ESA/STAT/AC.255
UNCEEA/7/8

DEPARTMENT OF ECONOMIC AND SOCIAL AFFAIRS
STATISTICS DIVISION
UNITED NATIONS

Seventh Meeting of the UN Committee of Experts on Environmental-Economic Accounting
Rio de Janeiro, 11-13 June 2012

Status report on the preparation of SEEA Extensions and applications

(for discussion)

REVISION OF THE SYSTEM OF ENVIRONMENTAL - ECONOMIC ACCOUNTING (SEEA)

SEEA Extensions and applications

Draft material prepared for the 7th Meeting of the Committee of Experts on Environmental-Economic Accounting (UNCEEA)

Meeting in Rio di Janeiro, Brazil 11-13 June, 2012

Status report on the preparation of SEEA Extensions and applications

Status report on SEEA Extensions and applications

1 Background

1.1 During the revision process of the System of Environmental-Economic Accounting (SEEA) a need emerged for material covering potential extensions and applications of SEEA based datasets with the aim of promoting and supporting the widespread adoption of the SEEA among official statisticians, researchers and policy makers. To this end, the UNSC supported the development of the SEEA Extensions and applications (referred to in this document as SEEA Part 3).

1.2 The Committee of Experts on Environmental-Economic Accounting (UNCEEA) has discussed the preparation of SEEA Part 3 on a number of occasions. Building on discussions within the London Group of Experts on Environmental Accounting on the possible format and content for SEEA Part 3, the UNCEEA, at its 5th meeting in June 2010, formed a sub-group to consider issues of broad focus and audience, structure and content, status, and issues of timing and process.

1.3 The sub-group reported back to the UNCEEA at its 6th meeting in June 2011 and the meeting reached conclusions regarding the intent, broad content and timing for the drafting of SEEA Part 3. These conclusions are discussed in the document outlining the proposed Project Management Framework for SEEA Parts 2 and 3.

1.4 This document gives an update on the current status of work in the context of the plans outlined in the Project Management Framework.

2. Contributions from experts

1.5 The basic approach to the drafting of SEEA Part 3 is to seek contributions from experts on specific applications, analytical techniques and extensions based on SEEA data sets. The process of seeking and receiving contributions is well underway. There are 12 separate topics that have been included in the draft outline for SEEA Part 3 (see Table 1 below) and at the end of May contributions have been received on 5 topics and contributions on the remaining topics are expected by the end of June. This is slightly behind schedule but, importantly, contact with contributors across all topics has been made and discussions are ongoing.

1.6 An initial review of the material by the SEEA Editor has confirmed that much of the material will be able to be used directly but a more common look and feel will need to be provided. A particular area that will need to be addressed is ensuring that the links between the SEEA data sets and the various applications, analytical techniques and extensions are clearly articulated. Generally, the length of the contributions has been able to be relatively constrained but this will also need to be considered further to avoid the document as a whole becoming overly large. The overall sense that needs to emerge is that there is significant potential embedded in the SEEA and that this material presents some useful methods of accessing that potential.

1.7 The material in Attachment 1 gives a sense of the type of content that has been contributed to date. At this stage these contributions have not been edited to fit a more consistent style and format.

Table 1 Draft outline of SEEA Extensions and applications

1.0	**Purpose and scope of SEEA Extensions and applications**
2.0	**Applications of SEEA data**
2.1	Analysis of resource efficiency and productivity
2.2	Analysis of sustainable consumption and production patterns
2.3	Analysis of environmentally related production and employment
2.4	Analysis of taxes and subsidies
2.5	Analysis of net wealth and depletion of resources
3.0	**Analytical techniques for using SEEA data**
3.1	Structural Input-Output analysis and General Equilibrium modelling
3.2	Consumption based I-O analysis /Footprint techniques
3.3	Decomposition analysis
3.4	Indicator sets, dashboards and composite indicators
3.5	Geo-spatial analysis
4.0	**Extensions of the SEEA**
4.1	Accessibility to resources and resource allocation
4.2	Tourism

3. Next steps

1.8 Using the available and the forthcoming contributions, the SEEA Editor will re-work the material to prepare a first draft of SEEA Part 3. It is intended that this draft be completed by the end of August, 2012. From this point the broader review processes outlined in the Project Management Framework will be followed.

1.9 A question for consideration is the extent to which some additional material may be included in SEEA Part 3 relating to the SEEA Experimental Ecosystem Accounts. There are a number of topics that might be included to provide a richer discussion on the potential of SEEA to assist in policy analysis and research.

Attachment 1: Draft material for SEEA Extensions and applications

A. Analysis of environmentally related production and employment

Prepared by Sjoerd Schenau and Maarten van Rossum, Statistics Netherlands

1. Introduction

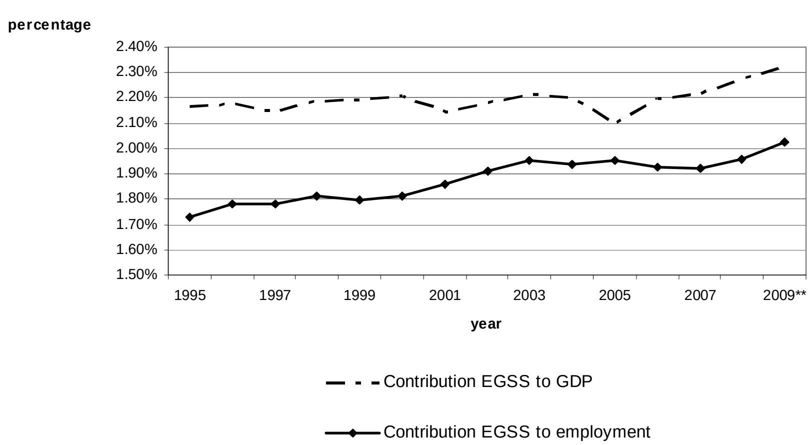
Environmental regulations and policies as well as the increased awareness about combating environmental pollution and preserving natural resources have led to the rapid increase in demand and supply of goods and services to prevent, measure, control, limit, minimise or correct environmental damage and resources depletion, i.e. environmental goods and services. The Environmental Goods and Services Sector (EGSS) consists of a heterogeneous set of companies that produces these environmental goods and services. Historically, environmental goods and services production mostly began with traditional markets driven by the demand for basic services, such as wastewater treatment or waste collection. With the drive towards cleaner and more resource efficient processes, products and materials, the activities of the sector have shifted to ‘resources management’. Therefore, the EGSS is both a traditional and an emerging sector which includes companies created specifically to serve this emerging market (such as renewable and sustainable energy systems) and companies in more traditionally defined sectors (such as sewage and refuse disposal services).

This short note describes the main indicators and some applications of the data provided by the EGSS statistics.

2. Description of the application, extension or technique

Analysis by economic variable: the key indicators

The key indicators for the EGSS correspond to the variable totals that can be directly derived from the EGSS table: total output, intermediate consumption, value added, employment, gross fixed capital formation and exports. These variables can be divided by the total for the economy in order to determine the share of EGSS activities in total activities. Time series on employment, output, value added and exports can give an indication of the evolution of the EGSS, its growth and its competitiveness.



Green employment. The employment of the EGSS may be considered Green jobs. It should be noted that there still is a discussion that the concept of green jobs broader than the employment of the EGSS, as sometimes also employment in resource efficient or less polluting industries may be considered as green jobs.

The value added of environmental activities represents the contribution made by these activitiestowards the income measure of GDP. The contribution of value added to GDP is an important indicator as it indicates what the EGSS contributes to the total domestic product. Similar to green jobs, one may term the value added of the EGSS “green GDP”. However, “green GDP” is usually referred to as the adjusted GDP that takes into account the depletion and degradation of natural resources. To avoid confusion it is recommended that this term should not be applied to the value added contribution of the EGSS.

Exports is an important indicator to monitor win-win situations of the EGSS. Production of EGSS which is consumed (intermediate) domestically does not lead to win-win situations for both the economy and the environment. Indeed production of EGSS which is consumed by foreign economies does lead to win-win situations. Share of exports in total production is a measure for the magnitude of these win-win situations. When also import data on the EGSS are available, the trade balance of the EGSS can be calculated.

Furthermore, these variables may be used to provide information on productivity and competitiveness, for instance. The shares of value added per employee can indicate how productive the industries carrying out the environmental activities are.

Beside the key variables identified in Table 4.3.5 in the SEEA Central Framework, some other economic variables may be of particular interest. Particular data on innovation (R&D expenditure, number of patents) is of interest. In addition, the environmental transfers to the EGSS, may indicator how much or the growth of the EGSS is driven my state support.

Analysis by economic sector/ industry

In comparing the private sector and government activities, this analysis provides information on, e.g., the importance of public ownership and the evolution of privatisation. Corporations and government activities can also be analysed at a more detailed level providing information on the magnitude of environmental activities of the different NACE sub-sectors (for corporations) and administrative levels (for General Government). For the corporations, data can also be analysed to measure the importance of ancillary activities and the evolution of outsourcing as well as the relative magnitude of market and non-market activities.

Analysis by environmental domain

Comparing data on the EGSS by environmental domains reveals which are the most important domains of specialisation for environmental producers in a country. This analysis is important because a large majority of environmental companies focus on only one of the environmental domains and the competitive conditions in each of the domains can vary significantly. Combined with the environmental protection expenditure data, the analysis of the EGSS can also provide an indication of the environmental opportunities of the countries.

One area of particular interest is the part of the EGSS belonging to CRUMA 13. The so called ‘sustainable energy sector’ consists of all companies and institutions that physically produce renewable energy (exploitation phase) as well as companies active in the value chains that come before it (pre-exploitation phase). Apart from renewable energy, the sustainable energy sector also includes companies and institutions that focus on energy saving activities. There is a lot of interest for this particular sector because energy supply and consumption have been changing in recent years. In the near future, the demand and supply of sustainable energy will become increasingly important. Secondly, newly developed energy systems have little or no dependence on fossil fuels. Thirdly, sustainable energy contributes to securing supplies, diversification of energy supply, the reduction of greenhouse gas emissions and the creation of green jobs.

In addition to the standard economic indicators (value added, production, employment, exports, imports, investments) the sustainable energy sector may be further broken down into product profiles and process profiles. The various product profiles include ‘solar PV’, ‘solar CSP’, ‘solar thermal energy’, ‘bio gas’, ‘bio mass (solid) & waste’, ‘bio fuels’, ‘bio refining’, ‘wind on land’, ‘wind at sea’, ‘heat & geo thermal energy’, ‘energy from water’, ‘energy saving’, ‘electric transport’, ‘smart grids’, ‘hydrogen technology’ and ‘CO2 capture and storage’. The process profiles include ‘R&D’, ‘consultancy’, ‘transport’, ‘preparation/raw material production’, ‘supply, assembly and construction’, ‘production of energy carriers’, ‘installation and maintenance’.

Analysis by type of environmental output

In comparing the figures for the different types of environmental goods, technologies and services, this analysis can highlight, for example, the importance of cleaner and resource-efficient technologies compared to end-of-pipe technologies. This is very important in the case of raising the awareness on the type of environmental output, in particular adapted goods and integrated technologies for which its development represents one of the most important goals of policies towards sustainable development. Given the peculiarities of adapted goods, particular attention should be paid to the producers of this class of environmental goods.

Regional analysis

The activities of the EGSS may also the analysed on a more regional level. Accordingly, it may be established whether EGSS activities are concentrated in certain areas and whether this is directly linked with other economic activities in the area. For example, the presence of electrical engineering and the technical university may play a key role for the development of companies specialised in the development of certain environmental equipment, such as solar panels (network economics). Regionalised data is of particular interest of policy makers.

Analysis of physical data

Data from the EGSS may be directly compared with physical data from the physical supply and use tables. For example, the physical data about the production of renewable energy and the data derived from the sustainable energy sector (CRUMA 13) can be very valuable in supplementing each other.

Multiplier analyses

The economic and environmental impact of policies to stimulate a particular industry often goes well beyond their direct effect on output, employment, or emissions. The growing interconnectedness of economic activities also leads to significant indirect or spill-over effects in the rest of the economy. These indirect effects can be determined by calculating multipliers derived from input-output (IO) analysis (e.g. Miller and Blair, 2009). Multipliers and multiplier effects can be useful instruments in economic analysis despite their limitations. While multipliers were traditionally compiled for economic variables such as output, value added, income, and employment (e.g. Eurostat, 2008; Miller and Blair, 2009), they can easily be extended to environmental parameters (Östblom, 1998; Lenzen 2001, Lenzen et al., 2004; Rueda-Cantuche and Amores, 2010). The most commonly used environmental variables are energy and CO2. In this study we also quantify multipliers for other environmental variables such as greenhouse gas emissions, acidification and emissions of heavy metals to water. Knowledge of the magnitude of a wide range of multiplier effects of individual industries provides relevant information for the evaluation of trade offs (Foran et al., 2005).

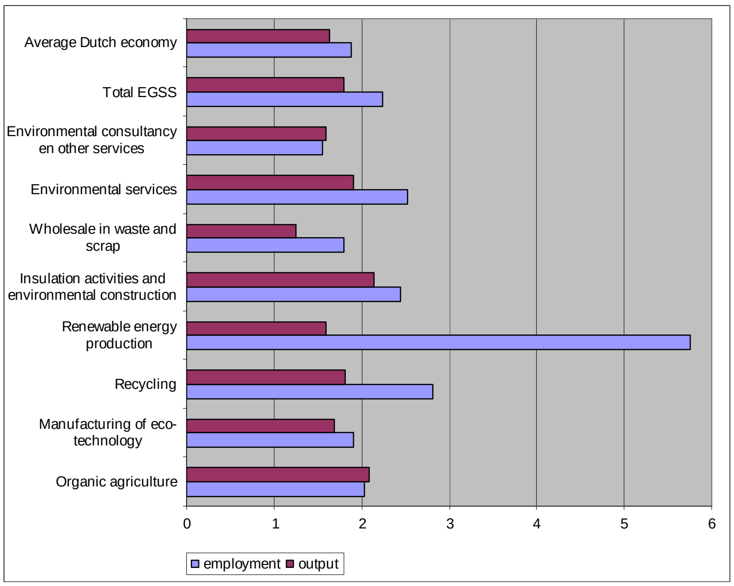
The importance of the Environmental Goods and Services Sector (EGSS) can be calculated by calculating the indirect effects of its further development. To obtain the appropriate multipliers for this sector, the data from the EGSS have to be linked to the data compiled in the National Accounts framework. The main challenge here is to adapt the original IO table in order to determine the associated input coefficients and multipliers for the EGSS. Section 4 provides a more detailed description on the methodology of multiplier analysis and its application for the EGSS.

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

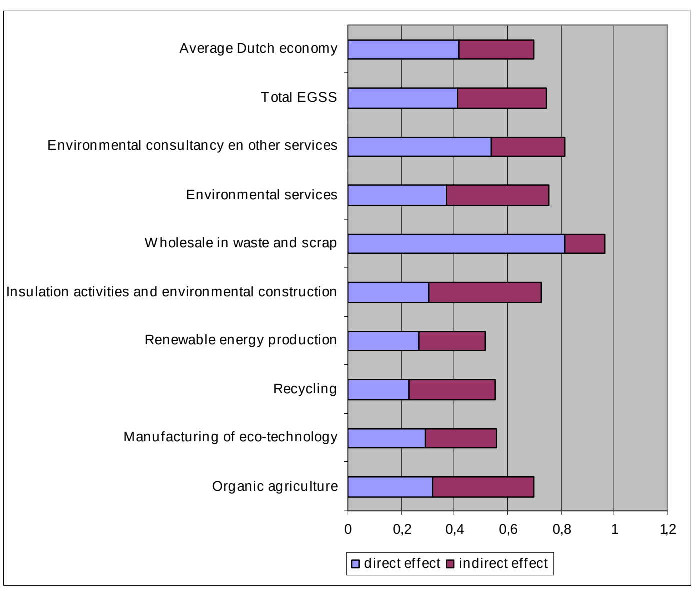
There is a major distinction between multiplier effects and multipliers. Multiplier effects show the direct and indirect effects of changes in final demand (i.e. output) on a range of variables. The employment multiplier effect shows for instance how many jobs would be created in the economy if the manufacturing industry were to increase its output by 1 million. Suppose the direct effect of this is the creation of 5 jobs in manufacturing, and 10 additional jobs in the rest of the economy. Then the employment multiplier effect is 15.

Multipliers are normalized multiplier effects. The employment multiplier shows how many jobs would be generated in the economy as a whole for each job that is generated in a specific industry. In the example of manufacturing, the employment multiplier would be 3 (15/5): for each job within manufacturing two additional jobs in the rest of the economy are created. Multipliers and multiplier effects serve different purposes.

Output and employment multipliers for the Dutch EGSS and related subsectors (2008).



Value added multiplier effects for the EGSS and relevant subsectors



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

Finally, also environmental multipliers may be calculated for the EGSS. For example, the greenhouse gas multiplier may indicate whether an overall increase in output of this sector will produce more greenhouse gasses, than a similar increase of output of the economy on average. To explain the total environmental multipliers the different activities of the EGGS have to be analysed. For example, for sewage and refuse disposal services in the EGSS, the production of large amounts of CO2 and methane are inherent in waste incineration and waste water treatment. The direct emission effect clearly dominates, although the contribution of the indirect effects is also quite substantial. On the other hand, renewable energy production has a very low GHG multiplier effect when compared to electricity production using fossil energy. Also the manufacturing of environmental goods, insulation activities and environmental consultancy have relatively low GHG multiplier effects. For these activities, the indirect effects clearly dominate the direct effects.

Micro analysis

In order to construct the meso and macro totals for the EGSS one has to gather all kind of micro information on different companies in the EGSS. Information on employment, production , value added, exports, imports, innovation, R&D and fiscal schemes and subsidies can be collected in a micro database in consistent manner. This database can be used for compiling meso and macro total for the EGSS but can also be used for all kind of scientific research on scientific research questions. For example:

- Do environmental subsidies lead to more R&D expenditures and therefore more environmental innovations?
- Is productivity growth of companies investing more in the environmental equipment on average larger than companies that invest less?
- Do high environmental taxes lead to more innovation incentives?
- Do innovative environmental companies export more than non-innovative ones?
- Do companies invest more in environmental friendly investment or do they prefer to pay taxes/buying emissions rights?
- To what extent are companies dependent upon subsidy schemes? (share subsidies in production)

3. Policy and analytical relevance

Environmental goods and services production mostly began with traditional markets driven by the demand for basic services, such as wastewater treatment or waste collection. Nowadays, the development of the environmental goods and services sector (EGSS) is driven more and more by the needs created by environmental legislation. This includes compliance with the environmental objectives of the European Union (EU) and other national legal requirements such as water quality targets or production targets for energy from renewable sources. Public and private funding resources that enable investment in innovative projects have also increased dramatically, backed up by social pressure and changes in lifestyle such as growing awareness on the part of consumers regarding the availability and benefits of new environmental technologies and products.

Economic consequences of environmental measures and environmental concerns are of great interest to policymakers. They approach these topics from two perspectives. On the one hand, their interest focuses on the financial burden that is placed on the polluting industries, as they have to invest in pollution abatement control in order to comply with environmental regulation. On the other hand, environmental measures will bring about new economic activities that may create new jobs and stimulate economic growth. Policymakers therefore need information on companies and institutions that produce goods and services that measure, prevent, limit, minimise or correct environmental damage, resource depletion and resource deterioration. All these companies and institutions belong to the environmental goods and services sector (EGSS).

The development of the Environmental Goods and Services Sector (EGSS) can play a key role in a transition towards a more sustainable economy and society. Growth of the EGSS induces more production of environmental goods and services for the benefit of the environment and contributes to economic growth. The environmental goods and services sector is nowadays seen as a promising business opportunity (e.g. Eurostat, 2009). An innovative environmental technology sector can help to stimulate growth if it is capable of tapping into rapidly growing export markets. In addition, the creation of ‘green jobs’ may help to reduce unemployment.

Data from the EGSS is particularly of interest for the Green growth / Green economy initiatives and underlying monitoring frameworks. Producing environmental goods and services has the potential for growth and employment contributing to a shift towards greener growth. However, it is noted that indicators from the EGSS provide only a partial picture of activities relevant for green growth.

4. Overview of steps and data requirements

Methodology for multiplier calculation

Input-output models are feasible instruments to trace the effects of changes in final demand through the economy over short periods of time, since they track the interconnections of production by industry at a high level of detail. In this function, they are called impact models or multiplier models. There are a number of different types of multipliers that can be generated by IO models (e.g. Eurostat, 2008; Miller and Blair, 2009). The first general categorisation consists of a distinction between type I and type II multipliers. Type I multipliers capture the direct and indirect effects of a change in output for a particular industry. Type II multipliers capture not only indirect effects but also induced effects on other industries from the extra consumption spending of people working in these industries. In this study we will restrict ourselves to type I multipliers.

Type I multipliers can be broken down into a direct and an indirect effect. If there is an increase in final demand for a particular product or service, there will also be an increase in the output of that product. This is the direct effect. In addition, as producers increase their output, there will also be an increase in demand on products from their suppliers and so on, all the way down the supply chain. This is called the indirect effect. Although various definitions can be found in the literature, according to the terminology that we use in this chapter the indirect effect can be separated into backward and forward linkages. Backward linkages consist of the effect an increase in output of a particular industry has on its suppliers. This is also sometimes called the first order effect. The increased output of the suppliers themselves also has effects on other industries. These are sometimes called higher order effects or forward linkages.

There is a major distinction between multiplier effects and multipliers. Multiplier effects show the direct and indirect effects of changes in final demand (i.e. output) on a range of variables. The employment multiplier effect shows for instance how many jobs would be created in the economy if the manufacturing industry were to increase its output by 1 million. Suppose the direct effect of this is the creation of 5 jobs in manufacturing, and 10 additional jobs in the rest of the economy. Then the employment multiplier effect is 15.

Multipliers are normalized multiplier effects. The employment multiplier shows how many jobs would be generated in the economy as a whole for each job that is generated in a specific industry. In the example of manufacturing, the employment multiplier would be 3 (15/5): for each job within manufacturing two additional jobs in the rest of the economy are created. Multipliers and multiplier effects serve different purposes.

Output multipliers

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

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

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

Multiplier effects

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

1.1

[1] Sometimes called revenue multipliers.

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

where f_j denotes the multiplier effect for industry j; e_i represents the vector of intensities for the effect of study; the superscript z denotes the subject of our effect (energy, employment etc.). For example, the energy multiplier effect for industry j provides an estimate of the direct and indirect increase in energy use that would result from an additional unit of output of industry j.

Multipliers

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

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

where $m^z{}_j$ denotes the z-multiplier for each industry j; the superscript z again denotes the subject of our multiplier (energy, employment etc.). For example, the employment multiplier for industry j expresses the number of jobs that would be created in the whole domestic economy due to the creation of one additional job at industry j. As a result of the normalisation, the direct effect is by definition equal to 1. The use of multipliers therefore facilitates the analysis of direct and indirect effects. It should be noted as well that due to the nature of the IO model, the output multiplier effect and the output multiplier are by definition equal.

Average multipliers and effects

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

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

where $\hat{m}^z$ denotes the average z-multiplier effect; x_j the output of industry j. Likewise, average multiplier effects can be calculated by weighting the industry specific multiplier effects with their respective output and dividing by the total output, using the formula:

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

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

Multipliers for the Environmental Goods and Services Sector

The activities of the Environmental Goods and Services Sector are scattered across different industries. For example, companies producing environmental equipment are part of manufacturers of machinery and the producers of renewable energy are part of the energy supply sector. In the statistics for the EGSS these activities have been allocated to the corresponding NACE classification, which is the same classification system that is used for the IO tables.

In order to calculate multipliers and multiplier effects for the EGSS, one has to identify where these activities take place within the IO framework:

- Some activities of the EGSS, such as sewage and refuse disposal services or recycling, are in the standard industry classification (ISIC) in the IO table. Their multipliers can be directly derived from the IO table used for this study.
- Other activities, such as organic farming and renewable energy production, have been separately identified in the IO table by creating additional columns and rows, using a variety of data sources. First, the output, intermediate use and value added for these activities was obtained from the EGSS statistics. Second, specific information on the inputs for these industries was used to distribute the total intermediate consumption over the columns. Third, the rows were filled by distributing the output over the industries and final demand categories, assuming that in most cases the distribution was the same as the distribution of the non-EGSS activity.
- The remaining activities of the EGSS are more difficult to separately identify in the IO table. Effectively, it can be assumed that these EGSS activities have identical multipliers as the ISIC category into which they are classified.

The multipliers and multiplier effects for the total EGSS sector can be calculated by multiplying the output of the different activities by their multipliers and dividing this total by the total output of the EGSS.

5. Links to relevant technical advice / theory and links to specific examples.

Eurostat (2009). The environmental goods and services sector.
Chapter 1: policy context
Chapter 6: presentation and interpretation of data

CBS (2010) Environmental accounts of the Netherlands 2009.
Chapter provides the methodology on multiplier analysis and its application for the EGSS

CBS (2011) Environmental accounts of the Netherlands 2010.
Analysis of EGSS end renewable energy sector

CBS (2011) Economic radar for the sustainable energy sector
http://www.cbs.nl/NR/rdonlyres/01A2777A-BAA8-47A6-B0B9-AAC8A7A155AA/0/2011managementsummaryeconomicradarsustainableenergysector.pdf

References for multiplier analyses:

Cross, P. and Ghanem, Z. 2006. Multipliers and outsourcing: how industries interact with each other and affect GDP. Canadian Economic Observer. Statistics Canada.

Eurostat Manual of Supply, Use and Input-Output Tables (2008). Eurostat methodologies and working papers.

Grady, P. and Muller, R.A. (1988). On the use and misuse of input-output based impact analysis in evaluation. The Canadian Journal of Program Evaluation 3, 49-61.

Foran, B. Lenzen, M. Dey, C. (2005) Balancing Act: A triple bottom line analysis of the 135 sectors of the Australian economy. CSIRO Technical report. www.cse.csiro.au/research/balancingact

Lenzen, M., 2001. A generalized Input-Output Multiplier Calculus for Australia, Economic Systems Research Vol 13, 65-92.

Lenzen, M. Pade, L,L., and Munksgaard, J. 2004. CO2 multipliers in multi-region input-output models. Economic Systems Research 16, 391-412.

Miller, R.E. and Blair, P.D (2009). Input-Output Analysis: Foundations and Extensions. Cambridge University Press; 2 edition.

Östblom, G. 1998. The environmental outcome of emission-intensive economic growth: a critical look at official growth projections for Sweden up to the year 2000. Economic Systems Research 10, 19-29.

Rueda-Cantuche, J.M. and Amores, A.F. 2010. Consistent and unbiased carbon dioxide emission multipliers: Performance of Danish emission reductions via external trade. Ecological Economics 69, 988-998.

B. Consumption based Input-Output analysis: Ecological Footprint application

Prepared by Alessandro Galli, Katsunori Iha and Mathis Wackernagel from Global Footprint Network. Brad Ewing from University of Alaska also provided inputs.

Global Footprint Network
Advancing the Science of Sustainability

1. Description of the application, extension or technique

1.1 The Ecological Footprint - a resource accounting system

Humanity relies on life-supporting ecosystem products and services including resources, waste absorptive capacity, and space to host urban infrastructure. Current environmental changes indicate that human demand is likely to be exceeding the regenerative and absorptive capacity of the biosphere. Careful management of human interaction with the biosphere is thus essential to ensure future prosperity and reliable accounting systems are thus needed for tracking the regenerative and waste absorptive capacity of the biosphere. The National Footprint Accounts aim to provide such an accounting system in a way that may be applied consistently across countries as well as over time (Ewing et al., 2010a; Borucke et al., forthcoming). Assessing current ecological supply and demand as well as historical trends provides a basis for setting goals, identifying options for action, and tracking progress toward stated goals.

With the aim of systematically calculating Ecological Footprint and biocapacity values for world nations, Global Footprint Network initiated its National Footprint Accounts program in 2003, with the most recent Edition – the 2011 edition - scheduled for release in May 2012.

The National Footprint Accounts constitute an accounting framework quantifying the annual supply of, and demand for, key ecosystem services by means of two measures (Wackernagel et al., 2002; Borucke et al., forthcoming):

- The Ecological Footprint tracks the human demand on nature. This demand is measured in terms of biologically productive areas a population uses for producing all the resources it consumes and absorbing all its waste - with prevailing technology and resource management of that year.
- The biocapacity tracks the supply of nature. This supply is measured by the amount of biologically productive land and sea area available to provide the ecosystem services that humanity consumes. This could be called the ecological budget or nature's regenerative capacity.

Ecological Footprint and biocapacity values are expressed in mutually exclusive units of area (Galli et al., 2007) necessary to annually provide (or regenerate) such ecosystem services: cropland for the provision of plant-based food and fiber products; grazing land and cropland for animal products; fishing grounds (marine and inland) for fish products; forests for timber and other forest products; uptake land to accommodate for the absorption of anthropogenic carbon dioxide emissions (carbon

Footprint); and built-up areas for shelter and other infrastructure (Ewing et al., 2010a; Borucke et al., forthcoming).

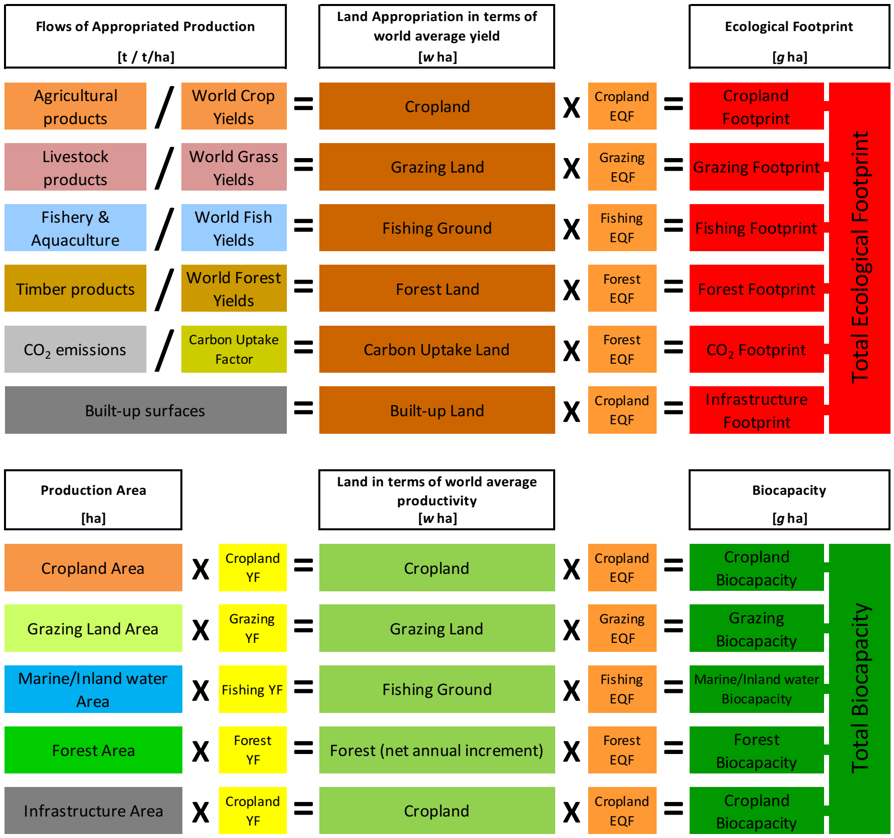
The National Footprint Accounts measure one main aspect of sustainability only - how much biocapacity human society demands, and how much is available - not all aspects of sustainability, nor all environmental concerns. The attempt to answer this particular scientific research question is motivated by the assumption that the Earth's regenerative capacity is the limiting factor for the human economy in times when human demand exceeds what the biosphere can renew.

1.2 Potential application of the National Footprint Accounts after harmonized with SEEA framework

Harmonizing the National Footprint Account with the SEEA framework provides a unique opportunity to link pre-existing national environmental accounts—produced by an NGO and well-received by the general public — with the SEEA. The National Footprint Accounts utilize approximately 50 million underlying source data points from approximately 30 data sets, mostly from UN statistical sources (see below as well as Borucke et al., forthcoming for additional details on the source data). The diversity of these data sets and their applicability to production, consumption, and trade in terms of appropriated biocapacity provides a valuable opportunity to harmonize this information with the inter-disciplinary functionality and compatibility of the SEEA. Linking the National Footprint Accounts with the SEEA is advantageous since the National Footprint Accounts contain physical flow indicators relevant to sustainable production and consumption. For instance, the carbon Footprint—in the form included in the National Footprint Accounts—measures the biosphere's uptake of anthropogenic carbon dioxide emissions; providing a key to understanding the driving forces behind ocean acidification and increased atmospheric concentrations of carbon dioxide. The overall Ecological Footprint value, in turn, complements this information by providing a more comprehensive assessment of the full palette of human-induced pressures on the planet (Global Footprint Network, 2010).

Within the National Footprint Accounts structure, Ecological Footprint and biocapacity results can be reported at the level of each individual product, land type, or aggregated into a single number (see Figure 1)—the latter being the most commonly used reporting format (Borucke et al., forthcoming). Normalizing factors, namely yield and equivalence factors, are used to scale the contribution of each single land type so that values can be added up into an aggregate number (Monfreda et al., 2004; Galli et al., 2007). Aggregating results into a single value has the advantage of monitoring the combined demand of anthropogenic activities against nature's overall regenerative capacity. It also helps to understand the complex relationships between the many environmental problems exposing humanity to a "peak-everything" situation. This is a unique feature since pressures are more typically evaluated independently (climate change, fisheries collapse, land degradation, land use change, food consumption, etc.) (Borucke et al., forthcoming). Aggregation, however, has the drawback of implying a greater degree of additivity and substitutability between the included land use types than is probably realistic (DG Environment, 2008; Giljum et al., 2009; Kitzes et al., 2009; Wiedmann and Barrett, 2010).

Figure 1: Diagram of the National Footprint Accounts framework.

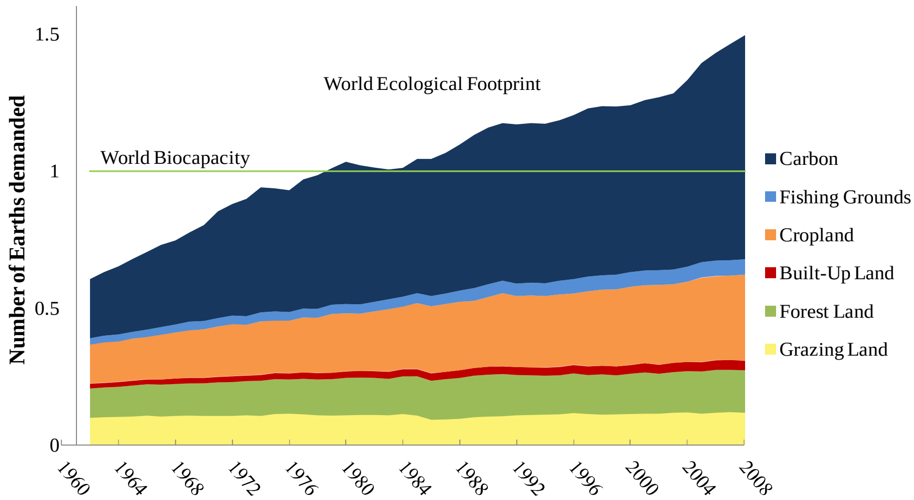


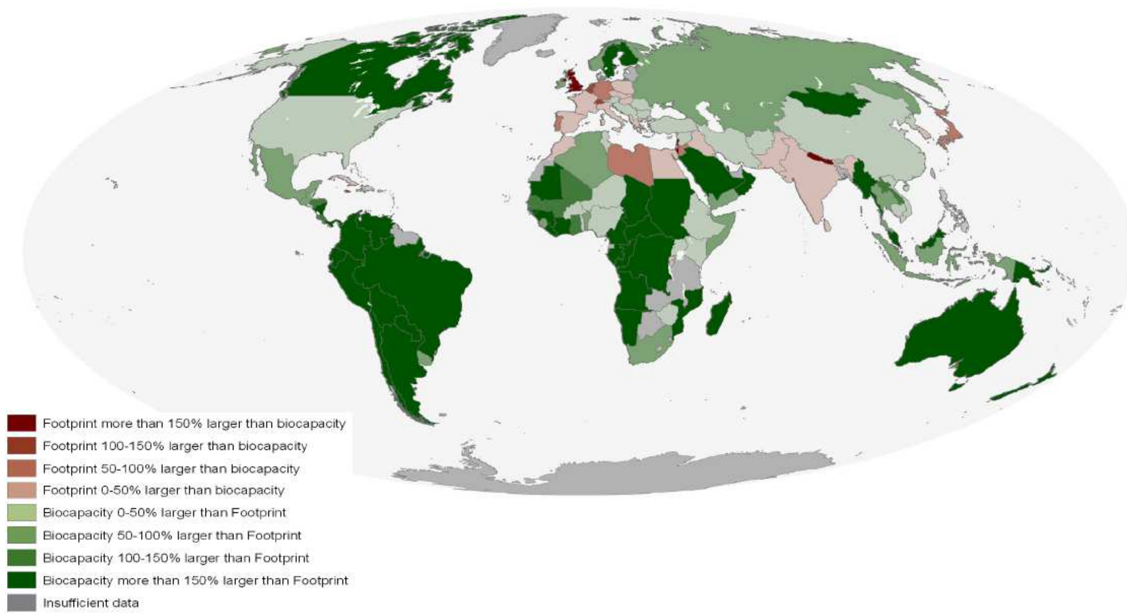
1.3 The key results: Humanity's Ecological Footprint and biocapacity over time

According to the most recent Edition of the National Footprint Accounts, humanity demanded the resources and services of 1.5 planets in 2008 (see Figure 2); this human demand to planet ratio has increased 2.5 times since 1961. Situations in which total demand for ecological goods and services exceed the available supply for a given location, are called 'overshoot'. 'Global overshoot' indicates that stocks of ecological capital are depleting and/or that waste is accumulating. While the world's Ecological Footprint and biocapacity trends indicate the existence of a global overshoot situation, each country is characterized by a different natural capital balance as reported in Figure 3.

Figure 2: World's Ecological Footprint and biocapacity, 1961-2008.

Humanity's Ecological Footprint, expressed in number of planets demanded, has increased significantly over the past 47 years.





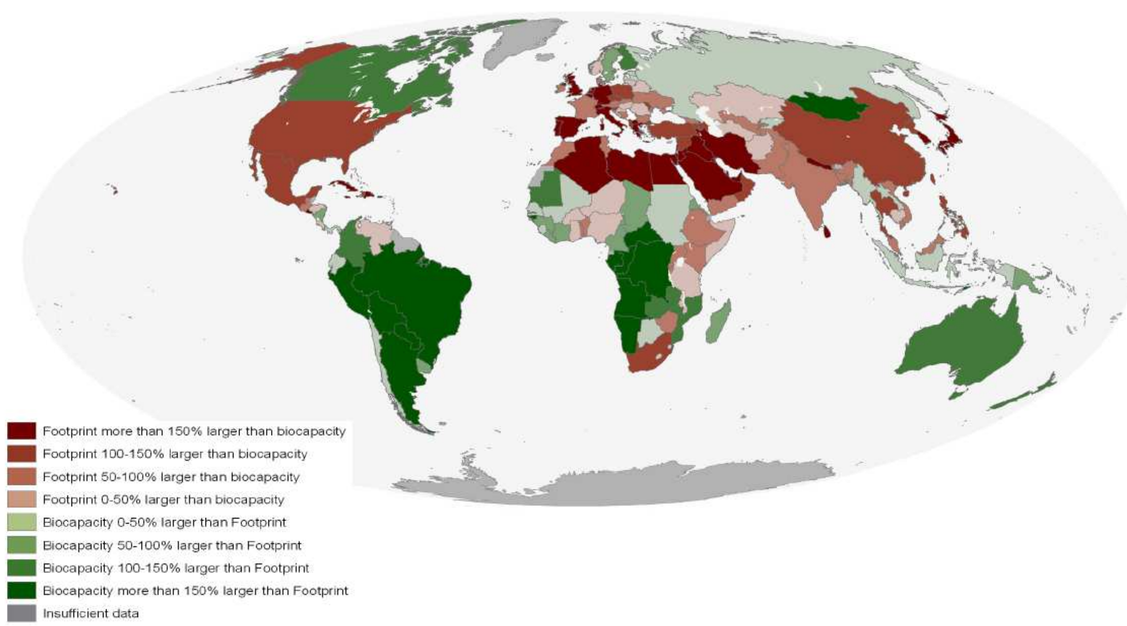


Figure 3: Ecological Footprint vs. biocapacity for world countries, 1961 (top) and 2008 (bottom). Biocapacity reserve (green) is defined as a domestic Ecological Footprint less than domestic biocapacity; biocapacity deficit (red) as an Ecological Footprint greater than domestic biocapacity. Source: Global Footprint Network, Ecological Footprint Atlas 2010 (Ewing et al., 2010b).

Figure 3 shows how the natural capital balances of world countries have changed dramatically in just a life-time. While most countries were experiencing positive balances (biocapacity reserve) in 1961, more than 80 percent of the world's population now lives in countries that use more biocapacity to support their activities than they have available within their boundaries. This comes in part from import of resources as well as through the overexploitation of domestic natural capital stocks and use of the global commons (for instance by emitting CO2 from fossil fuel into the global commons, hoping for global carbon sinks elsewhere).

2. Overview of steps and data requirements

2.1 The calculation methodology

The Ecological Footprint measures appropriated biocapacity across five distinct land use types. This is contrasted with six demand categories. The reason is that two demand categories, forest products and carbon sequestration, both compete for the same biocapacity category: forest land. Average bioproductivity differs between various land use types, as well as between countries for any given land use type. For comparability across land use types and countries, Ecological Footprint and biocapacity are usually expressed in units of world-average bioproductive area, referred to as global hectares (gha). Global hectares provide more information than simply weight - which does not capture the extent of land and sea area used - or physical area - which does not capture how much ecological production is associated with that land. Two important coefficients, the yield factors (YF) and the equivalence factors (EQF), allow results to be expressed in terms of global hectares (Monfreda et al., 2004; Galli et al., 2007), providing comparability between various countries' Ecological Footprints as well as biocapacity values.

Moreover, the Ecological Footprints measures human appropriation of biocapacity from a consumer rather than a producer perspective. It tracks the biocapacity appropriated because of local production activities as well as that embedded in trade flows to arrive at a final Ecological Footprint of consumption. The Ecological Footprint is thus able to track both the impact of who produces a good or service and that of the end-users that consume them.

Additional information on the calculation steps and the equations used is provided in Appendix A.

2.2 Data used in calculating National Footprint Accounts and possible harmonization with SEEA

The National Footprint Accounts product classifications are based mostly on UN Food and Agricultural Organization (FAO), Harmonized Commodity Description and Coding System (HS), International Energy Agency (IEA), and Standard International Trade Classification (SITC). Land cover classifications within the National Footprint Accounts are based on the FAO Land Cover Classification System (LCCS) (FAO 2000). For additional info see Borucke et al (forthcoming) and Global Footprint Network (2010).

The SEEA classifications for physical and hybrid product and industry flows are based on the Central Production Classification (CPC) and the International Standard Industrial Classification (ISIC). Classifications in physical and monetary supply and use tables for government and household consumption are based on the Classification of the Functions of Government (COFOG) and the Classification of Individual Consumption According to Purpose (COICOP) (SEEA 2003). The environmental assets (EA) of the SEEA are based on the non-financial assets (AN) of the SNA (SNA 2008). Land cover classifications have been proposed for the SEEA 2013 based on the FAO LCCS system.

The use of different coding systems between National Footprint Accounts and SEEA thus necessitates the creation of comprehensive bridge tables to harmonize the various products, resources, assets, and activities between accounting systems (Global Footprint Network, 2010). Bridge tables vary by land-use type, and even within these sub-categories, due to differing product and commodity classifications within both the National Footprint Accounts and SEEA. Overcoming this incongruity requires the use of bridge tables provided by the UN Statistics Division and/or Eurostat. A sample list of correspondence between the National Footprint Accounts and SEEA can be found in Global Footprint Network (2010).

3. Policy and analytical relevance of the Ecological Footprint

To assess the potential policy usefulness of any accounting system (including the Ecological Footprint), it is important to first define a) what being "policy relevant" means, b) what are the steps involved in developing and implementing policies, and c) what is it that decision makers need to know, compared with what an accounting system can offer, in each step of the policy formulation process (Bassi et al., 2011). In a first approximation, we could divide the process of developing policies - the "policy cycle" - into the following steps:

- **Early warning**: the big picture is initially given to decision makers; this can help generate political will (self-interest) and guide policy action; this is also the stage where new issues could be identified and new "ways of thinking" emerge;
- **Headline and Issue framing**: at this stage, causes of the problems and potential solution are identified via data, indicators, matrices, tools and accounting systems;
- **Policy development:** building on info drawn from previous stages, actions are taken and policies drafted and proposed;
- **Implementation:** political tools are used to ensure drafted policies are implemented;
- **Monitoring:** tools are used to quantitatively monitor the effectiveness of policies.

The policy usefulness of the Ecological Footprint resides in its capacity to track cross-cutting issues and multiple drivers, to capture rebound effect and unintended consequences, to enable change, and to stimulate a new "limits aware" risk analysis and decision-making in the policy process. These strengths make the Ecological Footprint relevant in all steps of the policy cycle, with a particular capacity to inform decision makers in the "early warning" stage (to identify Ecological Footprint "hot spots" and mitigation opportunities) and the "monitoring" stage (see below).

The methodological framework of the Ecological Footprint also provides an underpinning for other indicators, which focus on areas/sectors that the Footprint does not currently monitor. Once policies have been drafted and implemented to allow for a "greening" of the economy, systemic cross-cutting tools are needed again to monitor the full range of consequences of the implemented policies. In this context, indicators such as the Ecological Footprint and/or the Human Development Index can be used again to assess the effectiveness and the broad set of societal consequences due to the implemented policies (Moran et al., 2008).

Due to its consumption-based approach, the Ecological Footprint can also represent a quantifiable and rational basis on which to begin discussions and develop answers on the limits to resource consumption, the international distribution of the world‘s natural resources, and how to address the sustainability of the use of our ecological assets across the globe (Galli et al., 2011).

4. Links to relevant technical advice/ theory and links to specific examples

Today's governmental leaders are faced with the daunting task of addressing a plethora of environmental problems and creating environmental policy in the context of ecological overshoot. Global Footprint Network helps countries understand their ecological balance sheet, and weigh their options to ultimately shift ecological trends in the direction of sustainability. Central to this approach is for countries to apply the Ecological Footprint, biocapacity, and related calculations to make more informed policy decisions. Global Footprint Network is building a critical mass of governments (see www.footprintnetwork.org/reviews): nearly twenty nations have performed reviews of their National Footprint Accounts; seven nations have institutionalized the Footprint in some government policies on the premise that biocapacity is as valuable as financial capital and biocapacity deficits are an increasing drain on economic progress (e.g., Abdullatif and Alam, 2011).

Going forward, an environmentally extended MRIO framework would allow researchers to track environmental demands along the complete supply chain of products and services, thus highlighting links between economic activities and their environmental consequences (Wiedmann, 2009; Wiedmann et al., 2007). Utilizing the MRIO framework would be a crucial step in making Ecological Footprint accounting consistent with the SEEA and is in line with good practice in national environmental statistics (de Haan and Keuning, 1996). The EU-FP7 project OPEN:EU, for instance, has been using an Ecological Footprint extended MRIO framework for the evaluation of policy scenarios on a national and international level (http://www.oneplaneteconomynetwork.org).

5. Other Footprint techniques

William Rees and Mathis Wackernagel conceived and established the Ecological Footprint as a metric in the early 1990s (Wackernagel and Rees 1996). The term Footprint caught many people's attention, and some use it in a loser sense referring to all kinds of anthropogenic impacts upon the Earth. For instance, BP popularized one particular component of the Footprint, the carbon Footprint, which is now a widely used term in the popular climate debate. To maintain consistency in the understanding, Global Footprint Network developed Footprint method standards (www.footprintnetwork.org) with releases in 2006 and an update in 2009.

Some have developed more detailed methodology of Footprint components: Carbon Footprint (Hertwich and Peters, 2009) and water consumption and pollution by the Water Footprint (Hoekstra, 2003). Next to these more standardized and robust "footprint indicators", other emerging indicators can be mentioned (Galli et al., 2012; Čuček et al., 2012) such as the land footprint (Lugschitz et al., 2011), the nuclear footprint (Stoeglehner et al., 2005; Wada, 2010) and the nitrogen Footprint (Leach et al., 2012).

Building on the premise that no single indicator is able to comprehensively monitor (progress towards) sustainability, the EC funded FP7 project investigated the Ecological, Carbon and Water Footprints as a set of indicators – characterized by a consumption-based perspective – able to track human pressure on the surrounding environment, from multiple angles (Galli et al., 2012).

An environmentally-extended multi-regional input-output (EE-MRIO) model has then been developed to combine these metrics with national economic accounts and trade statistics. Such an EE-MRIO model takes into account full production chains with technologies specific to country of origin and opens the way for a new set of analyses and comparisons among the three footprint indicators. Using a common calculation framework significantly reduces the burden on a decision-maker to understand three independent models. The consumption-based footprint accounting complements traditional accounting of resource, land, or water use, which is based on a production perspective. Using this EE-MRIO framework for footprint accounting offers a clear mechanism for storing direct footprints and allowing the calculation of either producer or consumer-based aggregates (Ewing et al., 2012).

APPENDIX A: Basic formula for calculating the Ecological Footprint

For a given nation, the Ecological Footprint of production, EFP, represents primary demand for biocapacity and is calculated as

$$EF_P = \sum_i \frac{P_i}{Y_{N,i}} \cdot YF_{N,i} \cdot EQF_i = \sum_i \frac{P_i}{Y_{W,i}} \cdot EQF_i$$

(Equation 1)

where P is the amount of each primary product i that is harvested (or carbon dioxide emitted) in the nation; YN,i is the annual national average yield for the production of commodity i (or its carbon uptake capacity in cases where P is CO2); YFN,i is the country-specific yield factor for the production of each product i; YW,i is the average world yield for commodity i; and EQFi is the equivalence factor for the land use type producing products i.

All manufacturing processes rely to some degree on the use of biocapacity to provide material inputs and remove wastes at various points in the production chain. Thus all products carry with them an embodied Footprint, and international trade flows can be seen as flows of embodied demand for biocapacity.

In order to keep track of both the direct and indirect biocapacity needed to support people's consumption patterns, the National Footprint Accounts use a consumer-based approach; for each land use type, the Ecological Footprint of consumption (EFC) is thus calculated as

$$EF_C = EF_P + EF_I - EF_E$$

(Equation 2)

where EFP is the Ecological Footprint of production and EFI and EFE are the Footprints embodied in imported and exported commodity flows, respectively. For each traded product, EFI and EFE are calculated as in equation 1, with Production P being the amount of product imported or exported, respectively.

APPENDIX B: The calculation procedure for MRIO-based Footprinting

Alternative to the classical Ecological Footprint methodology described in Appendix A, which uses an "LCA type" of approach (Wiedmann et al., 2006; Kitzes et al., 2009; Galli et al., 2011), Ecological Footprint of consumption (EFc) values can be also calculated through a standardized accounting framework such as an input-output framework. In this case, Ecological Footprint of production (EFp) values, calculated as in equation 1 above, can be linked with an input-output modeling framework to derive EFc values. This calculation procedure also allows to obtain industrial sector-based results and is divided into three stages: initial allocation, total Ecological Footprint intensity, and Ecological Footprint of consumption.

1. Initial allocation: Ecological Footprint of production (EFp) for each land type is re-allocated into industrial sector categories of an input-output table with the reference of the National Footprint Accounts product classifications and the definition of each sector used in input-output tables. Ecological Footprint of production values (gha) in each sector are divided by a corresponding total output value (X) to obtain the direct Ecological Footprint intensity (EFdir), which represents the required Ecological Footprint input for a unit output in each sector.

$$\mathbf{EF}^{\mathbf{dir}} = \frac{EF_p}{X} \quad \text{(Equation 3)}$$

2. The Total Ecological Footprint intensity: The Total Ecological Footprint intensity (EFtot) is calculated by multiplying direct EF intensity by the Leontief Inverse matrix [(I-A)-1], which shows the monetary input requirements (direct and indirect) of all other producers for one unit of output. The total Footprint Intensity measures both the direct and indirect Footprints of industrial sectors needed to provide one unit of production to final demand.

$$\mathbf{EF}^{\mathbf{tot}} = \mathbf{EF}^{\mathbf{dir}} * (\mathbf{I} - \mathbf{A})^{-1} \quad \text{(Equation 4)}$$

3. Ecological Footprint of consumption: Finally, the Ecological Footprint of consumption is calculated by multiplying the total EF intensity by domestic final demand (FDD), which includes household consumption, government consumption, and gross fixed capital formation.

$$\mathbf{EF}_C = \mathbf{EF}^{\mathbf{tot}} * \mathbf{FD}_{\mathbf{D}} \quad \text{(Equation 5)}$$

A multi-regional input-output model (MRIO) is the extended model of the input-output approach described above, which is able to fully trace the global supply chain taking into consideration different regional productivities. The Ecological Footprint-Extended Multi-Regional Input-Output Analysis (EF-MRIO) can connect consumption activities of each region with various environmental pressures due to the production phase worldwide. Such an analysis has been developed for the first time in the OPEN:EU project, and integrated with the inclusion of both Carbon and Water Footprint within the same MRIO modeling framework (Weinzettel et al., 2011; Ewing et al., 2012).

References

Abdullatif, L., Alam, T., (Eds.) 2011. The UAE Ecological Footprint Initiative: summary report 2007-2010. Available at: http://awsassets.panda.org/downloads/en_final_report_ecological_footprint.pdf.

Bassi, S., Cranston, G., Galli, A., Mazza, L., Newman, J., Owen, A., Roelich, K., Stoessel, S., Turcotte, I., Wentrup, K., Withana, S., 2011. Summary Evaluation: EUREAPA as a tool for informing policy decisions on the basis of the Footprint Family of indicators. OPEN:EU project deliverable. Available at: http://www.oneplaneteconomynetwork.org/resources/work-package-6.html

Borucke, M., Moore, D., Cranston, G., Gracey, K., Iha, K., Larson, J., Lazarus, E., Morales, J.C., Wackernagel, M., Galli, A., forthcoming. Accounting for demand and supply of the Biosphere's regenerative capacity: the National Footprint Accounts' underlying methodology and framework.

Čuček, L., Klemeš, J., Kravanja, Z. 2012. A Review of Footprint analysis tools for monitoring impacts on sustainability. Journal of Cleaner Production doi: 10.1016/j.jclepro.2012.02.036.

de Haan, M., Keuning, S.J., 1996. Taking the environment into account: the NAMEA approach. The Review of Income and Wealth, 42 (2), 131–147.

DG Environment (Directorate General of the Environment, European Commission), 2008. Potential of the ecological footprint for monitoring environmental impact from natural resources use – analysis of the potential of the ecological footprint and related assessment tools for use in the EU's thematic strategy on the sustainable use of natural resources. Report to the European Commission, DG Environment, Final Report, 2 March 2008.

Ewing, B., Hawkins, T., Wiedmann, T., Galli, A., Ercin, E., Weinzettel, J., Steen-Olsen, K., 2012. Integrating Ecological and Water Footprint Accounting in a Multi-Regional Input-Output Framework. Ecological Indicators, 23, 1-8.

Ewing, B., Moore, D., Goldfinger, S., Oursler, A., Reed, A., Wackernagel, M., 2010b. The Ecological Footprint Atlas 2010. Oakland: Global Footprint Network. www.footprintnetwork.org/atlas.

Ewing, B., Reed, A., Galli, A., Kitzes, J., Wackernagel, M., 2010a. Calculation Methodology for the national Footprint Accounts, 2010 Edition. Oakland: Global Footprint Network http://www.footprintnetwork.org/images/uploads/National_Footprint_Accounts_Method_Paper_2010.pdf

Galli, A., Kitzes, J., Wermer, P., Wackernagel, M., Niccolucci, V., Tiezzi, E., 2007. An Exploration of the Mathematics behind the Ecological Footprint. International Journal of Ecodynamics. 2(4), 250-257.

Galli, A., Wiedmann, T., Ercin, E., Knoblauch, D., Ewing, B., Giljum, S., 2012. Integrating Ecological, Carbon, and Water Footprint into a "Footprint Family" of indicators: definition and role in tracking Human Pressure on the Planet. Ecological Indicators, 16, 100-112.

Galli, A., Wiedmann, T., Ercin, E., Knoblauch, D., Ewing, B., Giljum, S., 2011. Integrating Ecological, Carbon and Water Footprint: Defining the "Footprint Family" and its Application in Tracking Human Pressure on the Planet. OPEN:EU project deliverable. Available at: http://www.oneplaneteconomynetwork.org/resources/work-package-8.html

Giljum, S., Hinterberger, F., Lutter, S., Polzin, C., 2009. How to Measure Europe's Resource Use. An Analysis for Friends of the Earth Europe. Sustainable Europe Research Institute, Vienna.

Global Footprint Network, 2010. Harmonizing the national footprint accounts with the system of integrated environmental and economic accounting. Available at: http://unstats.un.org/unsd/envaccounting/ceea/meetings/UNCEEA-5-11.pdf

Hertwich, E.G., Peters, G.P., 2009. Carbon footprint of nations: a global, trade-linked analysis. Environmental Science and Technology 43, 6414–6420.

Hoekstra, A.Y. (Ed.), 2003. Virtual Water Trade: Proceedings of the International Expert Meeting on Virtual Water Trade. Delft, The Netherlands, 12–13 December 2002, Value of Water Research Report Series No. 12, UNESCOIHE, Delft, The Netherlands. www.waterfootprint.org/Reports/Report12.pdf (accessed 10.10.10).

Kitzes, J., Galli, A., Bagliani, M., Barrett, J., Dige, G., Ede, S., Erb, K-H., Giljum, S., Haberl, H., Hails, C., Jungwirth, S., Lenzen, M., Lewis, K., Loh, J., Marchettini, N., Messinger, H., Milne, K., Moles, R., Monfreda, C., Moran, D., Nakano, K., Pyhälä, A., Rees, W., Simmons, C., Wackernagel, M., Wada, Y., Walsh, C., Wiedmann, T., 2009. A research agenda for improving national ecological footprint accounts. Ecological Economics, 68(7), 1991-2007.

Leach, A., Galloway, J., Bleeker, A., Erisman, J.W., Kohn, R., Kitzes, J., 2012. A nitrogen footprint model to help consumers understand their role in nitrogen losses to the environment. Environmental Development, 1, 40–66.

Lugschitz, B., Bruckner, M., Giljum, S., 2011. Europe's global land demand: A study on the actual land embodied in European imports and exports of agricultural and forestry products. Available at: http://seri.at/wp-content/uploads/2011/10/Europe_Global_Land_Demand_Oct11.pdf

Monfreda, C., Wackernagel, M., Deumling, D., 2004. Establishing national natural capital accounts based on detailed ecological footprint and biocapacity assessments. Land Use Policy 21, 231–246.

Moran, D., Wackernagel, M., Kitzes, J., Goldfinger, S., Boutaud, A., 2008. Measuring Sustainable Development – Nation by Nation. Ecological Economics, 64(3), 470-474.

Stoeglehner, G., Levy, J.K., Neugebauer, G.C., 2005. Improving the ecological footprint of nuclear energy: a risk-based lifecycle assessment approach for critical infrastructure systems. International Journal of Critical Infrastructures 1 (4), 394–403.

Wackernagel, M., Schulz, B., Deumling, D., Linares, A.C., Jenkins, M., Kapos, V., Monfreda, C., Loh, J., Myers, N., Norgaard, R., Randers, J., 2002. Tracking the ecological overshoot of the human economy. Proc. Natl. Acad. Sci, 99(14), 9266-9271.

Wada, Y., 2010. Responsibility allocation over time within Ecological Footprint Analysis: A case study of nuclear power generation. In: Bastianoni, S. (Ed.), Footprint Forum 2010: The State of the Art in Ecological Footprint Theory and Applications, pp. 159–160 http://www.footprintnetwork.org/images/uploads/Academic_Conference_Book_of_Abastracts.pdf.

Weinzettel, J., Steen-Olsen, K., Galli, A., Cranston, G., Ercin, E., Hawkins, T., Wiedmann, T., Hertwich, E., 2011. Footprint Family Technical Report: Integration into MRIO model. OPEN:EU project deliverable. Available at: http://www.oneplaneteconomynetwork.org/resources/work-package-2.html.

Wiedmann, T., 2009. A review of recent multi-region input-output models used for consumption-based emission and resource accounting. Ecological Economics, 69(2), 211–222.

Wiedmann, T., Barrett, J., 2010. A review of the ecological footprint indicator—perceptions and methods. Sustainability, 2 (6), 1645-1693.

Wiedmann, T., Minx, J., Barrett, J., Wackernagel, M., 2006. Allocating ecological footprints to final consumption categories with input-output analysis. Ecological Economics, 56(1), 28-48.

Wiedmann, T., Lenzen, M., Turner, K., Barrett, J., 2007. Examining the global environmental impact of regional consumption activities. Part 2: review of input-output models for the assessment of environmental impacts embodied in trade. Ecological Economics, 61 (1), 15–26.