2008) provides additional descriptions and explanations of aggregation issues.

2.201 The standard metric in economic accounting is currency units (money). Aggregates in monetary terms may be formed by adding together relevant accounting entries expressed in common currency units. 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 wealth and GDP. It is to be noted that in many cases, there are a variety of assumptions required in order to assign monetary values to relevant accounting entries. Chapter V of the SEEA Central Framework discusses these measurement issues in detail.

Chapter III
Analytical techniques

3.1 Introduction

3.1 Analysis of the various topics and themes described in chapter II may often be carried out 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. The present chapter describes the most commonly used approaches.

3.2 Section 3.2 introduces the data sets constituting the core of these modelling and analytical techniques: environmentally extended input-output tables (EE-IOT) and 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 which 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 This chapter aims at providing a summary of the technical dimensions of the construction of relevant data sets and the related analytical techniques. The approach chosen often has important consequences including a material impact on the possible interpretations and conclusions that can be made. Since these impacts can be lost amid the technical complexity of input-output tables and the associated models, a summary is relevant. An extensive list of references on the various topics that are introduced is provided to support further consideration of the critical elements.

3.4 A key message of this chapter is that, once constructed, detailed EE-IOT data sets which 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 articulates precise measurement boundaries, it is possible to achieve a coherent integration of environmental data into standard input-output data sets that are compiled in accordance with the SNA. Notwithstanding the ongoing discussion on what constitutes an appropriate choice of analytical or modelling technique, it should be recognized that the establishment of detailed accounting-based input-output data sets is an important means of advancing the 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 data sets 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 goal of the present section is to introduce the main types of EE-IOT, examine key components of their compilation, and discuss some of the associated measurement issues. Section 3.2.2 presents 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. 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 rather than a complete description of the requirements for the compilation of EE-IOT.

3.6 The presentations of the EE-IOT tables in this section are simplifications and therefore do not include all the details that may be useful in environmental-economic modelling (for example, data on landfills or recycling in both monetary and physical terms, may be introduced into the EE-IOT [20]).[21] The discussion of the EE-IOT has been kept as simple as possible so that the basic premises of the analytical techniques described in section 3.3 can be explained. In each subsection, references to more detailed material are cited.

3.2.2 Single-region input-output (SRIO) tables

3.7 In order to apply analytical techniques, environmental data are often combined with input-output tables (IOT). The compilation of IOT is described in the System of National Accounts as an analytical extension being derived through the combination of supply and use tables (SUT), which are core accounts of the SNA.[22] Various mathematical and analytical approaches are available for converting SUT to IOT (see United Nations and others, 2009).

3.8 Table 3.1 presents a simplified version of a single-region input-output (SRIO) table. It provides 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 is an industry-by-industry table of *j* industries. The row entries show the outputs by industry while the column entries provide information about the inputs required in the production process of an industry.

[20] For waste input-output modelling see Nakamura (1999); Suh (2004); Hoekstra and van den Bergh (2006); Weisz and Duchin (2006); Nakamura and others (2007).

[21] Note also that for the sake of simplicity, the direct emissions from consumers are not included in the models. However, it is fairly straightforward to include them under the analytical techniques described in section 3.3.

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

Table 3.1
A single-region input-output (SRIO) table 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 laid out in a j by j matrix, and final demand in categories as final consumption (c), gross capital formation (f), including changes in inventories, and exports (e). Note that for all these categories, the value of each cell is the sum of domestically produced goods and services and imported products, i.e.,

$$Z = Z_d + Z_m \qquad c = c_d + c_m \qquad f = f_d + f_m \qquad e = e_d + e_m$$

Where subscript d denotes the use of domestically produced products and m the use of imported products. 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 the 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 in both the rows and columns are either all products or all industries).

3.11 To create an EE-IOT, 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 the data relate to flows of natural inputs and/or residuals (see SEEA Central Framework, chapter III).

- Natural inputs are all physical inputs that are moved from their location in the environment as a part of economic production processes or are used directly 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 (e.g., solar, hydro and wind sources) and other natural inputs (e.g., 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 (e.g., discard catch in fishing).

3.12 The use of data on flows of natural inputs and residuals from SEEA accounts is advantageous for the compilation of EE-IOT, since the information will have already been organized in a manner consistent with the classifications (e.g., for products or industries) and applying the 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 are most commonly collected and classified by industry. The adjustment of environmental flow data in terms of industries and products will also be needed when supply and use tables 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 (i.e., they are not symmetric tables). Examples of environmentally extended SUT are emerging in the literature and may be beneficial for some analyses 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 expressed in monetary units. However, it is also possible to record the output of an industry, i.e., its products, in physical terms. For example, many studies have analysed energy using an input-output table 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. 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
Single region input-output (SRIO) table 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, a better description is provided 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 used in the rows of the hybrid input-output tables. The details of these types of models (for energy) are provided in Miller and Blair (2009, chap. 9).

3.16 It is noted that this type of EE-IOT incorporates elements of life cycle assessment and process analysis, since in this case it is possible to reflect the chain of flows between economic units in physical terms within 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 like table 3.1. Subsequent input-output modelling that is based on an SRIO table has the limitation that it often entails adoption of the "domestic technology assumption". This assumption is that an imported product is produced using the same process as that used to produce the same product domestically (see sect. 3.3.3). To the extent that domestic technologies are not representative of those used to produce the imported product, input-output modelling under this assumption will produce estimates that do not reflect the likely environmental pressures. For example, the same product may be produced in different countries using different quantities of water or generating different levels of CO_2 emissions.

3.18 Given the significant and ongoing globalization of production processes, there is thus strong interest in the construction of EE-IOT data sets that take these international differences into account. Recently, a number of large projects have been undertaken through which multiregional input-output (MRIO) tables were created and made available in databases.[23] The number of countries covered has varied significantly (from 2 to about 190) depending on the regional breakdown used in each project. Further, the number of industry classes and the types of aggregation procedures used have varied as well. There has also been variation in respect of the inclusion of time series of information.[24, 25]

3.19 Table 3.3 presents the simplified structure of an MRIO table for two countries (A and B).[26] The accounting structure follows that of the SRIO: the rows signify the outputs (to both the domestic and export markets) and the columns represent the inputs (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} signifies the output of country A that is used as final consumption in country B.

Table 3.3
Multiregional (two-country) input-output table with environmental data

	Country A	Country B	Country A Final demand		Country B Final demand		
	Industries		Final consumption	Gross capital formation	Final consumption	Gross capital formation	Total output
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 by eliminating the need to use the domestic technology assumption. In many cases, the MRIO databases are linked to environmental and other socioeconomic 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. On the other hand, the integration of input-output data across countries generally reduces the level of industry detail at which analysis can be conducted and generally requires adjustment to individual national IOT to, inter alia, ensure harmonization of trade data and account for currency conversion. These and other measurement issues are described in section 3.2.5 directly below.

23 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 and others 2007; Wiedmann 2009; Wiedmann and others 2011). A special issue of *Economic Systems Research* (Volume 25, Issue 1) and a book (Murray and Lenzen, 2013) provide additional detail on MRIO.

24 There are data sets that cover only trade between two countries (bilateral trade input-output (BTIO) tables) and associated input-output models such as the emissions embodied in bilateral trade (EEBT) model. With developments in data availability and computing power, a focus on bilateral data sets and models is becoming less frequent. A comparison of different approaches can be found in Peters and Solli (2010).

25 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 data sets, generally referred to as Inter-Regional Input-Output (IRIO) tables are challenging to compile given the high data requirements.

26 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 per cent of world GDP. This "rest of the world" region has been omitted here for the purposes of exposition.

3.2.5 Measurement issues

3.21 Tables 3.1-3.3 provide simplified representations of the tables that may serve as underlying data sets for use in the application of the analytical techniques described in section 3.3. However, it is important to recognize the types of measurement issues that arise when accounts are being compiled for use in environmental-economic applications.

3.22 *Differences in the SEEA and the 2008 SNA*. In the most recent revision of the System of National Accounts (2008 SNA, United Nations and others, 2009) imports and exports are defined on the basis of ownership rather than in terms of physical flows. However, a difference in the recording of some flows of products (e.g., goods sent abroad for processing) may need to be taken into account in physical terms (see the SEEA Central Framework chap. III for more details on treatment in physical terms). Consequently, analysts seeking to utilize information in both monetary and physical terms may need to make adjustments to one data set or the other so as to ensure an alignment in the treatment of certain flows.

3.23 *Utilization 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 record appropriately, with adjustment as necessary, entries for purchases abroad by tourists and re-exports. Careful attention should also be paid to the general issue of recording data on a residence basis rather than on a territory basis (see the SEEA Central Framework sect. 3.3, for details).

3.24 *Construction of MRIO tables*. A range of measurement issues arise in respect of the construction of an MRIO table. Unavoidably, the data for an individual country within an MRIO is unlikely to be consistent with the data in an individual SRIO table produced by national statistical offices, since SRIO tables are produced using data from the individual country only, whereas, generally, compilation of MRIO tables requires data of all countries to be adjusted so as to ensure an overall balance at the multicountry level.

3.25 A common type of adjustment is associated with the phenomenon of "trade asymmetries", whereby the trade statistics on the imports of country A from country B are not found to be identical to the data on the exports of country B to country A. In the process of resolving these asymmetries, as well as through other construction procedures, it is most likely that differences between the MRIO and national SRIO tables of will emerge.

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

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

3.28 Given these compilation issues, it is reasonable to consider whether the benefits of adopting an MRIO approach, most notably the capacity to eliminate the domestic technology assumption, are sufficiently large. The decision to opt for an MRIO or SRIO approach may depend, for example, on the extent of the differences between the production processes of trading partners, or between their environmental and resource use profiles. The greater the differences, the greater the error arising from assuming that trading partners have the same production processes and technologies.

3.29 Another consideration is that the significance of the compilation issues, in terms of the quality of the estimates, can be assessed in terms of stochastic errors in those estimates, whereas the use of the domestic technology assumption for an SRIO may introduce systematic errors into subsequent analysis.[27]

[27] For example, see Lenzen and others (2013). See also Lenzen, Pade and Munksgaard (2004) for an analysis of aggregation errors in an MRIO model for Scandinavia.

3.30 For some purposes, it may be reasonable to construct MRIO databases by holding some country information constant instead of allowing the data of all countries to vary in the modelling process.

3.3 Techniques for the analysis of input-output data

3.3.1 Introduction

3.31 The history of input-output tables and modelling dates back to 1936 when Wassily Leontief published his seminal article entitled "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, which Leontief based on the *tableau economique*, proposed by François Quesnay in 1758. Subsequently, Leontief (1941) developed the first input-output model (see Leontief (1977)), which was based on theories developed by Léon Walras.

3.32 The first extensions of input-output tables and modelling to environmental concerns emerged in the late 1960s and early 1970s (Ayres and Kneese, 1969; Leontief, 1970; Leontief and Ford, 1972). In the 1970s and 1980s, input-output models appeared in a variety of academic publications and were also widely utilized in applied analysis. The mid- to late 1990s witnessed a significant surge in interest in environmental input-output modelling, and there was a large increase in the number of peer-reviewed journal articles on the subject starting at the end of the 1990s (Hoekstra, 2010). This increase coincided with a growing interest in and data on environmental accounts over the same period. Given the recent proliferation of input-output data and environmental extensions (see, for example, the work done by Eurostat, OECD, and the various initiatives set up to create multiregional input-output databases with environmental extensions), the number of applications is likely to increase.

3.33 Work in this area has led to the development of a broad array of input-output models. The present section does not attempt to examine all of the variations over the entire range of models. Instead, the goal is to introduce a basic environmentally extended input-output model with a view to suggesting possible types of analysis.

3.34 Equation 3.1 is associated with 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 (δ), the domestic output of each industry (L_d) and the various sources of final demand (y_d), including household consumption, capital formation and exports. Thus:

$$r_{tot} = \delta \cdot L_d \cdot y_d \qquad (3.1)$$

where

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

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

$$y_d = c_d + f_d + e_d$$

What each variable represents is indicated directly below (see also table 3.1):

r_{tot}	total environmental pressure (scalar)
d	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 j by 1)
r	environmental pressure per industry (vector 1 by j)
q	output per industry (vector 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 j by 1)

The symbol "^" signifies that the relevant vector has been diagonalized, i.e., transformed into a square matrix with the values of the vector lying on the diagonal.

3.35 The mathematical derivation of the Leontief inverse, which is the core concept underlying the input-output model, is set out in annex II. The interpretation of the coefficients in the Leontief inverse matrix model is important since the 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.

3.36 A number of analytical techniques based on this input-output model are discussed below, including two static applications: multiplier analysis (sect. 3.3.2) and the attribution of environmental pressures to final demand (sect. 3.3.3).

3.37 Input-output models are also used for dynamic analysis for example, for decomposition analysis (sect. 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.

3.38 While the input-output model has a number of advantages, it is also criticized for its underlying assumptions, especially when used for scenario or future modelling. The most notable assumption is that of perfectly elastic supply (i.e., of inputs of labour, capital and materials). Another concern is that substitution between inputs is not possible. Computable general equilibrium (CGE) modelling uses less restrictive assumptions while still being based on EE-IO data and is therefore another important analytical technique. CGE models are discussed in section 3.3.5.

3.3.2 Multiplier analysis

3.39 Multipliers provide a summary of input-output model results and typically supply 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 and others, 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 released to water. Overall, knowledge of the magnitude of a wide range of multiplier effects of individual industries is relevant for the evaluation of trade-offs (Foran and others, 2005).

3.40 Equation 3.2 sets out the basic formulation of the environmental multiplier (sometimes referred to as eco-efficiencies). The derivation of the multiplier (α) entails multiplying the intensity of the environmental flow for each industry (δ) by the structure of output for each industry (*L*). Thus:

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

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

α multipliers (vector 1 by *j*)

3.41 There are several varieties of multipliers, for example forward and backward linkages (Miller and Blair, 2009). The multipliers provide insight into the environmental pressures exerted 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 environmental pressure in one industry will 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 that there is a perfectly elastic supply of inputs, i.e., that there are no resource constraints.

3.42 The practical challenge of aligning environmental data with the input-output categories may be remediated by utilizing a supply and use table (SUT) framework and undertaking multiplier analysis within it, rather than converting to IO tables. Since SUT often contains many more products than industries, environmental data can be allocated to additional vectors by product as well as by industry, thereby enabling multipliers for both industries and products to be calculated in a single procedure. This more recently developed technique, described in detail in Lenzen and Rueda-Cantuche (2012), has been employed in case studies (Lenzen, Pade and Munksgaaard, 2004; Wachsmann and others, 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.

3.43 A wide range of multipliers covering different environmental themes have been compiled, including multipliers relating to energy, emissions, land, water, biodiversity, pollutants, phosphorus, nitrogen and the environmental goods and services sector.

3.3.3 Attribution of environmental flows to final demand

3.44 Input-output analysis is regularly used to attribute environmental flows to final demand categories. It can identify the link between final demand and resource use, emissions and other environmentally related flows and thereby highlight "hot spots" or "pressure points" that may be subjects for policy attention.

3.45 Three research topics are regularly tackled in the literature using this technique: footprints, consumption versus production perspectives and the global shifts in environmental pressures. A discussion of each of these topics is provided directly below, followed by a short presentation of the relevant mathematical details. As analysis under each of these topics is based on the same input-output approach, the analyses offer complementary rather than competing perspectives.

3.46 It is also possible to undertake analysis of the links to final demand by using life-cycle assessment (LCA). Under LCA-based approaches, the life cycles for particular products are traced through their production processes (creating supply or value chains), and the links to the use of various materials or emissions can then be determined. An LCA approach, unlike an input-output based approach, does not utilize the fully integrated industry and product information inherent in an IOT and consequently, the full range of effects may not be captured.[28] 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. Indeed, there are hybrid LCA approaches which utilise EE-IOT data together with specific data on certain production processes. The combination of physical and monetary relationships set out in the resulting hybrid data sets can be used to conduct process analysis and structural path analysis.

[28] Resulting in what are referred to as truncation errors.

Footprint calculations

3.47 "Footprint" calculation is a technique through 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 reveals the amount of land and water (surface area) that is necessary to produce a certain consumption bundle. The initial work in this area used an LCA-based approach rather than input-output techniques.

3.48 From an input-output perspective, the analysis of links between environmental flows and final demand is of relatively long standing. Over the past decade, a variety of footprints have been derived using input-output techniques, especially from MRIO models.[29] Examples include carbon footprints, land footprints, water footprints and ecosystems pressure footprints.[30] As noted above, footprints may also be derived using LCA-based data sets and those should be regarded as constituting a distinct, albeit related, family of footprint indicators. Although the methodologies are currently quite varied, there have been efforts to harmonize the required calculations (Galli and others, 2011; Weinzettel and others, 2011).

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

Production versus consumption perspective

3.50 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).

3.51 Underlying this discussion are the questions: which environmental pressures is a country responsible for? and, who is the polluter under the polluter pays principle? From what is commonly referred to as the production perspective, the polluter is the industry or the producer releasing the pollution during production. Some international environmental agreements, such as the Kyoto Protocol to the United Nations Framework Convention on Climate Change,[31] follow this logic because they are centred on greenhouse gas emissions released within the geographical boundaries of the country.[32]

3.52 The consumption perspective, on the other hand, is based on the premise that the ultimate polluter is the consumer of the end product. In accordance with the consumption perspective, the calculation of environmental footprints captures 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.

[29] The increased use of input-output techniques is attested by the publication in 2009 of a special issue *Economic Systems Research* by the International Input-Output Association

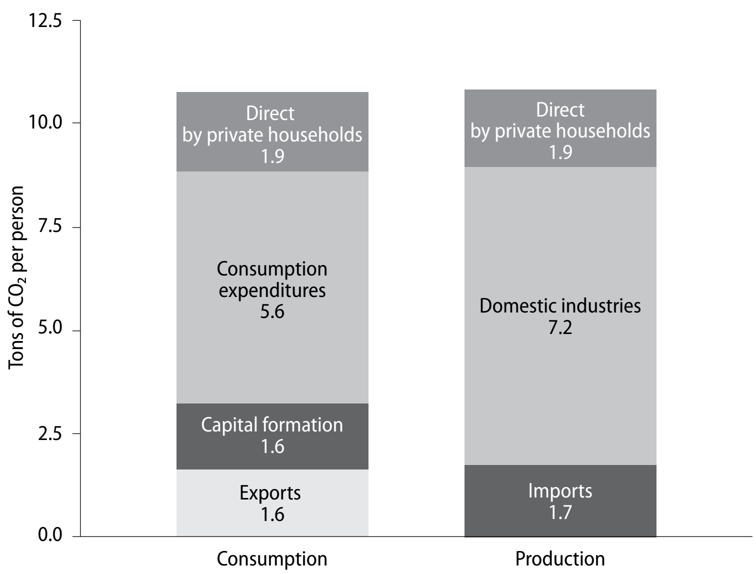
[30] Several national statistical offices and organizations such as OECD and Eurostat have also undertaken calculations of footprints. See Ahmad and Wyckoff (2003); Edens and Hoekstra (2012); Eurostat (2006); Lenglart, Lesieur and Pasquier (2010); Nakano and others (2009); Nidjam and others (2005); Statistische Bundesamt (2012); United Kingdom, Department for Environment, Food and Rural Affairs (2013); and Wilting and Vringer(2009).

[31] United Nations, Treaty Series, vol. 2303, No. 30822.

[32] Note that this view of production is based on the territory principle for attributing economic activity, whereas in the SNA and the SEEA, production is attributed to countries on the basis of the residence of the producing units. While there is likely to be significant overlap in these attribution methods, there are also notable differences, for example, in relation to international transport (the SEEA Central Framework, sect. 3.3, provides more details in this regard).

3.53 Figure 3.1 analyses CO_2 emissions per capita in 2006 for the then 27 countries of the European Union, from both a consumption and a production perspective (Eurostat, 2011). The starting point for this analysis comprises the total emissions related to final use or demand, including demand from the rest of the world. From the consumption perspective, the emissions are attributed to exports, capital formation and consumption, in terms of both expenditures and transport and heating activity undertaken by households. From the production perspective, the emissions are attributed to the industries and activities that supplied the relevant goods and services. It can be seen that about 70 per cent of the CO_2 emissions are ultimately attributable to households through their demand for (*a*) energy used in and around the house, (*b*) personal transport and (*c*) food. Further, it is apparent that there is a relative balance between the import and export of emissions, reflecting the fact that the products imported include raw materials that generate few emissions through extraction, whereas exports constitute finished products embodying a significant amount of emissions. Such insights are important for understanding which product and consumption-related policies may help limit CO_2 emissions.[32]

Figure 3.1
Production and consumption based CO_2 emissions per capita



Global shifts in environmental pressures

3.54 In a closed economy, the total environmental pressures from the producer perspective and those from the 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 CO_2 emissions. This trade balance, which is equal to the difference between the environmental pressures embodied in imports and those in exports, will change over time as a result of general economic development, international agreements concerning the environment, e.g., the Montreal Protocol on Substances that Deplete the Ozone Layer,[33] and international agreements concerning the economy, e.g., the agreements arising out of the Uruguay Round negotiations on multilateral trade.

[33] United Nations, Treaty Series, vol. 1522, No. 26369

3.55 A large body of research has been devoted to analysing these shifts in environmental pressures and 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 emissions-intensive products from countries that are not parties to the Protocol (Peters, 2008; Weber and Matthews, 2008; Peters and Hertwich, 2006, 2008; Babiker, 2005).[34] In a related field of research underpinned in this case by the "pollution haven hypothesis", the same shifts from developed to developing countries resulting from differences in environmental regulation are being investigated (Eskeland and Harrison, 2003; Cole, 2004).

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

Mathematical attribution of environmental pressures to final demand

3.56 How environmental pressures can be attributed to final demand categories 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 equation 3.4 is an expansion of equation 3.1 where the variable for final demand, y_d, is separated into its constituent parts, namely, consumption (c_d), capital formation (f_d) and exports (e_d):

$$\Phi_d = \Phi_d^c + \Phi_d^f + \Phi_d^e \qquad (3.3)$$

$$\Phi_d = \delta \cdot L_d \cdot c_d + \delta \cdot L_d \cdot f_d + \delta \cdot L_d \cdot e_d \qquad (3.4)$$

The variables (all scalars) that have not yet been defined are:

Φ_d environmental pressures attributed to final demand of domestic output

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

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

Φ_d^e environmental pressures attributed to exports of domestic output

3.57 The domestic technology assumption is often criticized because it is not an accurate reflection of the environmental pressures created by goods and services produced in other countries. Therefore, it is likely to be appropriate wherever possible and, taking into account the measurement challenges outlined in section 3.2.5, to carry out the attribution using MRIO data because this makes it possible to calculate the environmental pressures embodied in imports more accurately. The model (equation 3.3) also includes the feedback loops within the world economy since the Leontief inverse includes all of the inter-industry deliveries of all countries.

3.58 The formula for country A is provided in equations 3.5 and 3.6. They use the variables of table 3.3 for countries A and B to reflect the multiregional dimension to the model, and follow the general structure of the expression for multipliers shown in equations 3.3 and 3.4. Thus:

$$\Phi_A = \Phi_A^c + \Phi_A^f + \Phi_A^e \qquad (3.5)$$

$$\Phi_A = (\delta_A \quad \delta_B) \cdot \begin{pmatrix} L_{AA} & L_{AB} \\ L_{BA} & L_{BB} \end{pmatrix} \cdot \begin{pmatrix} c_{AA} \\ c_{BA} \end{pmatrix} + (\delta_A \quad \delta_B) \cdot \begin{pmatrix} L_{AA} & L_{AB} \\ L_{BA} & L_{BB} \end{pmatrix} \cdot \begin{pmatrix} f_{AA} \\ f_{BA} \end{pmatrix} + (\delta_A \quad \delta_B) \cdot \begin{pmatrix} L_{AA} & L_{AB} \\ L_{BA} & L_{BB} \end{pmatrix} \cdot \begin{pmatrix} e_{AA} \\ e_{BA} \end{pmatrix} \qquad (3.6)$$

Where the variables that have not yet been defined are:

Φ_A environmental pressures attributed to final demand of country A

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

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

Φ_A^e environmental pressures attributed to exports of country A

3.3.4 Decomposition analysis

3.59 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 that enables separate estimation of the particular driving forces influencing changes in environmental impacts. Examples of decomposition analysis are presented in section 2.3.3.

3.60 The driving forces that are distinguished depend on the model that is used. When decomposition analysis is specified using an input-output model, it is known as structural decomposition analysis (SDA).[35] The simplest specification, based on the SRIO model shown in equation 3.1, is provided in equation 3.7:

$$\Delta r_{tot} = \Delta\delta \cdot L_d \cdot y_d + \delta \ \Delta L_d \cdot y_d + \delta \cdot L_d \cdot \Delta y_d \tag{3.7}$$

3.61 In this equation, the changes in environmental pressures (Δr_{tot}) are determined by the changes in the intensity of environmental pressures ($\Delta\delta \cdot L_d \cdot y_d$), the changes in the industry structure of the economy ($\delta \cdot \Delta L_d \cdot y_d$) and the changes in final demand/economic growth ($\delta \cdot L_d \cdot \Delta y_d$).[36] Note that it is possible to provide more detailed decompositions by splitting final demand into subcomponents (i.e., export, consumption and capital formation) or to analyse their changes, i.e., the composition and level effects of changes in final demand categories. This enables analysis of the effect of changes in consumption patterns for example. Techniques also exist for decomposing the technological aspects of changes. For example, the Leontief inverse may be broken down further, or the intensity of environmental pressures may be broken down into a fuel mix and energy intensity effect.

3.62 To undertake a structural decomposition analysis it is necessary to possess data that permits analysis in volume terms, i.e., through the removal of price effects. This may be achieved by using input-output data in the current prices of a given reference year and in prices of a base year. Given that the decomposition is conducted using discrete data for years *t* and *t*-1, each variable in equation 3.7 must be weighted based on the relative importance of the variable at times *t* and *t*-1. There are many ways in which this weighting can be undertaken, which explains the lack of a time notation in the equation. Most recent studies in the SDA literature use the weighting method proposed by Dietzenbacher and Los (1998), which leads to results equivalent to those of Sun (1998).[37] In the related field of index decomposition analysis, other weighting methods are used.

3.63 Decomposition methods that do not use an input-output model are more prevalent because the data requirements are less restrictive. Those are often referred to as index decomposition analysis (IDA) or energy decomposition methods (Ang and Zhang, 2000; Ang, 2005).

3.64 The simplest IDA is represented by the following equation:

$$\Delta r_{tot} = \Delta\delta \cdot s \cdot q_{tot} + \delta \cdot \Delta s \cdot q \quad + \delta \cdot s \cdot \Delta q_{tot} \tag{3.8}$$

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

35 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).

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

37 The method of Dietzenbacher and Los is associated with 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) and Hoekstra (2005).

3.65 For the decomposition expressed in equation 3.7, that model, as noted, decomposes the change in environmental pressure into the effects of changes in intensity, changes in industry structure and changes in economic activity. However, the model shown in equation 3.8 requires only data on output by industry and not an entire input-output table. Hence, in equation 3.8 as compared with equation 3.7, the industry structure, *s,* replaces the matrix, *L*. Note also that in IDA 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.

3.66 Note that in equations 3.7 and 3.8 no residual term is included, hence, these decompositions should not be considered 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

3.67 Computable general equilibrium (CGE) models are a class of economic models that combine use of input-output data with the application of microeconomic 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.

3.68 CGE models consist of a system of non-linear demand, supply and market equilibrium equations. The main model equations are based on principles of neoclassical economics. Each industry in a CGE model reflects inputs of labour, capital and materials that minimize 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 that industry investment reflects rates of return on capital. Finally, it is assumed that there are markets for all possible goods and services and no externalities.

3.69 The key distinction between analysis using CGE models and analysis using input-output models lies in the fact 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 introduced concerning constraints on capital and labour. CGE models also allow for price-induced substitutions and do not require the assumption of fixed production technologies.

3.70 The use of CGE models can facilitate an understanding of what dynamic impacts may be expected in the case of policy interventions, or other developments. For example, CGE models can assist in understanding the dynamics arising from the introduction of a tax on CO_2 emissions, which will entail a shift away from relatively carbon-intensive inputs. Overall, while input-output models are an excellent means of understanding the current situation or the causes related to historical changes, they are not well suited to analysing the future effects of policies.

3.71 The incorporation of physical data within CGE models requires the inclusion of equations that link environmental to economic quantities. This may be particularly relevant in cases where there is not a close relationship between the monetary value of flows, e.g., water, and the underlying physical flows. Further, for some environmental flows, such as emissions and waste, relationships in monetary terms with industry activity measures may not exist.

3.72 EE-IOT databases are used to calibrate the main parameters of CGE models so that, in the initial reference year, the model reproduces the EE-IOT data. Overall, the core structure of CGE models is quite similar to that of EE-IOT. Usually, however, not all of the model parameters can be calibrated based on the EE-IOT data and these parameters are obtained from the relevant literature or estimated econometrically. Such parameters include, among others, elasticities of substitution and elasticities of demand with respect to income. Whether these additional elements and parameters are included depends on the purpose of the particular CGE models and significant variation exists among the existing models.

3.73 Building computable general equilibrium models is a job for specialists and as such falls outside the scope of this publication. In particular, within 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, and others, 1982)
- The MONASH model (see Dixon and Rimmer, 2002)
- The Global Trade Analysis Project (GTAP) Framework (built centred around the GTAP database adapting the ORANI model to a multi-country application) (see Hertel, 2012)
- The OECD Env-Linkages General Equilibrium model, used in *OECD Environmental Outlook to 2050* (Organisation for Economic Co-operation and Development, 2012) (see Burniaux and Chateau, 2010)
- The General Equilibrium Model for Economy-Energy-Environment (GEM-E3) used by the (see Capros and others, 2013)
- The WorldScan model used by European Commission Directorate General for the Environment and the Directorate General for Trade (see Lejour and others, 2006)
- The Massachusetts Institute of Technology (MIT) Emissions Prediction and Policy Analysis (EPPA) model (see Babiker and others, 2008).

Chapter IV

Extensions of the SEEA

4.1 Introduction

4.1 The focus of the present chapter is the potential of the accounts of the SEEA Central Framework to be extended and integrated with other information. Connecting SEEA accounts to a range of existing information sources can facilitate a better understanding of multifaceted issues, such as sustainable development. This chapter recognizes that appropriate responses to environmental pressures will usually rely on an understanding of the connections among the environment, the economy and individuals. In this context, while the SEEA accounts do not provide a complete information set, they can provide an important part of the information required. Generally, the 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 linkages to specific spatial areas, through further breakdown of the household sector or through a focus on certain areas, such as tourism or health, where there is an interaction between human activity and the environment. The second approach involves using the environmental-economic data of the SEEA as an input into the 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 for developing holistic accounting models that link the SEEA with so-called social accounting matrices (SAM). The SAM effects a connection between the SNA and social data sets, providing information in particular on household income and expenditure (see the 2008 SNA, chap. 28). While the present discussion does not aim at building up these broader models, it should nevertheless be recognised that the SEEA, given its strong connections with the SNA, may play an important role in the development of such integrated frameworks and data sets.

4.4 On the basis of the first approach to extending the SEEA, section 4.2 provides an introduction to the potential of the spatial disaggregation of SEEA-based data to yield information sets that are more suitable for the consideration of specific issues. Approaches to generating spatially disaggregated information have advanced significantly in recent years with the increasing adoption of geographic information system (GIS) in many areas and the increasing capability for organizing and analysing large data sets.

4.5 While the focus of the earlier chapters was on the industry dimensions, section 4.2 presents the extension of the SEEA to households and household activity—a shift reflecting their importance. The fact that households are often regarded as simply constituting a single vector belies the significant role that consumer behaviour plays in relation to environmental pressures. This extension of the SEEA enables further analysis of the behaviour of different types of households or households in different locations as regards access to natural resources and environmental pressures.

4.6 The final section (4.4) offers a discussion of the reorganisation and disaggregation of existing industry and product information to facilitate a focus on particular themes, using the example of tourism activity. The same type of approach may be applied to the analysis of other cross-cutting activities and specific themes such as transport, forest products and food industries.

4.7 The extensions described in this chapter are likely to require the integration of data additional to those required for compiling accounts in the SEEA Central Framework. Those data may already exist, but there may be cases where additional primary data collection activity is required. For example, surveys of household income and consumption providing the location and distribution of household incomes and household types are required in order to assign information at those 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 relate largely to specific materials, substances, assets and resources, and the various stocks and flows are accounted for without regard for the precise location of those materials, substances, assets or resources, aside from the country for which the accounts are compiled.

4.9 Of course, all materials, substances, assets 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 areas where high levels of emissions are released into water bodies may be a more powerful tool than knowledge of the total stocks or flows for a country as a whole. Indeed, national totals and averages often hide important local variations. In short, knowing locations can help to better identify environmental pressure points and determine policy responses.

4.10 In some cases, the basic source data may be collected and compiled with a view to ensuring that the location is accurately known (e.g., using geographical coordinates) or in reference to relatively detailed administrative areas. Often, however, integration of data that have been compiled at different spatial scales will be required, using aggregation and disaggregation as appropriate. In this regard, the structured framework of the SEEA provides a strong basis for the harmonization of data at desired levels of detail.

4.11 Increasingly, it is possible to use mapping and information technologies (e.g., GIS) to 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 enables existing information to be reorganized according to standard geographical classifications. Most commonly, the power of this approach is evidenced in the creation of maps capable of highlighting 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.[38] 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 arises from the fact that it may not be easy to attribute all the observations required for different types of data to the same level of spatial area.

[38] A specific geographical classification is not described in the SEEA Central Framework; however, related classifications for land use and land cover are discussed in chapter V of that publication. 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. Such a units model may be relevant in the development of a whole range of extensions of the type described in this chapter.

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

4.14 The potential of the conduct of geo-spatial analysis and the use of SEEA data is illustrated in two examples. These examples are elaborated within the general framework of land accounts as described in the SEEA Central Framework. The SEEA land accounts present measures of stocks of land and changes of stocks in terms of areas of land use and land cover. They could also be structured to consider land in terms of ownership by economic units, for example, by industry or institutional sector. It should be recognized that the completion of geo-spatial analysis requires the presence of strong underlying information systems. However, a description of such systems and the relevant methodologies and best practices is not provided in the SEEA Central Framework.

4.15 A focus on the use of specific spatial areas enables a strengthened, joint consideration of the social, economic and environmental implications of various policy choices and options. The expansion of the use of land for housing, for example, requires infrastructure such as roads, sewers, and water supply lines and can at the same time lead to encroachments upon 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, e.g., whether it is relatively high- or low-density in terms of the changes in human population, may also be significant. The two examples attest to the usefulness of spatially attributed information for policy purposes.

4.16 The first example entails analysis of settlements over time. Settlements have been defined as tracts of land where humans have altered the physical environment. The methodology, based on GIS technology, is statistical in essence through the combination of remote sensing technology and imagery with the most detailed data from the population census. Application of the methodology has provided detailed, harmonized and comparable data sets enabling a more complete national-level analysis of settlements, and has formed the basis for the development of indicators that can be used to track land-cover and land-use change. As a distillation of the types of maps that may be generated, figure 4.1 exhibits results for settlements in relation to dependable agricultural land (i.e., land free of severe constraints on crop production).

4.17 The second example concerns the integration of environmental and economic information over a large coastal area. Through careful deliniation of the spatial areas and attribution of various data sources to the spatial areas, a richly furnished data set was constructed. The types of information encompassed population; land use; landownership; land values; vegetation cover; forest extent and change; water consumption; agricultural production, in physical and monetary terms; land management practices, such as use of fertilizer and irrigation; and topographical features, e.g., elevation and slope. The integration of socioeconomic data and environmental data is a particular feature of this data set and enables the investigation of a broad range of issues. The data can be presented in tables and maps (Australian Bureau of Statistics, 2011; 2012). Figure 4.2 is a map in which selected data overlay a spatially defined area.

4.18 The development of geo-spatial information sets is particularly relevant to the development of ecosystem accounts, as described in SEEA Experimental Ecosystem Accounting. Since ecosystem accounts can utilize much of the information described in the SEEA Central Framework, the development of spatially referenced information sets through integrated approaches is likely to provide a wealth of information relevant to the analysis of many issues centring on the link between the economy and the environment.

Figure 4.1
Map of settlements and dependable agricultural land

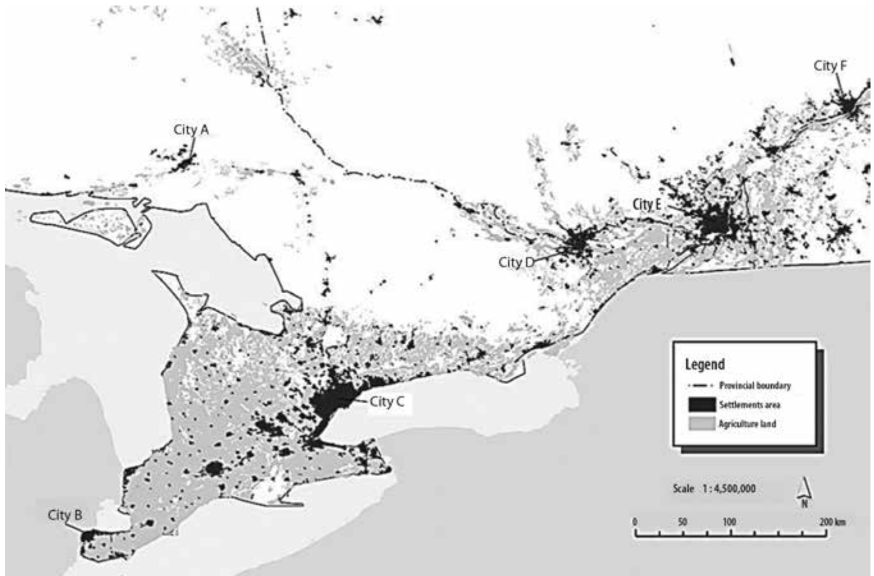
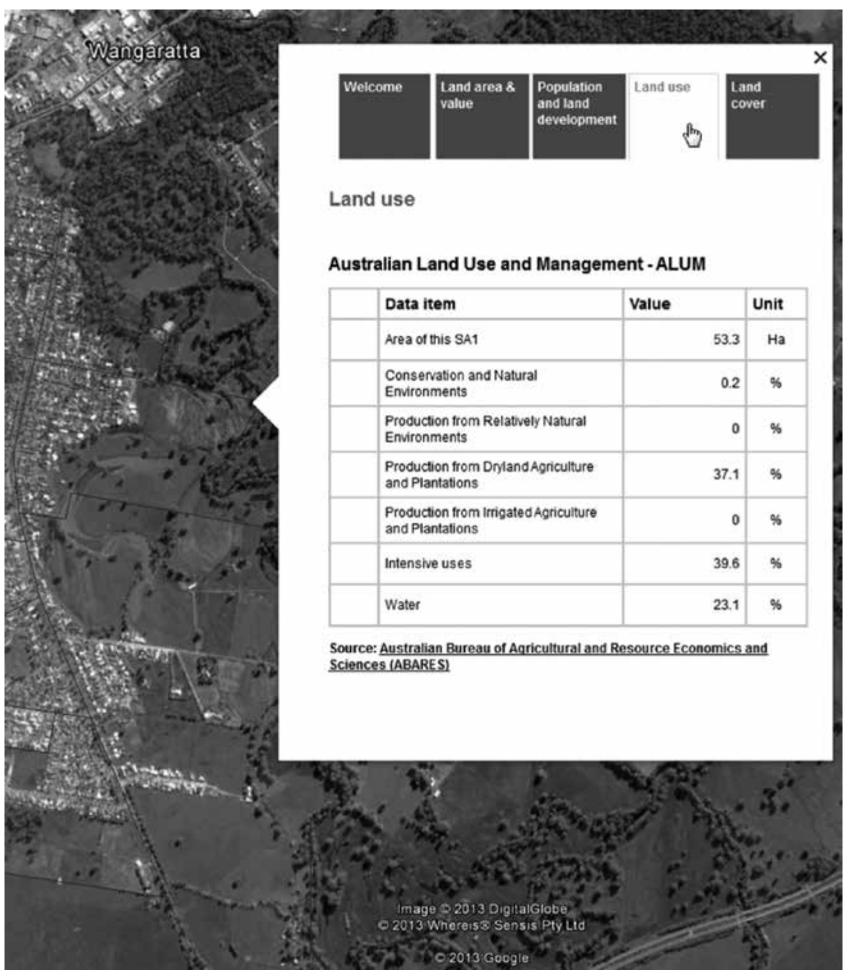


Figure 4.2
Map of statistical local area



Australian Land Use and Management - ALUM

	Data item	Value	Unit
	Area of this SA1	53.3	Ha
	Conservation and Natural Environments	0.2	%
	Production from Relatively Natural Environments	0	%
	Production from Dryland Agriculture and Plantations	37.1	%
	Production from Irrigated Agriculture and Plantations	0	%
	Intensive uses	39.6	%
	Water	23.1	%

Source: Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES)

4.3 Extensions of the 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 Sustainable Development Goals.

4.20 It is important that these common data be used to inform policymaking and implementation as part of integrated planning at all levels. Such data are 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 outcome document of the United Nations Conference of Sustainable Development, entitled "The future we want",[39] and are supported by several development programmes linking the collection and analysis of data to integrated policymaking.

[39] General Assembly resolution 66/288, annex.

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

4.22 As regards the connection among households, society and the environment, it is increasingly recognized that there are a range of non-marketed benefits such as air filtration, carbon sequestration, water regulation and various opportunities for recreation that are derived by societies and individuals from the environment. Also, societies and individuals often have strong cultural, including religious, connections with environmental sites. Measurement of various non-marketed benefits is not covered in the present chapter, but relevant developments in this area are considered in SEEA Experimental Ecosystem Accounting.

4.23 Some examples of key social indicators are already included in chapter IX of SEEA Water (United Nations, 2012b) and chapter 7 of SEEA-Energy (United Nations, forthcoming), 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. The present section highlights some of the key aspects of these potential extensions of the SEEA Central Framework, with a focus on information that relates to environmental sustainability.

4.3.2 Household access to natural resources

4.24 Expanded SEEA indicators should help capture and provide information on facets of the multidimensional poverty and environment nexus. Poverty may be linked to environmental conditions, and poor and vulnerable groups often rely on the environment for their livelihoods and well-being. Hence, they can both 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 data on income or on other financial characteristics, can reflect the multiple aspects of poverty, deprivation and their links to the environment. The linkages of poverty to the environment and the economy encompass multiple dimensions including 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 Stocks and flows of water resources and energy resources, which are central to the operation of well-functioning households and communities in all parts of the world, constitute the main areas in which SEEA might be extended to capture relevant data. The extension of most direct relevance is likely to be the breakdown of household consumption of water and energy. This entails analysing consumption data and integrating it within the physical supply and use tables (PSUT) for water and energy (see the SEEA Central Framework, chap. III) through the incorporation of additional columns in the use table.

4.27 The types of breakdown that are applied will depend on the analysts' interests and on data availability. There may be interest in decomposing information on household consumption of energy and water by purpose, i.e. differentiating the uses of energy, inter alia, for heating, cooking and transportation and the uses of water 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 may be relevant that differentiate between urban and regional areas, special population groups, e.g., the elderly, families with young children, specific ethnic groups, or consumption and activity of households by income decile or quintile.

4.28 Regarding these resource flows, an understanding of the extent to which households are dependent on finding their own water and energy resources, as opposed to using relevant distribution systems, may also be relevant. In this regard, additional columns can be added to the supply tables within the PSUT for water and energy with a view to recording explicitly household production of water and energy through collection of water and fuelwood, installation of solar energy panels, etc. In this regard, it would be useful to ensure that the rows of the table are designed so as to capture the various types of resources being sourced.

4.29 The focus of 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, e.g., in agriculture, fishing, forestry or 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 within the same industry.

4.30 An important determinant of the sustainability of access to resources will be the stocks and changes in stocks of those resources. In this context, the development of asset accounts for water resources and energy resources (especially timber resources) may be particularly relevant, with a focus on distinguishing those resources available to households for their own collection and consumption. Asset accounts are described in chapter V of the SEEA Central Framework. Depending on the economic structure of a country, land, soil resources and aquatic resources may be of particular relevance to lower-income households. Extended 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., through land accounts) and to then link this information to the location of households of various types.

4.31 The applicability of extended analysis using the SEEA concerning access to natural resources, including water and energy, can be seen in context of the Sustainable Development Goals. Annex III describes the potential connections between SEEA and the SDGs. Pursuant to the discussion in section 4.2, extensions in terms of spatial disaggregation may be of particular importance in distinguishing between rural and non-rural areas and in 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.

4.3.3 Linking household activity and environmental pressures

4.32 Another household-related SEEA extension consists in linking household activity to measures of residual flows related to that activity. This may cover the direct effects of household activity on the environment, e.g., through flows of solid waste, wastewater, air emissions and emissions to water, as well as the indirect effects of household activity as reflected in the residual flows that occur in the process of producing and distributing goods and services consumed by households. These indirect effects include the flows of residuals embedded in goods and services that are exported and imported. There are likely to be considerable challenges involved in establishing these types of data sets, with the quality of the analysis depending upon the quality of the data set formed.

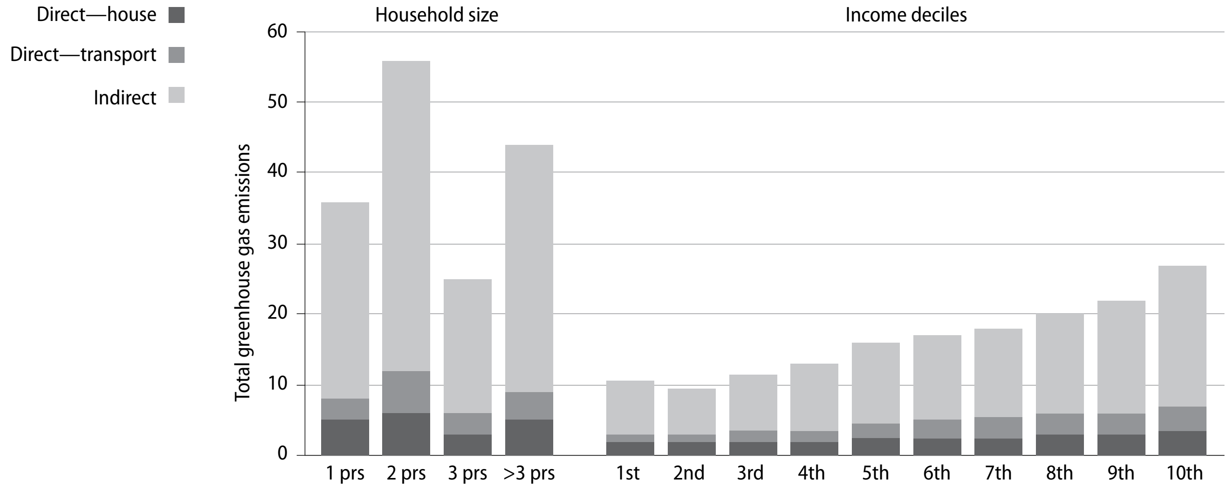
4.33 The extension of the SEEA in relation to these environmental pressures entails extending the physical supply and use tables (PSUT) for the residual flows of interest. The PSUT for air emissions, emissions to water and solid waste are described in chapter III of the SEEA Central Framework. In these tables, the household sector is generally assigned to a single column presenting the "supply" of residuals either for collection and treatment by other economic units or as direct releases to the environment. The first extension therefore entails introducing additional columns. Alternatives include household income, household structure (e.g., number of people, single person, couple with children, etc.), size and type of dwelling (e.g., number of bedrooms, floor area, apartment or detached house, etc.), and location (e.g., city or rural). The variable chosen to characterize households will depend on the data available and the nature of the policy or analytical research question under consideration. The choice of question may depend, in turn, on the aspects of household behaviour that are of most interest or on the places where household behaviour may have the greatest impact on the environment.

4.34 Utilizing 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 decile or quintile. For this purpose, data are likely to be required from household surveys or other sources that contain information on household size, income and consumption patterns (e.g., administrative records for housing construction, energy-efficient rating schemes, income tax, etc.). Work may be required to align those data with the concepts and classifications of the SEEA.

4.35 The measurement of indirect effects requires modelling of residual flows through EE-IOT which 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 then link those products to their source, i.e., domestic industry or imports. A more detailed discussion of the relevant modelling is described in chapter III.

4.36 Much of the focus for 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 for example, in terms of the choice of building materials.

Figure 4.3
Greenhouse gas emissions by household size (persons) and income (deciles)



4.37 Figure 4.3 gives an example of possible extensions in this area through use of a combination of air emissions data from the SEEA Central Framework and a range of data from household income and expenditures surveys. The figure shows total greenhouse gas emissions for direct and indirect emissions both by number of persons in a household and by decile of household income. Extensions of this figure include the presentation of measurements on a per household basis or in terms of equivalized of income, i.e., where household income is adjusted to account for differences in the number of people supported per household.

4.38 Table 4.2 shows the links between the types of consumption expenditure under the Classification of Individual Consumption According to Purpose (COICOP, (United Nations, 1999)) and the associated levels of greenhouse gas emissions, demonstrating that the proportion of total expenditure on a particular consumption item may not correspond directly to the proportion of greenhouse gas 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 greenhouse gas emissions, by COICOP category (percentage)

COICOP divisions	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

4.39 There are a number of perspectives on economic activity that may not be reflected easily in the structure of information on economic activity following standard international industry classifications. This may be the case for two reasons. First, a particular activity may involve a range of enterprises from different parts of the economy, each having different production functions and primary outputs. Consequently, while the enterprises are classified to different industries they may nevertheless engage in relationships that could be analysed jointly. Considered most commonly in this regard is tourism activity involving enterprises from transport, accomodation, restaurant, retail, etc.. Another example is the entities and activities involved in health, e.g., hospitals, pharmaceuticals, medical equipment, education, policy development, etc.

4.40 Second, a specified activity undertaken by many enterprises in different industries may be difficult to identify in standard industry statistics because often it is not the principal activity of an enterprise. The example most relevant to environmental-economic accounting is transport activity, which is a significant user of natural resources and a significant contributor to air emissions. Own-production of energy is another activity that may be suited to this type of analysis. In analysis of these specific activities an important consideration may be the own-account production of households in addition to production by enterprises.

4.41 The following section describes an extension of the SEEA Central Framework for tourism activity. Generally, the considerations applicable to tourism will also hold for other activities. That is to say, in most instances, it will 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, which 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

4.42 Recognition of the importance of good-quality environmental-economic information on the tourism sector is inherent in the principles and objectives set out in the Charter for Sustainable Tourism, the outcome of the World Conference on Sustainable Tourism, held in Lanzarote, Canary Islands, Spain, in 1995. Significantly, the participants at the Conference observed in the Charter that while tourism can contribute positively to socioeconomic and cultural development, it can at the same time also contribute to the degradation of the natural environment and loss of local identity. Integrated environmental, economic and social information is essential, then, for the definition of policies in the tourism field.

4.43 It is relevant to consider the links between the Tourism Satellite Account (TSA) (United Nations, World Tourism Organization, Eurostat and Organisation for Economic Co-operation and Development, 2010), the accounting approach that has been developed for analysis of tourism, and the SEEA since both frameworks are based on the accounting principles of the SNA. Combining the TSA and the SEEA would enable consideration, within an integrated data set, of both the contribution of tourism to the economy and the environmental uses and pressures related to tourism activities.

4.44 The expansion of the SEEA suggested here is along the lines of an approach presented in the *International Recommendations for Tourism Statistics 2008* (United Nations and

World Tourism Organization, 2010) whereby tourism, comprising a specific set of industries and consumers, is incorporated within environmental combined physical and monetary flow accounts of the SEEA Central Framework (see chap. VI of the Central Framework). The present section summarizes this approach and offers insights into its potential, using information from Italy where this approach has been trialled.

4.45 The coverage of tourism and the environment in this section is not limited to consideration of what may be referred to as "ecotourism", i.e., tourism activities designed to enhance the connection between the tourist and the environment, but rather encompasses all tourism activity and its use of natural inputs and generation of residuals. In principle, the approach described here may be applied more narrowly, data permitting.

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

Key aspects of integrating tourism and environmental information

4.47 In general terms, the focus of measurement should be on the regular monitoring of tourism activities, allowing for analysis of the pressures exerted by those activities. Within this scope, items considered to be 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) and relative contribution of tourism to the economy. All these elements are relevant for the application of a holistic approach to making assessments of tourism activity.

4.48 Satellite accounting, within the realm of official statistics, is the specific tool that, in principle, best enables the integration environmental, economic and social information, by focusing on the interrelationships among these three distinct spheres. One of the possible applications of the accounting approach is to apply it to tourism data, which allows for the linking of data on tourism, environment and economy aggregates in a common framework using of common concepts, definitions and classifications. This allows for the derivation of consistent and coherent indicators to inform sustainable tourism policies.

4.49 From a methodological point of view, compiling a TSA requires a definition of the boundary of tourism activity. This is produced through focusing on the qualitative and quantitative elements observed on the demand side, i.e., the goods and services (products) acquired by visitors.[40] Tourism consumption is therefore a key concept underpinning the 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-related goods and services acquired by visitors.

4.50 The link to the SEEA can be created by focusing on (*a*) the residuals generated as a result of tourism consumption (either by the visitors themselves or by the enterprises supplying them with goods and services; and (*b*) the natural inputs used in the production of tourism products. Important connections may also be established by linking measures of tourism activity to measures of ecosystem condition and extent. For example, activity undertaken to improve an area's attractiveness 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, however. Initial efforts in this area are summarized in SEEA Experimental Ecosystem Accounting.

[40] According to, *Tourism Satellite Account: Recommended Methodological Framework 2008, para. 1.1:* "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."

Table 4.3

Stylized 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 (000)	Air emissions	Water emissions	Solid waste	Energy resources	Minerals	Biological resources	Water
Supply (tourism industries)	Accommodation services												
	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												
	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

4.51 In line with the *International Recommendations for Tourism Statistics (paras. 5.10 and 5.12)*, the following tourism products are distinguished:

(*a*) 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;

(*b*) Tourism connected products: those of lower significance to tourism analysis.

4.52 Examples of characteristic products are transportation, accommodation, restaurant meals and tourist attractions. Tourism-connected products include, for example, products purchased by visitors in supermarkets.[41]

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

4.53 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 for distinguishing between visitor and non-visitor expenditures.

4.54 Using the defined set of economic activities and products of relevance, the connection can be made to relevant environmental flows, although some disaggregation of industry-level data normally recorded in the SEEA accounts is likely to be required. Thus, the core of the approach consists in establishing a more complex type of input-output matrix in which not only the "usual" inputs are considered, but also included are environmental and resource inputs. Furthermore, outputs also include waste, greenhouse gas emissions and other environmentally significant residual flows.

4.55 Table 4.3 presents the type of information that may be organized with the type of approach described above, based on research undertaken in Italy. Statistical information organized according to this framework is suited to providing valuable support to decision-making on sustainable tourism because it makes possible the identification of tourism-related trade-offs between economic activity and environmental pressures.

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

4.57 Through the use of the sequence of economic accounts outlined in chapter VI of SEEA Central Framework, it is also possible to consider the integration of information on relevant environmental taxes, subsidies and similar transfers and also the connection to information on environmental protection expenditure.

4.58 Table 4.4 offers a simple means of exhibiting tourism-related economic activity and environmental flows in contrast with other economic activities. As with the SEEA more generally, it is clear that the organization of information following the integrated use of classifications and accounting principles can help provide readily accessible information.

Table 4.4

Flows from tourism-environment accounts (*percentage of total economy flows*)

	Tourism industries	Other industries		Tourism industries	Other industries
Production	5.0	95.0	N_2O	0.2	99.8
Intermediate consumption	5.0	95.0	NH_3	0.0	100.0
Value added	7.0	93.0	Ni	5.0	95.0
Employment	9.5	90.5	NMVOC	1.5	98.5
As	0.0	100.0	NOx	16.0	84.0
Cd	0.3	99.7	Pb	2.0	98.0
CH_4	0.0	100.0	PM10	8.0	92.0
CO	2.5	97.5	PM2.5	10.0	90.0
CO_2	4.5	95.5	Se	3.5	96.5
Cr	0.5	99.5	SOx	15.0	85.0
Cu	6.0	94.0	Zn	0.0	100.0
Hg	0.0	100.0			

Annex I

Derivation of examples and links to the SEEA Central Framework

Background

A1.1 The present annex provides an explanation of each of the examples presented in chapters II to IV. 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 on the specific analytical topics at the country level. However, for the purposes of SEEA Applications and Extensions, the examples have been stylized to provide an indication of the potential outputs and analysis, since the intent is not to describe research pertaining to individual countries.

A1.2 At the same time, it is recognized that readers may be interested in understanding further the specific research projects at the country level. To this end, SEEA Applications and Extensions provides sources of information on individual country-level projects in the structured list of references which follows annex II. In addition, the United Nations Statistics Division maintains an online knowledge library with up-to-date references for a wide range of country studies, reports by international agencies, and other material on environmental-economic accounting.

A1.3 Interested users are also encouraged to consider the outcomes of the practical work on environmental-economic accounting that have been presented to, and discussed by, the members of the London Group on Environmental-Economic Accounting since its first meeting in 1994. Papers, presentations and other relevant material are available from the London Group website.[42]

[42] http://unstats.un.org/unsd/envaccounting/londongroup/.

Explanation of examples

A. Industry-level water-use intensity indicators (figure 2.3)

A1.4 The preparation of figure 2.3 entailed use of information on the intermediate consumption of water distributed under ISIC division 36 and used according to 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.

A1.5 In broad terms, this information may be regarded as being derivable from a table similar table 6.6, entitled “Combined presentation for water data” of the SEEA Central Framework. However, the industry classification in that table would need to be more detailed to enable provision of the type of information figure 2.3.

A1.6 Information needed to formulate estimates of water use by industry should be sourced from a physical supply and use table for water, as presented in table 3.6 of the SEEA Central

Framework since the data in figure 2.3 relate to the intermediate consumption of distributed water by industries. However, alternative measurement scopes for the general concept of water use may be appropriate (also sourced from table 3.6 of SEEA Central Framework), depending on data availability and analytical requirements. The SEEA Central Framework defines some alternative indicators (see paras. 3.219-3.223). Data on value added by industry should be sourced from the national accounts.

B. Decomposition of changes in CO_2 emissions (figure 2.4)

A1.7 The preparation of figure 2.4 required time-series information on (*a*) the generation of CO_2 emissions by industries (i.e., non-household CO_2 emissions), (*b*) changes in household consumption and (*c*) the various factors driving changes in emissions by industry. Estimates of emissions by industry may be organized following table 3.7, entitled "Air emissions account" of the SEEA Central Framework. Measures of household consumption should be sourced from the national accounts. Indicators of drivers of changes in emissions are based on information on (*a*) the location of production by product type, as derived from international trade data reflected in input-output tables; (*b*) the product composition of consumption, as reflected in input-output tables; (*c*) changes in the composition of industries as reflected in input-output tables; and (*d*) CO_2 emissions by industry, by type of fuel used and by non-fuel sources of emissions, which may be reflected in an extension of SEEA Central Framework table 3.7.

A1.8 The slope of the uppermost line in figure 2.4 represents an estimate of the time series of CO_2 emissions that would have been generated 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 CO_2 emissions.

A1.9 With the estimation under this alternative scenario, it is then possible, using the types of data described above, to apply decomposition techniques (see chap. III) to assess the differing impacts of reduced energy intensity, switches to low-carbon fuels, relocation of production and switch to services.

A1.10 The decomposition in this example, based on analysis using a multiregional input-output (MRIO) table, is considered a structural decomposition analysis. Similar types of analysis may be undertaken using index decomposition analysis.

C. Decomposition analysis for CO_2 emissions by households from stationary sources (figure 2.5)

A1.11 The preparation of figure 2.5 required information on (*a*) the generation of CO_2 emissions by households from stationary sources, i.e., excluding emissions related to transportation activity, compiled consistent with table 3.7, entitled "Air emissions account", of the SEEA Central Framework; (*b*) demographic information on the number and size of households (i.e., the number of people in a household), likely to be obtained from a population census or similar data source; (*c*) energy use by households by purpose, compiled consistently with table 3.5, entitled "Physical supply and use table for energy", of the SEEA Central Framework; and (*d*) changing external temperatures (from national meteorological agencies) which will influence the extent to which heating and air conditioning are required by households to regulate internal temperatures.

A1.12 Using index decomposition analysis techniques (see sect. 3.3), the contribution of each of these factors can be determined.

D. Analysis of imports and exports in physical and monetary terms (figure 2.6)

A1.13 The preparation of figure 2.6 is based on international trade data on flows of imports and exports of goods between European countries themselves and between European countries and countries external to Europe, in both physical terms (kilograms) and monetary terms (currency units) and adjusted to align with Balance of Payments (International Monetary Fund, 2009) and SNA measurement boundaries. A specific account for organizing information on trade flows is not displayed in the SEEA Central Framework, but it may be noted that, 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 (see Central Framework, tables 2.1 and 2.2).

A1.14 The classification of goods used in the figure follows the highest level of aggregation used for material flow accounting. However, it can be aligned with the Central Product Classification (CPC) which is the classification recommended for use in the SEEA Central Framework (see para. 3.72).

A1.15 Consideration should be given to ensuring the alignment of the conceptual scope of data in physical and monetary terms based on the discussion in section 3.3 of the SEEA Central Framework.

E. Food chain greenhouse gas emissions (figure 2.7)

A1.16 The preparation of figure 2.7 requires information on greenhouse gas emissions by industry and by type of household consumption activity, following the general structure of table 3.7, entitled “Air emissions accounts”, of the SEEA Central Framework. The level of detail required will depend on how precisely the flows related to the production and consumption of food can be traced within an economy.

A1.17 The nature of a food supply chain (i.e., an articulation of all economic activity involved in the production, distribution and consumption of food) is determined from the analysis of standard national accounts-based input-output tables. Emissions from the relevant activities—sourced from SEEA Central Framework table 3.7—are summed to provide an estimate of total emissions of greenhouse gases related to food. From the supply side, there is consideration of (*a*) the domestic production of food and a listing of the relevant industries and (*b*) 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 food distribution through transport, retailers, and restaurant and catering activities. On the demand side, the consumption of food requires measurement of 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 obtained through combining information on household final consumption expenditure by purpose (from the national accounts) with data from household surveys (e.g., time-use surveys) that measure food-related activity (e.g., cooking).

A1.18 The total emissions reflect the sum of supply- and 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 each demand activity are included.

A1.19 Relevant measurement considerations include determining (*a*) the boundary of food production in reference to industry output, for example, there might be non-food production by agricultural units, and (*b*) the treatment of agricultural outputs used for non-food purposes, e.g., biofuels.

F. CO_2 emissions and public sector expenditure (figure 2.8)

A1.20 The preparation of figure 2.8 requires information on CO_2 emissions for various industries whose outputs are commonly purchased by public sector agencies. As for the articulation of the food supply chain (figure 2.7), it is necessary to use relationships in standard national accounts-based input-output tables to identify those products that are purchased by public sector agencies and then determine the industries that supply those products. The figure includes those industries where the purchases by the public sector represent either a significant proportion of total industry output. e.g., pharmaceuticals, or a significant proportion of total public sector expenditure, e.g., construction. In the two cases 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 circle in figure 2.8.

A1.21 Once the relevant set of industries has been selected, the emissions information may be organized following the structure of table 3.7 ("Air emissions accounts") of the SEEA Central Framework. In figure 2.8, as the scope of emissions is limited to those arising from the use of energy products, 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 circle in the figure.

G. Contributions of the environmental goods and services sector to GDP and employment (figure 2.9)

A1.22 Figure 2.9 presents information that may be sourced from table 4.6, entitled "Environmental goods and services sector", in the SEEA Central Framework. That table includes information on the gross value added, compensation of employees, exports, gross fixed capital formation and employment of various producers in the EGSS. Comparison of the information on all of these variables with economy-wide aggregates for the same variables sourced from standard national accounts tables and labour-force survey data sets can yield ratios of the type presented in figure 2.9.

A1.23 Figure 2.9 shows the gross value added (GVA) generated by the environmental goods and services sector (EGSS) in basic prices as a percentage of GDP. Strictly speaking, the most appropriate comparison would be between EGSS gross value added in basic prices and economy-wide gross value added in basic prices. The use of GDP reflects a decision to choose a more commonly known indicator of economic size.

A1.24 All types of EGSS producers, i.e., specialist, non-specialist and own-account producers are encompassed by the estimates.

H. Environmental tax revenue by type (figure 2.10)

A1.25 The preparation of information for figure 2.10 requires time-series data on different categories of environmental taxes following the definition of an environmental tax given in paragraph 4.150 of the SEEA Central Framework. There are four categories into which environmental taxes are grouped: energy taxes, transport taxes, pollution taxes and resource taxes (SEEA Central Framework para. 4.155). Table 4.9 of the SEEA Central Framework organizes this information for a single accounting period. Figure 2.10 includes a comparison of total environmental taxes to GDP.

I. Energy taxes divided by energy consumption, by sector (figure 2.11)

A1.26 The preparation of figure 2.11 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 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 used in this example does follow the definition in paragraph 4.155 of the Framework. Data for compiling estimates of energy taxes by industry and activity may be available in detailed tax revenue statistics or may be modelled based on information on energy use by these activities and sectors combined with information on relevant tax rates.

A1.27 This figure also requires information on energy consumption across all sources of energy, measured in a common unit such as joules or tons of oil equivalent and classified by the relevant economic activities and sectors. An appropriately structured physical supply and use table for energy (e.g., SEEA Central Framework table 3.5) can provide such information.

A1.28 The ratio of energy taxes to energy consumption provides an implicit tax rate for energy.

J. Distribution of CO_2 tax revenues, emissions rights, CO_2 emissions covered by the trading scheme and total CO_2emissions, by industry (figure 2.12)

A1.29 The preparation of figure 2.12 requires a range of information from different sources pertaining to CO_2 emissions. Key to understanding the figure is the fact that all relevant information has been organized following the same industrial classification.

A1.30 CO_2 taxes constitute specific types of taxes within scope of the definition of environmental taxes (see SEEA Central Framework, sect. 4.4.3). CO_2 taxes include payments for tradable emissions permits (for carbon dioxide) following the treatment summarized in paragraphs 4.185-4.187 of the SEEA Central Framework. Analysis of government finance statistics by type of tax is likely to be the best source of information on these flows.

A1.31 Information on emissions rights distributed and flows of CO_2 emissions within the trading scheme may be structured along the lines of table 4.10, entitled "Account for tradable emissions permits", of the SEEA Central Framework, using an industrial activity rather than an institutional sector classification. Information on total CO_2 emissions may be structured in conformity with table 3.7, entitled "Air emissions account", of the SEEA Central Framework.

K. Asset lives for selected mineral and energy resources (figure 2.13)

A1.32 The information in figure 2.13 may be sourced from table 5.8, entitled "Physical asset account for mineral and energy resources", of the SEEA Central Framework and compiled for the relevant resource types. Both expected patterns of extraction and associated annual rates of extraction may be determined based on either historical or recent average rates of extraction or 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 detailed information on asset lives, see paras. 5.137-5.140 and 5.210-5.213 of the SEEA Central Framework.)

L. Production- and consumption-based CO_2 emissions per capita (figure 3.1)

A1.33 The data that underlie the construction of figure 3.1 are based on a combination of data on CO_2 emissions classified by industry and sector in accordance with standard structures of supply and use and input-output tables and table 3.7, entitled the "Air emissions account", of the SEEA Central Framework; and economic data contained in supply and use and input-output tables. Together, these data are used to construct an environmentally extended input-output table (EE-IOT) following the descriptions provided in chapter III of this publication.

A1.34 Using the data and relationships presented within the EE-IOT, it is possible to estimate the CO_2 emissions that are (*a*) induced by the final use of products in European Union (EU) member countries; and (*b*) embodied in the production of those countries, including their exports. Since the study covers the 27 countries (as of 2012) of the EU it is also possible to determine the extent to which emissions are embodied in the imports of products traded within the Union.

M. Geo-spatial analysis (figures 4.1 and 4.2)

A1.35 The data for the maps presented in figures 4.1 and 4.2 are derived from a variety of sources including population censuses, agricultural and land-use surveys, remote sensing imagery, and administrative data held by government agencies (e.g., land planning authorities). It is necessary to select a particular scale or region of analysis. Figure 4.1 covers a large area of roughly 600 square kilometres, while figure 4.2 covers 245 hectares. Application of geographic information systems (GIS) methods then enables the data to be attributed to the relevant areas. A range of tools are available for this undertaking.

A1.36 The particular challenge in developing figures such as these lies in aligning the desired information to a common scale which is appropriate for analysis of the different variables. The scale used is likely to vary depending on the available data and the nature of the analysis being undertaken.

N. Greenhouse gas emissions by household size (persons) and income (deciles) (figure 4.3) and by household final consumption expenditure (table 4.2)

A1.37 To develop the extension shown in figure 4.3 it is necessary, first, to ensure that the method for estimating greenhouse gas emission is consistent with that of 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 associated with their undertaking of various activities, particularly heating, cooling and transportation.

A1.38 In addition, it is necessary to have detailed data on household characteristics, such as number of people per household, income per household, etc., as well as information on the types of expenditure and activities that are undertaken by different household types. Most commonly, all of this information may be obtained from household budget or expenditure surveys.

A1.39 For the purposes of the SEEA, it is necessary to integrate these data from household surveys with estimates of household expenditure from the national accounts so that a coherent and comprehensive perspective on household activity can be achieved.

A1.40 Through the use of input-output table relationships, including assumptions regarding the emissions embodied in imports, it is possible to attribute emissions to the products consumed by different households, shown in table 4.2. There are a number of ways in which this series of steps may be undertaken. (The relevant methods are summarized in chap. III). It is key, from a SEEA perspective, to ensure that there is an alignment 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)

A1.41 For the presentation of the data in table 4.4, information is required 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 that in the standard air emissions account because it is necessary to distinguish between those industries that are considered tourism industries and all others. The definition of tourism industries should follow *International Recommendations for Tourism Statistics* (United Nations and World Tourism Organization, 2010). While the classification is common across countries, the set of industries will vary by country depending on the structure of tourism activity in each country. Whether additional data collection may be required to obtain emissions data for tourism industries will depend on the level of industry detail generally used to collect air emissions information.

A1.42 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 also possible to integrate air emissions information and standard TSA data into an environmentally extended TSA, in accordance with the logic underlying the presentation in table 4.3.

Annex II

Mathematical derivation of the Leontief inverse

A2.1 Calculation of the Leontief inverse is a standard operation in input-output analysis (see e.g., Miller and Blair, 2009). At the core of the IO model is the Leontief matrix, to be derived in the present annex.

A2.2 Equation A2.1. shows the technical coefficients matrix A for the SRIO model.

$$A_d = Z_d \cdot (\hat{q})^{-1} \tag{A2.1}$$

A2.3 Here, Z_d denotes the intermediate input matrix, while q is the output vector. Where a "hat" (^) is used, this indicates that the vector has been diagonalized, that is, the vector has been transformed into a square matrix with the values of the vector on the diagonal. The IO coefficient matrix, A_d, provides a technological description of the intermediate input-output structure: the quantity of intermediate input that is 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 functions exhibit constant returns to scale.

A2.4 The Leontief production function of the IO model, which results from the fixed-coefficient assumption, exhibits complementarity between inputs, i.e., output cannot be increased by substituting one input for another. This assumption deviates from that for most neoclassical production functions, which allow for substitution between inputs.

A2.5 By rearranging equation A2.1 and using the identities implicit in table 3.1, it is possible to derive equation A2.2:

$$A_d \cdot q + y_d = q \tag{A2.2}$$

A2.6 Rearranging the elements in this identity gives:

$$q = (I - A_d)^{-1} \cdot y_d \tag{A2.3}$$

A2.7 This equation is the best-known formulation of the IO model, where matrix $(I - A_d)^{-1}$ is usually referred to as the "Leontief inverse". Mathematically, the Leontief inverse can be found only if $(I - A_d)$ 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 $A \cdot y_d$, which constitutes an increase in the demand for all production units that provide inputs. This extra demand, in turn, will 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 A2.4 (see Miller and Blair, 2009):

$$q = (I + A_d + A_d^2 + A_d^3 + \cdots)^{-1} \cdot y_d \tag{A2.4}$$

A2.8 Mathematically speaking, equations A2.3 and A2.4 are equivalent. Therefore, elements on the diagonal of the Leontief inverse are always equal to 1 plus the indirect requirements per unit output. The off-diagonal elements constitute indirect demand only.

Annex III

SEEA and the Sustainable Development Goals

The Sustainable Development Goals (SDGs) and targets were adopted by the United Nations General Assembly in 2015.[43] The goals and targets cut across many economic, social and environmental issues. One key component of the SDGs is the measurement of progress towards meeting the various goals and targets through relevant indicators. As illustrated in the table below, the SEEA can be a useful tool to providing the necessary information or context for measuring progress on the SDGs. Note that the list below is non-exhaustive and is provided for illustrative purposes.

43 See General Assembly resolution A/RES/70/1.

Table A.1
SEEA and the Sustainable Development Goals

	Sustainable Development Goal Target	Relevant SEEA Publications and Tables
	Goal 2—Zero Hunger	
2.3	By 2030, double the agricultural productivity and incomes of small-scale food producers, in particular women, indigenous peoples, family farmers, pastoralists and fishers, including through secure and equal access to land, other productive resources and inputs, knowledge, financial services, markets and opportunities for value addition and non-farm employment	SEEA-Agriculture, Forestry and Fisheries provides a framework for measuring agricultural production.
2.4	By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality	SEEA-Agriculture, Forestry and Fisheries, combined with the SEEA-Experimental Ecosystem Accounting provide a framework for measuring agricultural production, as well as the link with the ecosystem condition of agricultural land.
2.a	Increase investment, including through enhanced international cooperation, in rural infrastructure, agricultural research and extension services, technology development and plant and livestock gene banks in order to enhance agricultural productive capacity in developing countries, in particular least developed countries	SEEA-Agriculture, Forestry and Fisheries provides a framework for measuring investment activity of agricultural, forestry and fisheries activities within the SNA.
	Goal 6—Clean Water and Sanitation	
6.1	By 2030, achieve universal and equitable access to safe and affordable drinking water for all	SEEA physical supply and use tables for water can provide contextual information on the magnitude of water consumption by households relative to other sectors, as well as information on government and private spending on water supply services and associate infrastructure.
6.2	By 2030, achieve access to adequate and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations	SEEA-Water can provide contextual information on the magnitude of water consumption by households relative to other sectors, as well as information on government and private spending on water supply and sanitation services and associated infrastructure.
6.3	By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally	SEEA-Water captures wastewater generation and treatment by economic activity, based on ISIC classifications and according to treatment ladders as defined in the International Recommendations for Water Statistics.
6.4	By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity	The SEEA Water provides the standard for measuring total water abstraction, use and water consumption by economic activity (based on ISIC). Using the SEEA means this information can easily be combined with value-added information from the SNA, which uses the same classifications, to calculate water use efficiency for the economy as a whole and disaggregated by economic activity.

	Sustainable Development Goal Target	Relevant SEEA Publications and Tables
6.6	By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes	SEEA land accounts and SEEA ecosystem accounts can provide useful information to measure the extent and condition of water-related ecosystems and the services they provide.
	Goal 7—Affordable and Clean Energy	
7.1	By 2030, ensure universal access to affordable, reliable and modern energy services	SEEA-Energy provides contextual information on the magnitude of electricity consumption by households relative to other sectors, as well as information on government and private spending on electricity services and associate infrastructure.
7.2	By 2030, increase substantially the share of renewable energy in the global energy mix	SEEA-Energy supply and use tables provide information on the generation and use of all energy sources including renewable energy
7.3	By 2030, double the global rate of improvement in energy efficiency	The SEEA-Energy shows the use of energy by economic activity (based on ISIC). Using the SEEA means this information can easily be combined with value-added information from the SNA (which uses the same classifications) to calculate energy use efficiency for the economy as a whole and disaggregated by economic activity.
7.b	By 2030, expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries, in particular least developed countries, small island developing States, and land-locked developing countries, in accordance with their respective programmes of support	SEEA-Energy has information on measuring investment activity in the energy sector within the SNA.
	Goal 8—Decent Work and Economic Growth	
8.4	Improve progressively, through 2030, global resource efficiency in consumption and production and endeavour to decouple economic growth from environmental degradation, in accordance with the 10-year framework of programmes on sustainable consumption and production, with developed countries taking the lead	Material flow accounts provide relevant information on domestic consumption of materials
8.9	By 2030, devise and implement policies to promote sustainable tourism that creates jobs and promotes local culture and products	The link between SEEA and the tourism satellite accounts is to contain information relevant for this target.
	Goal 9—Industry, Innovation and Infrastructure	
9.4	By 2030, upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes, with all countries taking action in accordance with their respective capabilities	SEEA emission accounts contain relevant information.
	Goal 11—Sustainable Cities and Communities	
11.3	By 2030, enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management in all countries	SEEA land accounts provide data on land cover and land use over time.
11.4	Strengthen efforts to protect and safeguard the world's cultural and natural heritage	SEEA environmental protection expenditure accounts contain information on expenses to protect and safeguard cultural and natural heritage
11.6	By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management	SEEA emission accounts and solid waste accounts provide relevant information
11.7	By 2030, provide universal access to safe, inclusive and accessible, green and public spaces, in particular for women and children, older persons and persons with disabilities	SEEA land accounts provide data on land cover and land use, and can be linked with socio-demographic information
	Goal 12—Responsible Consumption and Production	
12.2	By 2030, achieve the sustainable management and efficient use of natural resources	SEEA material flow accounts, water accounts, energy accounts and others resource specific accounts provide information of the physical use of natural resources. The information can be linked with SNA data as needed.
12.5	By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse	SEEA solid waste accounts contain relevant information.
12.b	Develop and implement tools to monitor sustainable development impacts for sustainable tourism that creates jobs and promotes local culture and products	The link between SEEA and the tourism satellite accounts is to contain information relevant for this target.

	Sustainable Development Goal Target	Relevant SEEA Publications and Tables
12.c	Rationalize inefficient fossil-fuel subsidies that encourage wasteful consumption by removing market distortions, in accordance with national circumstances, including by restructuring taxation and phasing out those harmful subsidies, where they exist, to reflect their environmental impacts, taking fully into account the specific needs and conditions of developing countries and minimizing the possible adverse impacts on their development in a manner that protects the poor and the affected communities	SEEA energy accounts and environmental taxes and subsidies accounts provide relevant information
	Goal 14—Life below Water	
14.1	By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution	SEEA-Agriculture Forestry and Fisheries and SEEA emission accounts provide relevant information.
14.4	By 2020, effectively regulate harvesting and end overfishing, illegal, unreported and unregulated fishing and destructive fishing practices and implement science-based management plans, in order to restore fish stocks in the shortest time feasible, at least to levels that can produce maximum sustainable yield as determined by their biological characteristics	SEEA-asset accounts for aquatic resources contains information on stocks and changes in stocks of aquatic resources.
14.5	By 2020, conserve at least 10 per cent of coastal and marine areas, consistent with national and international law and based on the best available scientific information	SEEA land accounts contains information on land cover/land use
14.6	By 2020, prohibit certain forms of fisheries subsidies which contribute to overcapacity and overfishing, eliminate subsidies that contribute to illegal, unreported and unregulated fishing and refrain from introducing new such subsidies, recognizing that appropriate and effective special and differential treatment for developing and least developed countries should be an integral part of the World Trade Organization fisheries subsidies negotiation	SEEA environmental taxes and subsidies accounts provide relevant information
14.7	By 2030, increase the economic benefits to small island developing states and least developed countries from the sustainable use of marine resources, including through sustainable management of fisheries, aquaculture and tourism	The SNA, SEEA Central Framework (aquatic resources accounts) and the SEEA-Agriculture Forestry and Fisheries provide information on the contribution to GDP of fisheries.
14.a	Increase scientific knowledge, develop research capacity and transfer marine technology, taking into account the Intergovernmental Oceanographic Commission Criteria and Guidelines on the Transfer of Marine Technology, in order to improve ocean health and to enhance the contribution of marine biodiversity to the development of developing countries, in particular small island developing States and least developed countries	SEEA environmental taxes and subsidies accounts provide relevant information
	Goal 15—Life on Land	
15.1	By 2020, ensure the conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services, in particular forests, wetlands, mountains and drylands, in line with obligations under international agreements	SEEA land accounts contain information on land cover/land use
15.2	By 2020, promote the implementation of sustainable management of all types of forests, halt deforestation, restore degraded forests and substantially increase afforestation and reforestation globally	SEEA land accounts and those included in SEEA Agriculture Forestry and Fisheries provide relevant information
15.3	By 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world	SEEA land accounts contain information on land cover and land use
15.4	By 2030, ensure the conservation of mountain ecosystems, including their biodiversity, in order to enhance their capacity to provide benefits that are essential for sustainable development	SEEA land accounts and ecosystem accounts provide relevant information
15.5	Take urgent and significant action to reduce the degradation of natural habitats, halt the loss of biodiversity and, by 2020, protect and prevent the extinction of threatened species	Ecosystem accounts contain information on biodiversity
15.9	By 2020, integrate ecosystem and biodiversity values into national and local planning, development processes, poverty reduction strategies and accounts	A number of ecosystem accounts are relevant including ecosystem condition accounts, ecosystem service accounts and biodiversity accounts

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