Potential of the Ecological Footprint for monitoring environmental impacts from natural resource 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

May 2008

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Suggested citation:

Best, Aaron, Stefan Giljum, Craig Simmons, Daniel Blobel, Kevin Lewis, Mark Hammer, Sandra Cavalieri, Stephan Lutter and Cathy Maguire. 2008. Potential of the Ecological Footprint for monitoring environmental impacts from natural resource 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.

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Acknowledgements

We want to thank a number of experts who contributed information and provided feedback on earlier versions of this report.

We would like to thank the members of the project steering committee, in particular Werner Bosmans (European Commission, DG Environment) Júlio Cabeça (Eurostat), Gorm Dige (European Environment Agency), Jörg Hanauer (Eurostat), Klaus Koegler (European Commission, DG Environment), Anne Teller (European Commission, DG Environment), Anne-France Woestyn (European Commission, DG Environment), Marc-Andree Wolf (European Commission, Joint Research Centre) and Oliver Zwirner (European Commission, DG Environment).

For preparing the research agenda for the different tools, special appreciation goes to the following persons:

- Ester van der Voet. Centre of Environmental Science (CML), Section Substances & Products, Leiden University, The Netherlands. Interview on 18.10.2007
- Stephan Moll. Wuppertal Institute for Climate, Environment, Energy, Research Group 3: Material Flows and Resource Management, Germany. Interview on 12.10.2007
- Helmut Haberl. Institute of Social Ecology, Klagenfurt University, Vienna, Austria. Interview on 20.11.2007
- David Vackar. Charles University Environment Center. Prague. Interview on 5.12.2007
- Jean-Louis Weber. European Environment Agency, Environmental Accounting and Spatial Assessment, Copenhagen, Denmark. Interview on 7.9.2007.

We would like to thank Steven Goldfinger, Justin Kitzes and Mathis Wackernagel (Global Footprint Network) for the feedback they provided on earlier versions of this report. Furthermore, we are grateful to a number of experts who provided feedback on earlier drafts of this report.

- Marc-Andree Wolf, European Platform on Life Cycle Assessment, European Commission, JRC.
- Julie L. Hass, Division for Environmental Statistics, Statistics Norway.
- Wes Ingwersen, University of Florida.
- Natacha Zuinen, Bureau fédéral du Plan – Task Force Développement durable, Brussels.

These acknowledgements do not necessarily imply that the experts mentioned above endorse the analysis and conclusions presented in this report. The responsibility for the content and for any errors lies exclusively with the authors.

Abbreviations

6EAP	Sixth Environmental Action Programme
EF	Ecological Footprint
EFA	Energy Flow Accounting
EMC	Environmentally Weighted Material Consumption
ESI	Environmental Sustainability Index
EVI	Environmental Vulnerability Index
EVIL	Environmental Impact Load
GDP	Gross Domestic Product
GPI	Genuine Progress Indicator
GS	Genuine Savings
HANPP	Human Appropriation of Net Primary Production
ISEW	Index of Sustainable Economic Welfare
LCA	Life Cycle Assessment
LEAC	Land and Ecosystem Accounts
LUA	Land Use Accounts
MFA	Material Flow Analysis
NAMEA	National Accounting Matrix including Environmental Accounts
PIOT	Physical Input Output Tables
SDS	Sustainable Development Strategy
SFA	Substance Flow Analysis
SHDI	Sustainable Human Development Index
SNA	System of National Accounts
SEEA	Integrated Environmental and Economic Accounting
UN	United Nations

Abstract

The Ecological Footprint is a useful indicator for assessing progress on the EU's Resource Strategy and is unique among the 13 indicators reviewed in this study in its ability to relate resource use to the concept of carrying capacity. The indicator is most effective, meaningful and robust at aggregate levels (national and above). Further improvements in data quality, methodologies and assumptions are required, however, and the study identifies a short- and medium-term research agenda for the Ecological Footprint that focuses on experts' top recommendations for further development of the methodology. To effectively monitor EU progress on the Resource Strategy, additional indicators are required. This study recommends adoption of a small indicator basket consisting of four resource indicators: Ecological Footprint (EF), Environmentally-weighted Material Consumption (EMC), Human Appropriation of Net Primary Production (HANPP) and Land and Ecosystem Accounts (LEAC). The identified basket of indicators can be applied to monitor de-coupling of economic growth from environmental impacts as well as illustrating the effectiveness of a number of specific policies aiming at a more sustainable use of natural resources (especially energy and climate policies, agriculture and forestry policies, material policies and spatial planning/urban planning). Capturing the geographical distribution of pollution impacts and impacts on ecosystems and biodiversity requires the use of indicators additional to those in the basket.

Executive Summary

Providing for the well-being of a growing human population within the limits of a finite planet is a key challenge for our future. Many people still need more natural resources just to meet basic needs. Yet many of nature's life support systems are already overburdened. To maintain and improve long-term human well-being, societies will have to reduce the environmental impacts of resource use and also use resources more efficiently. Due to their high levels of economic development and resource consumption, industrialised countries such as those of the EU share a special responsibility and opportunity for addressing these challenges.

In the Lisbon Strategy and the renewed Sustainable Development Strategy, the European Union recognised that using resources more efficiently is crucial for the economic development of the EU, for the European environment, and for a positive role of the EU in the world. Increasing energy and resource efficiency of the EU can accelerate innovation, create jobs, increase competitiveness and improve the state of the environment. But how far does Europe need to go? Certainly, there can be no sustainable development in the EU without reducing human demand on global natural resources. A main strategy is enhancing resource efficiency. Progress in industrialised countries therefore needs to be measured against the ability to increase resource productivity and decrease the demand for natural resources.

Objective of this study

The main aim of this study is to guide the development of indicators as called for in the EU's Thematic Strategy on the Sustainable Use of Natural Resources[1] (referred to shorthand as "Resource Strategy"). More precisely, the intended focus is on resource-specific indicators to evaluate the environmental impact of resource use.

The study should give input to further work on these indicators by the Data Centre on Resources hosted by Eurostat[2], in collaboration with the Joint Research Centre (JRC), in particular the European Platform on Life Cycle Assessment[3], and the European Environment Agency (EEA)[4], in particular the Topic Centre on Sustainable Consumption and Production[5].

This study is an evaluation of the Ecological Footprint indicator, including the specific advantages and shortcomings of the Ecological Footprint. The study also assesses how the Ecological Footprint could best be combined with other tools to meet the EU's desired monitoring objectives. The evaluation consists of three main tasks:

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1 COM (2005) 670 final.

2 http://ec.europa.eu/eurostat, In particular see Environmental Accounts: http://epp.eurostat.ec.europa.eu/portal/page?_pageid=2873,63643317,2873_63643793&_dad=portal&_schema=PORTAL

3 http://lca.jrc.ec.europa.eu

4 http://www.eea.europa.eu/themes/waste

5 http://waste.eionet.europa.eu/

1. An assessment of the potential of the Ecological Footprint as an aggregated indicator to measure resource-specific impacts as called for in the Resource Strategy.

2. An assessment of how other assessment tools and derived indicators can complement the Ecological Footprint in combination to fulfil EU policy requirements (e.g. through development of a basket of aggregated indicators capable of monitoring the environmental impact of natural resource use).

3. Identification of essential near-term improvements needed in the Ecological Footprint and the indicators in the basket of indicators (over the next 1 to 5 years).

Policy context

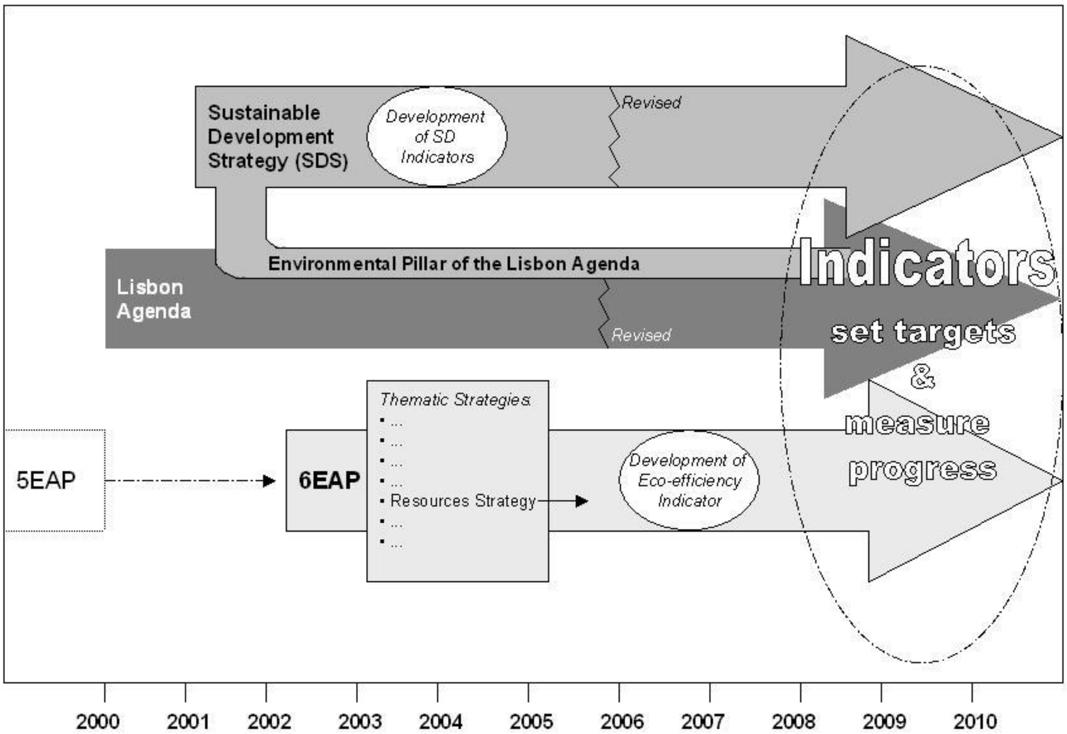
The EU's resource policies aim to reduce environmental impacts through the sustainable use of natural resources. Both the EU's 2001 Sustainable Development Strategy (SDS) (renewed in 2006) and the 2005 Resource Strategy build on the goal of sustainable development through the decoupling of economic activity from environmental impacts by considering the entire life cycle of resource use.

Underscoring the need for this decoupling is the fact that EU policy is also committed to the continued economic growth in the EU. In March 2000, the Lisbon European Council agreed the Lisbon Agenda, which aims at increasing competitiveness and employment within the EU. The Lisbon Agenda as initially formulated came under criticism due to a lack of consideration for the environment in its socio-economic goals. At the June 2001 Gothenburg European Council, the European Commission adopted the Sustainable Development Strategy (SDS), which provides an environmental pillar to the Lisbon Agenda. The revised goal for the Lisbon Agenda is to focus primarily on job growth until 2008, after which the policy will be reviewed. The revised SDS sets enhanced objectives and action items for seven key priority areas and proposes ways to improve government co-ordination. The revised SDS will be reviewed every two years, beginning in 2007, to monitor progress towards its goals.

Both the SDS and Resource Strategy cite a lack of suitable indicators as a key challenge to setting targets and measuring progress on global resource impacts. Thus, both strategies propose that indicators be developed that consider the entire life cycle of resource use to achieve the overall objective of decoupling economic activity from environmental impacts.

The figure below illustrates the relationships among the different EU natural resource policies over a ten-year period beginning in 2000. Each of the policies is shown in a different arrow with a policy timeframe that extends beyond 2010.

Figure I: Relationships among the EU's natural resource policies: 2000-2010



The basket of indicators

After extensive evaluation in this study, the following four aggregate indicators were found suitable as complementary tools capable of monitoring the environmental impact of natural resource use: Ecological Footprint (EF), Environmentally Weighted Material Consumption (EMC), Human Appropriation of Net Primary Production (HANPP) and Land and Ecosystem Accounts (LEAC). It should be clarified that three of the four elements of the basket (EF, EMC, HANPP) are indicators or indices, while LEAC is an accounting framework from which aggregated indicators can be derived. As LEAC-based indicators are currently only under development, we decided to include the overall framework in the basket.

The selection of those four tools and related indicators is based on the current state of the art. The Resource Strategy defines the ultimate objective to develop one aggregated indicator, illustrating the environmental impacts related to resource use with a single score. Therefore, future efforts will be devoted to the analysis of overlaps among the different indicators and their further development and extension. This might allow integration of some of the components in the basket (in particular, the Ecological Footprint with indicators based on life cycle analysis such as EMC) and thus reduce the number of indicators in the basket.

Ecological Footprint (EF). The Ecological Footprint measures how much biologically productive land and water area is required to provide the resources consumed and absorb the wastes generated by a human population, taking into account prevailing technology. The annual production of biologically provided resources, called biocapacity, is also measured as part of the methodology. The Ecological Footprint and biocapacity are each measured in *global hectares*, a standardised unit of measurement equal to 1 hectare with global average bioproductivity. This study only evaluated the EF methodology used at the national level (and did not evaluate subnational applications).

Environmentally Weighted Material Consumption (EMC). EMC is a weighted indicator of material consumption based on environmental impacts. It currently is the most advanced indicator capable of illustrating how data on material flows (for example, data included in the indicator Direct Material Consumption, DMC) can be linked with information on the life-cycle wide environmental impacts of these materials, derived from Life Cycle Assessment (LCA) (Oers et al., 2005). EMC estimates the environmental impacts of materials throughout a product's life cycle. The underlying data for the EMC overlaps with that of the Ecological Footprint to some extent but unlike the Footprint's expression in a single spatial unit (global hectares), the EMC combines a set of specific impact indicators (e.g. CO_2 emissions, land use) that are then aggregated using weighting factors. Environmental issues not captured by the Ecological Footprint are included in the EMC, including the human-health and eco-toxicity impacts of certain materials, and the issues of ozone depletion, eutrophication, and acidification.

Human Appropriation of Net Primary Production (HANPP). HANPP is a measure of human use of ecosystems and can be defined as the amount of terrestrial net primary production required to derive food and fibre products consumed by humans, including the organic matter that is lost during the harvesting and processing of whole plants into end products. HANPP is complementary to the Ecological Footprint as it measures how much bioproductivity is appropriated in a given territory, whereas the Ecological Footprint measures how much biocapacity a country utilizes wherever that biocapacity is located in the world (Haberl et al., 2004). HANPP can thus illustrate the "depth" of the Footprint by tracking how intensively given ecosystems are being harvested.

Land and Ecosystem Accounts (LEAC). LEAC is a method developed and used by the EEA to account for the interactions between nature and society on the basis of a detailed grid (1km x 1km) for land use and land cover changes within the European Union. It is based on CORINE land cover data and its goal is to provide information on land cover and related land use changes. Within LEAC, ecosystem accounts incorporate material and energy stocks and flows, health of ecosystems counts and ecosystem services measurements. The ultimate goal is to measure the resilience of natural capital, its services and maintenance costs. As an example indicator derived from LEAC, we selected "land cover change" for the illustration of the basket in this report.

EF and EMC can be applied on the national, regional, sectoral as well as on the product level.[6] Although there are current efforts to calculate HANPP of products, both HANPP and LEAC are mostly used for analysing land use-related impacts of regions or countries. It shall be emphasised that HANPP and LEAC thus differ from EF and EMC, as the former do not include aspects of burden shifting related to international trade of goods and services. Therefore, HANPP and LEAC in general do not include life-cycle aspects related to the production and use of products.

HANPP and LEAC focus on issues related to land cover and land use and their changes over time. Also EF and EMC cover land use-related impacts; however, the latter two

[6] The report at hand, however, focuses on their national application and methodology of the Ecological Footprint.

approaches do not provide geographical specifications of these impacts, i.e. do not inform, where exactly those impacts take place. For some key policy areas, geographically explicit indicators are required, which explain the land-related impacts of natural resource use in specific regions or countries. These policy areas include urban planning, regional planning (in particular, of infrastructure) and ecosystem management and protection, with the particular issue of how resource use impacts on biodiversity. These questions cannot be addressed (only) with product-related approaches; therefore HANPP and LEAC are suggested to be included in the basket.

Table I provides a summary of the key aspects related to each tool in the basket.

Table I: Basket of tools / indicators – summary of key aspects

Tool	Main issues addressed	Covered impact categories *	Complementary property in basket	Data requirements	Strengths	Limitations and weaknesses
EF	How much of the regenerative capacity of the planet is occupied by a given human activity or population? In which countries is biocapacity located?	Resource consumption (Climate change) (Land use) (Impact on ecosystems and biodiversity)	Provides clear benchmark for assessments of carrying capacity and overshoot. Allows assessing the impacts of natural resource use on the regenerative capacity of ecosystems.	Data on material flows, land use and CO_2 emissions. Conversion factors for transformation of resource and waste flows into necessary biocapacity to sustain flows (measured in global hectares)	Integrates all resource use in terms of demand on regenerative capacity. Allows relating human demand to supply by nature and determining clear target. Considers trade flows (incl. embodied energy). Based on a clear research question.	EF cannot cover impacts for which no regenerative capacity exists (e.g. pollution in terms of waste generation, toxicity, eutrophication, etc.). EF shows pressures that could lead to degradation of natural capital (e.g. reduced quality of land or reduced biodiversity), but does not predict this degradation.
EMC	What is the global environmental impact potential of materials consumed in a national economy and where does it occur in the production and recycling of materials?	Climate change Human health (Land use) Stratospheric ozone depletion Eco-toxicity Photo-oxidant formation Acidification Eutrophication Ionizing radiation	Covers impacts independent from absorption capacities, such as human health and eco-toxic impacts of certain materials or issues of ozone depletion, eutrophication, acidification, etc.	Material flow data / production and trade statistics. Data on life-cycle wide emission inventories and environmental impacts of different materials.	Comprehensive measure based on biotic and abiotic resource accounts. Covers a large number of LCA impact categories. Includes direct trade flows and life-cycle wide impacts associated with these flows.	Not an accounting approach, but an aggregate of separate assessments. Subjective weighting involved to calculate aggregated indicator. No endogenous definition of benchmarks / sustainable levels.
HANPP	How intensely are ecosystems being used by human beings?	(Impact on ecosystems and biodiversity) Land use	Relates material flows (biomass extraction) to pressures on ecosystems. Monitors the intensity of ecosystem and land use and establishes links to natural capital deterioration (e.g. soil erosion) and pressures on biodiversity.	Agricultural and forestry statistics and inventories, land use statistics, remotely-sensed (satellite) data.	Provides an illustrative and spatially explicit indicator on human pressures on ecosystems. Can serve as early warning indicator for land degradation and pressure on biodiversity.	No endogenous definition of benchmarks / sustainable levels. No consideration of trade and trade-related demand on biosphere.
LEAC	For which economic activities are different land areas being used? Which are the socio-economic drivers for land cover changes?	(Impact on ecosystems and biodiversity) Land use	Links land cover change to socio-economic (sectoral) aspects of land use. Assesses spatially explicit consequences of resource use for land cover change.	Remotely-sensed (satellite) data. Data on net primary production. Demographic data and spatially distributed economic data.	Provides a SEEA-compatible account for impacts of resource use on land cover and land use and changes over time. Bridges with monetary valuation of ecosystem services and maintenance costs of ecosystems.	Sectoral information (in particular, industry and service sectors) very aggregated. No endogenous definition of benchmarks / sustainable levels. No consideration of trade.

* Note: Brackets indicate that impact category is only partly covered.

Key findings of the study

Key findings: Ecological Footprint (*National Footprint Accounts only*)

The Ecological Footprint could be an effective indicator for assessing and communicating progress toward the policy objectives of the EU's Resource Strategy. National data can be aggregated at EU scales, disaggregated to understand key drivers, and used to track long-term changes in how resource use relates to carrying capacity. The EU could also capitalise now on a 'window of opportunity' by participating in efforts to make the indicator more robust through independent third party review, methodological improvements, and the development of a collective database for resource use, furthering and relating to the ongoing efforts for a European Reference Life Cycle Data System. These efforts to improve the Ecological Footprint could also benefit the development of complementary indicators.

Key additional findings regarding the Ecological Footprint are:

- The Ecological Footprint is a useful indicator for assessing progress on the EU's resource policies and is unique among the reviewed indicators in its ability to relate resource use to carrying capacity.
- The Ecological Footprint is an intuitively appealing indicator (easy to communicate and understand with a strong conservation message). The indicator is most effective, meaningful and robust at aggregate levels (national and above).
- Further improvements in data quality, methodologies and assumptions are required. There remains a lack of transparency regarding certain aspects.
- A strong stakeholder network has emerged around the indicator, and opportunities exist for public sector involvement to develop and refine the methodology.
- This study identified a short/medium term research agenda for the Ecological Footprint (National Footprint Accounts methodology). The final research agenda is compiled of 9 research proposals, which focus on the top issues identified by experts as needing further development.

Key findings: basket of indicators

The main objective of analysing the various resource-related indicators was to identify those methods and indicators which could best complement the Ecological Footprint in assessing and monitoring the environmental impacts of natural resource use.

RACER evaluation performed for 13 potential tools and indicators. Out of a list of 25 methodological approaches that were initially identified as potentially relevant for the purpose of this study, the project team selected 13 approaches, for which a detailed RACER[7] evaluation was performed. Results of the RACER evaluation, which were summarised

[7] RACER is an acronym for the criteria on which the indicators were evaluated (**R**elevant– i.e. closely linked to the objectives to be reached; **A**ccepted – e.g. by staff, stakeholders; **C**redible for non experts, unambiguous and easy to interpret; **E**asy to monitor (e.g. data collection should be possible at low cost); **R**obust against manipulation and error.

through indicative numerical scores, revealed significant differences in the overall quality and suitability of the different approaches for the respective purpose.

The suggested basket contains four complementary tools. The tools included in the basket were selected through a set of three main criteria: policy relevance, high ranking in the RACER evaluation and completeness/complementarity. Four tools and related indicators passed all criteria and were therefore suggested to form the basket of indicators: Ecological Footprint (EF), Environmentally-weighted Material Consumption (EMC), Human Appropriation of Net Primary Production (HANPP) and Land and Ecosystem Accounts (LEAC). These four tools and related indicators all scored high in the RACER evaluation, in particular with regard to the criterion of policy relevance. Applied as a basket, these four tools are comprehensive regarding the coverage of a large number of different environmental impacts. At the same time, they are complementary and each impact category is well covered by (at least) one of the tools. (Impacts on biodiversity and ecosystems are the only category, which is only indirectly covered. For this impact category, development of robust indicators is still ongoing.) The RACER evaluation of the whole basket of tools delivered higher scores for the basket than for any single approaches.

The basket allows monitoring the impacts of a wide range of policies. The identified basket of tools can be applied to monitor de-coupling of economic growth from environmental impacts as well as illustrating the effectiveness of a number of specific policies aiming at a more sustainable use of natural resources. Main policy fields covered by the basket are energy and climate policies, agriculture and forestry policies, material policies and spatial planning/urban planning. The main deficits regard missing information about the geographical distribution of pollution impacts as well as the impacts on ecosystems and biodiversity. To capture the regional and local impacts, indicators from the basket (in particular, EMC) must be combined with other data, for example on the exposure to pollutants in cities and industrial regions or with data from health statistics.

Table II: Summary of policies that can be addressed by the basket of indicators

Tool	Policy area / issue	Examples
EF	**De-coupling:**	
	De-coupling of economic growth from demands on biosphere	Measuring “overshoot” and countries’ ecological deficit; comparing human demand against local and global ecological supply (‘carrying capacity’)
	Sectors:	
	Energy and climate	Impacts of changes in energy supply structure on land appropriation and CO_2 emissions
	Agriculture and forestry	Conventional vs. organic farming; trade-offs between renewable energy sources and land availability
	Other policies:	
	Sustainable household consumption	Informing consumers regarding resource impacts of household consumption

Tool	Policy area / issue	Examples
EMC	**De-coupling:** De-coupling of economic growth from impacts on the natural environment and human health	Aggregated de-coupling indicators as called for by the Resource Strategy.
	Sectors: Agriculture Products and services (including materials) Energy and climate	Impacts of production of agricultural production, in particular animal products Identifying materials' production and energy carriers' use with highest impacts along life-cycle Impacts on GHG emissions of changes in energy supply structure
	Other policies: Sustainable production / cleaner production	Changes in environmental impacts due to substitution of materials, e.g. composite materials vs. metals
HANPP	**De-coupling:** De-coupling of economic growth from intensity of ecosystem use	
	Sectors: Agriculture and forestry	CAP policies to de-intensify agricultural production
	Other policies: Biodiversity (indirectly)	Increasing ecosystem exploitation through intensified agriculture and related loss of (forest) ecosystems
LEAC	**De-coupling:** De-coupling of economic growth from undesired land cover change	Increase of built-up land, extension of intensive agriculture for biofuels production
	Sectors: Agriculture and forestry	Land cover changes between agricultural, pasture and forest areas
	Other policies: Land use management and urban planning Biodiversity (indirectly)	Policies to moderate urban sprawl and related fragmentation of landscapes. Conservation of protected and non protected ecosystems

Key recommendations

Key recommendations: Ecological Footprint (*National Footprint Accounts only*)

The following are key recommendations for EU institutions and policy makers to use in considering how to implement the Ecological Footprint within the current indicator framework.

1. **Combine with complementary sustainability indictors.** The Ecological Footprint is designed to measure a specific aspect of sustainability (i.e. human demand for renewable resources for production and consumption as compared to available biocapacity). It is not designed to comprehensively measure overall sustainability. Therefore, many aspects of sustainability are missing from the calculation that should be covered by complementary indicators. This is further explored in Task 2 within the project (Final Report Part III).
2. **Use within the Sustainable Development Indicator (SDI) framework.** The Ecological Footprint should be used by EU institutions within the Sustainable Development Indicators (SDI) framework. The SDI framework consists of 155 indicators organised hierarchically to measure 10 broad sustainability themes. It was created by the SDI Task Force in order to monitor the implementation of the Sustainable Development Strategy and was adopted by the European Commission in 2005. The SDI framework currently lacks a measure of global carrying capacity, and the Ecological Footprint can provide a measure of biocapacity with respect to human demand. Thereby it could add an important missing element to the SDIs, specifically with respect to Theme 6 “Production and consumption patterns”.
3. **Join the effort to improve the EF methodology.** Global Footprint Network and its partner organisations are dedicated to improving the Ecological Footprint. This includes developing standards, identifying higher quality data and refining the calculation to increase transparency and reproducibility. In order to ensure objectivity in the methodology, EU institutions should partner with Global Footprint Network to ensure that its criteria are met and that the Ecological Footprint can be a useful indicator at the European level.
4. **Develop and use highest quality data.** Resources are required to improve data quality at all levels of government. While this recommendation is not specific to the Ecological Footprint, it is important that resources for data collection and management be dedicated in order to measure all aspects of resource use (i.e. fisheries) to accurately identify sustainability targets. In addition, it is important that different data sources link together. For example, if the system of National Footprint Accounts was compatible with the UN System of National Accounts, it would be possible to link the aggregate Ecological Footprint with GDP. Presenting these two indicators together could help further communicate the problems related to overuse of natural resources (Giljum et al. 2007).
5. **Dedicate resources for implementation and require third party review.** In addition to dedicating resources to improve the data quality and methodology of the Ecological Footprint, resources are also required to implement the Ecological Footprint at the EU level. The quality of the National Footprint Accounts would need to be consistent with national data and experts will be needed to draw data related to policies and progress toward sustainability targets. Findings from the Ecological Footprint could be bolstered by

independent third party review, which would enhance data accuracy and credibility. Third party reviews have already been done in Ireland, Finland and Switzerland.

6. **Explore further possibilities to derive meaningful and easily understood indicators from National Footprint Accounts.** It has become clear from the analysis of the Ecological Footprint that while a nation's total Footprint can serve as a valuable headline indicator, the underlying account system provides a great deal of information that could be used to provide more specific guidance to policies. However, at present, much of such information is "hidden" in the calculation tables. An effort should be made to explore the possibilities to convert the available data into easily understood indicators that could guide sectoral policies, e.g. by assessing the sustainability of trade flows for certain groups of products.

Key recommendations: basket of indicators

1. **Apply basket instead of single indicators**. The use of natural resources entails a large number of different environmental impacts. These range from pressures on the planet's overall biocapacity, impacts on land, ecosystem functions and biodiversity, impacts on climate, to the release of different forms of emissions and pollutants, which effect health of humans and ecosystems. One single tool or indicator is unable to illustrate the complexity of these impacts and their interrelations, in particular, regarding burden shifting between different types of impacts. Applying a basket of tools allows monitoring the spectrum of environmental impacts from different perspectives. Each tool is constructed to illustrate particular environmental impacts in a consistent and robust manner. A basket of tools and related indicators thus produces results of higher quality than one single aggregated indicator, which aims at covering all impact categories.

2. **Dedicate resources to further improve the basket**. All four tools suggested for the basket are of high relevance for the objectives of the Resource Strategy and improvement of the quality of results is one key task. The main priorities for improving the Footprint are formulated in Annex 1: *Agenda for short/medium term improvements to the basket and its individual indicators: The Ecological Footprint*. As the EMC is the tool in the basket that covers the largest number of impact categories and applies life-cycle assessment (LCA) as one key approach to measure environmental impacts of products, further improvement of EMC and related LCA approaches should receive high priority. EMC requires particular improvement regarding the calculation of the amounts of different materials being consumed in a national economy as well as increasing the transparency and quality of the factors representing the life-cycle wide impacts of different materials. Priority focus in improvement of HANPP should be put on increasing data quality regarding potential and actual net primary production as well as application of land cover and land use data from LEAC to calculate a detailed HANPP indicator for Europe. The main objectives for future improvement of the LEAC system are to increase availability of data on land use for socio-economic purposes corresponding to certain types of land cover as well as to further develop macro-indicators regarding human pressures on land cover change and ecosystem integrity. Some of the indicators in the basket partly overlap in their coverage (e.g. energy use and greenhouse gas emissions play an important role both in the EF and in EMC). Further development of the different

tools and indicators should thus aim at integrating some of the suggested indicators in the basket and thus reduce their number.

3. **Create joint data infrastructure on the European level**. The four tools suggested for the basket could significantly profit from the creation of joint and harmonised European databases. The three currently established data centres on natural resources, waste and products at Eurostat will play a key role with this regard. These data centres should develop into the core data provider on extraction, production, trade and consumption of different materials and products for the calculation of combined indicators on the impacts of material consumption.
4. **Cooperate closely with the LCA community**. It is recommended to carry out all future efforts to improve the LCA-oriented indicators in the basket in close cooperation with the Joint Research Centres' *European Platform on Life Cycle Assessment* and other institutions in the LCA community. In particular, the currently established European Reference Life Cycle Data System at the JRC should be continued as the main provider of consistent and quality-proved information on life-cycle wide impacts of different materials and products.
5. **Feed in project results into Eurostat Task Force on Impacts**. In 2007, Eurostat initiated a Task Force on Impacts, with the explicit objective to develop indicators for monitoring the objectives of the Resource Strategy. Apart from defining long-term, strategic objectives for further research and data compilation, the Task Force has the mandate to quickly conclude on recommendations for indicators, which could already be applied in 2008. It is recommended that the results of this project are fed into ongoing discussions in the Task Force as one suggestion, how existing indicators informing about environmental impacts could be applied in the short run.
6. **Create a joint data infrastructure**. The four tools suggested for the basket could significantly profit from the creation of joint databases on the European level. The following table illustrates the data requirements necessary for the calculation of indicators derived from the four tools.

Table III: Data requirements for calculating the different indicators in the basket

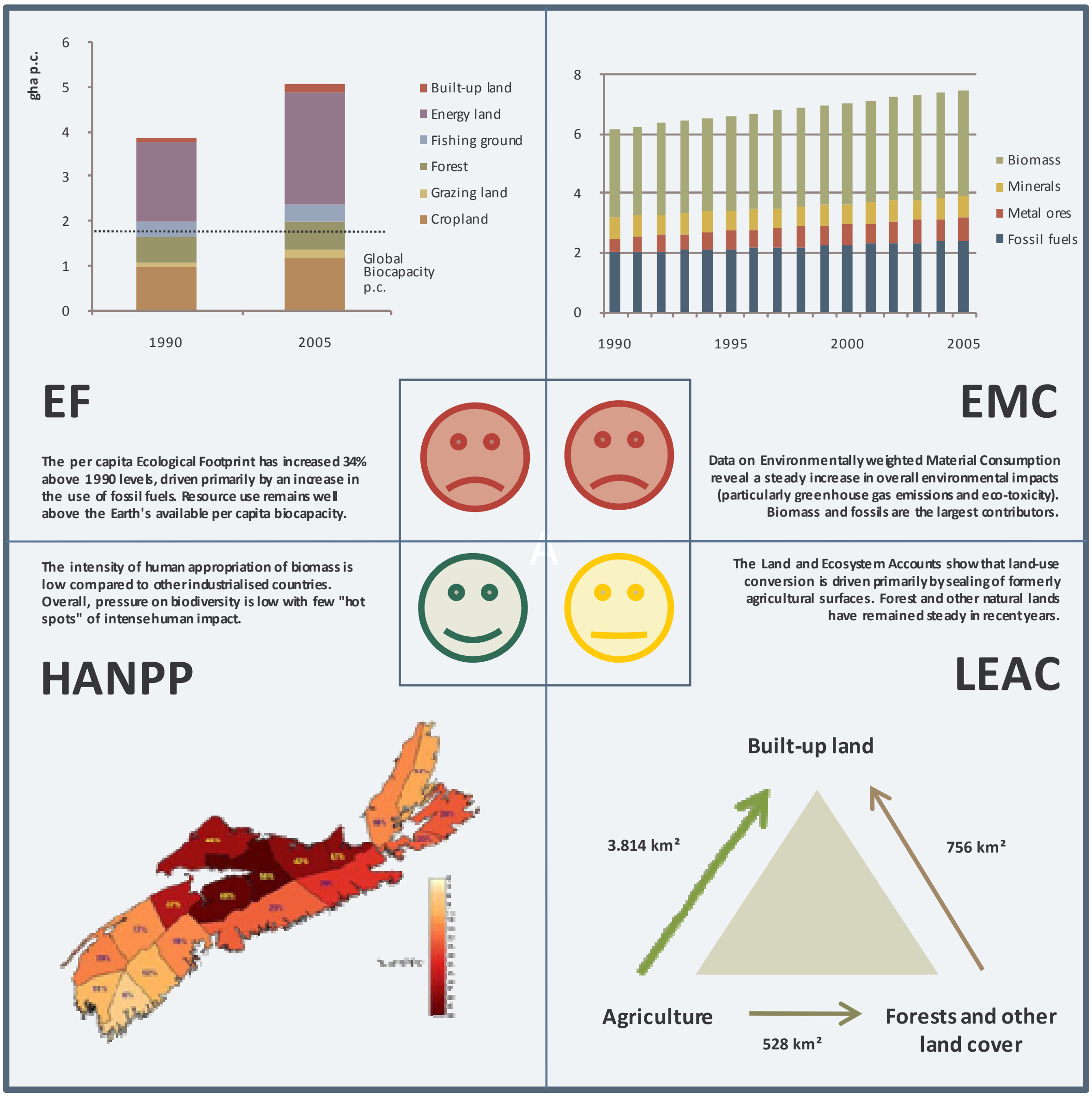
Data	EF	EMC	HANPP	LEAC
Production and consumption of materials and products	X	X	X	
Life-cycle wide environmental impacts of materials and products		X		
Generation of emissions and waste	X	X		
Land cover / Land use	X	X	X	X
Productivity of ecosystems / Biocapacity	X		X	X

Except for the part of the LEAC system which is built upon the data base of European land cover, all the tools/indicators require information on the physical production and consumption of materials and products. One major need therefore is to create a harmonised data base for the different indicators in the field of material and product use. This data base should build on the methodological recommendations for material flow accounting as published by Eurostat (2001a; 2007). However, in addition to the economy-wide material flow accounts, which regard the economic systems as a “black box”, the data base should include data on the production and consumption of specific materials and products, in order to enable linking this information to LCA impact factors.

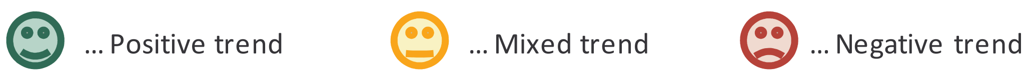
Illustrative presentation of the basket

The following figure illustrates how the four different tools in the basket could be visually presented. We suggest presenting each of the four indicators separately instead of aggregating them into one overall number or figure. On the one hand, this form of illustration avoids weighting of the different indicators of the basket against each other. If desired by the Commission, establishing such a weighting scheme would need to be performed in a large forum including academic experts, policy makers and civil society organisations. Creating an ad-hoc weighting scheme by the project team would be beyond the scope of this project and not deliver a broadly accepted result. On the other hand, the disaggregated form of presentation allows keeping important detail information that would be lost when aggregating to one overall figure.

Figure II: Illustrative presentation of the basket of indicators



Note: HANPP map adapted from O'Neill et al. 2006



Suggested Research Agenda

As part of the project, a short- to medium-term research agenda was developed for each of the indicators in the basket. The following table summarises the key topics identified as needing further research. The shortcomings for each indicator/tool that have been identified and listed in the table are recommended to improve and fill out the gaps of the basket. The listed tasks for the tools are considered in a coherent manner to maximise complementarities.

Table III: Suggested tasks in the research agenda of the basket of tools

Tool	Tasks	Time frame
EF	1. Accounting anthropogenic carbon and other greenhouse gas emissions with the Ecological Footprint	short to medium term
	2. Accounting traded goods and services with the Ecological Footprint, instead of using sector data alone.	
	3. Documenting the Ecological Footprint methodology	
	4. Development and calculation of Ecological Footprint equivalence factors	
	5. Improving the utility of the Ecological Footprint for policy-makers	
	6. Evaluating the robustness, validity and accuracy of source data used to derive the National Ecological Footprint Accounts	
	7. Accounting sustainable land use with the Ecological Footprint	
	8. Evaluating and testing the key constant assumptions of the National Ecological Footprint Accounts	
	9. Testing the sensitivity of the National Ecological Footprint Accounts	
EMC	1. Improvement of material consumption data	short term
	2. Validating EMC results against national statistical data	short term
	3. Increasing transparency and robustness of life-cycle inventory data	short to medium term
	4. Geographical expansion and regular update of the life-cycle inventory data	medium term and beyond
	5. Improving methods to calculate the overall environmental impact (incl. weighting schemes)	medium term
HANPP	1. Improving the data base for HANPP calculations	short to medium term
	2. Calculation of HANPP embodied in traded products	short term
LEAC	1. Further development of aggregated indicators based on LEAC data	short to medium term
	2. Specification of the relations between land cover and land use	medium term
	3. Further development towards integrated ecosystem accounts (physical and monetary)	medium term

1 Introduction

1.1 Background

Providing for the well-being of a growing human population within the limits of a finite planet is a key challenge for our future. Many people still need more natural resources just to meet basic needs. Yet, many of nature's life support systems are already overburdened. To maintain and improve long-term human well-being, societies will have to reduce the environmental impacts of resource use and also use resources more efficiently. Due to their high levels of economic development and resource consumption, industrialised countries such as those of the EU share a special responsibility and opportunity for addressing these challenges.

The past 30 years have seen a change in the complexity and scope of environmental problems in industrialised countries. Early environmental policy was mainly concerned with the reduction of local or regional environmental degradation through pollution via emissions into air and water, and the generation of hazardous waste. Starting with reports such as "Limits to Growth" in the early 1970s, however, concerns about resource constraints became increasingly prominent in environmental debates. Much of the initial discussion of global resource constraints focused on the depletion of non-renewable resources, such as minerals, ores and petroleum. Today, however, it is becoming increasingly evident that renewable resources, and the ecological services they provide, are also at great or even greater risk of degradation and collapse.[8] Signs of ecological pressure include collapsing fisheries, carbon-induced climate change, stratospheric ozone depletion, species extinction, deforestation, desertification, and the loss of groundwater in many areas of the world. Human society depends on ecosystems for a steady supply of the basic requirements for life: food, water, energy, fibre, waste sinks, and other services. As human demand for these resources grows, the Earth's life-supporting natural capital is being depleted at ever faster rates.

These environmental problems are closely related to the overall scale of economic activities, rather than a result of environmental harm from specific substances. Today, key issues of concern include climate change, loss of biodiversity, conversion of land use and land cover, and high levels of energy and resource consumption. These problems are difficult to address, as they are typically highly complex, international or global in scope, and involve multi-dimensional cause-effect-impact relationships, and time lags. The overuse of resources also poses problems for economic stability, international security, social equity, and international cooperation.

In the Lisbon Strategy and the renewed Sustainable Development Strategy, the European Union recognised that using resources more efficiently is crucial for the economic development of the EU, for the European environment, and for a positive role of the EU in the world. Increasing energy and resource efficiency of the EU can accelerate innovation, create jobs, increase competitiveness and improve the state of the environment. But how far does Europe need to go? Certainly, there can be no sustainable development in the EU

[8] See, for example, WRI et al. (2000) or Millennium Ecosystem Assessment (2005).

without reducing human demand on global natural resources. A main strategy is enhancing resource efficiency. Progress in industrialised countries therefore needs to be measured against the ability to increase resource productivity and decrease the demand of natural resources.

1.2 Objectives of the project

Through its Thematic Strategy on the Sustainable Use of Natural Resources[9] (hereinafter referred to as "Resource Strategy"), the European Commission is undertaking an effort to use natural resources in a sustainable way, and more specifically, to decouple economic growth from environmental impacts. There is a need for effective indicators that allows policy makers to measure resource impacts, assess whether a given strategy is efficient and inform the public regarding progress toward sustainability. So far, the current set of indicators used by the European Commission to assess the sustainability of production and consumption lacks a measure that relates EU resource consumption to the concept of global carrying capacity. The Resource Strategy also explicitly addresses the lack of necessary indicators and asks for the development of new indicators. Hence the Commission is searching for indicators that allow the measurement of resource-specific impacts. As prices are unable to provide all the necessary information for monitoring the environmental impacts of resource use, these indicators must be based on physical units.

On the EU-level especially, indicators are needed that can deal with the problem of transnational impacts, since an increasing part of the resources used within the EU are extracted from outside the EU. Such indicators depend on careful tracking of resource stocks and flows within the economy, as well as assessment of ecological capacities. It is doubtful whether one single indicator can be developed that captures all the environmental impacts associated with resource consumption. Therefore, a small basket of indicators is probably required—one that is able to cover all impact domains and provide information that informs and guides policymaking. Together these indicators could function in much the same way as an airplane dashboard, providing accurate and actionable information on the key issues facing policymakers and the public.

This study is an evaluation of the Ecological Footprint (EF) indicator and an assessment of whether a combination of the Ecological Footprint with other tools could fulfil these requirements. The objective of the study is to identify the specific advantages and shortcomings of the Ecological Footprint and assess whether other resource indicators could be used in conjunction with the Ecological Footprint to meet the EU's desired monitoring objectives. The evaluation consists of three main tasks:

1. An assessment of the potential of the Ecological Footprint as an aggregated indicator to measure resource-specific impacts as called for in the Thematic Strategy on the Sustainable Use of Natural Resources.
2. An assessment of how other assessment tools can complement the Ecological Footprint in combination to fulfil EU policy requirements (e.g. through development of a basket of aggregated indicators capable of monitoring the environmental impact of natural resource use).

9 COM (2005) 670 final.

3. Identification of essential near-term improvements needed in the Ecological Footprint and the indicators in the basket of indicators (over the next 1 to 5 years).

1.3 Structure of this report

Sections 2 and 3 of this report describe the evaluation methodology used in the study, including both the policy needs for which resource indicators are to be evaluated as well as the analytical framework used to evaluate the indicators. Section 2 (Policy Context) describes the policy context for the analysis. The Ecological Footprint and basket of indicators are being evaluated for their suitability to fulfil specific policy objectives. Section 3 (Analytical Methodologies) describes the evaluation methods that will be used (i.e. RACER, impact categories analysis and SWOT analysis) and also provides detail on the evaluation criteria.

In Section 4, the Ecological Footprint indicator is evaluated. As called for in the original study design, the Ecological Footprint was evaluated in greater detail than the other indicators. The section describes the EF methodology being evaluated, details the evaluation results, and provides summary conclusions and recommendations.

Section 5 addresses the complementary resource indicators considered for the basket of indicators. The section addresses the selection of indicators for in-depth evaluation, the results of these evaluations, and describes the proposed basket of indicators emerging from the evaluation process. This basket of four indicators is then also evaluated as a whole and a proposed research agenda is discussed. As done for the Ecological Footprint, recommendations are provided regarding use of the basket. Details of the basket evaluations are provided in Annex 3.

Annex 1 lays out a proposed research agenda of short and medium-term improvements to the Ecological Footprint indicator.

2 Policy Context for the Analysis

The EU's resource policies aim to reduce environmental impacts through the sustainable use of natural resources.[10] Both the EU's 2001 Sustainable Development Strategy (SDS) (renewed in 2006) and the 2005 Resource Strategy build on the goal of sustainable development through the decoupling of economic activity from environmental impacts by considering the entire life cycle of resource use.[11] The Resource Strategy further specifies natural resources as *"…raw materials such as minerals, biomass and biological resources; environmental media such as air, water and soil; flow resources such as wind, geothermal,*

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10 The EC Treaty of the European Community (Article 2) establishes sustainable development and protection of the environment as a core principle of the European Community, tasking the Community to promote a "harmonious, balanced and sustainable development of economic activities" and "a high level of protection and improvement of the quality of the environment", among other key goals. Source: The Treaty on European Union and the Treaty establishing the European Community as in force from 1 February 2003 (Nice consolidated versions) http://www.europa.eu/eur-lex/pri/en/oj/dat/2002/c_325/c_32520021224en00010184.pdf

11 For more information on the EU's commitment to sustainable development, see http://ec.europa.eu/environment/eussd/

tidal and solar energy; and space (land area)". On the use of resources it is said that *"... resources are used to make products or as sinks that absorb emissions (soil, air and water)..."* (European Commission 2005e: 3).

Underscoring the need for decoupling is the fact that EU policy is also committed to the continued economic expansion of the EU. In March 2000, the Lisbon European Council agreed the Lisbon Agenda, which aims at increasing competitiveness and employment within the EU.[12] The Lisbon Agenda as initially formulated came under criticism due to a lack of consideration for the environment in its socio-economic goals. At the June 2001 Gothenburg European Council, the European Commission adopted the Sustainable Development Strategy (SDS), which provides an environmental pillar to the Lisbon Agenda.

In 2002, following the adoption of the Lisbon Agenda and the SDS, the Sixth Environmental Action Programme (6EAP) established environmental priorities for the period covering 2002-2012. While the 6EAP was set within the context of the SDS and complementary Lisbon Agenda, it was developed to follow the Fifth Environmental Action Programme (5EAP) which covered the period from 1992-2000. The 6EAP broadened its scope beyond the 5EAP to propose the adoption of Thematic Strategies to address seven different environmental issues at a global scale, rather than by specific pollutant or economic activity type as in the past.[13] This cross-sector approach is founded on the principle of 'life cycle thinking', which considers the entire life cycle of products from cradle to grave.[14] The resulting 2005 Resource Strategy—the thematic strategy relevant to this indicators study—is one of the seven Thematic Strategies originally proposed in the 2002 6EAP.

It is important to note that both the Lisbon Agenda and the SDS were separately revised and renewed in 2006. Both revisions propose enhanced communication between different levels of government to achieve stated objectives and will be evaluated more often and within a shorter timeframe. The revised goal for the Lisbon Agenda is to focus primarily on job growth until 2008, after which the policy will be reviewed. The revised SDS sets enhanced objectives and action items for seven key priority areas and proposes ways to improve government co-ordination. The revised SDS will be reviewed every two years, beginning in 2007, to monitor progress towards its goals.

Both the SDS and Resource Strategy cite a lack of suitable indicators as a key challenge to setting targets and measuring progress on global resource impacts. Thus, both strategies propose that indicators be developed that consider the entire life cycle of resource use to achieve the overall objective of decoupling economic activity from environmental impacts.

Figure 1 below illustrates the relationships among the different EU natural resource policies over a ten-year period beginning in 2000. Each of the policies is shown in a different arrow with a policy timeframe that extends beyond 2010. The adoption of the SDS in 2001 is shown in the top arrow. The SDS incorporated environmental goals into the Lisbon Agenda and acts as a stand-alone overarching sustainable development policy that extends beyond 2010. The 6EAP, shown in the bottom arrow, follows the 5EAP and provides a framework for the

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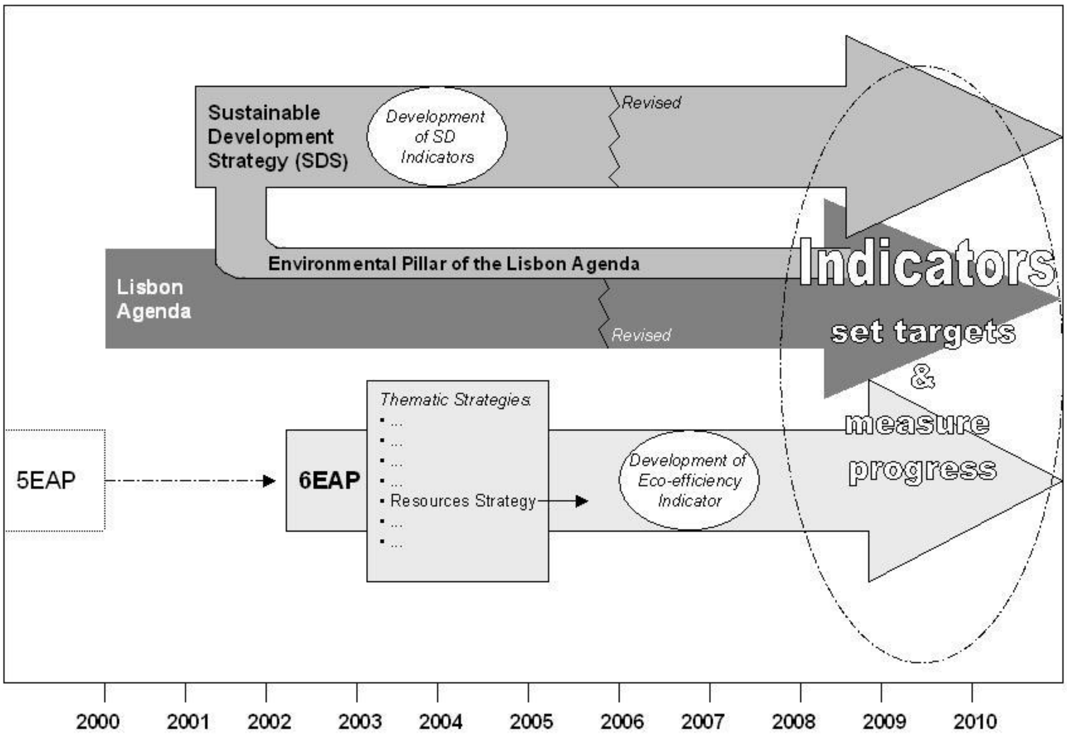
12 For more information on the Lisbon Agenda, see http://ec.europa.eu/growthandjobs/

13 For more information on the Sixth Environmental Action Programme (6EAP), see http://ec.europa.eu/environment/newprg/index.htm

14 For more information on Life Cycle Assessment (LCA), see the European Platform on Life Cycle Assessment project, available at http://lca.jrc.ec.europa.eu/.

resulting seven Thematic Strategies. The top-left and bottom-right circles show that whereas initial indicators were developed for the SDS through the Sustainable Development Indicators Task Force between 2002 and 2005, they are currently being developed for the Resource Strategy, and are to be developed by 2008. Following their development, as shown in the far right oval, the indicators will be used to set targets and measure progress toward goals that are outlined in all three policies.

Figure 1: Relationships among the EU's natural resource policies: 2000-2010



Source: Ecologic graphic

This study focuses on developing resource-specific impact indicators for the Resource Strategy. These indicators should fit the criteria established by the Sustainable Development Indicators Task Force in order to be transferable to the overall goals of sustainable development and life cycle thinking. Relevant indicators will be used to set targets and measure the EU's impact on global carrying capacity.

This section on EU natural resource policy provides further background information on the Sustainable Development Strategy (Section 2.1) and Resource Strategy (Section 2.2) with a focus on the indicators needed to achieve the overall policy goals. Section 2 concludes with a description of how the two strategies form an integrated policy framework that provides an essential backdrop to analysing the indicators included in this study.

2.1 Sustainable Development Strategy

The Sustainable Development Strategy (SDS) outlines a long-term vision for sustainable development across Europe. The Strategy was adopted by the European Commission at the Gothenburg European Council in 2001 and renewed in 2006. The SDS was developed in part to provide a third environmental pillar to the Lisbon Strategy (adopted in 2000 and renewed in 2006), which sets socio-economic targets for significant European economic growth by 2010. The SDS addresses a broad range of 'unsustainable trends' ranging from public health, poverty and social exclusion to climate change, energy use and management of natural resources. A key objective of the SDS is to promote development that does not exceed ecosystem carrying capacity and to decouple economic growth from negative environmental impacts.

In 2002, an external dimension was added to the SDS, highlighting the needs and priorities for the European Union's contribution to global sustainable development (European Commission, 2002). This document contains a section on "Sustainable management of natural and environmental resources" which sets out two priority objectives:

- Ensure that current trends in the loss of environmental resources are effectively reversed at national and global levels by 2015; and
- Develop sectoral and intermediate objectives in some key sectors – water, land and soil, energy and bio-diversity

In addition, the section on "fighting poverty and promoting social development" makes allusion to the unequal distribution of resources among and within global regions: "It is not absolute scarcity of resources which is the key problem of poverty, but the unequal distribution of resources and opportunities to take advantage of them. [...] Lack of access to resources in some areas, abundant availability and unsustainable consumption and production patterns in others – all of this has a direct bearing on the state of the global environment" (European Commission, 2002, p. 10).

Also in 2002, the World Summit on Sustainable Development (WSSD) adopted the Johannesburg Plan of Implementation that aims to change consumption and production patterns world-wide.[15] The EU's Sustainable Development Indicators (SDI) Task Force incorporated this goal into its Theme 6: 'Production and consumption patterns', to take into account the EU's impacts on global carrying capacity.

To monitor progress toward the implementation of the SDS, a Sustainable Development Indicators (SDI) Task Force comprised of national experts was established to develop indicators according to ten categories that reflect the goals of the SDS, the WSSD, and the Lisbon Agenda. The resulting Sustainable Development Indicators (SDIs) were adopted by the European Commission in 2005. The 155 indicators are organised based on a hierarchical framework that adheres to current policy priorities but also allows flexibility for future adaptation. These indicators were developed according to the criteria established by the SDI Task Force for sustainable development indicators (see Box 1).[16]

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15 For more on the WSSD, see http://www.un.org/events/wssd/. For more on the SDI Task Force Indicators, see Eurostat 2007.

16 For the purposes of this project, an extended framework of criteria was used, which is described in section 3.1.

Box 1: Criteria for a Sustainable Development Indicator (SDI)

- An indicator should capture the essence of the problem and have a clear and accepted normative interpretation.
- An indicator should be robust and statistically validated.
- An indicator should be responsive to policy interventions but not subject to manipulation.
- An indicator should be measurable in a sufficiently comparable way across Member States, and comparable as far as practicable with the standards applied internationally by the UN and the OECD.
- An indicator should be timely and susceptible to revision.
- The measurement of an indicator should not impose on Member States, on enterprises, nor on the Union's citizens a burden disproportionate to its benefits.

Source: European Commission 2005c

It is important to note that the SDI criteria rely on a level of data that may not be available to set all necessary targets. The SDI Task Force itself states that it has taken a pragmatic approach to try to include detailed indicators that address sustainable development objectives. The 155 SDIs are therefore divided into two categories that identify 'best available' and 'best needed' options to show varying levels of current knowledge.[17]

The renewed SDS mandates the further development of the SDIs by the European Commission, supported by a Working Group on SDIs set up by Eurostat which also includes representatives of Member States. The goal is to "further develop and review indicators to increase their quality and comparability as well as their relevance to the renewed EU SDS, also taking into account other indicator initiatives and focusing on those indicators marked as most needed."[18]

2.2 Thematic Strategy on the Sustainable Use of Natural Resources (Resource Strategy)

The Thematic Strategy on the Sustainable Use of Natural Resources (Resource Strategy)[19], launched on 21 December 2005, is one of seven Thematic Strategies resulting from the Sixth Environmental Action Programme (6EAP). The 6EAP is a 10-year vision for EU environmental policy that outlines goals for four environmental priorities: climate change, nature and biodiversity, environment and health, and natural resources and waste. The 6EAP is the first EAP to request cross-sector Thematic Strategies to be developed and used to implement the broad goals of the 6EAP. The resulting Thematic Strategies address seven themes: air quality; soils; pesticides; the marine environment; the urban environment; waste and recycling; and the management of natural resources.

The 6EAP's cross-sector Thematic Strategies are founded in the life-cycle thinking approach, which supports various tools that are used to analyse the entire life cycle of a product.

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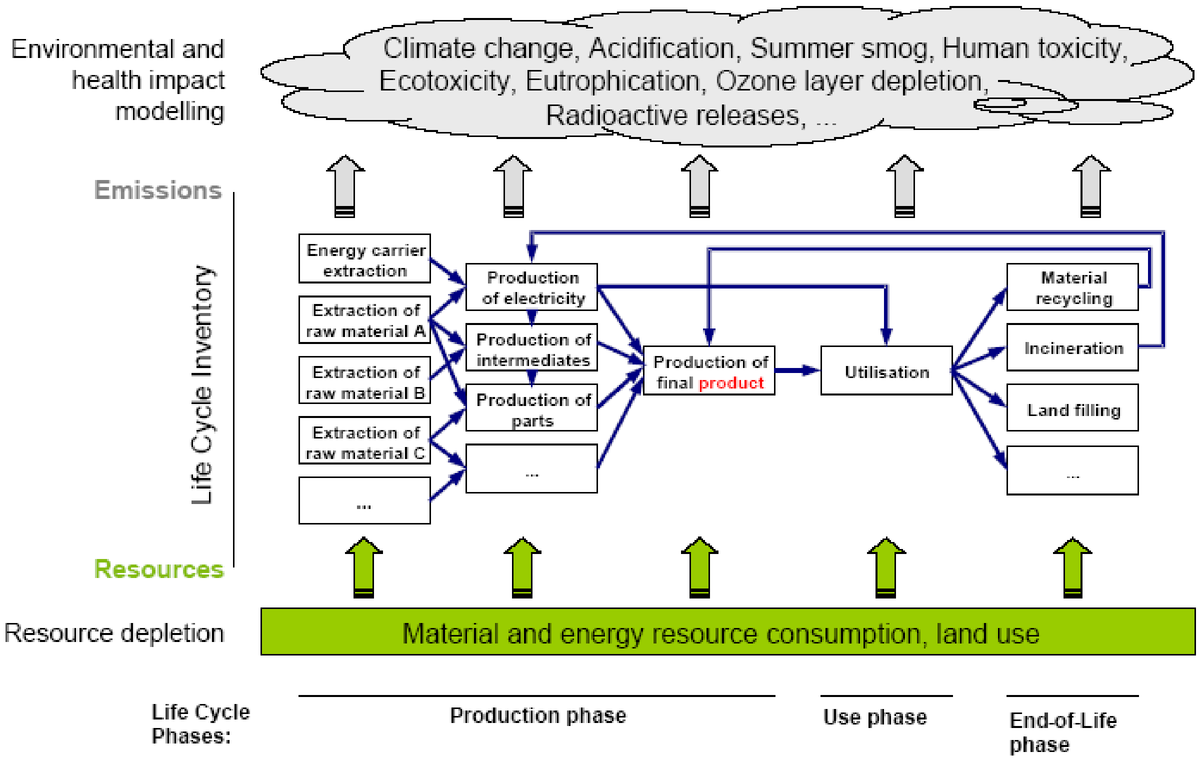
17 The Sustainable Development Indicators Task Force (CPS 2005) has described 'best-available' indicators as those that are feasible now, and 'best-needed' indicators as those that still need further development.

18 Council of the European Union 2006, paragraph 35.

19 http://ec.europa.eu/environment/natres/pdf/com_natres_en.pdf

According to the Resource Strategy, identifying the environmental impacts of resource use – both materials and energy used – from manufacturing, to use, to disposal, is key to minimising cumulative negative effects. In addition, life-cycle thinking is crucial to the understanding of global impacts to ensure that environmental burdens are not shifted from one geographic region to another.[20] Figure 2 below shows a schematic diagram of the life cycle of a product from cradle to grave. The figure illustrates the complexity and importance in determining where in the product's life cycle environmental impacts are greatest.

Figure 2: Life cycle thinking: environmental impacts from "cradle to grave"



Source: Reproduced from Wolf, M.A. and R. Bersani (2007).

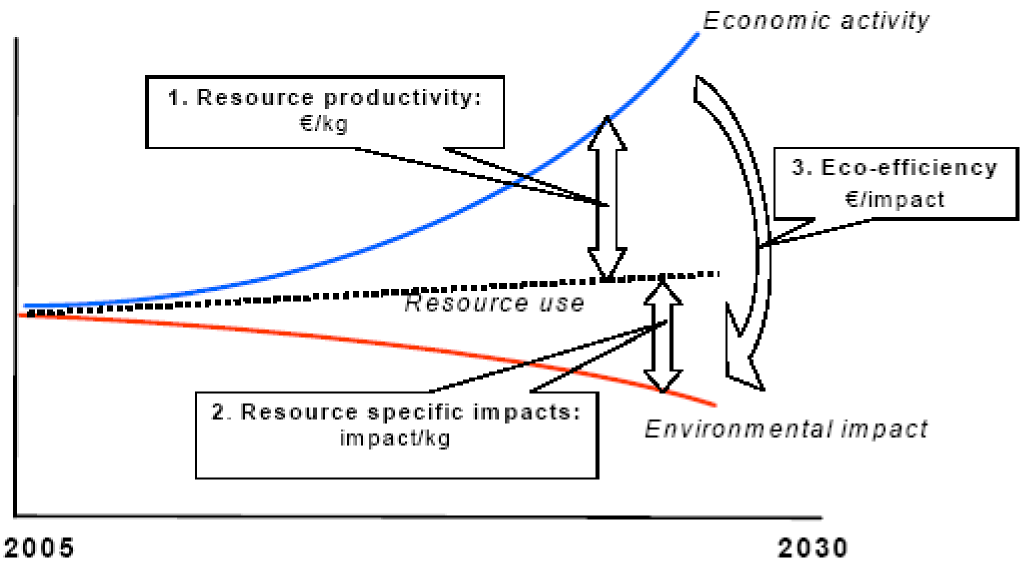
The overall goal of the Resource Strategy is "to reduce the negative environmental impacts generated by the use of natural resources in a growing economy". This concept—referred to as *decoupling*—suggests that by separating the links between resource use and environmental impacts, sustainable development will be more achievable. In fact, the Strategy calls for a double decoupling through its 'eco-efficiency' concept, which aims both to increase resource efficiency, and to reduce negative impacts on the environment.

Figure 3 below provides an illustration of the eco-efficiency concept. The top line shows increasing economic activity, while the bottom line shows decreasing environmental impacts.

20 For additional information on life-cycle thinking and sustainable use and management of natural resources, see EEA 2007. See also the EC's report on the Life Cycle Workshop in Cyprus of January 2007, held by JRC together with DG ENV, Eurostat and with EEA, UNEP and Member state's administrations represented. (see e.g. intro and point 2, page; download report at http://viso.jrc.it/lca-indicators/JRC%20ST%20Report%20-%20Worksop%20Outcomes.pdf)

The dotted line in the middle shows resource use, which only increases slightly over time as resources are used more efficiently. *Resource productivity* is an indicator that measures the production value per unit of resource input (€/kg), thereby decoupling resource use from economic activity. *Resource-specific impacts* measure the environmental impacts per unit of resource use (impact/kg), thereby decoupling environmental impacts from resource use. *Eco-efficiency* takes into account both resource productivity and resource specific impacts by measuring the economic value created per unit of environmental impact (€/impact). Eco-efficiency measures the decoupling of environmental impacts from economic activity. Note that in Figure 3, the curves are idealised to illustrate the objective of de-coupling.[21]

Figure 3: Relationships among three indicators used to assess resource-use impacts



Source: Reproduced from European Commission 2005d.

Figure 4 below illustrates the double decoupling implicit in the eco-efficiency concept. Resource productivity divided by the resource-specific impact results in a measure of eco-efficiency.

Figure 4: Eco-efficiency indicator equation

$$\underset{(Euro\ /\ impact)}{\text{Eco-efficiency}} = \text{Resource Productivity} \Big/ \text{Resource-specific Impact}$$

[21] In actuality, the relationships among economic activity, resource use and environmental impact are more varied and more complex, often characterised by feedback loops and critical thresholds that, if exceeded, can lead to dramatic changes in the environmental impact associated with a particular activity.

(Euro/kg) *(impact/kg)*

Source: Adapted from European Commission 2005d.

Currently, there is in particular a lack of sufficient resource-specific impact indicators, thus eco-efficiency is not a measurable target. One of the main goals of the Resource Strategy is to develop indicators to set targets to limit negative environmental impacts. Overall, the Strategy states that there is a need for three types of indicators to measure the following:

- the progress in efficiency and productivity in the use of natural resources ("Euro/kg")[22],
- resource-specific indicators to evaluate the environmental impact of resource use ("impact/kg"), and
- an overall eco-efficiency indicator to measure progress toward reducing global environmental impacts as compared with overall economic growth ("Euro/impact").

2.3 Development of resource indicators

The main aim of this project is to guide the development of indicators as called for in the Resource Strategy. More precisely, the intended focus is on the second of the three indicator types mentioned above: **resource-specific indicators to evaluate the environmental impact of resource use**.

However, the broader policy context needs to be taken into account, since there are various important linkages between different EU policy documents currently in force. Notably, the 6EAP, the SDS and the Resource Strategy all contain objectives related to a more sustainable use of natural resources. The key objectives in this context, however, are stated in each policy document in a slightly different way. In order to put the analysis of policy relevance on a solid foundation, it appears useful to cite the individual goal definitions of the policy documents. Box 2 provides the relevant passages of each document.

All three documents have in common two objectives with regard to resource use: 1) decoupling the negative environmental impacts of resource use from economic growth, and 2) not exceeding nature's carrying capacity. The way these objectives are stated varies among the three documents. For example, in comparison with the 6EAP and the SDS, the goal formulation in the Resource Strategy puts a greater emphasis on the decoupling objective. While it does not contain the term "carrying capacity", it mentions the objective of "staying below the threshold of overexploitation" of renewable resources.[23] This could be read as including the natural environment's absorption capacity for waste materials, but unlike in the 6EAP, this aspect is not explicitly stated. Furthermore, the objective of "staying

[22] While the wording in the Strategy is "efficiency and productivity", it can be assumed that efficiency is meant to be synonymous with productivity. Annex 3 to the communication (European Commission 2005d) only speaks of "resource productivity" in the same context.

[23] Another reference to carrying capacity is given in the introduction: "The way in which both renewable and non-renewable resources are used and the speed at which renewable resources are being exploited are rapidly eroding the planet's capacity to regenerate the resources and environment services on which our prosperity and growth is based." (European Commission 2005e, p. 3).

below the threshold of overexploitation" is stated to be implicit in the decoupling objective, rather than an objective on its own.

Box 2: Goal definitions with respect to resource policies in key EU documents

6th Environmental Action Programme:

Article 2.2:

"The Programme aims at:

[...]

better resource efficiency and resource and waste management to bring about more sustainable production and consumption patterns, thereby decoupling the use of resources and the generation of waste from the rate of economic growth and aiming to ensure that the consumption of renewable and non-renewable resources does not exceed the carrying capacity of the environment."

Article 8.1:

"The aims set out in Article 2 should be pursued by the following objectives:

aiming at ensuring that the consumption of resources and their associated impacts do not exceed the carrying capacity of the environment and breaking the linkages between economic growth and resource use. [...]"

EU Sustainable Development Strategy:

Sustainable consumption and production

[...]

<u>Operational objectives and targets</u>

- Promoting sustainable consumption and production by addressing social and economic development within the carrying capacity of ecosystems and decoupling economic growth from environmental degradation.
- ...

Conservation and management of natural resources

Overall objective: To improve management and avoid overexploitation of natural resources, recognising the value of ecosystem services

<u>Operational objectives and targets</u>

- Improving resource efficiency to reduce the overall use of non renewable natural resources and the related environmental impacts of raw materials use, thereby using renewable natural resources at a rate that does not exceed their regeneration capacity.
- ...

Thematic strategy on the sustainable use of natural resources:

3. MEETING THE CHALLENGE – THE STRATEGY'S OBJECTIVE

"The strategic approach to achieving more sustainable use of natural resources should lead over time to improved resource efficiency, together with a reduction in the negative environmental impact of resource use, so that overall improvements in the environment go hand in hand with growth. The overall objective is therefore to reduce the negative environmental impacts generated by the use of natural resources in a growing economy – a concept referred to as decoupling. In practical terms, this means reducing the environmental impact of resource use while at the same time improving resource productivity overall across the EU economy. For renewable resources this means also staying below the threshold of overexploitation. "

Due to this multitude of aspects, this study will take a somewhat broader view on policy-relevant indicators than focusing exclusively on the "resource-specific impact" indicator mentioned in the Resource Strategy.

3 Analytical methodologies

3.1 RACER Analysis

3.1.1 General approach

As the European Commission specified in its publication *Impact Assessment Guidelines*[24], indicators should fulfil the RACER criteria. RACER is an evaluation framework applied to assess the value of scientific tools for use in policy making. RACER stands for relevant, accepted, credible, easy and robust:

Relevant – i.e. closely linked to the objectives to be reached

Accepted – e.g. by staff, stakeholders

Credible for non experts, unambiguous and easy to interpret

Easy to monitor (e.g. data collection should be possible at low cost)

Robust against manipulation

In order to specify and operationalise the RACER criteria, one or more subcriteria have been added to each of them. These were proposed by the project team and adjusted following discussion within the project consortium as well as with representatives of the European Commission and other European institutions. The definition of subcriteria under this extended RACER framework is given in section 3.1.2.

A simple numerical score was assigned to the Ecological Footprint and complementary assessment tools for their performance under each of the criteria. The scoring was made by subcriterion, and an average score was calculated within each of the five main RACER criteria. The range of scores was between 0 (criterion is not addressed) and 4 (criterion is fully addressed). It was attempted to sort the subcriteria within each criterion by importance, which does not affect the summary score but makes visible whether high scores concentrate on important or less important criteria. The scoring was not weighted. The scores were summed for each assessment tool along all subcriteria, producing a total RACER score for each tool. Narrative summaries accompany the scores.

3.1.2 RACER sub-criteria

Relevant

Policy support, identification of targets and gaps

[24] European Commission, 2005a.

Is the indicator/methodology related to existing EU-specific policy objectives? Does it provide guidance in monitoring, strategic policy making and/or target setting? Does it quantify gaps between the current situation and specified targets? Does it provide adequate early warning to guide policy action? Does it react to short-term changes that can (among other things) show whether policies are having an effect?

Identification of trends

Can the methodology/indicator be used to track changes through time? This implies that at least one input variable will require time series data (e.g. a series of annual measurements).

Forecasting and modelling

Can the methodology/indicator be used in a predictive sense to forecast future environmental impacts from natural resource use or for more sophisticated modelling where the impact of different potential policies or of technology progress and/or change of consumption patterns can be simulated? Can the indicator function as an early warning indicator?

Scope/levels of application

Does the indicator provide information relevant to the effective levels of application? Disaggregations – either spatial, by product, by industry or by ecosystem type – may be required for effective policy. For example, if policy decisions are made at the local level, does the indicator provide the required local information? Or, if decisions are specific to a certain industry, is industry-level data provided by the methodology/indicator?

Function- and needs-related analysis

The indicator should allow for comparisons among material and energy resources in terms of their functions and competition in the real world (e.g. in a case where one energy carrier, foodstuff or construction material is substituted by another). Similarly, the methodology should allow the comparison of different ways of fulfilling basic human needs (housing, mobility, food, etc.) with regard to their resource-use implications.

Accepted

Stakeholder acceptance

The underlying rationale and meaning of a methodology/indicator should be easily understood and accepted by stakeholder groups. This will be facilitated by conceptual simplicity and simplicity of calculation. For effectiveness in public communication the methodology/indicator must resonate with widely held values and concerns to motivate stakeholders to calculate or provide data and accept interpretations of the meaning of the methodology/indicator.

Credible

Unambiguous

The indicator should be suited to convey a clear, unambiguous message. This relates to the interpretation by political decision-makers (i.e. does it allow for clear conclusions to guide political action?) as well as to its interpretation by the general public (does it indeed provide the information that non-experts believe it to?).

Transparency of the method

The underlying data and calculation methods should be fully disclosed, interpretable and reproducible.

Easy

Data availability

The methodology/indicator does not require inputs of data that are overly excessive, expensive or onerous to collect, or that cannot be properly measured. Ideally the methodology/indicator should be based on data that are already collected and readily available in electronic form.

Technical feasibility

The methodology is simple enough to be carried out using software and expertise appropriate to the scale of application and the typical capabilities of the institution doing the calculations. The input and the calculation methodology are clearly defined to avoid ambiguity and consequent error in implementation.

Complementarity and integration

Are there potential complements between the methodology/indicator and the others being assessed? Is there the potential for further integration of the methodology/indicator with the others? This can refer to the data collection, storage, analysis and reporting, but also the way indicators work together to guide policy makers and the public in formulating and fulfilling policy objectives.

Robust

Defensible theory

The methodology/indicator is based on sound theory; avoids double counting or omissions of resources used; is consistent in its units of measure; relies on assumptions that are clearly stated and reasonable and does not require the use of ill-defined or poorly quantified parameters. The methodology should normally avoid the use of subjective factors to weight different components. In cases where subjective weighting is used, it must at least be justified and made explicit.

Sensitivity

The value of the indicator outputs change rapidly enough with respect to input parameters to pick up policy-significant changes and can detect non-linearities, discontinuities and thresholds.

Data quality

The underlying data should be of sufficient quality so that inaccuracies in the data do not lead to false results (i.e. if data are uncertain or are not fully accurate, variations within the uncertainty margin would not lead to opposite findings and conclusions)

Reliability

The methodology/indicator is reliable in terms of its accuracy, repeatability, and the clear specification of protocol and formulas used in the calculations. This aspect includes that all details of calculation are openly exchanged among researchers in order to avoid different standards (i.e. there may be disputes about the right methodology but methodological differences must be accounted for).

Completeness

Is the indicator/methodology complete in terms of the safeguard object it is assessing (e.g. natural environment, human health, future resource availability)? Is a shifting of burdens avoided among single problems/impact types (e.g. from climate change to nuclear risks), among the safeguard subjects (e.g. from human health to the natural environment) and among regions (e.g. relocation of production may shift environmental burden away from the place of consumption)?

3.1.3 A note on the subjectivity of the scoring exercise

It is important to note that the RACER evaluation was undertaken by one expert for each method and reviewed by at least two additional experts from the project team to cross-check both the verbal explanations and the scoring. However, the subjective dimension of the evaluation process could not be fully removed, as the assessment illustrated that different authors have different opinions with regard to the scores. Even if the wording of the argument was similar, authors allocated different score numbers. Cross-reading of evaluations undertaken by other partners helped avoiding clear biases, but evaluations of this type per definition remain subjective.

3.2 Impact categories analysis

The suitability of the Ecological Footprint and related assessment tools to address various categories of environmental impacts was assessed as part of the *policy support* aspect under the “relevant” criterion. For this evaluation, scores were allocated to each category, from 0 (impact category is not covered) via 1 (impact category is partly covered) to 2 (impact category is fully covered).

Some impact categories have higher relevance to current EU strategies on environment and sustainable development than others. Three different degrees of relevance were assigned to the different impact categories (see Table 1). Following discussions among those involved in the project, it was decided not to use a formal weighting system to account for the different policy relevance[25] of impact categories.

3.2.1 Definition of impact categories

The impact categories used in the evaluation were derived from conventional LCA classifications (see, for example, Udo de Haes, 2002). It should be noted that the purpose was not to assess the suitability of the different approaches for life cycle assessment; rather, independently of the LCA concept itself, the impact categories commonly used in LCA have been found a useful tool in order to cover a broad range of possible impacts of resource use on the quality of the environment. Some modifications were made, reflecting, inter alia, that LCA is a method applied to specific products, whereas the present analysis targets the broader notion of "environmental impact of resource use". Notably, "effects on biodiversity" was included, recognising that this represents an important area of concern in EU environmental and sustainable development policies. "Effects on human health" was used instead of "human toxicity" to broaden the scope of this category.

The following impact categories were considered:

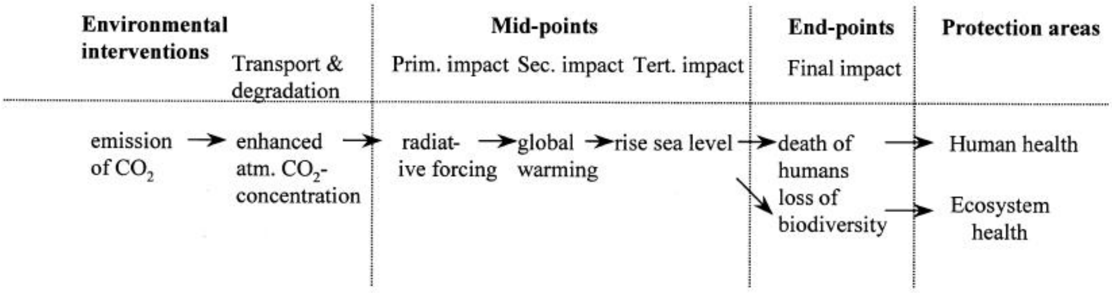
1. Resource consumption
2. Land use
3. Climate change
4. Stratospheric ozone depletion
5. Human health impacts
6. Eco-toxicity
7. Photo-oxidant formation
8. Acidification
9. Eutrophication
10. Ionizing radiation
11. Impacts on ecosystems and biological diversity

For each of these categories, characterisation models define specific cause-effect chains. In Figure 5, such an impact chain is illustrated for the example of CO_2 emissions and climate change.

The chain starts with the environmental interventions (such as the emission of greenhouse gases) and causes impacts via changed ecosystems states (increased atmospheric CO_2 concentration), which leads to global warming, which then causes e.g. loss of biodiversity. "Protection areas" are those areas, where actual damage can be observed. The full cause-effect chain is in many cases very complex. Thus, in LCA, only a limited number of indicators, in many cases so-called "mid-point indicators", are selected to illustrate the impacts in the different categories, assuming that the effect on the midpoint reflects or has a (more or less known) relation to the effect on the end point.

[25] Policy relevance, as understood here, means relevance to EU strategy documents currently in force, without prejudice to future policy developments.

Figure 5: The intervention–effect chain in LCA (with global warming as example)



Source: Tukker, 2000

It is important to note that these LCA impact assessments follow a different classification than the "DPSIR" (Driving Force – Pressure – State – Impact – Response) framework used by European institutions (e.g. the EEA). In the DPSIR classification, "environmental interventions" of LCA would be termed indicators of "environmental pressure". This is the case for material flows (impact category: resource consumption), as well as for most of the air emissions (pollution categories and climate change). In the DPSIR classification, an indicator would be called an "impact indicator" only if these impacts would be measured as exposure effects of ecosystems to, for example, acidification, eutrophication and ozone (EEA, 2005). These "impact indicators" in the DPSIR framework relate to mid-point indicators in LCA.

One should also keep in mind that the different impact categories can also influence each other. For example, material consumption is one driving force for land use and land cover change, changes in land use patterns are in many cases driving forces for the loss of biodiversity, and this loss might again influence material consumption (for example, by reducing productivity and stability of agricultural ecosystems or by increasing environmental hazards). These basic questions go far beyond a technical evaluation of methods but are crucial for the development of the respective indicators for the Resource Strategy.

3.2.2 Impact categories in the EU policy context

The suggested impact categories are not of equal weight within the current framework of EU strategies for the environment and sustainable development, as the following analysis shows. While the assessment of potential indicators will take into account a broad range of impact categories, it seems appropriate to dedicate specific attention to those impact categories that are most closely related to key priorities in current EU strategies.

<u>Resource Strategy:</u>

The Resource Strategy makes general reference to "life-cycle thinking", but does not specifically address any impact categories. Rather, it is process-oriented, outlining activities to improve knowledge, set up indicators and improve international consultation processes related to resource use and its environmental impacts. While it is obvious that the Resource Strategy relates to the impact category of "resource consumption", all the other impact categories are potentially relevant as well, since they are all part of potential "negative environmental impacts generated by the use of natural resources".

6EAP:

The 6EAP has four key priority areas, each of which can directly be related to an LCA impact category:

- Climate change
- Nature and biodiversity
- Environment and health and quality of life
- Natural resources and wastes.

Other impact categories can be found among the priority areas identified under each of these key priority areas. Some (acidification, eutrophication and ionising radiation) are not mentioned but may at least be implicitly related to one or more of the key priority areas. In conclusion, no one of the impact categories is completely out of scope of the 6EAP.

SDS:

The renewed EU SDS of 2006 identifies seven “key challenges”:

1. Climate Change and clean energy
2. Sustainable Transport
3. Sustainable consumption and production
4. Conservation and management of natural resources
5. Public health
6. Social inclusion, demography and migration
7. Global poverty and sustainable development challenges

With the exception of challenge No. 6, all of these areas have environmental aspects at their core or at least strongly relate to environmental aspects. However, they are less congruent to individual LCA impact categories than the key priority areas of the 6EAP. Challenge No. 4 encompasses both resource consumption (which is also strongly related to Challenge No. 3) and ecosystems / biological diversity. Although, in parallel to the 6EAP, all impact categories may be in some way related to one or more of the “key challenges”, the relationship is still more indirect here. Eco-toxicity is addressed under the “Public Health” heading as reference is made to chemicals and the REACH regulation; photo-oxidant formation and acidification can be said to be covered by the objective to reduce pollutant emissions from transport under the “Sustainable Transport” heading; land use might be claimed to be implicitly include in biodiversity aspects and the mention of agriculture under the “Conservation and management of natural resources” heading. For the remaining impact categories, the relationship is even weaker.

In order to reflect the differences among impact categories in their relevance to current EU strategies, they have been assigned a scoring for relevance (Table 1).

The table illustrates the following priorities of impact categories:

- Priority 1: Resource consumption, climate change, human health and impacts on ecosystems/biodiversity.
- Priority 2: Land use, ozone depletion, eco-toxicity, photo-oxidant formation

- Priority 3: Acidification, eutrophication, ionising radiation

This prioritisation of impact categories will be useful for the selection of the basket of complementary tools in Section 5.

Table 1: Relevance of LCA impact categories for current EU strategies

Impact category	6th EAP			SDS			Resource Strategy		Priority
	Key priority area	Explicitly included in key priority area(s)	Implicitly included in key priority area(s)	Priority area	Explicitly included in priority area(s	Implicitly included in priority area(s)	Explicit	Implicit	
Resource consumption	x			X			x		1
Land use		Biodiversity				Conservation and management of natural resources		x	2
Climate change	x			X				x	1
Stratospheric ozone depletion		Human health						x	2
Human health impacts	x			X				x	1
Eco-toxicity		Human health, biodiversity			Public health			x	2
Photo-oxidant formation		Human health				Transport		x	2
Acidification			Biodiversity			Transport		x	3
Eutrophication			Biodiversity					x	3
Ionising radiation			Human health, biodiversity					x	3
Impact on ecosystems and biological diversity	x			X				x	1

3.3 SWOT Analysis

SWOT analysis is a tool used to identify the strengths, weaknesses, opportunities and threats of an organisation or programme's ability to achieve a stated objective. In this study, a SWOT analysis was undertaken exclusively for the Ecological Footprint, not for the other assessment tools. This analysis was intended to feed into the discussion on whether the EF can be used as an indicator to further EU policy goals as outlined in the Resource Strategy and Sustainable Development Strategy.

For the purposes of this study, the individual components of the SWOT analysis were defined as follows.

Strengths

The positive aspects of the EF identified through the previous RACER and impact categories analysis were regrouped as either 'core' or 'important' strengths. These two distinguish between those strengths that are specific to the Ecological Footprint (core strengths) and those that are shared qualities with other sustainability indicators (important strengths).

Weaknesses

The negative aspects of the EF identified through the RACER and LCA impact categories analyses were re-categorised into critical and important weaknesses. A "critical weakness" is a weakness that, as it currently stands, makes it inadvisable for EU institutions to produce or use the EF as an official sustainability indicator. Critical weaknesses must therefore be addressed before implementation by EU institutions. An "important weakness" is a weakness that, as it currently stands, limits the EF's usefulness as an EU sustainability indicator in some way, but is not an argument against implementing it near term. Improvements on these aspects would enhance the EF's value but could be made successively even after implementation of the EF as an EU indicator.

In addition, there is a third category: 'outside the scope of the EF'. These aspects are only indirectly included or not included at all in the EF, and therefore should be covered by complementary indicators.

Opportunities

For the purposes of this analysis, "opportunities" mean those aspects of the institutional, political, intellectual and technological environments that could help improve the Ecological Footprint, lead to its successful adoption, or both.

Threats

For the purposes of this analysis, "threats" are defined as those aspects of the institutional, political, intellectual and technological environments that could hinder successful adoption.

4 Evaluation of the Ecological Footprint

This section provides an in-depth analysis of the Ecological Footprint methodology. In line with the overall objective of the project, the guiding question is the suitability of the Ecological Footprint as an indicator to support the EU Resource Strategy. Three evaluation methods are used to assess the Ecological Footprint – RACER analysis, impact categories analysis and SWOT analysis.

There are three subsections:

Section 4.1 (Ecological Footprint methodology) describes both the Ecological Footprint methodology and application that will be the focus of the evaluation.

Section 4.2 (RACER analysis) contains the findings of the RACER analysis. In addition to the core RACER assessment, the findings of an impact categories analysis are presented.

Section 4.3 (SWOT analysis) summarises the core strengths and weaknesses of the methodology and identifies external factors that affect its adoption and use.

4.1 The Ecological Footprint – methodology and application to be evaluated

This section defines the Ecological Footprint methodology that will be evaluated in this study. In the interests of brevity, a basic knowledge of the Ecological Footprint is assumed, meaning a thorough background on the indicator and methodology is not provided in this report. Box 3 provides a concise summary of the Ecological Footprint. For more detail on the Ecological Footprint, please refer to the list of selected publications listed at the end of the References section of this study.

The EU policies relevant for this evaluation of the Ecological Footprint focus on developing indicators at the EU and national levels. This study therefore evaluates the methodology used in the National Footprint Accounts, which are calculated annually for over 150 countries by Global Footprint Network. The National Footprint Accounts have their own characteristics and methodology as compared to EF applications at subnational levels (e.g. region, city, enterprise, individual). The analysis in this report reflects the status of the methodology for National Footprint Accounts as of June 2007.[26]

National Footprint Accounts are based on a "compound method" which uses aggregated national and international data. In the compound method, a nation's total consumption is determined by adding imports to domestic production and subtracting exports. The National Footprint Accounts methodology is considered the most accurate and developed methodology for Ecological Footprint assessment due to the availability of international trade statistics and the widespread availability of national statistics on domestic consumption. In addition, the national methodology is simpler to calculate because only information on total

26 For a description of the National Footprint Accounts methodology, see Wackernagel et al. 2005.

aggregate demand is needed. Subnational methodologies require additional consumption and final-use data specific to the subnational entity being assessed in the Footprint analysis.

The compound method used in the National Footprint Accounts is considerably different from the "component method" that was originally used for EF calculations. The component method takes a bottom-up approach adding up the individual "footprints" of various consumption categories, which in turn are calculated on the basis of life cycle assessment (LCA). Pure component approaches are not applied any longer due to severe methodological problems (such as double counting). Instead, recent subnational applications usually combine bottom-up calculations with data from the National Footprint Accounts. At present there are two basic types of methodologies for subnational Footprint calculations (RPA 2007): process-based approaches which use life cycle assessment (LCA) data[27]; and input-output based approaches[28].

Box 3: A concise description of the Ecological Footprint indicator

The Ecological Footprint measures how much biologically productive land and water area is required to provide the resources consumed and absorb the wastes generated by a population, taking into account prevailing technology. The standard unit of measurement is a *global hectare*, which is equal to one hectare with global average bioproductivity.[29] Use of this normalised unit allows Ecological Footprints to be expressed in comparable area terms, despite differences in bioproductivity among land types, regions and countries. Humanity's Ecological Footprint can also be expressed in terms of the „number of planet Earths" required to support human resource use and waste generation.

The Ecological Footprint tracks the use of six categories of productive areas: cropland, grazing land, fishing grounds, forest area, built-up land, and carbon demand on land.[30] The areas of these six land types are translated into global hectares using *yield factors* and *equivalence factors*, which relate the bioproductivity of each land type to the global average bioproductivity. Because the bioproductivity of land types varies by country, *yield factors* are used to relate national yields in each category of land to the global average yields. Equivalence factors adjust for the relative productivity of the six categories of land and water area.

The annual production of biologically provided resources, called *biocapacity*, is also measured as part of the Ecological Footprint methodology, and is also accounted for in terms of global hectares.

If the Ecological Footprint of the residents within a region exceeds the biocapacity of the region, the region is said to be in *ecological deficit*. The opposite of an ecological deficit is an *ecological reserve.* An ecological deficit at the global level is referred to as *ecological overshoot* and signifies that in the year in question, humanity used more of the Earth's biocapacity than was available that year, which can only happen if the natural asset base (which produces biocapacity) is also being consumed. Long-term consumption of the natural asset base yields a degradation in some forms of natural capital.

Source: Condensed summary based on GFN (2006a).

27 This includes the Stepwise™ model developed by Best Foot Forward. See BFF 2005a and 2005b.

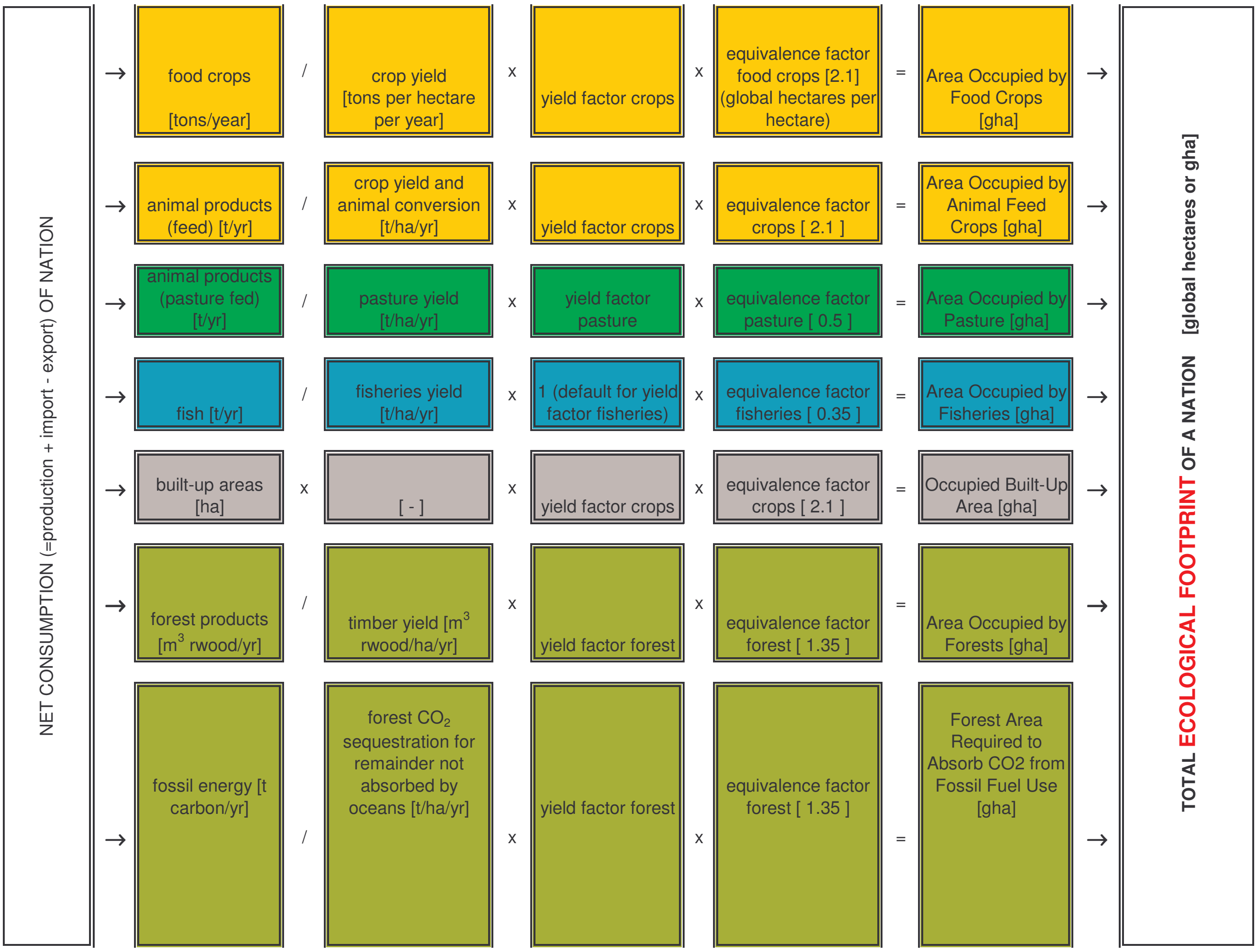
28 E.g. Wiedmann et al. (2006).

29 Global average bioproductivity per hectare = (total bioproductivity of the Earth's bioproductive land and water) / (total number of hectares of bioproductive land and water).

30 The Carbon Footprint is the amount of forest land required to capture those carbon dioxide emissions not sequestered by the world's oceans.

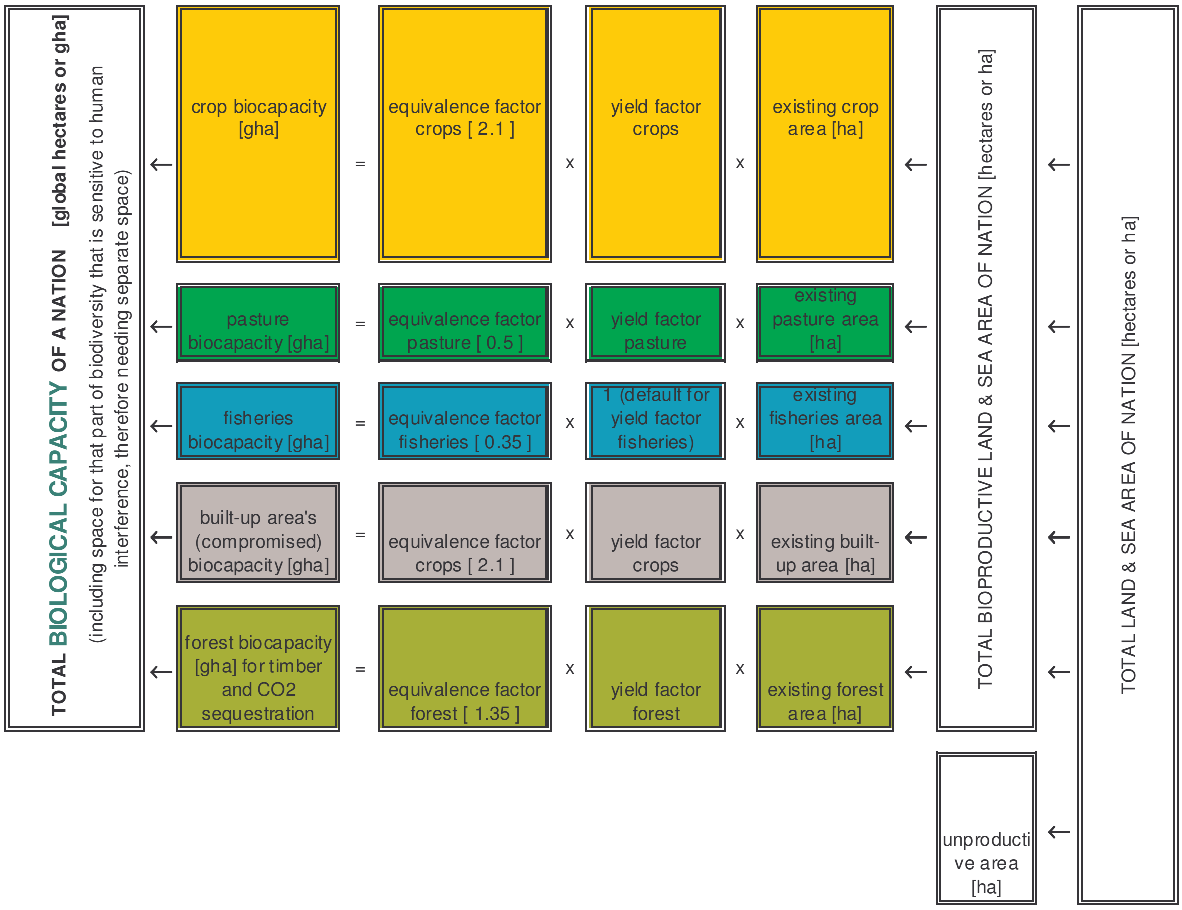
The National Footprint Accounts constitute a full accounting system for calculating biocapacity and Ecological Footprint statistics at the national level. For an overview of the structure of the National Footprint Accounts, see Figure 6. Summary information from the full accounting tables may be used as indicators, e.g. a nation's total Ecological Footprint, its per-capita Ecological Footprint, or the ratio of a nation's Ecological Footprint and the biocapacity available within its borders. In addition, analysis of the National Footprint Accounts can be done at the line-item level or the level of various subaggregations to generate a more detailed view of the key contributory factors to a country's (or group of countries') Ecological Footprint.

Figure 6: Structure of the National Ecological Footprint Accounts



Source: Global Footprint Network

Figure 7: Structure of the National Biological Capacity Accounts



Source: Global Footprint Network

4.2 RACER Analysis of the Ecological Footprint

This section provides an analysis of the Ecological Footprint along the RACER criteria and subcriteria, RACER stands for relevant, accepted, credible, easy and robust:

Relevant – i.e. closely linked to the objectives to be reached

Accepted – e.g. by staff, stakeholders

Credible for non experts, unambiguous and easy to interpret

Easy to monitor (e.g. data collection should be possible at low cost)

Robust against manipulation and error

In order to specify and operationalise the RACER criteria, one or more subcriteria have been added to each of them, as described below. Table 2 provides a summary of the evaluation, which complements the qualitative analysis with a simple numerical scoring system. Each subcriterion is scored individually; subsequently, an average score for each of the five RACER criteria is given. The summary score is equal to the average of scores for these five main criteria.

4.2.1 Relevant

4.2.1.1 Policy support, identification of targets and gaps

Is the indicator/methodology related to existing EU-specific policy objectives?

This study is intended to support the implementation of the EU Resource Strategy. More specifically, one of the main questions to be addressed is to what extent the Ecological Footprint is suited as a *resource-specific indicator to evaluate how negative environmental impacts have been decoupled from resource use*. However, it seems appropriate to assess the policy relevance of the Ecological Footprint in a somewhat broader context. The analysis of policy relevance of the Ecological Footprint will start from the aforementioned question and then gradually broaden its scope.

In order to provide a clearer understanding of what “environmental impact” may mean, 11 “impact categories” were derived from those commonly applied in life cycle assessment (LCA) and assessed for relevance with respect to current EU strategies on the environment and sustainable development. The suitability of the Ecological Footprint to address these categories of environmental impact was assessed. The result is that the EF at least partly addresses three out of the four impact categories most relevant to current EU strategies (i.e. resource consumption, climate change and biological diversity). However, no impact category is fully covered by the Ecological Footprint. Those impact categories that the Ecological Footprint addresses best are resource consumption and land use. Impact categories related to the release of waste products in the biosphere are only covered to a minor extent. Overall, the Ecological Footprint scores better on the impact categories that are currently most relevant to EU policies than those that are less policy relevant.

Although the Ecological Footprint has some relevance to more than one category of environmental impact, it also suggests that the particular strength of the Ecological Footprint does not lie in tracking down the impacts of resource use on a broad range of environmental parameters. The Ecological Footprint addresses the specific research question: how much of the biosphere's regenerative capacity is occupied by given human activities? Because of this specific focus, however, it does not intend to and thus does not measure all the specific *impact dimensions* of resource use. Rather, it measures the *amount* of resource use and, to a certain extent, waste generation associated with human activity. The *impact* addressed by the Ecological Footprint is the amount of biological regenerative capacity used by resource consumption relative to the regenerative capacity that is actually available. However, the Ecological Footprint does not directly measure the annual impact that resource use has on future biological carrying capacity (i.e. whether resource consumption leads to a degradation of ecosystems and thereby a reduction of carrying capacity). Such degradation, however, will be reflected in future biocapacity accounts, which are determined anew each year. Thus the National Footprint Accounts (as currently implemented) do not specify the relationship between resource consumption and the degradation of biological productivity, other than assuming that when resource consumption exceeds carrying capacity, liquidation of ecosystem stocks or accumulation of wastes is occurring.[31]

To some extent, it is a matter of definition whether the Ecological Footprint measures "impacts". The Ecological Footprint is a quantitative measurement of one particular issue: human consumption of biocapacity. The EF calculation basically translates one quantitative dimension of resource use—mass—into another quantitative dimension—land area. Within the overall eco-efficiency equation referred to in the Resource Strategy, the Ecological Footprint alone does not explicitly measure efficiency in terms of reduced environmental impact per mass of output. In order to assess efficiency in this sense, the product output (in mass units) in the National Footprint Accounts would have to be divided by the "input" of biologically productive land. Another option would be to create an overall resource use efficiency indicator ("Euro per impact"), as called for in the Resource Strategy, by relating the Ecological Footprint to a measure of economic activity (e.g. GDP).

Strictly speaking, assessing the progress made in decoupling resource use from economic growth says nothing about whether resource use stays below nature's carrying capacity. This observation is important because the Ecological Footprint is intimately connected with the notion of carrying capacity, which is a key concept referred to in the relevant EU policy documents. While the Ecological Footprint may also support the measurement of resource-use efficiency, its unique strength can be seen in defining absolute boundaries to resource use (i.e. the amount of available biocapacity) and relating presently occurring resource use to these ecological limits. Another of its strengths is to reflect the resource use that domestic consumption requires at a global scale; thus it has the potential to provide a tool for assessing how the EU meets its global responsibilities. According to Rees (2006):

> *"Ecological Footprint analysis . . . was introduced explicitly to reopen the debate on human carrying capacity . . . . Indeed, the method gains much of its analytic strength by inverting the standard carrying capacity ratio. If carrying capacity asks 'how large a population can a particular area support' (a question that can be rendered seemingly irrelevant by trade) [Ecological Footprint analysis] asks 'how large an area is required to support a particular population' (a question that includes those areas that are effectively 'imported' through trade)."*

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31 Steps in this direction were taken by Lenzen and Murray 2001 and 2003, as well as Lenzen et al. 2007. The idea of integrating Emergy and/or HANPP into equivalence factor calculations, as discussed in Kitzes et al. 2007, may also address this point.

Having identified the Ecological Footprint's ability to relate resource consumption to carrying capacity, it still needs to be examined more closely *in which way* it does this. The limits of global carrying capacity are reflected in the *global* Ecological Footprint. The relationship between national Ecological Footprints and carrying capacity is less straightforward. A nation's total Ecological Footprint, in the form it is usually represented, does not show whether the carrying capacity of *national territory* is really being exceeded, as it includes net imports. However, National Footprint Accounts also contain a separate "production Footprint" which provides this information.

A global Ecological Footprint that is lower than available biocapacity is a necessary, but not sufficient, condition for environmental sustainability. Even if humanity's total Ecological Footprint were still well below global carrying capacity, this would not exclude the possibility that specific resources are being used in an unsustainable way, thereby degrading the global carrying capacity. Biocapacity is also used by species other than humans, meaning to the extent that nature conservation is a desirable goal, a corresponding quantity and quality of biocapacity must be conserved for this purpose.

While the Ecological Footprint can determine whether or not a particular allocation of biocapacity is occurring, it cannot say whether or not this allocation is desirable or fair. In policy decisions regarding what level of resource consumption is appropriate, value judgements are required regarding what share of biocapacity a nation (or other entity) should consume. This is fundamentally an ethical question regarding intra- and intergenerational resource allocation, views on conservation of species and ecosystems, and expected effects on resource prices and the potential for conflicts.

A nation's per-capita Ecological Footprint allows conclusions to be drawn as to whether its per-capita resource consumption would be sustainable were all individuals on Earth to consume an equal amount. In addition, it shows how far a country's individual consumption levels are above, or below, global average resource consumption. Here again, it is subject to a separate ethical judgement whether, to what extent and under which conditions such inequalities are desired.

Possible EF-related policy goals for Europe *could* be:

- Europe's consumption of resources should be reduced by a certain amount in order to consume less biological capacity.
- Europe's imports of biological resources should be reduced by a certain amount in order to consume less biological capacity in other parts of the world.
- Europe's consumption of biological resources should not exceed the biocapacity available within its territory (i.e., Europe should be 'potentially self-sufficient' and not run an ecological deficit).
- Europe's domestic extraction should not exceed the biocapacity available within its territory (i.e., Europe should not overshoot its own resource base).

- Europe's per capita Ecological Footprint should not exceed the global average per capita level required to ensure that global carrying capacity is not exceeded.[32]

Using EF accounting as a tool to guide policies does not imply that trade flows between the EU and the rest of the world should be reduced. However, capturing the implications of trade for resource consumption is important, and the Ecological Footprint extends the scope of analysis of EU resource use beyond the borders of the EU. EF accounting thereby provides a means of assessing resource-related implications of different trade options (within the limits of detail and accuracy that the underlying statistical material supports). Assessing the quantity and quality of trade flows provides a window into the "trade balance" in terms of ecological sustainability.

In addition to its possible contribution to assessing overall resource use, the Ecological Footprint is also related to other objectives mentioned in the relevant EU documents. The SDS mentions among the operational objectives and targets for "Sustainable consumption and production":

> *"Improving the environmental and social performance for products and processes and encouraging their uptake by business and consumers."*

The National Footprint Accounts methodology is not designed to evaluate product- and process-level Ecological Footprints because it does not allocate demand on biocapacity by type of economic activity. However, other types of EF applications have been developed to provide this type of information.[33]

Among the operational objectives and targets under the heading of "Conservation and management of natural resources", the SDS mentions:

> *"Improving management and avoiding overexploitation of renewable natural resources such as fisheries, biodiversity, water, air, soil and atmosphere, restoring degraded marine ecosystems by 2015 in line with the Johannesburg Plan (2002) including achievement of the Maximum Yield in Fisheries by 2015."*

Among the resources mentioned in the SDS, fisheries, in particular, are within the scope of the Ecological Footprint. Soil and water are only reflected in the Ecological Footprint accounts in terms of the extent to which they determine biological productivity. Air and atmosphere are not strictly speaking biologically productive media. Air pollution could in principle be included in the Ecological Footprint through analysing biological absorption capacity for these pollutants. In practice, this has been so far confined to the greenhouse gas carbon dioxide, which is translated into the amount of forest land required to sequester CO_2 emissions (less the amount absorbed by oceans). In general, the Ecological Footprint analytically accounts for pollution by determining the amount of biological capacity required to absorb a pollutant. In practice, however, there are limits to this conversion approach: where the biological capacity needed to absorb a pollutant has not been determined (as is the case for most non-biological pollutants), emissions of this pollutant do not enter the

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32 This admissible global average footprint currently (i.e. as of 2003) lies at 1.8 global hectares (WWF et al. 2006). It is adjusted each year in order to take account of both changes in global population numbers and global biological capacity.

33 Examples of such product-level analyses are: BFF 2005 and Wiedmann et al. 2007a.

current Ecological Footprint method; and where a pollutant cannot be decomposed by biological processes, it is declared out of scope of the Footprint concept. Thus the EF calculations exclude most environmental pollutants.

Even where EF accounting has a more or less close relationship to the protection targets mentioned above, this does not necessarily imply that the Ecological Footprint has the potential to become policy relevant for the respective sectoral policies. For instance, it is unlikely that the EU fisheries policy will be guided by the Ecological Footprint of each fishery due to the fact that catch statistics, fish stock estimates, population dynamics and ecological attributes are probably better guides to policy. Or, to take the example of climate policy, the public perception of the need to reduce greenhouse gas emissions and dependency on fossil fuels is certainly driven by other arguments than the observation that the Ecological Footprint of carbon is too high. The strength of the Ecological Footprint as an indicator emerges when there is a need to understand aggregate issues involving multiple resource types (rather than single-resource issues).

Does the indicator provide guidance in monitoring, strategic policy making and/or target setting? Does it quantify gaps between the current situation and specified targets?

The Ecological Footprint could be used as an aid to formulate strategic goals related to human use of the biosphere's regenerative capacity. If the policy goal was, for instance, to have an Ecological Footprint not exceeding Europe's biocapacity, or to reduce the Ecological Footprint by a certain percentage, then the Ecological Footprint would allow quantification of the gap between the current situation and this target.

Does the indicator provide adequate early warning to guide policy action? Does it react to short-term changes that can (among other things) show whether policies are having an effect?

As the National Footprint Accounts are updated each year on the basis of the most recent statistical material, the Ecological Footprint is able to reflect short-term changes (see the "identification of trends" subcriterion below). By its nature as a highly aggregated indicator, a nation's total Ecological Footprint does not allow one to trace back observed changes to specific policies. It also does not contain variables that are directly policy driven.[34] However, an analysis of the individual components of National Footprint Accounts would have the potential of providing guidance to policies related to specific sectors or land types (e.g. forestry, fisheries, energy trade and agricultural policy).

Addendum

Review of the draft final report for this study found that some questions contained in the terms of reference should be addressed more fully in the report. Focused responses to the questions raised are given in the form of an addendum, which is placed here because we feel that all three questions raised are essentially related to the "policy support" criterion.

34 This is also true for most other indicators and indicator systems, other than "response" type indicators (e.g. "designated areas" as a biodiversity indicator).

1. To what extent does the EF take into account the life cycle approach?

As an introductory remark, a “life cycle approach” becomes particularly relevant when it comes to an examination of environmental impacts at the product level. While Footprint calculations at product level are clearly based on a life cycle approach, National Footprint Accounts can reflect life cycle aspects only to a limited extent. For instance, the footprint associated with waste disposal will be reflected in the part of built-up land that is occupied by landfills, as well as the CO_2 emissions from incineration, but cannot be traced back to individual products used. Similarly, energy use will be monitored as such, but not attributed to any particular energy-using products.

The general recognition of a life cycle approach also in National Footprint Accounts becomes visible in the concept of an “embodied footprint” in imported goods. In practice, this means that, firstly, that secondary products (such as food, furniture) are analysed for their content in primary products (such as cereals, wood) and these “embodied resources” are then counted like traded primary products. Secondly, the “embodied energy” in traded products is taken into account. This, in turn, is calculated on the basis of average factors and therefore does not reflect the differences in energy efficiency of different countries of origin. Current National Footprint Accounts do not provide a complete picture of “embodied resources”. For instance, the Ecological Footprint associated with imported metal ores and the products manufactured from them should in theory include built-up area in the country of origin in order to take account of the potentially biologically productive area occupied by mining and its associated waste products; in the current methodology, these aspects are not accounted for in this way.

As detailed elsewhere in the report, life-cycle impacts are only addressed within the general scope of the EF concept, i.e. in terms of quantities of biologically provided resources and the land area required to produce them. This means that the EF does not capture (or does not capture well) most of the impact categories usually applied in life cycle analysis (e.g. ecotoxicity, acidification, ionizing radiation). It does not comprehensively take into account waste flows, except for CO_2 emissions.

2. To what extent does the EF address natural capital losses?

The EF addresses natural capital losses in the way that any losses in regenerative capacity will be reflected in a diminished biocapacity in future EF accounts. However, EF accounting does not establish any direct relationship between current (past) nature use and future (present) losses of biocapacity. This also implies that EF accounting does not allow to distinguish whether a loss in biologically productive capacity is caused by factors measured in the EF accounts (e.g. extraction of biological resources) or beyond the scope of EF accounting (e.g. contamination with non-biodegradable pollutants).

Furthermore, the scope of what can be characterised as “natural capital” is broader than the range of natural resources addressed by the EF concept. The EF does not account for the depletion of non-renewable resources. Likewise, EF accounting does not reflect losses in biological diversity or environmental quality as such; such losses are only reflected indirectly to the extent that they contribute to a decrease in biologically productive capacity. This also implies that EF accounting reflects at best losses in natural capital in the sense of quantity of available biological material; this does not mirror the potential economic value of e.g. plant species that can be used for medical purposes, or the recreational value of attractive landscapes.

3. How far does the EF fulfil the criteria to become an SDI?

The RACER criteria, the use of which was prescribed in the terms of reference, were refined by the project team and the subcriteria agreed upon at the start of the project. In our understanding, the RACER framework comprises the criteria for EU Sustainable Development Indicators (cf. section 2.1, Box 1) and addresses them in a more detailed way. The following text provides an indication of how the results of the RACER analysis can be grouped by the SDI criteria in Box 1. However, it should not be seen as replacing or modifying the conclusions from the RACER assessment given in section 4.2.6.

An indicator should capture the essence of the problem and have a clear and accepted normative interpretation. The EF relates resource use to carrying capacity. This does not embrace the whole problem of resource use but captures an important element of it. The normative interpretation in its most general terms (resource use should not exceed carrying capacity) is clear and widely accepted, but the EF concept leaves scope for various interpretations when it comes to its application in a more specific context.

An indicator should be robust and statistically validated. The robustness of the EF remains subject to debate. Its methodology is being continuously improved. Margins of error have not yet been tested comprehensively.

An indicator should be responsive to policy interventions but not subject to manipulation. The EF will generally respond to policies that change resource use patterns, but there is no straightforward relationship between most policy interventions and changes detectable in the National Footprint Accounts. Systematic over- or underestimates may occur as results of differences in national methods of data collection but are unlikely to occur as results of manipulations of the Footprint Accounts themselves.

An indicator should be measurable in a sufficiently comparable way across Member States, and comparable as far as practicable with the standards applied internationally by the UN and the OECD. The data needed for calculating National Footprint Accounts are available for all Member States from international statistics. An improved compatibility with related national and international accounting systems is recognised as desirable, including by the proponents of the EF methodology.

An indicator should be timely and susceptible to revision. National Footprint Accounts are published annually. The methodology is being revised regularly on the basis of an ongoing scientific discussion.

The measurement of an indicator should not impose on Member States, on enterprises, nor on the Union's citizens a burden disproportionate to its benefits. National Footprint Accounts are based on data that are already being collected. A refinement of the methodology may bring about additional efforts for data collection and processing but this is unlikely to impose a disproportionate burden.

4.2.1.2 Identification of trends

Can the methodology/indicator be used to track changes through time? This implies that at least one input variable will require time series data (e.g. a series of annual measurements).

National Footprint Accounts are updated each year and available as a time series back to 1961. Most underlying data are around three years old, meaning that the Ecological Footprint is therefore able to track change in a quite timely manner. Due to the level of aggregation of a nation's total Ecological Footprint, however, trends in different variables may compensate each other. It will therefore be needed to complement communication of the overall Ecological Footprint with an analysis of how the individual components of National Footprint Accounts have developed.

4.2.1.3 Forecasting and modelling

Can the methodology/indicator be used in a predictive sense to forecast future environmental impacts from natural resource use or for more sophisticated modelling where the impact of different potential policies or of technology progress and/or change of consumption patterns can be simulated? Can the indicator function as an early warning indicator?

The Ecological Footprint accounts are an accounting tool, not a forecasting tool. They measure the magnitude of current resource use and rely on ex-post input variables. They do not contain feedback loops that would link today's decisions with resource consumption in the future, or today's resource consumption to impacts occurring in the future. Nevertheless, the Ecological Footprint can and has been used to do "what if" modelling (e.g., what would the global Ecological Footprint be in 2050 based on UN projections about population growth, food and fibre consumption, agricultural productivity, etc.?).

By relating resource use to biocapacity, the Ecological Footprint provides a "warning light" regarding long-term degradation of natural resources. It has a certain predictive quality in suggesting that present resource use patterns will run into problems. This warning light, however, remains rather abstract. The harm that present resource consumption does to specific geographical areas, ecosystems or environmental media can only be detected to a limited extent. National Footprint accounting can be used to show whether the total biocapacity of the area for which the Footprint is calculated is being exceeded; it also shows how resource consumption relates to biocapacity for specifically defined land types; but current accounts do not allow more precise localisation of where damage will actually occur.

The usefulness of the Ecological Footprint for identifying trends and causal links can be expected to grow with subsequent years of calculations. The multi-year biocapacity and EF data can then be analysed to see where existing biocapacity is being degraded (or enhanced) and the relationship of these changes to ecological deficits within countries. The ability to extrapolate trends will also improve as the number of years for which there is EF data increases.

4.2.1.4 Scope/levels of application

[Please note that EF methodologies other than the National Footprint Accounts methodology were not systematically evaluated in this study. Study conclusions should not be assumed to apply to subnational methodologies.]

Does the indicator provide information relevant to the effective levels of application? Does it allow for disaggregation – either spatial, by product, by industry or by ecosystem type?

While National Footprint Accounts are regarded as the most accurate and developed form of Footprint calculation, the EF can also be, and has been, applied at other geographical or administrative levels (e.g. for cities) and to single activities, products, persons, enterprises or industries. As mentioned above, recent subnational applications usually use data from National Footprint Accounts as a basis. However, they are not pure disaggregations of National Footprint Accounts, but require additional data. When using process-based approaches, the quality and reliability of data is a key problem (RPA 2007:42). Input-output based approaches have usually used financial input-output data, which is not necessarily a good proxy for physical consumption (RPA 2007: 44). The process of standardising subnational footprint calculations (GFN 2006b) is still at a relatively early stage.

Another issue relates to spatial disaggregation. While the concept of "global hectares" is useful in order to make calculations comparable at a global scale, "local hectare" approaches may be more appropriate when addressing actual land use problems in a given region.[35] Even where EF calculations are based on "local hectares", however, they still use average figures for the whole region (e.g. country) for which the Ecological Footprint is being measured. A detailed spatial disaggregation of land use is not part of the EF methodology. The basis for EF calculations is resource-consuming human activity within a given area, not impact on actual existing ecosystems within that area. Indicators other than the Ecological Footprint would need to be used to assess these issues.

4.2.1.5 Function- and needs-related analysis

Does the indicator allow for comparisons among material and energy resources in terms of their functions and competition in the real world (e.g. in a case where one energy carrier, foodstuff or construction material is substituted by another)? In a similar vein, does the methodology allow the comparison of different ways of fulfilling basic human needs (housing, mobility, food, etc.) with regard to their resource-use implications?

The Ecological Footprint is sensitive to a change in the ways human needs are fulfilled (e.g. high- versus low-meat diets, different types of housing developments or transportation systems; fossil fuels versus biofuels). While the National Footprint Accounts are not designed as a tool to compare different options (they are strictly ex-post accounts), EF studies have been undertaken at the individual sector and enterprise levels to explore these issues. However, not all substitutions are currently reflected in the EF calculation (e.g. organic farming versus conventional agriculture[36], or electricity generation from nuclear versus fossil energy sources).[37]

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35 Kitzes et al. 2007: 6-7; Lenzen & Murray 2003; Wackernagel et al. 2004a.

36 The Ecological Footprint takes account of the energy input required for intensive agriculture (e.g. for tractors, fertilizers, or pesticides), but not of harmful material outputs such as excess fertilisers and pesticides, or other undesirable consequences associated with certain land use practices (e.g. soil erosion, leaching, salinisation). – See Kitzes et al. (2007: 16) and Wackernagel (2005: 21).

37 Substitution is reflected by the change in resource requirements for producing energy (e.g. for all steps in the production and supply of fuels used in a power plant, as well as building the power plant) but is not reflected in the carbon Footprint since the accounting convention takes nuclear energy as equivalent to fossil energy in this regard. (Note: a change in the accounting methodology for nuclear energy is being considered for implementation in 2008.)

For imported products, assumptions are more simplified than for domestic production (e.g. for embodied energy, global average factors are currently used).[38] These assumptions can lead to errors in EF estimations if imports are produced with technology with impacts that differ from the global average (Wiedmann et al. 2007b). Resource use or emissions from the transport of products are included in national totals, but not separately accounted for. Therefore, there is only limited possibility to reflect substitution between domestic and imported products, and substitution between different imported sources. Further work is needed to refine the methodology and its data bases in this respect.[39]

4.2.2 Accepted

4.2.2.1 Stakeholder acceptance

Is the underlying rationale and meaning of the methodology/indicator easily understood and accepted by stakeholder groups? Does the methodology/indicator resonate with widely held values and concerns to motivate stakeholders to calculate or provide data and accept interpretations of the meaning of the methodology/indicator?

The easy communication of a complex matter is one of the main strengths of the Ecological Footprint. The existing popularity of the indicator shows its suitability to address a broad public. At the same time, other groups of stakeholders, in particular representatives from statistical offices, are critical of the accounting framework as being over-reliant on conversion factors and imputations of missing data, some of which are not documented in a way that can be independently reviewed. Such criticism was raised, for an example, in a paper by Eurostat (Schaefer et. al., 2006, p. 8). However, the same paper also offered a partnership to Global Footprint Network to develop the necessary data sources to improve the National Footprint Accounts methodology.

The Ecological Footprint measures the consumption of biotic resources but not the consumption of abiotic resources. It does not cover all categories of pollution and their resulting environmental and ecological impacts. For these reasons, stakeholders (including EF practitioners and proponents) call for the use of other resource indicators to assess issues not addressed by the Ecological Footprint indicator.

There are a number of formal endorsements of the Ecological Footprint. The Convention on Biological Diversity has adopted it as an indicator of progress toward meeting the 2010 goals. Global Footprint Network is also engaged in research collaborations with five national governments: Belgium, Ecuador, Japan, Switzerland and United Arab Emirates. The 2005 version of the National Footprint Accounts was sponsored by the European Environment Agency. The 2006 version was published in co-operation with WWF.

Improvement of the National Footprint Accounts methodology is guided by a consensus committee process, with representatives from Global Footprint Network's 80 or more partner organisations. Opportunities for public input are also part of that process.

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38 Significant improvements in estimating embodied energy in traded products have been made by basing Footprint accounts on COMTRADE statistics, which comprise more than 600 import and export categories (Dige 2006; Wackernagel et al. 2005).

39 For recent developments in this field, see BFF 2005b, Moran et al. 2007 and Wiedmann et al. 2007c.

4.2.3 Credible

4.2.3.1 Unambiguous

Is the indicator suited to conveying a clear, unambiguous message? Does it allow for clear conclusions to guide political action? Does it actually provide the information that non-experts believe it does?

While the basic concept of the Ecological Footprint (relating resource use to the capacity available to provides these resources) can be easily understood, its limitations (e.g. not addressing the use of non-renewable resources beyond the demand their use places on productive ecosystems; addressing waste products other than CO_2 only to a very limited extent) are far less easily understood and therefore can lead to confusion about what the Ecological Footprint actually measures.

The Ecological Footprint does not lead to immediate policy conclusions. Where ecological overshoot is identified, it needs to be traced back to the individual EF components within the National Footprint Accounts in order to find out what the drivers of the problem are.

In any case, the policy implications of EF findings are subject to interpretation and valuation. Normative judgments must be made before deriving policy goals from EF accounting. Even environmentally harmful conclusions are possible, e.g. that biocapacity should be increased by intensifying land use, which could come at the expense of biological diversity and could increase pollution from fertiliser runoff. Such potential trade-offs need to be identified and taken into account in the communication of results[40], in formulating political goals and in decisions regarding how to complement the Ecological Footprint with other indicators.

4.2.3.2 Transparency of the method

Are the underlying data and calculation methods fully disclosed, interpretable and reproducible?

The basic principles of EF calculation are publicly available and are standardised for national EF accounts. Still, not all calculation steps and underlying assumptions are sufficiently documented (Schaefer et al., 2006: 9); most notably, this is the case with the equivalence factors, as noted by Kitzes, et al. (2007a). According to Global Footprint Network (GFN), most of what is being perceived as a lack of transparency is not a problem of availability of calculation details, but is due to the high complexity of the calculations and a shortage of resources to present them in a more user-friendly way. Efforts are currently underway to improve the transparency of the calculations (through simplifying the calculation templates and by developing a more detailed handbook). Global Footprint Network expects these

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40 With respect to biodiversity, see, for instance, the discussion in WWF et al. (2006: 24): "Increasing biocapacity – by expanding the productive area or boosting yields, for example through irrigation – can play an important role in bringing humanity out of overshoot. However, these increases may also have costs – energy intensive farming methods can add to the carbon footprint; expansion of grazing areas into forest can endanger wild plant and animal species; irrigation can lead to salinisation or groundwater depletion, and the use of pesticides and fertilisers can negatively impact wildlife far downstream or downwind from where they are applied. These biocapacity increases must therefore be carefully managed if they are to help reduce both overshoot and the threat to biodiversity."

revisions to be finished for the 2008 edition of the National Footprint Accounts. Generally, there is a lively and open scientific discussion on various aspects of the EF methodology.

4.2.4 Easy

4.2.4.1 Data availability

Does the methodology/indicator work without inputs of data that are overly excessive, expensive or onerous to collect, or that cannot be properly measured? Ideally, is it based on data that are already collected and readily available in electronic form?

The EF calculation requires a large amount of data from different sources. However, no primary data collection is required, and data availability has been sufficient to calculate national EF accounts since 1961 for more than 150 countries. For many countries, data quality is more of a problem than actual availability of data. This is particularly true for countries outside the OECD. There are certain data gaps, e.g. related to trade flows. Imputation techniques have to be used where data are missing. Also, data availability and quality are connected to each other as the more readily available data from international organisations are often less precise, or less detailed, than data available from individual nations. Furthermore, as international statistics draw on data reported by national authorities, the use of standardised international data sources may hide differences in the quality of underlying national data. Many researchers, as well as some national governments, have expressed concerns regarding the quality of available source data sets (Kitzes et al., 2007a, p. 3).

Other difficulties are connected not to the availability of data as such but on the lack of scientifically established relationships (e.g. between biocapacity and greenhouse gases other than CO_2, or biocapacity and nuclear energy).

4.2.4.2 Technical feasibility

Is the methodology simple enough to be carried out using software and expertise appropriate to the scale of application and the typical capabilities of the institution doing the calculations?

The large number of National Footprint Accounts published so far demonstrates the feasibility of the calculation. EF calculations have also been carried out at local and other levels. No specifically designed software is required; calculations can be done with commonly available spreadsheet programs. The calculation, however, requires a considerable depth of methodological understanding and might be facilitated by specifically designed software tools to be further developed.

Are the input and the calculation methodology clearly defined to avoid ambiguity and consequent error in implementation?

EF accounting involves numerous calculation steps, not all of which are sufficiently documented. This also implies that calculations are not fully reproducible (Schaefer et al. 2006, p. 9; see also 2.3.2 “Transparency of the method” and 2.5.4 “Reliability”). Further, it has been acknowledged that the calculation spreadsheets are unnecessarily complicated. Efforts by Global Footprint Network are underway to address this shortcoming.

4.2.4.3 Complementarity and integration

Are there potential complements between the methodology/indicator and the others being assessed?

Among the resource indicators assessed in this study, the Ecological Footprint is unique in relating resource use to the concept of carrying capacity. The impact it measures is whether biological regeneration capacity, on the whole, is exceeded by use of the resource that are biologically generated. Other indicators (in particular, environmentally weighted material consumption, EMC), in turn, are better suited to assess environmental impacts in terms of individual impact categories. If implemented in a basket of indicators, the Ecological Footprint would complement other resource-impact indicators.

Is there the potential for further integration of the methodology/indicator with the others?

A large part of the underlying data for EF accounting relates to material flows and is therefore similar to the data used for Material Flow Analysis (MFA), on which, in turn, EMC is based. However, although National Footprint Accounts rely largely on UN data and classification systems, the design of the National Footprint Accounts is not directly linked to the definition of system boundaries of the System of National Accounts (SNA). In this respect MFA, as well as Land Use Accounting (LUA), is better integrated with national and international statistical systems (Giljum et al. 2007: 43). There is a need as well as potential to further improve integration of EF accounting with accounting systems such as the NAMEA (National Accounting Matrix including Environmental Accounts) at the EU level, or the Integrated Environmental and Economic Accounting (SEEA) system at UN level (Giljum et al., 2007; Schaefer et al., 2006) and it is recommended that efforts in this direction be pursued (SERI et al. 2006; Kitzes et al. 2007a: 22).

4.2.5 Robust

4.2.5.1 Defensible theory

Is the methodology/indicator based on sound theory? Does it avoid double counting or omissions of resources used? Is it consistent in its units of measure? Does it rely on assumptions that are clearly stated and reasonable? Does it avoid the use of ill-defined or poorly quantified parameters? In cases where subjective weighting cannot be avoided, is it justified and made explicit?

Proponents of the EF methodology emphasise that the first point to examine should be whether the EF is based on a valid (i.e. both scientifically sound and practically relevant) research question. The second and third points to address would then be whether the current National Footprint Accounts answer this research question sufficiently well, and what it would take to make the results more reliable.[41]

EF accounting is meant to address the research question: “How much of the planet’s regenerative capacity is occupied by human activity?” The fundamental relevance of this question for sustainable development strategies has already been discussed under the “policy support” aspect of the “relevant” criterion. It can also be assumed that there is little scientific contestation of the fact that there are limits to the amount of biological resources

[41] Mathis Wackernagel, personal e-mail communication of 3 February, 2008.

that the planet can produce over a given period of time (although it is possible in principle not only to decrease, but also to increase the biocapacity of a given area), and that excessive exploitation of resources may lead to a degeneration of biological capacity. This makes it plausible that a certain threshold of over-exploitation exists, which could be detected (at least with some degree of approximation) by scientific investigation. More questions remain about whether the EF concept sets the boundaries of the system right (e.g., whether it identifies the relevant stressors of regenerative capacity), and whether its calculations lead to accurate results.

Certain fundamental questions about methodological choices remain—choices which greatly influence the total size of the Ecological Footprint. In particular, there are disputes on whether land area calculated for CO_2 absorption under the current method corresponds to real land area or has to be taken as symbolic. Rees (2006) states that "the large energy footprint due to excessive carbon dioxide emissions is not a fault of [the Ecological Footprint method] (which is merely the bearer of the bad news) but of over-consumption relative to available biocapacity. In this sense, the large contemporary energy [Ecological Footprint] is actually a *robust finding of the [EF] method*." However, a remark by the same author in the same paper casts some doubt about the objectivity and robustness of the methodology used. At the same time, the remark underscores the conservative preference of EF proponents for understating rather than overstating the Ecological Footprint:

> *"Part of the reason we do not account for the unsustainable use of nature is the sheer labour intensity of determining erosion and depletion rates of areas in question. The question does arise, however, of how would one use the data were they available? Suppose soil degradation were 30 times the rate of renewal (probably close to the world average). If we inflated the arable land component of the [Ecological Footprint] to reflect such information per capita [the Ecological Footprint] would be numbingly large – would anyone take them seriously? As matters stand, the estimated average EFs, unadjusted for land degradation, show everything needed for a reasoned policy response in the right direction without being intimidating or discouraging."*

Problems with double counting have been associated with applications of the component method (a bottom-up approach) of Footprint calculation for sub-national analyses. These problems—also an issue for life cycle assessments—are avoided when using the compound method (a top-down approach), which is the standard method for National Footprint Accounts. However, a problem opposite to double-counting occurs as land use forms are taken as mutually exclusive, while in reality an area of land may fulfil several functions simultaneously. This has been raised as a point of criticism as it may lead to overestimation of the Ecological Footprint and underestimation of biocapacity (Giljum et al. 2007, citing RPA 2005). However, proponents of the Footprint methodology argue that the accounts are constructed to not include two demands on the same area as double to the Ecological Footprint. The principle of accounting for mutually exclusive ecosystem areas is sound, but one would have to test in more detailed scrutiny whether the current accounts are truly implementing this principle. Proponents claim that this principle is indeed applied, at least within the boundaries of those ecosystem services that Footprint accounting actually considers (resource extraction and waste absorption) (Kitzes et al. 2007a, p. 20). Even while a given forest area may well serve both supply of timber and absorption of carbon dioxide, trees that are logged will no longer absorb CO_2.

The translation of various fields of consumption into one single unit “global hectare” requires certain assumptions and simplifications to be made. Being an abstract unit of accounting based on national averages, the global hectare does not report actual physical units (e.g. actual hectares or units of mass) though these input data are available in the National Footprint Accounts spreadsheets. Arguably, however, such assumptions and simplifications are necessary in order to create an aggregate indicator. Present EF calculation methods are the result of a considerable effort to base relationships between consumption and biological regeneration capacity on sound theory. There is a broad and open discussion about the problems of the methodology and ways to improve it. This is conducted via two committees (the Standards Committee and National Accounts Committee), instigated and facilitated by Global Footprint Network, but made up of Global Footprint Network partner organisations from around the globe and with varying interests.

The methodology requires the application of conversion factors (*equivalence factors* to convert world-average land of a specific land type to global hectares and *yield factors* that account for national differences in the productivity of each land type). It has been disputed whether the methodology converts all input variables accurately into global hectares. The underlying assumptions for the factors applied have not been sufficiently documented to allow for independent reviews (Schaefer et al. 2006). This lack of transparency lowers the score of the Ecological Footprint under the “defensible theory” subcriterion, but transparency could be improved in principle. It should be noted that conversion factors are based on physical estimates of biocapacity and productivity.[42]

4.2.5.2 Sensitivity

Do the values of the indicator outputs change rapidly enough with respect to input parameters to pick up policy-significant changes?

EF values are sensitive to changes in input variables, but the Ecological Footprint is most appropriately seen as a long-term aggregate indicator rather than a tool focussed on short-term changes. No direct link to policy changes is provided by the underlying data, but to the extent that relationships between policies and resource use can be established, it would also be possible to determine the effect of these policies on the Ecological Footprint. For this purpose, it would be necessary to analyse the individual components of National Footprint Accounts. Given the fact that typically several policies affect the resource consumption monitored in the Footprint, attributing changes in the Ecological Footprint to single policies would be the exception rather than the rule. A more typical use would be inter-country comparisons and identification of long-term trends.

Is the methodology suited to detect non-linearities, discontinuities and thresholds?

Non-linearities are not reflected in the accounting method. However, comparison of annual EF accounts can detect non-linear changes (e.g. time trends in Cuba and North Korea show rapid Footprint and biocapacity reductions in the years after the Soviet Union disintegrated and could no longer provide resource imports to the two countries). The EF indicator is also

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[42] Global Footprint Network plans for the 2008 handbook to contain a more in-depth discussion of conversion factors.

designed to detect whether a threshold that could lead to nonlinear changes is reached, namely whether the Ecological Footprint is exceeding biologically productive capacity.

4.2.5.3 Data quality

Is the underlying data of sufficient quality so that data lead to correct results? Could inaccuracies and variations within the uncertainty margin lead to opposite findings and conclusions?

Not all data used for the EF calculation are of equal value. This applies to different types of input variables as well as countries from which data are reported (see also the "Data availability" criterion). Improvement of data quality is an important issue. However, little systematic analysis about the margin of error has been carried out so far (Kitzes et al. 2007a: 5). Therefore it is difficult to estimate how significantly data quality problems and data gaps affect the results of EF calculations. Such analysis is complicated by the fact that for the underlying data, error margins are seldom reported. Giljum et al. (2007) describe a Monte Carlo analysis done to assess the sensitivity of the German National Footprint Account to variations in source data and the Account's own in-built assumptions. This was presented by the authors as a first step towards carrying out more systematic analyses in this respect. Given the high level of aggregation and use of generalised conversion factors, data quality should be validated and error margins should be reported and taken into account when drawing conclusions from the Ecological Footprint.

4.2.5.4 Reliability

Is the methodology/indicator reliable in terms of its accuracy, repeatability, and the clear specification of protocol and formulas used in the calculations? Are all details of calculation openly exchanged among researchers in order to avoid different standards?

The use of other data sources, modifications in the choice of input variables and/or conversion factors can change the message significantly (Schaefer et al., 2006). Calculation methods are not yet fully documented and, therefore, calculations are not entirely reproducible. Notwithstanding, as it has been stated earlier, there is a broad and open exchange among researchers on the best methodology to use, including efforts to achieve a higher level of standardisation, with improved documentation currently being prepared.

4.2.5.5 Completeness

Is the indicator/methodology complete in terms of the safeguard object it is assessing (e.g. natural environment, human health, future resource availability)? Is a shifting of burdens avoided among single problems/impact types (e.g. from climate change to nuclear risks), among the safeguard subjects (e.g. from human health to the natural environment) and among regions (e.g. relocation of production may shift environmental burden away from the place of consumption)?

The Ecological Footprint's ability to take into account the global dimension of local resource use is one of its main strengths. The methodology achieves a comprehensive coverage of elements within the boundaries of the research question (use of biotic resources). However, the system boundaries are not clearly defined in all cases, or the definition of boundaries could be questioned. Notably, this is the case with emissions and waste materials, where

CO_2 emissions are taken into account but other substances, including other greenhouse gases, are currently not.

The argument is that for CO_2 emissions, a sufficiently sound method is available for calculating the land area required to absorb them, while this is not the case with other greenhouse gases. Thus, in this case, the boundaries are determined by whether or not a methodology is available, rather than by the logic of the research question. At least, this is the case for methane, where Ecological Footprint accounting methodologies are currently being discussed (Kitzes et al. 2007a:14; Walsh et al. 2007). Other greenhouse gases, such as hydrofluorocarbons, may be systematically excluded on the argument that these are synthetic gases for which no biological absorption rate can be defined. A related discussion is whether it is appropriate to reflect global warming potentials in Ecological Footprint accounts (in terms of CO_2 equivalents). While the global warming potential of a greenhouse gas is essential for assessing its effect on the global climate, it is arguably not connected to the biological absorption capacity it requires (Kitzes et al. 2007a: 14). This discussion shows that the boundaries of the system the Ecological Footprint relates to are not always evident.

Though limiting the indicator to biotic resources may be justified in principle, there is a considerable risk of problematic interpretations where resource uses are shifted between aspects that the Ecological Footprint takes into account, and those that are outside its scope. For instance, the use of non-renewable resources is reflected by the Ecological Footprint only to the extent that it affects the biosphere’s regenerative capacity, while the problems associated with the depletion of non-renewable resource stocks are typically outside the Ecological Footprint’s scope. Therefore a shift from the use of some types of non-renewable resources to renewable resources (e.g. from petrol-based to biologically based plastics) could increase the Ecological Footprint.

Similarly, substitution of persistent, toxic substances by biodegradable materials may result in an increase of the Ecological Footprint because it is associated by a shift of the problem from outside to within the boundaries of EF accounting. EF practitioners can be expected to have a very precise understanding of these boundaries. The EF audience, however, is likely to have an imprecise understanding of the safeguard object actually measured by the indicator, thinking it to be broader than it actually is.

The fact that human health impacts and biological diversity are not measured by the Ecological Footprint implies that a shift of burdens at the expense of these factors can only be detected if the Ecological Footprint is complemented by other indicators able to account for these additional impacts.

4.2.6 Summary of RACER assessment

Table 2 summarises the key findings of the RACER assessment of the Ecological Footprint and provides a scoring of how well it fulfils each criteria and subcriteria.

Table 2: Summary of RACER assessment of the Ecological Footprint

Criteria and Subcriteria	Analysis	Score[43]
Relevant		**2.6**
POLICY SUPPORT	+ relevant to the EU policy objective of reducing environmental impacts from resource use (except for monitoring of abiotic resources and most emission sinks) + could provide support for the definition of targets and measuring gaps of implementation towards these targets + compares human demand against "carrying capacity", an otherwise overlooked aspect – leaves scope for interpretation and does not immediately lead to policy recommendations – Although the facts measured by the Ecological Footprint are clearly sustainability relevant, the messages that can be derived from EF accounting may not be fully congruent with EU policy goals as they are currently stated, signifying that complementary indicators are required.	3
IDENTIFICATION OF TRENDS	+ reflects changes over time + National Footprint Accounts are updated each year. Most underlying data are also being updated on a regular basis. – When only looking at the aggregated, total Ecological Footprint, opposite trends in individual variables may compensate each other.	3
FORECASTING AND MODELLING	– not a forecasting tool. It is an accounting tool that relies on ex-post data. – does not provide for feedback loops that would link current policies to future resource use, or present resource use to impacts occurring in the future + By relating resource use to carrying capacity, the Ecological Footprint provides a "warning light" regarding long-term degradation of natural resources. + sensitive to changes in input parameters, and thus can easily translate the results of scenarios and models.	2
SCOPE / LEVELS OF APPLICATION	+ National Footprint Accounts can also serve as the basis for EF accounts at other geographical or administrative levels (e.g. for cities) and to single products, persons, enterprises or industries. – Sub-national EF applications are not feasible by simple disaggregation of National Footprint Accounts, but require additional data. The availability and reliability of such data remains problematic. Standardisation of subnational applications is still at an early stage. – Even where "local hectares" are used instead of "global hectares", EF accounts do not contain spatially disaggregated data on actual land use and do not provide precise information on ecosystem impacts.	2[44]

[43] For main RACER criteria: average of subcriteria scores under this criterion; for summary appraisal: average of main criteria scores.

Criteria and Subcriteria	Analysis	Score[43]
FUNCTION- AND NEEDS-RELATED ANALYSIS	+ generally sensitive to changes in the ways human needs are fulfilled (e.g. high vs. low meat diets, different types of housing developments or transportation systems; fossil fuels vs. biofuels) – Not all kinds of substitutions are fully reflected in the EF calculation (e.g. food products from organic farming vs. conventional agriculture, or intensive vs. extensive forms of land use; substitution between nuclear and fossil energy) – impact of a substitution between domestic and imported products, or between different import sources, are incompletely assessed	3
Accepted		**2.0**
STAKEHOLDER ACCEPTANCE	+ The easy communication of a complex matter is one of the main strengths of the Ecological Footprint. + The existing popularity of the EF indicator shows its suitability to address a broad public. – Important stakeholder groups oppose the accounting system (e.g. statistical offices and some indicator experts have expressed reservation about applying EF accounting).	2
Credible		**2.5**
UNAMBIGUOUS	+ addresses a clear research question + The basic concept of relating resource use to carrying capacity can be easily understood. – The limitations of the research question are not readily understood. This may lead to confusion about what the EF really measures. – does not lead to immediate policy conclusions. Policy implications depend on interpretation and valuation. – Undesirable conclusions (from an environmental point of view) are possible, signifying that complementary indicators are required.	2
TRANSPARENCY OF THE METHOD	+ The basic principles of EF calculation are publicly available and are being increasingly standardised, notably for national EF accounts. + There is a lively and open scientific discussion on various aspects of the EF methodology. – Not all calculation steps and underlying assumptions are sufficiently documented (though documentation is improving).	3

[44] Please note that EF methodologies other than the National Footprint Accounts methodology were not systematically evaluated in this study. Study conclusions should not be assumed to apply to subnational methodologies.

Criteria and Subcriteria	Analysis	Score[43]
Easy		**3**
DATA AVAILABILITY	+ Data availability has been sufficient to calculate national EF accounts for more than 150 countries since 1961. + Primary data collection is already done by international statistical agencies. – Imputation techniques have to be used where data gaps exist (e.g. with trade flows) – Other difficulties are connected not to the availability of data as such but on the lack of established relationships.	3
TECHNICAL FEASIBILITY	+ The great number of national EF accounts published so far demonstrates the feasibility of the calculation. + With additional work, considerable further improvements in user-friendliness would be possible. – EF accounting involves numerous calculation steps, not all of which are sufficiently documented. Consequently, calculations are not fully reproducible. – Calculation spreadsheets are unnecessarily complicated.	3
COMPLEMENTARITY AND INTEGRATION	+ provides complementary information to the other resource use indicators assessed within the “basket”. – At present there is a lack of compatibility between national EF accounts and established national accounting systems. This also affects the compatibility with existing accounting systems that take into account environmental aspects. Significant work would be required to improve integration with these.	3
Robust		**2.6**
DEFENSIBLE THEORY	+ Present EF calculation methods are the result of a considerable effort to base relationships between consumption and biological regeneration capacity on sound science and accounting practices. – The translation of various fields of consumption into one single unit “global hectare” requires certain assumptions and simplifications to be made. It does not report actual physical units (e.g. actual hectares or units of mass), though these input data are available in the National Footprint Accounts spreadsheets. – The methodology requires the application of conversion factors. The underlying assumptions for the factors applied have not in all cases been sufficiently explained to allow for independent reviews. – It has been disputed whether the methodology converts all input variables correctly into global hectares.	3
SENSITIVITY	+ EF values are sensitive to changes in input variables. – Policy changes are typically not directly detectable via the indicator. – Thresholds and non-linearities are not accounted for pre-emptively, but are clearly reflected when they occur.	3

Criteria and Subcriteria	Analysis	Score[43]
DATA QUALITY	– Not all data used for the EF calculation are of equal accuracy and completeness. This applies to different types of input variables as well as countries from which data are reported. – In certain cases, the lack of compatibility with existing national accounts prevents EF accounting from being based on the most precise available data. – Data quality problems and data gaps might significantly affect the results of EF calculations. + There are continuous efforts to improve data quality.	2[45]
RELIABILITY	– The use of other data sources, modifications in the choice of input variables, and/or conversion factors might change some findings significantly. A more systematic sensitivity analysis would be needed to confirm or reject this possibility. – Calculation methods are not fully documented and, therefore, calculations not fully reproducible. + At least part of the shortcomings could be overcome in principle, and mostly in the short term.	2[46]
COMPLETENESS	+ The Ecological Footprint's ability to take into account the global dimensions of resource use and attribute them to consumers is one of its main strengths. + achieves a comprehensive coverage of elements within the boundaries of the research question (use of biotic resources). – System boundaries are not in all cases clearly defined (e.g. consideration of CO_2 emissions but not of other emissions/waste materials). – does not cover all environmental impact categories (e.g. emissions), signifying a need for complementary resource indicators – A shift of environmental burdens from within the system (i.e. the use of biotic resources) to categories outside (i.e. the use of abiotic resources) cannot be detected but may be of high practical relevance (e.g. .replacement of biodegradable paper with non-biodegradable plastics).	3
Summary appraisal	+ **A unique feature of the Ecological Footprint is that it relates resource use to biological carrying capacity, which is a core issue of environmental sustainability.** + **A core strength of the Ecological Footprint lies in its capacity to condense many aspects of the use of biological resources in one indicator that resonates with a broad public.** + **Another strength of the Ecological Footprint is that it**	

45 The EF's scoring on the Data Quality and Reliability criteria is difficult to estimate. More systematic analysis of marginal errors, as well as third-party review, could provide more certainty on these aspects.

46 See above footnote.

47 On the positive side, it reflects the clear-cut research question that the Ecological Footprint addresses.

Criteria and Subcriteria	Analysis	Score[43]
	reflects the global implications of local resource consumption. + **The Ecological Footprint is suited to monitor changes over time and is sensitive to shifts in the patterns of renewable resource use.** + **EF calculations are based on a complex, advanced, scientifically based and widely discussed methodology that is being refined on an ongoing basis. Many of the remaining methodological shortcomings could be addressed in principle.** – **The scope of the Ecological Footprint excludes, or incompletely addresses, a number of important aspects of resource use, such as the exhaustion of non-renewable resources, the impacts of pollutants on the biosphere and human health, as well as the quality of land use and its implications on biological diversity. While this limitation in scope need not be regarded as a weakness in itself[47], caution is nevertheless required when communicating the results of EF calculations and deriving policy conclusions from them.** – **Transparency, reproducibility and reliability of calculations are to some extent put into question by variable data quality, incomplete documentation and unnecessary complexity.** – **Standard EF accounts are currently not compatible with other international and national accounting systems.**	

+ Aspect rated positively

– Aspect rated negatively

Scoring system:

The indicator/methodology . . .

0 . . . does not address the requirement at all.

1 . . . inadequately addresses the requirement.

2 . . . partly addresses the requirement.

3 . . . suits the requirement well.

4 . . . completely fulfils the requirement.

4.2.7 Annex to the RACER analysis: Impact categories analysis

The suitability of the Ecological Footprint to address various categories of environmental impacts is assessed as part of the *policy support* aspect under the “Relevant” criterion of the RACER analysis. This assessment is done on the basis of a separate checklist based on the impact categories used in life cycle assessment. The scoring system applied in this checklist ranges from 0 (impact category is not covered) via 1 (impact category is partly covered) to 2 (impact category is fully covered). A summary score for all impact categories is given.

As stated previously, some impact categories have higher relevance to current EU strategies on environment and sustainable development than others. Three different degrees of relevance were assigned to the different impact categories. Following discussions among those involved in the study, it was decided not to use a formal weighting system to account for the different policy relevance[48] of impact categories.

The relationship of the Ecological Footprint to individual impact categories requires explanation more detailed than that given in the overview table (Table 3).

Those impact categories associated with harmful emissions (i.e. stratospheric ozone depletion, eco-toxicity, photo-oxidant formation, acidification, eutrophication and ionising radiation)[49] are not directly addressed by the Ecological Footprint but are reflected indirectly to the extent that they lead to measurable alterations in biocapacity. Regarding acidification, studies have acknowledged that accurate data on its detrimental effects on biocapacity are not yet available, but there may be the prospect of including this aspect in the future if better data become available (WWF et al. 2005, p. 14; Dige, 2006, p. 51).

48 Policy relevance, as understood here, means relevance to the EU strategy documents currently in force, without prejudice to future policy developments.

49 Climate change also belongs to this group of impacts but will be discussed in a different context.

Table 3: Impact categories analysis for Ecological Footprint

Impact category	EU Priority[50]	Analysis	Score
Resource consumption	1	+ Resource consumption is at the core of what the Ecological Footprint indicates. + aims for a complete coverage within the category of biotic resources. + unique among indicators in addressing the issue of carrying capacity – does not directly address consumption of non-renewable material resources, nor abiotic renewable resources (e.g. freshwater). [Note: an indicator to monitor depletion of non-renewable resources is not called for in the EU policies relevant to this analysis]	2
Climate change	1	– Effects of resource consumption on climate change are not directly included in the analysis. + The EF calculation includes land required to sequester CO_2 released by energy production, which acknowledges the problematic effects of greenhouse gases. + Some EF studies have started to include other greenhouse gases than CO_2 and emissions from non-energy use related sources.	1
Human health impacts	1	– Not measured by the Ecological Footprint.	0
Impact on ecosystems and biological diversity	1	– EF calculations do not explicitly address these issues. – Focus on biological productivity may lead to policy conclusions that adversely affect biological diversity. + provides some indication about the stress imposed on ecosystems as it is connected with overall pressure from the use of biotic resources. The Ecological Footprint also helps link national consumption with global biocapacity consumed via imported resources (which in turn links to global biodiversity issues). + A methodological discussion on whether and how to include biodiversity criteria is ongoing.	1

50 For the analysis leading to the EU priority scores, see the assessment done in Table 1.

Impact category	EU Priority[50]	Analysis	Score
Land use	2	+ expresses the amount of resources used in terms of land area required to produce these resources, or to absorb wastes. – While there is a certainly a connection to land use, the typical EF applications do not analyse specific land-use patterns.	1
Stratospheric ozone depletion	2	– does not directly address this issue	0
Eco-toxicity	2	– does not directly address this issue (though if eco-toxicity results in lower biocapacity, this will be reflected in future EF accounts)	0
Photo-oxidant formation	2	– does not directly address this issue	0
Acidification	3	– does not directly address this issue (though if acidification results in lower biocapacity, this will be reflected in future EF accounts)	0
Eutrophication	3	– does not directly address this issue (though if eutrophication results in lower biocapacity, this will be reflected in future EF accounts)	0
Ionising radiation	3	– does not directly address this issue	0
Summary appraisal		+ **mainly suited to measure resource consumption and aggregate land use.** – **Impact categories related to the release of waste products in the biosphere (other than CO_2) are only covered to a minor extent.** – **Biological diversity is not directly addressed. Evaluated on the objective to preserve biological diversity, EF calculations show ambiguous outcomes.**	**5**

\+ Aspect rated positively

– Aspect rated negatively

Scoring system: The indicator/methodology . . .
0 . . . does not address impact category at all.
1 . . . partly addresses impact category.
2 . . . fully covers impact category.

4.3 SWOT Analysis of the Ecological Footprint

SWOT analysis is a tool used to identify the strengths, weaknesses, opportunities and threats of an organisation or program's ability to achieve a stated objective. In this study, the SWOT is used somewhat unconventionally to provide the framework to identify the strengths and weaknesses of the Ecological Footprint, as well as the opportunities and threats posed by external factors that could help or hinder its implementation. This analysis will add to the discussion on whether the Ecological Footprint can be used as an indicator to further EU policy goals as outlined in the Resource Strategy and Sustainable Development Strategy.

4.3.1 Strengths

In this section, positive aspects of the Ecological Footprint identified through the previous RACER and impact categories analyses are regrouped as either 'core' or 'important' strengths. These two distinguish between those strengths that are specific to the Ecological Footprint (core strengths) and those that are shared qualities with other sustainability indicators (important strengths).

4.3.1.1 Core Strengths

Easy to understand. The Ecological Footprint can provide a single number to represent the complex relationship between consumption and production across multiple types of resource use and at multiple scales. Both supporters and critics of the indicator agree that condensing these aspects into one number provides a useful communication/education tool (Giljum et al., 2007). The indicator provides a 'warning light' that is easily understood at the individual level and as a comparison among countries and country groupings.

Relates resource use to carrying capacity. The EF measures resource use as compared to the earth's carrying capacity. It links resource use to final consumption, whereby, for example, energy impacts generated to produce a traded good are attributed to the consumer country rather than the producer country (Lenzen et al., 2006b).[51] As discussed above, the Ecological Footprint provides a 'warning light' that calls attention to the long-term degradation of biotic resources. It focuses primarily on energy and land use, and is sensitive to variables related to individual life-style choices (e.g. diet, transportation, housing).

Comparable over time and among countries. The Ecological Footprint is comparable over time and among countries, measuring resource use based on global time series data (Giljum et al., 2007). Although EF results themselves are independent of moral judgements, the EF is particularly well suited as an indicator for global environmental justice (e.g. by relating a country's resource use to its own biocapacity, or relating a nation's per-capita Ecological Footprint to the global average per-capita Ecological Footprint).

Applicable at various levels. While the analyses in this project focuses on National Footprint Accounts and the indicators that can be derived from them, another strength of the Ecological Footprint is that the methodology can also be applied in order to measure resource use at regional and local scale, as well as the product, individual, and enterprise-

[51] Recently, trade data that attributes traded goods to both the consumer and producer countries has been incorporated into the Ecological Footprint through COMTRADE data (Dige, 2006 and Wackernagel et al, 2005).

levels, though these methods are currently not as accurate as the National Footprint Accounts.

Large network supports implementation. There is a large global network hosted by Global Footprint Network consisting of more than 80 government, academic, corporate and NGO partners aiming to improve data quality and the EF calculation to increase its usefulness to policy makers. They are currently developing a guide to the Footprint that will help ensure practitioners use a consistent methodology and obtain comparable results. A key activity of Global Footprint Network is the 'Ten in Ten Campaign' that seeks to implement the Ecological Footprint at the national level in ten countries by 2015. Collaborations have been established so far in five countries: Belgium, Ecuador, Japan, Switzerland and United Arab Emirates. To date, National Ecological Footprint Accounts have been calculated for more than 150 countries (Kitzes et al. 2007a).

4.3.1.2 Important Strengths

Related to policy objectives. The Ecological Footprint is related to the Resource Strategy's objective to reduce environmental impacts from resource use, as its primary focus is on comparing human resource consumption against nature's regeneration of those resources. Detailed information from the national accounts could be useful in setting targets to achieve sustainability goals.

Can be compared with other indicators. The Ecological Footprint can act as a stand-alone figure or can be compared with other indicators. For example, in the 2006 WWF *Living Planet Report*, the global footprint was graphically linked with the UN's Human Development Index (HDI) (WWF et al., 2006). However, when indicators have differing methodologies and systems boundaries, comparisons should avoid overstating the relationship between two indicators (e.g. the per capita of the Ecological Footprint and GDP can be compared among nations, but not meaningfully combined into a system of statistics).

Addresses world-wide environmental implications of local economic activity. As the Ecological Footprint focuses on consumption, not production within a defined geographic area (which can be a country, but also a region or a city), it relates local economic activity to the underlying global consumption of resources. This makes the Ecological Footprint particularly well suited to address global impacts of industry and consumers. By contrast, tracking resource with production-based indicators may lead to interpreting a shift of resource-intensive production to other world regions as a progress in terms of sustainability.

Increased data standardisation and methodological improvements. There is increased focus on data standardisation and methodological improvements to the EF calculation. A research agenda to improve National Footprint Accounts calls for sensitivity analysis of the global data sets and independent review of the Ecological Footprint statistics (Kitzes et al. 2007a). The global network of partners is dedicated to making the indicator more user friendly, while at the same time ensuring that the relationship between consumption and ecological impacts is based on the best-available data and scientific theory.

4.3.2 Weaknesses

In this section, negative aspects of the Ecological Footprint identified through the RACER and impact categories analyses are re-categorised into critical and important weaknesses. A "critical weakness" is a weakness that, as it currently stands, makes it inadvisable for EU institutions to produce or use the Ecological Footprint as an official sustainability indicator. Critical weaknesses should therefore be addressed before implementation by EU institutions. An "important weakness" is a weakness that, as it currently stands, limits the Ecological Footprint's usefulness as an EU sustainability indicator in some way, but is not an argument against implementing it near term. Improvements on these aspects would enhance the Ecological Footprint's value but could be made successively even after implementation of the Ecological Footprint as an EU indicator.

In addition, there is a third category: 'outside the scope of the Ecological Footprint'. These aspects are only indirectly included or not included at all in the calculation, and therefore should be covered by complementary indicators.

4.3.2.1 Critical weaknesses

(Critical weaknesses must be addressed for public sector implementation of the indicator)

Lack of transparency. There is a significant effort being made to make the Ecological Footprint more transparent and user friendly; the National Footprint Accounts and other aspects of the Ecological Footprint are publicly available and in June 2006, Global Footprint Network and its partners adopted the Footprint Standard.[52] However, in some cases, the calculation involves insufficiently documented steps based on underlying assumptions that are not always documented. Thus, calculations are not always reproducible. This will make it difficult for policy makers to develop objectives based on the results of the Ecological Footprint, especially since the results can change if different data sources are used or if different conversion factors are used on the heterogeneous mix of input variables (Schaefer et al., 2006). Efforts are being made by Global Footprint Network to provide more transparency and standardise the methodology (Kitzes et al. 2007a). Global Footprint Network plans to make a complete handbook available for the 2008 edition of the National Footprint Accounts.

Subjectivity in conversion factors and assumptions. In order for governments to adopt the EF as an official statistic, it is crucial that the indicator be science-based and objective. EF results are affected by data sources, choice of input variables and the methodologies chosen for calculating certain conversion factors assigned to them – particularly for the equivalence factors. This may distort the objectivity of the results (Schaefer, 2006). Although the choice of data sources will arguably affect the results of any indicator, it is important that these choices be transparent and consistently adopted. Further, Some of the EF calculations are under-documented, particularly in the case of the equivalence factors. These procedures would need to be more thoroughly documented and tested to ensure they meet the validity criteria of governmental statistical offices. Assumptions need to also be carefully documented and in some cases revised (e.g. treatment of nuclear energy) to be suitable for public sector implementation.

Oversimplification could lead to lack of clarity for policy makers. The strength of the EF as a simple, single-number indicator is also a potential critical weakness. The underlying accounting concept, including the boundaries of the system to be analysed and the reasons

[52] National Footprint Accounts can be downloaded at: http://www.footprintnetwork.org/gfn_sub.php?content=national_footprints ; The Footprint Standard can be downloaded at: http://www.footprintstandards.org

why certain aspects of resource use are included and others excluded, is far less well known by a broader public than the simple 'headline indicator" and this may lead to confusion about what the final, overall indicator actually measures.[53] A significant concern also is that opposite trends in individual input variables may cancel each other out in the final EF calculation. This points to a need to report and interpret data about the components of the aggregate Ecological Footprint. It is also possible that policy conclusions could be drawn from the Ecological Footprint that are actually harmful to the environment (van den Bergh, 1999). The risk of drawing perverse conclusions when using one single indicator is not specific to the Ecological Footprint, but also occurs with other indicators – for instance, when measuring economic performance by GDP alone, or environmental damage exclusively by greenhouse gas emissions. However, it points to the necessity that the indicator be considered among a suite of sustainability indicators and that details from the Footprint accounts be analysed and used to understand the specific drivers behind the aggregate numbers.

4.3.2.2 Important weaknesses

(Important weaknesses could be addressed after public-sector implementation)

Use of global hectares makes 'real' impacts difficult to determine. The EF does not provide information on impacts that can be tied geographically to actual land use (Lenzen, 2003). The calculation is based on a 'global hectare' unit, which abstracts from actual land use in order to allow the aggregation of the Footprint at multiple scales. However, use of this abstract unit makes it difficult to show the actual environmental impacts of an activity. Generally, the use of global hectares is most meaningful when assessing resource use at large geographic scales and across land types. As an activity gets more specific to a particular type of land or smaller in geographic scale, then global hectares become a less useful abstraction. The full EF accounts show actual hectares in addition to global hectares, addressing this concern to some extent. Still, for most people, it is difficult to understand the nuances and relationships of these abstract and actual spatial units. Even where global hectares are converted into local hectares, the EF is not a tool that would make it possible to locate any specific impacts in space.

Multi-functional land use patterns are not considered. Only one type of extractive or waste absorptive land use activity can be considered at a time. This prevents double counting, but also prohibits incorporating the benefits of using land for additional non-extractive uses, some of which have significant environmental and sustainability implications (e.g. water catchment and filtration, biodiversity).

Calculation of energy use is controversial. Energy use (from fossil fuels and nuclear energy) is calculated as the amount of forest that would be needed to sequester CO_2 emissions (less the amount absorbed by oceans). It makes up the largest portion of both the global Ecological Footprint and the national Ecological Footprint of most developed countries. The calculation is controversial for two reasons: 1) there needs to be an in-depth review to verify to what extent the conversion factors used are consistent with the scientific knowledge of forest productivities, and 2) forest-based carbon sequestration may not be the

53 For example, the term "ecological" in the name of the Ecological Footprint suggests that ecosystem and biodiversity aspects are directly assessed, when, in fact these impacts are only indirectly measured, if at all.

preferred means of addressing increases in emissions.[54] Additional concerns are that other greenhouse gases as well as emissions from land use are not included in the calculations due to data and methodological challenges (RPA, 2005 and Kitzes et al., 2007a).

Calculation of nuclear energy is controversial. For lack of a method, and in order to avoid taking sides between nuclear and fossil energy, the stop-gap solution has been to calculate the Ecological Footprint of nuclear energy at par with fossil energy. Nuclear power produces few greenhouse gases (mainly in mining and processing), but has other more diffuse long-term and short-term risks. There is a lack of a clear relationship between nuclear energy and biocapacity that needs to be addressed. Since nuclear energy cannot be adequately assessed from within an EF framework, there is now renewed discussion among those working on developing the Footprint methodology whether nuclear energy should be taken out of the EF accounts. In May 2007, Global Footprint Network's National Accounts Committee voted to exclude nuclear energy from the methodology for National Footprint Accounts.[55] The main argument is that the EF assesses quantitative land areas and does not account for qualitative issues, such as radiation-health interactions; therefore, the most critical impacts of nuclear energy would fall outside of the scope of the Ecological Footprint and require a different indicator.

Data quality/gaps and lack of compatibility with existing databases. There are known weaknesses in the source data used for the EF (Kitzes et al. 2007a). Even though now, the great majority of data used in National Footprint Accounts stem from UN statistics, there are still data inconsistencies that need to be better understood. Some of these inconsistencies come from differences how these data are being collected by countries. In addition, the EF National Footprint Accounts are not yet made compatible with established environmental national accounting systems in Europe, such as the European National Accounting Matrix including Environmental Accounts (NAMEA) (Schaefer et al., 2006). This reduces the ability to compare results and to integrate the Footprint accounts into statistical systems of national government agencies and Eurostat. In addition, although the Ecological Footprint can be combined with other sustainability indicators, due to the fact that it is not aligned with the international System of National Accounts, it is not yet possible to directly link its components to GDP and other mainstream economic indicators (Giljum et al., 2007). However, comparison over time to show general trends between the Footprint and GDP is possible (Dige, 2006).

Lack of data on traded goods. Until recently, it was not possible to consider the energy impacts of traded goods in the exporting country. Instead, the calculation attributed all impacts to the importing country only. While this follows the principle of linking resource demand to final consumption, it does not accurately tie the impacts to the biocapacity of the region producing the traded goods. To date, the "embodied energy" of imported goods has been accounted for by world average values, which does not take into account the specific production conditions in the different exporting countries (see Giljum et al., 2007, pp. 29, 53). In addition, the Footprint of the products a country imports cannot be allocated to specific exporting countries, meaning the effects of a national Ecological Footprint on other countries'

54 EF calculations actually support the conclusion that forest sequestration is not the preferred strategy for dealing with CO_2 emissions; there is not enough possible biocapacity in forests to pursue such a strategy.

55 For the current status of this discussion, see GFN 2007.

ecosystems cannot be localised (see Giljum et al., 2007, pp. 52, 63). Therefore, until trade flows become country-specific, it is not possible to analyse the EF effects of international trade among individual countries. This has been a widely discussed flaw in the Ecological Footprint, but is a difficult analytical challenge that faces international resource indicators generally, as there are data limitations and production chains are complex, frequently involving a number of countries. Global Footprint Network is addressing this issue and new accounts are based on COMTRADE statistics that have data on approximately 600 import and export categories (Dige, 2006 and Wackernagel et al., 2005). In addition, the use of input-output analysis is being considered as a means to make trade balances more sensitive to country differences.

Lack of data on tourism. There is a lack of data on tourism that makes it necessary to attribute tourism impacts to the visited country, rather than the home country of the tourist. This is has been recognised as a methodological inconsistency by Global Footprint Network (Kitzes et al., 2007a).

Difficulties in measuring fisheries yields. Current Ecological Footprints do not show a significant overshoot in fisheries yields. This is likely due to a lack of consideration of declining fish stocks that would be shown through time series fisheries data gathered at the species level. As of now, this data is not easily available, thus the calculation is based on single-year estimates from the FAO (Kitzes et al., 2007a). More work is required to make fisheries measurements more robust.

Difficulties in measuring cropland impacts. While for other land types such as forests, the growth yield is determined by natural productivity and harvest yields may exceed growth yields, this is not the case for cropland. Here, because it is a human-created land type, harvest yields are by definition equal to growth yields, meaning that, by definition, local overshoot for cropland is not possible. This accounting convention fails to detect unsustainable agricultural practices that may lead to high yields in the short term at the price of long-term degradation of soils and ecosystems (Kitzes et al., 2007a). The EF methodology does not take into consideration the fact that there are often unsustainable impacts from intensive agriculture. In light of these concerns, Global Footprint Network is discussing adding additional impacts (e.g. nutrient leaching, groundwater contamination and soil erosion) (Kitzes et al., 2007a). The current methodology does capture conversion of forest and grasslands to agricultural use—an important impact of expanding agricultural activity.

Difficulties in measuring waste flows. Current Ecological Footprints do not include calculations for many waste flows due to lack of data. In cases where relationships are unclear (e.g. SO_x emissions from power plants that result in acid rain) or data do not exist, the particular waste flow is excluded, thereby underestimating the Ecological Footprint as compared to biocapacity (Dige, 2006). This is an intentionally conservative approach, to avoid exaggerating the Ecological Footprint. Though such conservative reasoning is generally acceptable in an NGO application of the Ecological Footprint (e.g. by WWF, where it is seen as against that organisation's own interests), in public-sector applications, there is an expectation of neutrality in statistics, and this issue would need to be addressed in public-sector use of the Ecological Footprint.

4.3.2.3 Outside the scope of the Ecological Footprint (indirectly included or not included at all in the calculation)

Many aspects of resource use are indirectly addressed in the calculation. These aspects include the following:

- Non-renewable resources (e.g. oil, natural gas, coal, and metal deposits) are not directly measured. Energy use is only measured indirectly by calculating the area of forest land required to sequester the equivalent amount of CO_2 emissions. Alternative ways of measuring the carbon footprint have been suggested (see Kitzes et al., 2007a), however the Ecological Footprint will likely not include other aspects of non-renewable resources beyond the amount of biocapacity occupied by their extraction and use (e.g. processing).
- Freshwater resources are only measured indirectly through declining bioproductivity, which is included in the calculation of the amount of available biocapacity. The Ecological Footprint can potentially be paired with the UN SEEA water accounts or could be calculated within the Ecological Footprint as the amount of land needed to provide a certain amount of water (Luck et al., 2007 and Kitzes et al., 2007a). In addition, the 'water footprint' (see Hoekstra 2007a) could be used as a complement to the Ecological Footprint to specifically address the use of water.
- Biodiversity is not explicitly considered in the Footprint because it is not directly related to consumption and production. Global Footprint Network's research agenda suggests that biodiversity could be considered more explicitly in future Ecological Footprint calculations based on links between biodiversity and consumption and production developed in other indicators (e.g. human appropriation of net primary productivity (HANPP)).

Many aspects of resource use are not included in the calculation. The Ecological Footprint is designed to compare human consumption of biological resources against nature's supply of those resources; it is not intended to measure specific environmental impacts. Inevitably, assumptions have been made in order to calculate humans' overall Ecological Footprint. For example, CO_2 emissions are calculated as the amount of forest area required to sequester the same amount of carbon–clearly not a measure that represents the impact of carbon emissions. The Ecological Footprint was designed to be a consumption indicator and not an "impact indicator". Rather, like all indicators, the Ecological Footprint should be coupled with other indicators to provide clear messages for policy makers related to specific impacts of concern. Those aspects that are not addressed at all in the Ecological Footprint are outlined below:

- Non-productive ecosystems (i.e. deserts and icecaps) are not included because they do not have anthropocentrically defined biocapacity. The Ecological Footprint includes 11.2 billion hectares of bioproductive areas that includes 2.3 billion hectares of marine and inland fisheries and 8.8 billion hectares of land (forest, crop, pasture, fisheries, and built-up land) (Wackernagel et al., 2005).
- Coastal estuaries and wetlands are not considered in the Footprint primarily due to lack of data; however, because they represent such a small percentage of the Earth, their contribution to overall biocapacity is not considered significant (Giljum et al., 2007). Human activity in these critical ecosystems can have significant environmental impacts.
- Toxic substances (e.g. PCBs, dioxins, etc.) are excluded from the EF calculation because their impact is not directly tied to a quantifiable land area and, in addition, would render

the calculation meaningless if the time needed to assimilate these chemicals were incorporated on the human timescale (Dige, 2006).

- Future biocapacity is not considered, rather the Ecological Footprint focuses on the present relationship between consumption and production, which can be compared with previous Ecological Footprints to show overall trends. Thus, the Ecological Footprint is not predictive, but will show loss of biocapacity (e.g. that result from environmental degradation) in future accounts (Dige, 2006).
- Social aspects of sustainability, such as, health, social equity, and quality of life, are not considered in the Ecological Footprint. The Ecological Footprint is not intended to be an indicator of social, economic and political aspects of sustainability; rather it is designed as an indicator to measure humans' overall consumption of biological resources and compare it to the Earth's regenerative capacity. However, the Footprint can be plotted over time against the UN Human Development Index (HDI), GDP, and other indicators to create a more complete assessment of our overall progress towards sustainability (Dige, 2006). Data regarding the percentage of biocapacity consumed by certain populations can be used to provide information on social equity issues related to resource consumption.

4.3.3 Opportunities

This section identifies those aspects of the institutional, political, intellectual and technological environments that could help improve the Ecological Footprint, lead to its successful adoption, or both.

Relevance to EU policy. In order to set and achieve measurable targets, indicators need to be identified that measure progress. According to the Sixth Environmental Action Programme and the Resource Strategy, the EU will develop sustainability targets to meet the overarching goals of the Sustainable Development Strategy and UN Commission on Sustainable Development. At the core of these policies is a focus on consumption and production, which is exhibited in the EU's incorporation of life-cycle thinking into its Green Public Procurement (GPP) initiative and effort to develop alternative mainstream indicators. Thus, there is an opportunity to combine the efforts of Global Footprint Network with Eurostat and the Sustainable Development Working Group to develop the EF indicator to inform EU policies, so that it can be used to set targets and guide future policy development.

Window of opportunity. There is a window of opportunity to shape the Ecological Footprint into an indicator that is useful to the European Union. As mentioned above, there is an active network committed to improving the Ecological Footprint that is comprised of more than 80 partners organised by Global Footprint Network. The Network has launched the 'Ten in Ten Campaign' dedicated to supporting the expansion of the Ecological Footprint to ten countries by 2015. Furthermore, the Ecological Footprint is being considered as a potential indicator in the EU set of Sustainable Development Indicators (SDI). Current indicators do not adequately measure the environmental, social, and economic impacts of resource use, thus both NGOs and government agencies are working to align sustainability indicators with mainstream economic indicators. Against this background, there is a significant opportunity to improve the Ecological Footprint.

Improve data quality. Underlying data for the Ecological Footprint comes primarily from the UN Food and Agriculture Organisation (FAO) and other international datasets. Where international data do not exist, gaps are filled from other governmental, NGO, academic or private sources. Where data do not exist or are inconsistent, the Footprint excludes the aspect from the overall calculation, thereby ensuring that the demand on natural resources is not overestimated (Wackernagel et al., 2005). Researchers have suggested that sensitivity analyses and comparison between international and national datasets be performed on these underlying datasets to provide confidence limits on the results (Giljum et al., 2007). Efforts to improve data quality at the EU level could also include co-operation between GFN and Eurostat to include the Integrated Product Policy (IPP), Waste and Natural Resources databases in the Footprint (Schaefer, 2006). In addition, links to existing environmental accounting systems should be improved (NAMEA National Accounting Matrix including Environmental Accounts) at European level or SEEA (Integrated System of Economic and Environmental Accounts) UN level. Databases should be publicly accessible and easy to navigate (Giljum et al., 2007).

Independent review. There is an opportunity to improve individual Footprints and overall methodology through independent third party review. Giljum et al. (2007) note that third party reviews were used by the Irish, Finnish and Swiss governments to improve the data and develop methodology that can be incorporated into the National Footprint Accounts methodology. A review for Japan is currently underway, with additional country reviews to follow.

4.3.4 Threats

This section identifies those aspects of the institutional, political, intellectual and technological environments that could hinder successful adoption.

Lack of standard, transparent methodology. If a standard, transparent methodology cannot be fully developed or is used inconsistently, it could significantly hinder successful adoption of the Ecological Footprint. While significant effort is being made by GFN and its partners to develop a robust national methodology, involvement of European statistical agencies in this process could help ensure that changes in methodology adequately address weaknesses. Global Footprint Network is working to develop a guide to incorporate the undocumented aspects of the calculation and details on specific data sources. As noted by Kitzes et al. (2007a), it will be important to clearly explain differences between old and new Ecological Footprints as the methodology evolves. This will help ensure that Ecological Footprints are comparable over time. Subnational and sectoral EF methodologies are being developed and refined, a process that could actually undermine the credibility of the National Footprint Accounts if it leads to inconsistent methodologies or results.

Lack of unbiased, high-quality data. In order to be useful to government, the Ecological Footprint needs to be unbiased and rely on the best-available high-quality data. There are multiple efforts being made by Global Footprint Network to create lasting collaboration between NGOs and government in order to improve underlying data sources and improve the methodology for specific resource use (e.g. fisheries yields and traded goods). It is important to note that at the global level, differences exist in data collection among countries. Eurostat can help ensure that similar underlying data is used for countries within the European Union and EFTA countries.

Lack of dedicated personnel and resources. The Ecological Footprint requires resources to improve its methodology, data quality and implementation. This threat is tempered by the current momentum created by Global Footprint Network and partners, which provides an opportunity to strategically place resources into the development of the indicator so that it can further the EU's policy objectives.

Use as a stand-alone indicator would be inadequate. Although the Ecological Footprint relates an effective, simple message on its own, it is important to consider the Ecological Footprint within a 'basket of indicators' to be sure that the full range of ecological and social aspects of resource use are considered.

Table 4: Summary of key findings from SWOT analysis

	Helpful to achieving policy objectives	Harmful to achieving policy objectives
Internal attributes of the Ecological Footprint	**Strengths** • Easily understood by the public • Condenses many aspects of resource and land use into one indicator • Can be applied at multiple scales • National EF accounts have been conducted for 150 countries *See also other strengths mentioned in the text.*	**Weaknesses** • Lack of transparency (e.g. calculations are not always reproducible) • Data quality problems and some underlying assumptions are controversial • Oversimplification could lead to lack of clarity for policy makers. • Several environmental impacts not included
External conditions for developing strengths and overcoming weaknesses	**Opportunities** *(potential for improvement)* • Active network improving EF methodology and applications • Opportunities to improve data quality and availability • Could further EU policy goals (especially related to Consumption and Production) • Third party independent reviews would improve validity	**Threats** *(conditions for success)* • Need for high-quality, unbiased data • Collaboration between Eurostat and Global Footprint Network (GFN) is essential • Needs to be used within a 'basket of indicators' • Resources needed to improve methodology and implement it

4.4 Research Agenda for the Ecological Footprint

As part of this study, a thorough analysis was done to identify a research agenda for short- and medium-term improvements to the Ecological Footprint. The results of this work are summarised in a companion report to this one entitled *Agenda for short/medium term improvements to the basket and its individual indicators: The Ecological Footprint*.

4.5 Conclusions and Recommendations

The Ecological Footprint could be an effective indicator for assessing and communicating progress toward the policy objectives of the EU's Resource Strategy. National data can be aggregated at EU scales, disaggregated to understand key drivers, and used to track long-term changes in how resource use relates to carrying capacity. The EU could also capitalise now on a 'window of opportunity' by participating in efforts to make the indicator more robust through independent third party review, methodological improvements, and the development of a collective database for resource use. These efforts to improve the Ecological Footprint could also benefit the development of complementary indicators.

Collaboration between governments and NGOs as well as significant resources are needed to ensure transparent, unbiased and high quality data are used in the calculations. The Ecological Footprint should not be expected to measure all aspects of resource use, but should be considered within a 'basket of indicators' to ensure sustainability at multiple scales and across multiple dimensions.

In addition to its role in the basket of indicators as a measurement of the EU's progress toward sustainability, the Ecological Footprint has the potential to guide policy-making or outreach activities. It is the only indicator that can measure the relationship between a nation's use of global renewable resources and biological carrying capacity at the global levels. It is an intuitive concept that highlights the overuse of renewable resources, and its detailed system of accounts can provide data for various subaggregations and particular activities that could be useful for policy development.

It is important to note that there are many stages in policy making, which often move in a cycle from problem identification to policy selection to policy evaluation, and back to problem identification again. The Ecological Footprint may be best suited to both the initial and final stages in the policy process. The aggregated number is useful in the first two stages of policy development (i.e. problem recognition and investigating the problem/conflicting assumptions), while the detailed system of accounts is useful in the final two stages of the process (i.e. monitoring and evaluation). The overall evaluation of the Ecological Footprint suggests that it can be used within the SDI framework (e.g. in Theme 6: "Production and consumption patterns").

The following are key recommendations for EU institutions and policy makers to use in considering how to implement the Ecological Footprint within the current indicator framework.

1. **Combine with complementary sustainability indictors.** The Ecological Footprint is designed to measure a specific aspect of sustainability (i.e. human demand for renewable resources for production and consumption as compared to available biocapacity). It is not designed to comprehensively measure overall sustainability. Therefore, many aspects of sustainability are missing from the calculation that should be covered by complementary indicators. This is further explored in Task 2 within the project (Final Report Part III).

2. **Use within the Sustainable Development Indicator (SDI) framework.** The Ecological Footprint should be used by EU institutions within the Sustainable Development Indicators (SDI) framework. The SDI framework consists of 155 indicators organised hierarchically to measure 10 broad sustainability themes. It was created by the SDI Task Force in order to monitor the implementation of the Sustainable Development Strategy and was adopted by the European Commission in 2005. The SDI framework currently lacks a measure of global carrying capacity, and the Ecological Footprint can provide a measure of biocapacity with respect to human demand. Thereby it could add an important missing element to the SDIs, specifically with respect to Theme 6 "Production and consumption patterns".

3. **Join the effort to improve the EF methodology.** Global Footprint Network and its partner organisations are dedicated to improving the Ecological Footprint. This includes developing standards, identifying higher quality data and refining the calculation to increase transparency and reproducibility. In order to ensure objectivity in the methodology, EU institutions should partner with Global Footprint Network to ensure that its criteria are met and that the Ecological Footprint can be a useful indicator at the European level.

4. **Develop and use highest quality data.** Resources are required to improve data quality at all levels of government. While this recommendation is not specific to the Ecological Footprint, it is important that resources for data collection and management be dedicated in order to measure all aspects of resource use (i.e. fisheries) to accurately identify sustainability targets. In addition, it is important that different data sources link together. For example, if the system of National Footprint Accounts was compatible with the UN System of National Accounts, it would be possible to link the aggregate Ecological Footprint with GDP. Presenting these two indicators together could help further communicate the problems related to overuse of natural resources (Giljum et al. 2007).

5. **Dedicate resources for implementation and require third party review.** In addition to dedicating resources to improve the data quality and methodology of the Ecological Footprint, resources are also required to implement the Ecological Fooprint at the EU level. The quality of the National Footprint Accounts would need to be consistent with national data and experts will be needed to draw data related to policies and progress toward sustainability targets. Findings from the Ecological Footprint could be bolstered by independent third party review, which would enhance data accuracy and credibility. Third party reviews have already been done in Ireland, Finland and Switzerland.

6. **Explore further possibilities to derive meaningful and easily understood indicators from National Footprint Accounts.** It has become clear from the analysis of the Ecological Footprint that while a nation's total Footprint can serve as a valuable headline indicator, the underlying account system provides a great deal of information that could be used to provide more specific guidance to policies. However, at present, much of such information is "hidden" in the calculation tables. An effort should be made to explore the possibilities to convert the available data into easily understood indicators that could guide sectoral policies, e.g. by assessing the sustainability of trade flows for certain groups of products.

5 Evaluation of the basket of tools

5.1 Objectives of the evaluation

The main objective of this evaluation was to analyse a large number of assessment tools, in order to identify those methods and indicators which could best complement the Ecological Footprint in assessing and monitoring the environmental impacts of natural resource use.

The evaluation was divided into three sub-tasks.

- Review, cluster and analyse alternative approaches with a set of well-defined criteria.
- Selection of a basket of methods and indicators that could provide complementary information to the Ecological Footprint on the impacts related to natural resource use.
- Develop and present guidelines for how uncertainties and risks should be handled and communicated, when applying this set of methods and related indicators for the evaluation of policies.

5.2 RACER and impact analysis of alternative approaches

In the first step the project team assessed a large number of alternative and possibly complementary approaches to the Ecological Footprint. A two-step approach was applied.

5.2.1 Pre-selection of approaches

In a first step, all approaches listed in the project proposal were briefly described and assessed with a set of criteria. These criteria included, among others, the coverage of one or several dimensions of sustainability, the coverage of different environmental categories (materials, energy, land, emissions, etc.) and the location of the method and indicator in the DPSIR framework. The full description of the different approaches as well as the presentation of the summary tables can be found in Annex 2.

This assessment allowed reducing the number of approaches from 25 to 13, which entered the more detailed RACER analysis in step 2. The selection was guided by the demand to remove methods and indicators, which were out of scope for the purpose of this study and to avoid parallel assessments of approaches covering similar fields, while ensuring that the whole range of environmental categories was covered in the selected set.

These following 13 approaches were selected for the RACER analysis:

- Environmental Sustainability Index (ESI)
- Environmental Vulnerability Index (EVI)
- Genuine Savings (GS)
- Index of Sustainable Economic Welfare (ISEW) / Genuine Progress Indicator (GPI)

- Sustainable Human Development Index (SHDI)
- Material Flow Analysis (MFA)
- Environmentally Weighted Material Consumption (EMC)
- Environmental Impact Load (EVIL)
- Physical Input-Output Tables (PIOT)
- Substance Flow Analysis (SFA)
- Energy Flow Accounting (EFA)
- Land and Ecosystems Accounts (LEAC)
- Human Appropriation of Net Primary Production (HANPP)

The selection comprised two environmental score cards (ESI and EVI); three economic-environmental indices/indicators (GS, ISEW/GPI, SHDI); six accounting approaches, focusing on different environmental categories (materials, substances, energy and land); as well as two impact-oriented indicators (EMC and EVIL), which are derived from MFA data in combination with information from life cycle inventories (used for performing LCAs).

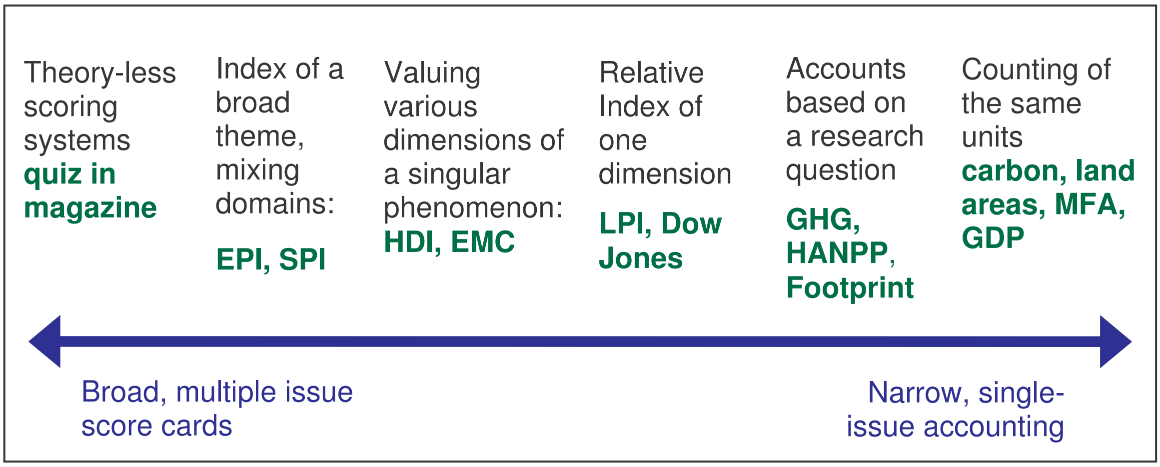
5.2.2 Notes on the selected approaches

Before presenting and discussing the results of the RACER evaluation, it is important to describe some of the main differences of the selected methods and indicators.

Evaluated methods and indicators differ significantly with regard to the underlying research question and policy-oriented purpose of use. The selection of approaches comprises mostly physical measures and indicators, but also economic measures, such as Genuine Savings (GS), the Indicator of Sustainable Economic Welfare (ISEW) and the Genuine Progress Indicator (GPI). The assessment of both types of measures was undertaken within the same evaluation framework, but users of these approaches should be aware that these measures were constructed to answer completely different research questions and address different policy issues. Discussions in the course of the project resulted in the decision that methods and indicators designed for economic research questions (e.g. in the case of ISEW the question whether the benefits of economic growth are being exceeded by additional environmental and social costs) are out of scope for the requirements of Resource Strategy and are therefore not selected in the basket of indicators (see below).

Methods and indicators include both accounting approaches and indices (score cards). Accounting approaches (including, for example, material flow accounting, land use accounting and Ecological Footprint accounting) are designed to address specific and method-independent research questions, such as the use of material resources by societies (MFA), the use of land areas for different purposes (LUA) or the appropriation of regenerative capacities of the biosphere (EF). Indices and score cards, including the Environmental Sustainability Index (ESI) and the Environmental Vulnerability Index (EVI) are a compilation of a large number of sub-indicators, which address multiple environmental issues. These compilations are underpinned by a theory or storyline, but are not built on a specific method-independent research question. Since any environmental issue can in principle be added to such a score card, these approaches tend to be more comprehensive and relate to a larger number of policy issues than single accounting approaches. Therefore they also get ranked higher in the RACER analysis with regard to these aspects. However, there is no specific, empirical definition of what exactly these score cards measure (e.g. in the case of ESI, the very general notion of "environmental performance" is applied). Score cards are therefore useful for policy choices because they make explicit the score card designers' value judgements. Accounting approaches, on the other hand, are more based on scientific inquiries and hence more suited for independent analysis of specific issues. Therefore, the more aspects can be covered using accounting methods, the higher is the scientific robustness. Therefore, in the selection of the basket of indicators, measures as far to the right of the scale (see Figure 8 below) as possible should be picked, while ensuring that the breath of aspects can be covered. However, while accounts are preferable over indices because they can show trade-offs within the issues covered by the accounts, indices work more like alarms. They are sensitive to alarming levels within any of the covered domains, but cannot accurately describe trade-offs among the domains since the weighting is based on relatively arbitrary choices.

Figure 8: The spectrum of approaches from score cards to accounts (with examples)



With regard to the RACER evaluation of the score card approaches undertaken in this project, it should be noted that only the composite indicator was evaluated as a whole, not all its single components. This means that any uncertainty or weakness of sub-components does not affect the undertaken evaluation of the composite indicator. For example, scores in the criterion "transparency" were allocated based on whether or not the method is transparent in the procedure to aggregate the different components of the composite indicators to the overall score. A detailed evaluation of all the underlying sub-indicators was beyond the scope of this project.

Some methods and indicators require weighting of sub-components. Indices or score cards (such as ESI or EVI), but also composite indicators (such as Environmentally-weighted Material Consumption, EMC) require assignment of weighting factors to the different components, in order to enable aggregation. While the method of the aggregation can be clearly described, the reason for the aggregation method is always based on expert judgements, not scientific inquiry. Even if the weights are given equally to the sub-components (as it is the case with different impact categories covered by EMC or with different indicators forming the ESI), this decision is taken on a normative and non-empirical basis. Therefore, users of methods and indicators face a trade-off between more narrowly designed accounting systems (and derived indicators), which are in general more transparent and scientifically sounder (i.e. answering specific research questions), and more aggregated indices, which are broader in scope, but could lead to arbitrary results due to the need for aggregation and scoring of sub-components. If the EU Commission aims at generating one aggregated index on environmental impacts related to resource use in the medium term, weighting of different components will need to be undertaken.

Only EF and EVIL set absolute targets and provide benchmarks for policy evaluation. Apart from the Ecological Footprint (see the Footprint-related chapters in the report for details), the indicator Environmental Impact Load (EVIL) is the only indicator analysed in this document which directly informs users about the gap between the current situation and defined targets. Thus, the Ecological Footprint and EVIL are the only methods that set absolute benchmarks for the evaluation of resource use and environmental policies. An important difference between these two methods is the fact that the absolute limit of sustainable anthropogenic resource use results endogenously from the Ecological Footprint and related biocapacity accounts, while in the case of EVIL targets are scientifically derived, and in some cases further transformed into policy targets (e.g. keeping global warming within a limit of 2 degrees compared to pre-industrial levels). However, it should be noted that the Footprint does not derive legal or normative targets by comparing results to biocapacity. Rather it shows to what extent demand is within or exceeding ecological capacities.

5.2.3 General strengths and weaknesses of the selected approaches

The following table summarises key strengths and key weaknesses of the approaches selected for the detailed RACER evaluation and illustrates potentials for further development. It should be noted that only selected aspects are listed in the table; more detailed information is available in the RACER evaluations (see Annex 3).

Table 5: Key strengths, key weaknesses and future potentials of different approaches

Indicator/Method	Key strengths	Key weaknesses	Potential
Ecological Footprint (EF)	Easy to communicate indicator relating resource use to carrying capacity; addresses world-wide implications of national consumption; can be used to make time comparisons and compare countries.	Missing description of methodology and assumptions for parts of the accounts. Non-renewable resources only indirectly included as demands on biocapacity. Some assumptions (e.g. nuclear energy) still controversial/unresolved	Could be useful as part of a basket of indicators assessing resource use in relation to carrying capacity. Methodology and assumptions could benefit from public-sector participation. Data quality could be improved over time.

Indicator/Method	Key strengths	Key weaknesses	Potential
Environmental Sustainability Index (ESI)	Includes a large number of environmental issues (also the EF); developed with stakeholders and policy makers.	Highly aggregated index (but can be split into components); index design, scoring and aggregation requires normative decisions. Weighs more process than outcome. Method still being refined.	Methodology could be standardised and extended to time series.
Environmental Vulnerability Index (EVI)	Focus on vulnerability issues. Comprehensive index covering many environmental issues.	Scoring and aggregation requires normative decisions. Difficult to evaluate quality of underlying indicators.	If more transparent, could well cover issues related to environmental risks.
Genuine Savings (GS)	Economic indicator, measuring overall capital stock and depletion in monetary units.	Controversial method, but based within the methods included in the SEEA; concept of weak sustainability, assuming substitutability, many core data points need to be estimated.	Could cover a broader range of impacts, if monetary evaluations would be available.
Index of Sustainable Economic Welfare (ISEW) / Genuine Progress Indicator (GPI)	Covers many impact categories in monetary units, illustrates the broader costs related to resource use.	No standard methodology; not compatible with SNA; only case studies available so far.	Could cover a broader range of impacts, if monetary evaluations would be available.
Sustainable Human Development Index (SHDI)	Sustainability index based on reliable data on selected economic, social and environmental indicators.	So far only conceptually developed and tested with data for a few countries.	Could be developed into an easy and communicative index comparing the selected sustainability aspects between nations.
Material Flow Analysis (MFA)	Internationally harmonised methodology for accounting overall resource use. Underlying data base for other indicators (EF, EMC, EVIL).	Low information on impacts; some flows excluded (e.g. water); bulk materials with relatively low data quality dominate aggregated indicator; thus bias in the interpretation of aggregated results. No sectoral information.	Can be valuable data basis for other indicators. High analytical potential, if disaggregated by materials and sectors and linked to economic models.

Indicator/Method	Key strengths	Key weaknesses	Potential
Environmentally Weighted Material Consumption (EMC)	Based on MFA and related production and trade data; covers overall resource use and environmental impacts.	Methodological improvements required how to link material flows and LCA data. LCA data currently used for EMC not freely available and updated only irregularly. Subjective weighting involved to form aggregated indicator. No limits/benchmarks.	Could be developed in short term into a standardised indicator to measure impacts from overall resource use, but method needs partly to be refined and communication / interpretation properties need to be improved
Environmental Impact Load (EVIL)	Based on MFA data; includes several key impact categories; allows illustrating "distance-to-target"	Pilot phase (Germany); so far only abiotic minerals covered; normative decisions involved (definition of EVILs).	High potential as indicator for evaluating raw material policies. Could be expanded to cover also other impact categories and other countries.
Physical Input Output Tables (PIOT)	Complete accounting of nature-economy relationship, including sectoral disaggregation.	Huge efforts for compilation; data only available for few countries; no standards; weak links to impacts.	Potential to develop indicators based on PIOT data, illustrating the (sectoral) driving forces of resource use.
Substance Flow Analysis (SFA)	Detail of analysis; links to specific impacts (depending on substances analysed).	Large efforts for compilation; no standards; missing completeness of scope (substitution!).	Potential to cover all impacts, if substances and questions of analysis are appropriately selected.
Energy Flow Accounting (EFA)	Complete coverage of the energetic metabolism of countries. Complementary to MFA.	Difficult to compile, as EFA goes beyond conventional energy statistics, covering energetic dimension of all products.	Potential to analyse incorporated energy in products and energy consumption induced by use of certain materials.
Human Appropriation of Net Primary Production (HANPP)	Can be linked to MFA and EFA. Good data quality. Possible complements to EF.	Difficult to understand meaning of the indicator. No inherent sustainable threshold. No consideration of international trade of goods and services	Could be developed into one key indicator of human pressures on biodiversity. Accounting of HANPP of traded products possible.
Land and Ecosystems Accounts (LEAC)	Good data quality (for EU); availability of regional and local data. Framework for future integration of ecosystem services, resilience and economic data.	Data deficits for linking to socio-economic activities (land use). Full implementation of ecosystem accounts not available so far.	Could illustrate impacts on ecosystems and biodiversity, if LEAC would be fully developed.

5.2.4 Results and discussion of the RACER evaluation

Numerical scores are subjective and only serve indicative purposes. The 13 tools and indicators shortly presented above were analysed in detail with the extended RACER evaluation framework. The following table provides the results of the numerical scores for each of the five main categories plus the overall score. The range of scores for each sub-criterion lies between 0 (criterion is not addressed) and 4 (criterion is fully addressed). One score was devoted to each group of sub-questions within on criteria and then summed up with equal weighting among the sub-questions.

It shall be emphasised that the scores are only indicative and represent one possible way to allow comparisons between the results of the RACER evaluations of the different methods. The major motivation for preparing this summary table was to highlight those tools and indicators, which stand out compared to the others and to get a rough overview of the overall performance of the single tools and methods concerning the different criteria, which should assist in the identification of the most suited tools for the basket in the next chapter. As noted in the introduction chapter to the RACER evaluation, numerical scores illustrate the subjective opinions of the evaluators. Although the scoring was undertaken in cooperation of at least three representatives of the project team, other evaluators would likely put other scores to different criteria. Therefore, in order to make full use of the information provided by the RACER evaluation, readers should refer to the text of the detailed evaluations for each method, which are attached as Annex 3 to this document.

The following table provides a summary overview of the results of the RACER evaluations. Below the table, notes inform about the main reasons, why the respective methods have not been considered for the basket. The detailed identification of the tools included in the basket through a set of criteria can be found in the next chapter of this report.

Table 6: Summary table of the RACER evaluation

(grey cells indicate main exclusion criteria)

Approach	Relevant	Accepted	Credible	Easy	Robust
EF	2.6	2.0	2.5	2.7	2.6
ESI	1.0	2.0	2.5	2.3	2.4
EVI	1.0	1.0	2.5	2.0	1.6
GS	1.0	2.0	1.5	1.6	1.4
ISEW / GPI	1.2	2.0	1.5	1.3	1.4
SHDI	1.0	1.0	2.5	2.3	1.8
MFA	1.6	2.0	2.0	3.0	2.0
EMC	2.4	2.0	2.0	2.6	2.6
EVIL	2.0	1.0	2.0	1.6	1.6
PIOT	1.6	2.0	2.0	1.3	2.0
SFA	2.2	2.0	2.0	2.3	2.0
EFA	2.2	2.0	2.0	2.3	2.4
HANPP	2.4	2.0	2.5	2.6	2.4
LEAC	2.4	2.0	2.5	2.6	2.4

Notes on main exclusion criteria:

GS & ISEW / GPI... Economic approaches excluded as out of scope for the Resource Strategy

ESI & EVI & MFA ... Excluded due to low scoring in "Relevance" with regard to monitoring impacts

SHDI & EVIL ... Excluded due to low scoring in "Accepted", as approaches only in stage of development

PIOT ... Excluded due to low ranking in "Easy", in particular huge efforts to compile data

SFA ... Despite middle-range score in "Robust" excluded due to focus on single substances (missing comprehensiveness)

EFA ... Despite middle-range score in "Easy" excluded due to significant overlaps with higher scoring methods providing similar information regarding environmental impacts of energy and biomass use (EF, EMC, HANPP)

With regard to the criterion "**Relevant**", which includes both policy relevance and different possibilities for application, the methods EF, EMC, HANPP and LEAC rank highest. All four received high scores in this criterion due to the high relevance for current EU policies, in particular the Resource Strategy, the possibility to identify trends in environmental impacts as well as to the wide spectrum of possible applications (for example, modelling and forecasting studies, regional or local studies).

Most approaches received a scoring of "2" in the criterion "**Accepted**". This reflects the fact that all evaluated approaches have their supporters and opponents in different stakeholder groups. For example, the EMC is a preferred tool with policy makers, as it is an index covering a wide range of environmental impacts, while rather rejected by the basic industry, which receives high impact scores for its products. Approaches involving the monetary evaluation of environmental impacts might be favoured by economists, while environmental scientists will take a very critical opinion on the possibilities and limits of monetarising these impacts.

The methods ranking highest in the criterion "**Credible**" are ESI, EVI, SHDI, EF, HANPP and LEAC (all received a score of 2.5). The first three indices received the high scores due to the high transparency in the calculation of the aggregated index. As emphasised above, only the procedure of aggregation was evaluated here, not the transparency of the different sub-indicators composing the index. Inclusion of these aspects might change the scoring of these score card approaches. The methods EF, HANPP and LEAC scored relatively high as the results can be clearly communicated to policy makers as well as the general public, for example in the form of maps.

In the criterion "**Easy**", MFA received the highest score. This is explained by the good data availability on the national level and the high potentials of integration with other evaluated methods (MFA forms the data base for a number of other indicators, such as SHDI, EMC, EF, EVIL). Other approaches scoring high in this criterion are the EF, HANPP and LEAC. This is in particular due to the high potential of providing complementary information on environmental impacts to other evaluated approaches.

In the criterion "**Robust**", the EF and EMC indicators score highest. Both indicators are comprehensive in terms of natural resources and related environmental impacts covered. Both have a defensible theory, in particular the aim to eliminate one of the main weaknesses of MFA, i.e. the weak link to actual environmental impacts. Also the sensitivity of the sub-components of the two indicators to changes in resource use and related environmental impacts is highly rated.

5.2.5 Results and discussion of the analysis of impact categories

The following Table summarises the results of the analysis of the impact categories covered by each of the evaluated methods and indicators. The detailed analysis tables can be found in Annex 3.

Table 7: Summary of scoring in the analysis of covered impact categories

	EF	ESI	EVI	GS	ISEW / GPI	SHDI	MFA	EMC	EVIL	PIOT	SFA	EFA	HANPP	LEAC
Resource consumption	2	2*	1*	1°	1°	2	2	2	2	2	1#	1	1	
Land use	1	1*	1*		1°			1	1				2	2
Climate change	1	2*	1*	1°	1°	1	1	2	2	1	2#	2		1
Strat. ozone depletion					2°			2			2#			
Human health impacts					1°			2	1		2#			
Eco-toxicity					1°			2	1		2#			
Photo-oxidant formation								2	1		2#			
Acidification								2			2#			
Eutrophication								2	1		2#			
Ionizing radiation								2			2#			
Impact on ecosystems and biodiversity	1	2*	2*		1°			1					1	1
Total score	**5**	**7***	**5***	**2°**	**8°**	**3**	**3**	**20**	**9**	**3**	**17#**	**3**	**4**	**4**

Notes: 2 ... Impact category is well covered.

1 ... Impact category is partly covered.

Empty fields are evaluated with a score of zero.

* ... Composite indices: specific impacts can only be assessed through single underlying indicators.

° ... Economic approaches: impacts are measured in monetary units.

... SFA: impact category covered depends on selected substance.

EMC is leading the score list with regard to the integration of impact categories, directly covering most impact categories. The direct matching between the list of impacts and EMC impact categories is not surprising, as EMC applies LCA data in order to weight different material flows according to their specific environmental impacts. Land use is only partly covered (as quantitative land appropriation of different natural resources, e.g. through mining), biodiversity issues are not addressed.

SFA ranks second in the scoring, however, it must be noted that single SFAs are focusing on one substance only, so depending on the selected substance, one or the other impact category is covered (e.g. a SFA of methane links to climate change, while a SFA of nitrogen links to eutrophication).

With 9 points in total scoring, EVIL ranks third, however, impacts are not calculated on a cradle-to-grave basis (as is the case with EMC), but only for the provision of the raw materials (e.g. impacts of mining).

HANPP and LEAC score best for the impact categories of land use and relate to impacts to ecosystems and biodiversity. Further development of LEAC into full Land and Ecosystem Accounts (LEAC) have large potentials for providing direct links between land cover / land use and biodiversity (see below for details).

The composite indices EVI and ESI address a number of impact categories, however, detailed information about specific impacts cannot be extracted from the aggregated index, but only from the underlying indicators (for example, carbon emissions per capita linking to climate change or fertilizer consumption per hectare of arable land linking to eutrophication). Some of the underlying indicators directly relate to biodiversity issues (for example, the indicator of “Threatened mammal species as percentage of known mammal species in each country” as part of ESI).

Economic indicators (such as GS and ISEW) measure impacts in monetary units and thus could complement physical measures with an economic perspective.

5.3 The basket of tools

One key objective of this project is to identify a basket of a limited number of complementary methods and indicators, which are suited for evaluating progress towards the objectives of the Resource Strategy, in particular the reduction of negative environmental impacts related to natural resource use through de-coupling from economic growth.

5.3.1 Selecting the basket through a set of criteria

We start with a description of the criteria, which the basket of tools needs to fulfil. Three main criteria were considered in the selection: (a) policy relevance, (b) high ranking in the RACER evaluation (c) completeness and complementarity. Applying these criteria will help identifying the most suitable tools and indicators, which will be considered in the basket.

5.3.1.1 Policy relevance

As described in detail in the introduction chapters of this final report, there are various policy documents elaborated by the Commission, in particular the Resource Strategy (European Commission 2005e), which aim at a more sustainable use of natural resources. In general, this should be brought about by achieving a decoupling of economic growth from resource use and its negative environmental impacts, which should also prevent exceeding nature’s carrying capacity.

It is worth emphasising that the Resource Strategy demands in particular for aggregated indicators, providing an overall assessment of the large number of policy initiatives, which contribute to the objectives of the Resource Strategy. These related policy initiatives include product- and technology-oriented strategies (e.g. IPP, ETAP), sectoral reforms (e.g. CAP), and regulations for specific types of materials (e.g. REACH).

Tools and indicators selected for the basket should allow applications as aggregated measures on the macro level as well as calculation of more disaggregated and more specific indicators based on the detailed underlying accounts and data structures. While the first application is suited for evaluation of the overall objectives of the Resource Strategy, the second application is better suited to assess the effectiveness of specific sectoral policies or to provide assessments on different spatial scales (e.g. regional or local levels; see chapter on policy application of the basket for details).

The Resource Strategy demands for physical measures illustrating environmental impacts from resource use. Therefore, the economic measures GS and ISEW/GPI will not be considered in the basket. All other tools and indicators relate to existing EU-specific policy objectives and can, in different forms, be used for monitoring, strategic policy making and target setting. They therefore pass this criterion as possible candidates for the basket.

5.3.1.2 High ranking in the RACER evaluation

As specified in the EC's *Impact Assessment Guidelines* for indicators in general, one important criterion for being selected into the basket of tools/indicators is a high score in the RACER evaluation. The RACER evaluation undertaken for a number of potential candidates for the basket (see above) illustrates the overall quality of the different methods.

Apart from the two economic approaches already excluded from the basket, seven other approaches scored low in one or several of the RACER categories and thus received a lower overall scoring compared to other approaches. The low scoring can be explained specifically for the different indicators. The score card approaches ESI and EVI score low in the criterion "Relevant", in particular as potentials for use in forecasting and modelling are very limited, availability of data on sectoral and regional/local level is very poor and as the criterion to allow function- and needs related analyses is not fulfilled. The SHDI also performs low in "Relevant", but in particular in "Acceptance", as the concept is only under development and has only been tested in one pilot study. The same holds true for EVIL, which is currently in the stage of development. Finally, PIOT scores particularly low in the category "Easy", as data collection is very expensive and time consuming and therefore PIOTs so far only exist for a small number of countries and years.

5.3.1.3 Completeness and complementarity

The identified basket of tools should cover a maximum number of different categories of environmental impacts through the set of derived tools and indicators. At the same time the number of selected tools should be as small as possible, in order to keep data collection and data transformation efforts low and to allow a concise and easy communication of results to policy makers and the general public. Therefore, methods should be selected, which cover different impact categories, while ensuring that the complementarities between the different indicators are fully taken into account.

After having excluded a number of approaches, which either are not relevant regarding the objectives of the Resource Strategy or are not of sufficient overall relevance or quality, the following seven approaches remain as the most suitable candidates for the basket: EF, MFA, EMC, SFA, EFA, HANPP and LEAC.

From this list, Substance Flow Analysis (SFA) is excluded, as it is not comprehensive in terms of including a large number of natural resources into an overall indicator or index (which is demanded by the Resource Strategy). SFA therefore does not pass the criterion of completeness.

Material Flow Analysis (MFA) is excluded, as the physical quantities of resource flows provide limited information on related environmental impacts, although some correlation between the physical quantities and the related environmental impacts can be observed on the aggregated level (van der Voet et al., 2005). Other indicators of the group of potential indicators are better suited for this purpose. However, material flow accounts are a key accounting framework which is used as an underlying data base by several other indicators, in particular the Footprint, EMC and HANPP.

Finally, we exclude Energy Flow Accounting (EFA), as all environmental impacts related to energy flows are covered by other indicators, i.e. climate change impacts as well as pollution (e.g. from fossil fuel use) is covered by EMC, land use impacts by HANPP and LEAC and impacts on the overall demand on biocapacity can be illustrated by the Footprint.

Consequently, four tools and indicators remain for consideration in the basket:

- Ecological Footprint (EF)
- Environmentally Weighted Material Consumption (EMC)
- Human Appropriation of Net Primary Production (HANPP)
- Land and Ecosystems Accounts (LEAC)

We want to emphasise that the selection of those four tools and related indicators is based on the current state of the art. The Resource Strategy defines the ultimate objective to develop one aggregated indicator, illustrating the environmental impacts related to resource use with a single score. Therefore, future effort will be devoted to further development and extensions of the different tools, which might allow integration of some of the components in the basket and thus reduce the number of indicators.

In the following, we provide a short description of the state of the art of these four indicators before discussing which impact categories can be directly and indirectly covered by each of the tools/indicators.

5.3.2 Summary description of the four tools included in the basket

5.3.2.1 Ecological Footprint

The state of the art in Ecological Footprints is described extensively in the Footprint-related parts of this report. Therefore, we refer to the respective chapters in the report.

5.3.2.2 Environmentally-weighted Material Consumption (EMC)

The EMC was developed in 2003 (van der Voet et al., 2003) as a method to track the contribution of different materials to environmental problems. Thereby, following the simple idea to multiply data on raw material and energy use with a factor representing their environmental impact (van der Voet et al., 2005), information on environmental impacts per mass unit is combined with information on the weight of material flows. This environmental impact is derived by using life cycle inventory data sets together with life cycle impact assessment methods, for each single emission. LCA is an internationally standardised method (ISO 14040 series). In comparison with the other indicators reviewed, the EMC is the only one incorporating the lifecycle approach in such an extensive degree, giving it a special significance for the indicator basket. The EMC is one example of how physical production and consumption data on the product level can be combined with LCA data to form an aggregated indicator on environmental impacts related to resource use.

In the EMC, for every considered material its contribution to environmental problems throughout its life cycle is estimated, using the total cradle-to-gate plus recycling/depositing impact of the material per kilogram and the number of kilograms of this material being produced and/or used. For the former information, the CML LCA software (Heijungs, 2003) and a LCA database, the ETH database (Frischknecht, 1996) and its further developed version, the Ecoinvent database (Frischknecht et al., 2004), are used in the EMC method. The elaborated life cycle inventory (LCI) aims at the specification of all environmental interventions in terms of extractions and emissions related to the production and recycling/disposal life cycle stages of 1 kg of each material. For energy carriers their use, i.e. incineration, is considered analogously. Importantly, out of these results the contribution to 13 different impact categories was derived (van der Voet et al., 2005). For the latter information – production/consumption of materials – the main source of information were the MFA accounts presented in the Zero study (Moll et al., 2003), refined in the project by van der Voet el al. (2005). It should be emphasised that in various cases – e.g. due to too high aggregation levels or lacking confidentiality – national sources are incorporated, in order to refine the basic data on consumption of different raw materials and products. As the MFA-based indicator “Domestic Material Consumption (DMC)” includes raw materials extracted from the domestic environment (in addition to imports and exports), while the cradle-to-grave impact factors refer to finished materials, imported or domestically extracted raw materials have to be translated into finished materials (van der Voet et al., 2005).

Some of the conclusions stated in the work by van der Voet et al. (2003) underline the importance and the potential this indicator could have in the basket. The authors were able to show that materials have a large contribution to environmental problems, whereby the contribution of specific materials to specific problems is variable. Comparing the production and the waste management phase, it was elaborated that the majority of the examined materials cause the main environmental problems during the production process. Here it is important to state that not only the material itself but especially the energy and auxiliary materials used for their extraction significantly influence the total contribution to environmental impacts. This is an important aspect where the EMC could provide valuable information for policy makers. For policies aiming at improving the processing of the material with regard to the use of energy and auxiliary materials, this is significant. In contrast, the data do not allow deriving policies aiming at limiting the use of certain materials, as this would only result in a shifting of burdens to other materials; there is no link between the products and the use phase and such misleading use of the data is a risk and should be avoided. This risk is also one of the two main reasons why basic materials industry is opposing the EMC, but ask for more complete product-related indicators of overall resource use and impacts.

Generally, materials with a high contribution per kilogram in connection with large volume flows are found among the top-scorers, while this is to be expected with such an approach. It was illustrated that biomass from agriculture, iron and steel, aluminium, concrete and cement, some plastics, and some heavy metals deserve special policy attention with regard to their contribution to environmental problems and measures to improve their production.

We see the EMC – or related approaches that mainly base on life cycle inventory data combined with MFA or production and trade statistics – as complement in the basket of indicators. Their strengths certainly lies in the fact that it is providing the main part of the information concerning human toxicity, acidification, ecotoxicity, etc. and better capture climate change emissions in a consistent approach, and that it fully captures the life cycle perspective which other indicators are mainly or fully lacking.

5.3.2.3 Human Appropriation of Net Primary Production (HANPP)

HANPP, the "human appropriation of net primary production", was first scientifically described by Vitousek et al. (1986). There are various approaches for defining and calculating HANPP. The concept presented here is based on the definition of Haberl (1997), who defined HANPP as "the difference between the amount of NPP that would be available in an ecosystem in the absence of human activities (NPP_0) and the amount of NPP which actually remains in the ecosystem, or in the ecosystem that replaced it under current management practices (NPP_{act})". Following Haberl et al. (2007), in order to call an indicator HANPP, it has to refer to areas of land, not to the biomass consumed by a defined population; it has to comprise the assessment of the difference between NPP_0 and NPP_{act}, the amount of NPP produced by the actual vegetation; avoids being too inclusive, while not being restricted only to biomass directly used by humans.

HANPP has been considered as especially valuable as a measure of the physical size of an economy relative to the ecosystem, in which it is embedded (Daly, 2006). Hence, it is indicating to which extend human society is dominating the ecosystem (Vitousek et al., 1997). In other words, as NPP is a central parameter of an ecosystem's functioning, HANPP can be seen as an indicator of human pressures on the same. Regarding the steadily growing world population, the discussed indicator draws attention to the risk of using biomass for energy production as this would conflict the increasing demand for biomass products for nutrition purposes. But apart of this rather 'modern' competitor for biomass, it is primarily the pressure put by the ongoing conversion of valuable ecosystems (e.g., forests) to infrastructure, cropland or grazing land (Millenium Ecosystem Assessment, 2005, Lambin and Geist, 2006, FAO, 2004) which HANPP is relating to. Recently, the first estimations of HANPP on the global level were presented (Haberl et al., 2007).

5.3.2.4 Land and Ecosystem Accounts (LEAC)

Work on land cover and land use accounts are part of the international efforts to create environmental accounts as satellite accounts to conventional SNA. These satellite accounts should inform policy makers about the contribution that natural systems provide for socio-economic processes as well as impacts of the economy on the environment (United Nations et al., 2003).

In 1985, the EC started to build-up a harmonized land cover database, the so-called Corine (Coordination of Information on the Environment) land cover (CLC) system, which was recently used by the EEA for producing land cover change accounts. Corine is a standardized land cover inventory derived from satellite image, using a 100 m x 100 m grid. CLC data is currently available for 24 countries, most of them producing data for two time periods (around year 1990 and 2000). The system is currently being updated and it is planned to increase the number of countries to 35 (EEA, 2006).

The CLC aims to describe the geographical patterns of different land cover types across Europe, the way they changing over time and the types of processes that are driving these transformations. Therefore, in addition to stock account and change accounts, which inform about size and change in the individual land cover categories (artificial areas, crop land, pastures, wetlands, etc.), flow accounts have been established. These flow accounts illustrate in detail, which developments drove the observed stock changes. For example, urban land in Europe in the past 15 years increased in particular due to land uptake by housing, services and industrial/commercial sites, and the increase was mainly on the cost of arable land (almost 50%) and pastures (36%).

Although the CLC data focus on land cover, it is the explicit goal to further develop the accounts towards better inclusion of aspects related to land use. In theory, land cover flows can be related to socio-economic activities through a transformation matrix of land use functions, which illustrates, which land cover is appropriated by which socio-economic land use function. The relationship between land cover and land use is relatively straight-forward for some land cover / land use categories (e.g. arable land correlating with agriculture), but is difficult for other categories (e.g. built-up land and the relation to different industry / service sectors). Therefore, the analysis of the linkages between land cover and the economy remain one of the key objectives for further development of the CLC data base.

The CLC data base has recently been further developed into the Land and Ecosystem Account database (LEAC). In this data base, the 100 m x 100 m raster files from the CLC data base were assimilated into larger grids, in particular 1 km x 1 km, in which the detailed information on CLC stocks and changes are fully included. This allows the processing of the underlying data more easily into different maps representing Dominant Landscape Types, or the so-called Green Background Index, and recently the Net Landscape Ecological Potential (NEP), which combines landscape natural values and fragmentation.

The EEA recently presented its views on the use of ecosystem accounting for integrating economic-environmental accounting to the Beyond GDP Conference (Brussels, Nov. 2007)[56] and to the UN London Group (Rome, Dec. 2007).

5.3.3 Impact categories covered by the basket

In the following, we provide a description of the impact categories, which can be covered by the basket. Based on the policy priorities of current EU environmental policies, a

[56] http://www.eea.europa.eu/highlights/beyond-gdp

prioritisation of the different impact categories was elaborated in a previous chapter of this report. Three levels of priorities are distinguished:

- Priority 1: Resource consumption, climate change, human health, impacts on ecosystems/biodiversity.
- Priority 2: Land use, ozone depletion, eco-toxicity, photo-oxidant formation.
- Priority 3: Acidification, eutrophication, ionising radiation.

It should be emphasised that this priority setting is only indicative and explicitly takes the perspective of current EU environmental policies. Consequently, priority 1 issues reflect the main thematic priorities of the 6^{th} EAP (and Thematic Strategies) and the EU SDS.

Other approaches for grouping the impact categories are possible, since some categories are closely linked to each other. For example, resource consumption, climate change, land use and impacts on ecosystems and biodiversity could form one group of impacts.

In the following we will discuss the different impact categories as presented above and select the most suitable tool/indicator for each category, starting with priority level 1.

5.3.3.1 Priority 1: Consumption of resources / materials

- Selected tool/indicator: **Ecological Footprint**

Two specifications of impacts can be distinguished for this impact category:

- depletion of abiotic resource and
- impacts related to the (over)use of biocapacity / carrying capacity of the planet.

Resource depletion of abiotic resources is not regarded as a key issue in the Resource Strategy, as it is regarded rather as an economic issue, and thus no indicators are presently considered for this impact field.

Regarding the impacts on biocapacity and the assessment of the (over)shoot beyond the carrying capacity of the global ecosystems, the Ecological Footprint to our view is the indicator best suited to illustrate these types of impacts. By answering the question, how much of the regenerative capacity of the planet is occupied by a given human activity or population, the Ecological Footprint allows setting the demand for biological capacity in relationship with the availability of this biocapacity over time and around the globe. In the context of environmental sustainability, the EF's value therefore is to enable a quantification of human demands against the background of ecological limits and to illustrate possible "overshoot" beyond the carrying capacity of the planet or local ecosystems.

5.3.3.2 Priority 1: Climate change

- Selected tool/indicator: **EMC**

We suggest applying EMC as the indicator for this impact theme. The main argument for the selection of EMC is that it is based on a large number of different (biotic and abiotic) material flows and thus provides clear links to the amount of natural resources used by different sectors or economies. EMC therefore allows analysing the causal links between the energy basis of economies and climate impacts as well as analysing the consequences for global warming of those materials, which require huge amounts of energy for extraction and processing (such as aluminium). Furthermore, the GHG impact factors applied in the EMC concept cover the whole life-cycle of materials and thus are more comprehensive than those used by other methods (e.g. EVIL).

The EMC methodology transforms emissions of greenhouse gases to the air (in kg) into global warming potential (expressed as equivalents of carbon dioxide).

5.3.3.3 Priority 1: Impacts on human health

- Selected tool/indicator: **EMC**

Also for this impact category, we suggest applying EMC, as it operationalises this impact category by the life-cycle wide human toxicity impacts of a wide range of material resources.

Impacts are measured in terms of emissions of toxic substances to air, water and soil (in kg) and transformed into human-toxicity potential by using a unified references unit (kg of 1,4-dichlorobenzene equivalent/kg emission).

5.3.3.4 Priority 1: Impacts on ecosystems and biodiversity

- Selected tool/indicator: (**HANPP and LEAC)**

Of the group of remaining candidates for the basket, three tools/indicators are of relevance for this impact category: EF, HANPP, and LEAC. However, as the impact analysis revealed, none of those three indicators directly relates resource use to impacts on ecosystems and biodiversity; therefore, the indicators are put in brackets. They only allow assessing indirect consequences on this impact category through providing information on the intensity of ecosystem use by human beings (HANPP) and the main socio-economic driving forces leading to land cover and ecosystem changes (LEAC).

The Ecological Footprint measures how much of the overall biocapacity is under human dominance, but not how intensely each piece of the biosphere is being used. HANPP measures this intensity of use by illustrating how thoroughly ecosystems are being exploited by humans compared to a natural state of the ecosystem, uninfluenced by human beings. Typically, high demand on ecosystems is correlated with biodiversity pressure. HANPP and Footprint could therefore complement each other in that HANPP measures the “depth” of the Ecological Footprint, i.e., how intensely these Footprint areas are being occupied by human activities. We suggest including HANPP as one indicator in this impact category.

LEAC is suggested as an additional tool under this category, as it provides additional and complementary information to HANPP and the Footprint. LEAC allows analysing the main *socio-economic drivers for land cover changes*, which are one of the main causes for changes in ecosystem functions and biodiversity loss. Thus the LEAC system is better suited than HANPP to monitor the impacts of land management policies, as it links the actual patterns of land cover with the land areas used for different economic purposes (e.g. industrial production, transport, construction).

5.3.3.5 Priority 2: Land use

- Selected tool/indicator: **HANPP and LEAC**

As stated in the last paragraphs, both HANPP and LEAC provide valuable information on the impacts of natural resource use on land cover and land use and their changes over time. Also for this impact category, we suggest keeping both HANPP and LEAC as tools in the basket. As with biodiversity, these two tools provide complementary information.

HANPP allows transforming extraction of biomass in agricultural and forestry sectors into an illustrative measure of the level of human pressure on used land areas, normally presented as a map. Time series of HANPP can illustrate, whether human pressure on land areas have been increasing or decreasing in a specific geographic area.

On the other hand, the LEAC data system is more comprehensive, as it distinguishes a large number of different categories of land cover and land use. However, macro indicators based on this complex data system are only currently being developed (see research agenda below). The key advantage of LEAC here is it allows analysing patterns of land use change and their underlying socio-economic driving forces. One example is the process of sub-urbanisation, driven both by spread of industrial/commercial areas beyond the city borders and expansion of residential areas, and the consequences for transformations of one land cover category (e.g. arable land) into another (e.g. urban land).

5.3.3.6 Priority 2: Ozone depletion, eco-toxicity, photo-oxidant formation

- Selected tool/indicator: **EMC**

For all three sub-categories, EMC was identified as the best-suited indicator, providing the most direct link to natural resources used by sectors and economies. Properties such as the life-cycle perspective and the comprehensive data basis, which have already discussed above, made EMC the favourite choice.

5.3.3.7 Priority 3: Acidification, eutrophication, ionising radiation

- Selected tool/indicator: **EMC**

Also for those impact categories representing priority level 3, EMC was selected as the best available tool to monitor these impacts. EMC is based on data from economy-wide material flow accounts and thus enables establishing a direct link between the amounts of resources used by a society and the consequences for acidification, eutrophication and ionising radiation.

Table 8 summarises the suitability of the four indicators to cover the identified categories of environmental impacts. All selected tools and indicators cover more than one impact category, however, only the dark cells represent those tools that cover the respective impact category sufficiently and are therefore suggested as the main tool/indicator in the basket.

Table 8: Coverage of different impact categories by the tools/indicators in the basket

Impact category	Priority level	EF	EMC	HANPP	LEAC/Corine
Resource consumption	1	fully covered	partly covered	partly covered	
Climate change	1	partly covered	fully covered		
Human health	1		fully covered		
Ecosystems and biodiversity	1	partly covered		partly covered	partly covered
Land use	2	partly covered	partly covered	fully covered	fully covered
Ozone depletion	2		fully covered		
Eco-toxicity	2		fully covered		
Photo-oxidant formation	2		fully covered		
Acidification	3		fully covered		
Eutrophication	3		fully covered		
Ionising radiation	3		fully covered		

- Impact category fully covered
- Impact category partly covered

5.3.4 Summary presentation of the basket of tools

After the discussion of the different impact categories and the corresponding tools/indicators, the following table presents the basket of tools in a summarised form. The table lists the main issues and questions, which the different tools/indicators address, the covered impact categories, the complementary properties of the tools in the basket, the data requirements as well as the general strengths and limitations/weaknesses.

It should be noted that the approaches HANPP and LEAC differ from the EF and EMC, as the former do not include aspects of burden shifting related to international trade of goods and services. Therefore, HANPP and LEAC in general[57] do not take a life-cycle perspective related to the production and use of products.

57 It shall be emphasised that current research work is ongoing to calculate HANPP embodied in internationally traded products. However, both HANPP and LEAC are so far mostly applied on the regional and national level, without taking into account trade issues.

Table 9: Basket of tools, summary table

Tool	Main issues addressed	Covered impact categories *	Complementary property in basket	Data requirements	Strengths	Limitations and weaknesses
EF	How much of the regenerative capacity of the planet is occupied by a given human activity or population? In which countries is biocapacity located?	Resource consumption (Climate change) (Land use) (Impact on ecosystems and biodiversity)	Provides clear benchmark for assessments of carrying capacity and overshoot. Allows assessing the impacts of natural resource use on the regenerative capacity of ecosystems.	Data on material flows, land use and CO_2 emissions. Conversion factors for transformation of resource and waste flows into necessary biocapacity to sustain flows (measured in global hectares)	Integrates all resource use in terms of demand on regenerative capacity. Allows relating human demand to supply by nature and determining clear target. Considers trade flows (incl. embodied energy). Based on a clear research question.	EF cannot cover impacts for which no regenerative capacity exists (e.g. pollution in terms of waste generation, toxicity, eutrophication, etc.). EF shows pressures that could lead to degradation of natural capital (e.g. reduced quality of land or reduced biodiversity), but does not predict this degradation.
EMC	What is the global environmental impact potential of materials consumed in a national economy and where does it occur in the production and recycling of materials?	Climate change Human health (Land use) Stratospheric ozone depletion Eco-toxicity Photo-oxidant formation Acidification Eutrophication Ionizing radiation	Covers impacts independent from absorption capacities, such as human health and eco-toxic impacts of certain materials or issues of ozone depletion, eutrophication, acidification, etc.	Material flow data / production and trade statistics. Data on life-cycle wide emission inventories and environmental impacts of different materials.	Comprehensive measure based on biotic and abiotic resource accounts. Covers a large number of LCA impact categories. Includes direct trade flows and life-cycle wide impacts associated with these flows.	Not an accounting approach, but an aggregate of separate assessments. Subjective weighting involved to calculate aggregated indicator. No endogenous definition of benchmarks / sustainable levels.
HANPP	How intensely are ecosystems being used by human beings?	(Impact on ecosystems and biodiversity) Land use	Relates material flows (biomass extraction) to pressures on ecosystems. Monitors the intensity of ecosystem and land use and establishes links to natural capital deterioration (e.g. soil erosion) and pressures on biodiversity.	Agricultural and forestry statistics and inventories, land use statistics, remotely-sensed (satellite) data.	Provides an illustrative and spatially explicit indicator on human pressures on ecosystems. Can serve as early warning indicator for land degradation and pressure on biodiversity.	No endogenous definition of benchmarks / sustainable levels. No consideration of trade and trade-related demand on biosphere.
LEAC	For which economic activities are different land areas being used? Which are the socio-economic drivers for land cover changes?	(Impact on ecosystems and biodiversity) Land use	Links land cover change to socio-economic (sectoral) aspects of land use. Assesses spatially explicit consequences of resource use for land cover change.	Remotely-sensed (satellite) data. Data on net primary production. Demographic data and spatially distributed economic data.	Provides a SEEA-compatible account for impacts of resource use on land cover and land use and changes over time. Bridges with monetary valuation of ecosystem services and maintenance costs of ecosystems.	Sectoral information (in particular, industry and service sectors) very aggregated. No endogenous definition of benchmarks / sustainable levels. No consideration of trade.

* Note: Brackets indicate that impact category is only partly covered.

5.4 RACER analysis of the basket of tools

In the following, we provide a RACER analysis of the basket of tools and indicators selected to monitor the negative environmental impacts related to natural resource use.

The following table provides a summary of the RACER analysis for the basket. It shall be emphasised that putting numerical scores to the single criteria was in some cases challenging, as one tool/indicator fulfilled a certain criterion, while another failed. The scoring should thus is as an average scoring across all four tools/indicators in the basket. For a detailed description for each tool, the reader should refer to the detailed verbal explanations.

Table 10: Summary results of RACER evaluation of the basket

	Relevant	Accepted	Credible	Easy	Robust
Basket of tools	2.4	2.0	3.0	3.0	3.0

In comparison to the RACER evaluation of the single tools and indicators, the basket performs better than any of the single methods. The basket receives a high score for the criterion “Relevance”, as it fully relates to the objectives of the Resource Strategy and other key policy documents, helps guiding monitoring and strategic policy making and allows identifying and analysing trends in environmental impacts. The basket receives a medium result with regard to “Acceptance”, as the tools/indicators have so far only partly been considered in official EU indicator sets, although acceptance in the academic world of several tools in the basket is well established. “Credibility” of the basket is rated higher than any of the single approaches, as it expected that results derived from different tools in the basket reinforce each other to provide a more unambiguous overall message, which can also easily communicated to policy makers and the general public. Scoring is also high for the criterion “Easy”, as data availability is in general good and the four tools selected for the basket complement each other, with potentials to further integration in the future. Finally, the basket also scores high in the criterion “Robustness”, particularly as the underlying theory of the selected approaches is robust (i.e. the tools and indicators are oriented towards accounting approaches rather than score cards) and the basket is complete, allowing to monitor potential shifts of environmental burden between different environmental categories as well as between different countries and world regions.

In the following table, we provide the detailed RACER evaluation of the basket.

Table 11: Detailed results of RACER evaluation of the basket

Criteria and Subcriteria	Analysis	Score
Relevant		**2.4**
Policy support, identification of targets and gaps	• *Is the indicator/methodology related to existing EU-specific policy objectives?* The basket of tools/indicators fully relates to the objectives of the Resource Strategy and the key policy priorities stated in other related environmental and sustainability policy documents (such as the 6th EAP and the EU SDS). • *Does it provide guidance in monitoring, strategic policy making and/or target setting?* All four tools/indicators suggested for inclusion in the basket allow monitoring past trends of different types of impacts related to resource use. Different aspects of strategic environmental policy making are supported by the basket of tools/indicators. The Footprint highlights those consumption areas (in particular fossil energy consumption), which cause environmental pressures beyond the carrying capacity of local or global ecosystems. EMC allows identifying those natural resources with the most severe impacts on climate change and on pollution-related and health impacts. HANPP and LEAC enable to identify geographical areas with the highest pressures on land area, ecosystems and, indirectly, on biodiversity. LEAC in addition allows establishing links between socio-economic pressures on land areas (e.g. expansion of commercial areas). In terms of target setting, the Footprint is the only indicator, which sets a reduction target endogenously by comparing Footprint against biocapacity. All other indicators require external setting of (policy) targets. In terms of target setting, the EF is the only indicator, which sets a reduction target endogenously from the structure of the (Footprint and biocapacity) accounts. All other indicators require setting (policy) targets external to the method. • *Does it quantify gaps between the current situation and specified targets?* All four methods allow quantifying these gaps, whether the target can directly be derived from the accounts (Footprint) or is externally defined (EMC, HANPP, LUA). On the global level, the Footprint terms this gap "overshoot", defined as the gap between the current annual use of biocapacity and the available supply by ecosystems. Targets can be defined also for the other tools/indicators and gaps	3

Criteria and Subcriteria	Analysis	Score
	can be quantified. Targets for extensification of the use of natural systems (e.g. through reforms in agricultural policies) can be monitored with HANPP. Targets for land cover change within a given territory (e.g. maximum annual level of increase of built-up land) can be monitored quantitatively with LEAC. • *Does it provide adequate early warning to guide policy action?* The basket is relatively weak in terms of early warning messages for policy makers, as all four indicators are outcome measures. In other words, they are designed to document past and current occurrences rather than predict the likely future impacts. The Footprint illustrates human pressures that could lead to degradation of natural capital (e.g. reduced quality of land or reduced biodiversity), but does not predict this degradation. Current high HANPP, i.e., an intensive harvesting of ecosystems, could be seen as a proxy measure of issues such as degradations. Also, overshoot as measured by the Footprint indicates that somewhere ecosystems are being degraded or ecological assets liquidated, with detrimental implications for future productivity. • *Does it react to short-term changes that can (among other things) show whether policies are having an effect?* For this criterion, it is important to note that all tools/indicators in the basket can either be applied on an aggregated level (e.g. total Footprint, overall EMC), or selected parts of the underlying accounts can be extracted to monitor more specific changes (carbon Footprint, GHG component of EMC, etc.). The more detailed sub-accounts and derived sub-indicators are more appropriate to monitor short-term changes and to evaluate the effectiveness of policies.	
Identification of trends	Time series are available for most tools/indicators in the basket. Footprint time series are currently available for the period from 1961 to 2003 for over 150 countries. Estimations of HANPP for certain areas go back as far as to the year 1700. LEAC data are available for a time series from around 1990 to around 2000 for most of the 24 countries currently included in the data base. EMC is the only indicator, which so far has only been calculated for one year (around 2000), but could be transformed into time series, as material consumption data is available. Changes in used LCA factors over time, however, would need to be tested and, if necessary, adapted.	3

Criteria and Subcriteria	Analysis	Score
Forecasting and modelling	• *Can the methodology/indicator be used in a predictive sense to forecast future environmental impacts from natural resource use or for more sophisticated modelling where the impact of different potential policies or of technology progress and/or change of consumption patterns can be simulated?* The tools/indicators in the basket are outcome measures and have all been designed to monitor past developments, so the predictive strength of the methodologies as such is limited. Outcome measures are a powerful base for understanding future possibilities. The measures of this basket have similar predictive power as financial accounts that can help assess the financial health of an organization, and its potential for bankruptcy. In addition, some broad scenarios for future developments of the Footprint have been included in the latest Living Planet Report (2006). Only very few studies on HANPP and LUA exist, which provide future land cover change scenarios. EMC has not been predicted to the future. However, methods could be linked to predictive economic models to address these questions. • *Can the indicator function as an early warning indicator?* As explained above, the basket is relatively weak in terms of early warning messages, but provides a basis for identifying future threats.	2
Scope/levels of application	• *Does the indicator provide the required local information?* Footprint and EMC are indicators mainly applied on the national level. Regional/city Footprints have been calculated in pilot studies, but standards for making assessment more comparable only exist since June 2006 (www.footprintstandards.org). EMC has only been calculated for the national level. On the other hand, HANPP and LEAC are explicitly local analyses, and are based on very detailed geographical information and work with grids of a magnitude of a few km² or even lower. Therefore, for land-use related tools in the basket, the local information is available. • *Is industry-level data provided by the methodology/indicator?* For EMC and Footprint, one would find business-oriented applications for a variety of uses: from production and product use	2

Criteria and Subcriteria	Analysis	Score
	analysis, to plant performance, supply chain analysis, etc. More standardized methods for businesses are currently under development for the updated Footprint standards. EF data has also been linked to industries (in the format of input-output tables) in some pilot studies. EMC has only been compiled on the macro level. HANPP does not consider industries as a separate category, as its focus is on appropriation of biomass, in particular in agricultural and forestry systems. LEAC does provide land cover and land use data, but only on a very aggregated level (e.g. one category for industrial/commercial sites).	
Function- and needs related analysis	This property is only partly covered by the basket. The Footprint can illustrate trade-offs between different human needs, e.g. with regard to bioproductive land appropriated for different purposes (e.g. food versus biofuels production). With EMC as a score card approach, which aggregates different sub-components, which cannot directly be compared, such trade-offs cannot be analysed. LUA can show changes in land use functions for different types of land cover. If land use data is combined with economic data it could also show impacts on land cover and land use from alternative ways to fulfil specific needs.	2
Accepted		**2**
Stakeholder acceptance	Among the four tools/indicators in the basket, LEAC is probably the most widely accepted and least contested approach, providing a detailed data base on land cover (change), which can be used for a range of analyses. The Footprint is widely accepted as a communication and education tool, and is widely published in the academic literature. Yet it is less accepted as a headline indicator in official indicator sets although the governments of several countries have or are exploring the validity of the Footprint accounts for their respective countries. Further, work is ongoing to strengthen the scientific basis of the Footprint. HANPP is widely accepted in the academic community, but has not been considered in indicator sets on the European level so far. Stakeholder acceptance of EMC cannot yet be judged, as only one study exists so far.	2
Credible		**3**
Unambiguous	• *Convey a clear, unambiguous message.* With regard to the negative environmental impacts related to natural resource use, the basket provides a clear message. It can be expected that messages derived from one tool are reinforced by	3

Criteria and Subcriteria	Analysis	Score
	other tools (e.g. if the carbon Footprint is the fastest growing part of the overall Footprint, this trend can also be identified in the GHG sub-indicator of EMC). The tools in the basket allow covering all the impact categories, with the most significant gap being the missing explicit link to ecosystem quality and biodiversity. However, further methodological improvements are needed in order to make the tools/indicators more robust (see separate chapter "research agenda" in the final report). • *Allow for clear conclusions to guide political action.* The basket provides a wide range on information, which allows drawing clear conclusions for political action: the basket informs about the main consumption areas driving overshoot beyond carrying capacity, identifies those resource flows contributing most to negative environmental impacts and establishes a clear link between resource use and land cover/land use. However, one weak point is that the explicit link to specific sectors is rather tenuous, as most indicators are designed for application at the macro level. This decreases the potential of the basket to provide clear policy action on the sectoral level. • *Interpretation by the general public.* Most of the different tools and indicators in the basket can be easily communicated and interpreted by the public. HANPP and LEAC are illustrated via maps, which can easily be understood also by non-experts. The Footprint is well known as a visual tool very well suited to communicate the general ideas of environmental sustainability and limited carrying capacity. For EMC, results so far have been presented in graphs and illustrations; for this tool there is potential to better visualise the results for this indicator.	3
Transparency of the method	Detailed methodological descriptions are available for all of the four tools/indicators in the basket, although expert knowledge is required to judge the quality of the underlying data and data conversions undertaken to calculate the indicators.	3
Easy		**3**
Data availability	Data availability is very good for LEAC, where data sets can be obtained from the EEA website. Also aggregated Footprint data is freely available through Global Footprint Network and detailed national accounts for all countries can be purchased. Availability of HANPP data is more limited, but some data sets (e.g. data sets on HANPP by product and country) are freely available. Detailed data	3

Criteria and Subcriteria	Analysis	Score
	on the results of the EMC calculations have also been published in the corresponding reports, but the basic data to calculate EMC (in particular, the LCA factors) are not freely available.	
Technical feasibility	Calculation methodologies are clearly defined for all four tools in the basket. However, application of the methods requires expert knowledge, e.g. on LCA, on geographic information systems or on the conversion of consumption data into corresponding areas of global productivity (Footprint accounts).	3
Complementarity and integration	• *Are there potential complements between the methodology/indicator and the others being assessed?* This criterion is fully fulfilled, as those tools were selected for the basket, which best complement each other in monitoring environmental impacts. • *Is there the potential for further integration of the methodology/indicator with the others?* Further integration is in particular possible with regard to underlying basic data. LEAC data could be one key input to calculate HANPP in European ecosystems. Both EF and EMC are to a large extent based on material flow data on the national level, so the establishment of a common and harmonised data base on material flows would be one important step towards integration. The Footprint (and to a less extent, EMC) covers also the environmental impact dimension outside of the country – a significant component since more than half of Europe's demand on ecosystems is provided by ecosystems outside of Europe.	3
Robust		**3**
Defensible theory	The tools and indicators selected for the basket contain several types of approaches. The basket includes accounts based on one single unit (land cover in the case of LEAC), approaches with a specific research question (Ecological Footprint, HANPP) and one approach, which combines various indicators into a single aggregated index (EMC). No score-card approaches (apart from EMC) were selected for the basket, which are less defensible from a theoretical point of view than accounting-oriented approaches (EMC is somehow an exception to this rule since it is a hybrid between score card and accounting approach: it covers a broad dimension of issues, and pure accounting is therefore not possible) Overall, therefore, the defensibility of the theories of the approaches	3

Criteria and Subcriteria	Analysis	Score
	selected in the basket is high.	
Sensitivity	Again with this criterion, a main distinction must be made regarding the aggregated indicator versus the more detailed underlying accounts. While the sensitivity of the aggregated indicators (total Footprint, overall EMC) will not be sufficient to reflect short-term policy changes, the more detailed underlying accounts will react more sensitive to policy changes. This is similar to the GDP that moves little from year to year, while aspects of the accounts can shift widely due to policy shifts.	2
Data quality	Data quality can be rated as good, although differences between the four indicators of the basket can be observed. LEAC data quality can be regarded as reliable, although quality differs between countries. Estimations on the potential NPP of different ecosystems can differ considerably according to different assumptions and reveals different results for HANPP. Most parts of the Footprint accounts have good data quality and are standardised across countries, but improvements are still needed in some areas (e.g. embodied energy of traded products). Quality of the life-cycle wide impacts factors used for calculating EMC is difficult to be judged, as the data base is not freely available.	3
Reliability	Reliability of the methodologies and generated results can in general be regarded as good. Clear specifications of the procedures applied to arrive at the results exist for all four tools. However, parts of the calculation methodologies are still under discussion. Progress is undertaken with the Footprint, where a Standard Committee has been established to produce international and transparent standards for Footprint accounting and a National Footprint Accounting Committee is guiding the methodological development of the national Footprint assessments. With regard to HANPP, different approaches still exist alongside how to estimate NPP potentials and to assess current NPP appropriation. Application of different assumptions may lead to significantly different results of HANPP. Reliability of EMC results depend largely on the applied LCA factors and on weighing between the various categories of environmental impacts.	3

Criteria and Subcriteria	Analysis	Score
Completeness	This criterion is fully fulfilled by the basket as a whole, with single components covering specific objectives. The basket is complete in terms of environmental impact categories covered. It allows illustrating shift of burdens from one environmental category to another (e.g. increased production of biofuels will improve the performance with regard to GHG emissions, but will increase competition between different demands on land). Footprint and EMC do include trade flows and can thus illustrate possible shifting of environmental burden from one country/region to another. However, in particular with this regard, improvements are required to more accurately assess embodied resource and energy flows in trade.	4

5.5 Policy-oriented application of the basket

In the previous sections, we identified a basket of four tools capable of monitoring a range of environmental impacts related to resource use. This section turns to the policy-oriented application of the basket. We will first summarise for which policy issues the tools and indicators of the basket can be applied. Secondly, we provide a suggestion for the graphical illustration of the basket of tools in reports by the Commission and other EU and national institutions.

5.5.1 Policies addressed by the basket of tools

The four tools and indicators suggested for the basket allow monitoring success or failure of a number of policies related to the environmental impacts of resource use. Table 12 summarises the policy issues and themes, for which the individual tools are suited. It shall be emphasised that macro-economic issues can be covered by the aggregated indicators (e.g. total Footprint; total EMC), while specific sectoral issues can be covered by extracting data from the more detailed underlying accounts (e.g. energy or trade data from the Footprint accounts; specific results for human health or acidification from the EMC calculations). Note that some policy issues (e.g. energy policies) are covered by more than one tool/indicator. We aim at emphasising those aspects for each policy theme, which can best be covered by the different tool/indicators in a complementary manner.

In the following, we briefly describe the various policy areas summarised in the table and the function of different tools of the basket for monitoring the effectiveness of policies. At the end of the section, we also provide a short description of policy-related aspects, which cannot be covered by the basket and require additional information.

5.5.1.1 Monitoring de-coupling

The Resource Strategy calls for indicators to monitor de-coupling of economic growth from resource use and related environmental impacts. The basket allows illustrating and monitoring de-coupling between growth from the following environmental impacts:

- From demand on the regenerative capacity of the planet (EF)
- From pollution and toxicity-related impacts, such as greenhouse gas emissions, ozone depletion, acidification, eutrophication and ionizing radiation (EMC)
- From the intensity of ecosystem use (HANPP)
- From land cover changes, in particular the increase of built-up land (LEAC)

Table 12: Summary table of policies that can be addressed by the basket

Tool	Policy area / issue	Examples
EF	**De-coupling:**	
	De-coupling of economic growth from demands on biosphere	Measuring "overshoot" and countries' ecological deficit; comparing human demand against local and global ecological supply ('carrying capacity')
	Sectors:	
	Energy and climate	Impacts of changes in energy supply structure on land appropriation and CO_2 emissions
	Agriculture and forestry	Conventional vs. organic farming; trade-offs between renewable energy sources and land availability
	Other policies:	
	Sustainable household consumption	Informing consumers regarding resource impacts of household consumption
EMC	**De-coupling:**	
	De-coupling of economic growth from impacts on the natural environment and human health	Aggregated de-coupling indicators as called for by the Resource Strategy.
	Sectors:	
	Agriculture	Impacts of production of agricultural production, in particular animal products
	Products and services (including materials)	Identifying materials' production and energy carriers' use with highest impacts along life-cycle
	Energy and climate	Impacts on GHG emissions of changes in energy supply structure
	Other policies:	
	Sustainable production / cleaner production	Changes in environmental impacts due to substitution of materials, e.g. composite materials vs. metals
HANPP	**De-coupling:**	
	De-coupling of economic growth from intensity of ecosystem use	
	Sectors:	
	Agriculture and forestry	CAP policies to de-intensify agricultural production
	Other policies:	
	Biodiversity (indirectly)	Increasing ecosystem exploitation through intensified agriculture and related loss of (forest) ecosystems

Tool	Policy area / issue	Examples
LEAC	**De-coupling:** De-coupling of economic growth from undesired land cover change	Increase of built-up land, extension of intensive agriculture for biofuels production
	Sectors: Agriculture and forestry	Land cover changes between agricultural, pasture and forest areas
	Other policies: Land use management and urban planning Biodiversity (indirectly)	Policies to moderate urban sprawl and related fragmentation of landscapes. Conservation of protected and non protected ecosystems

5.5.1.2 Energy and climate policies

The basket of indicators allows monitoring the effectiveness of policies targeted towards reducing energy use and greenhouse gas emissions. These policies include, among others

- the introduction of energy taxes (e.g. Directive for the taxation of energy products and electricity 2003/2004);
- the EU Emissions Trading System (ETS) (Directive on GHG emission allowance trading, 2003);
- policies to foster renewable energy for electricity production, cooling and heating (e.g. Directive on the promotion of electricity produced from renewable energy sources, 2001);
- policies to promote the use of biofuels in transport (e.g. Directive on the promotion of the use of biofuels or other renewable fuels for transport, 2003);
- policies to increase energy efficiency in products (e.g. household appliances), energy services, transport and buildings (e.g. Buildings Directive, 2002).

Reduced CO_2 emissions resulting from changes in the composition of energy supply (e.g. shifts from coal to natural gas) or increased eco-efficiency are reflected in the energy-related component of the EF ("energy land") as well as in the component on GHG emissions in the EMC.

The Ecological Footprint additionally illustrates the bioproductive areas required to produce the renewable energies. This aspect is in particular relevant for biomass-related production (e.g. production of biofuels or production of wood for heating purposes). It is also useful for other forms of renewable energy (e.g. wind, solar, geothermal energy), since they use (much smaller) surface area which, in addition, might even be of lesser biological productivity (e.g., solar power in deserts, offshore wind power stations).

5.5.1.3 Agriculture and forestry policies

The basket of tools allows monitoring the effects of agricultural policies (in particular, the Common Agricultural Policy) and forestry policies (e.g. EU Forest Action Plan, 2006) on the environmental impacts related to agricultural and forestry production. Different tools focus on different aspects.

The Ecological Footprint illustrates changes in demand on the biosphere through changes in agricultural production practices, such as the de-intensification of agriculture through de-coupling of subsidies from production quantities or increased shares of organic farming. One particular feature of the Ecological Footprint in this respect is that this measurement tool allows illustrating the trade-off between the production of biomass for heating, transport (biofuels) and biotic raw materials on the one hand and agricultural products for food and feed purposes on the other hand within one consistent accounting framework. The bioproductive surface area of the planet is limited and the Ecological Footprint allows estimating to what extent biomass production for non-food purposes can still be increased, without contributing to a (further) overuse of the planet's biological capacities.

Several sub-components of the EMC (for example, global warming and aquatic ecotoxicity) highlight the major impacts due to the production of animal products. Policies to limit or reduce the amounts of animal products being produced and consumed within the EU would significantly reduce the EMC with regard this consumption area.

HANPP illustrates the overall pressure on ecosystems due to the extraction of biomass in agriculture and forestry in a geographical area. If, for example, current CAP reforms lead to de-intensification of the use of agricultural systems, this change would result in the measurable decrease of human appropriation of net primary production. However, it should be emphasised that HANPP (so far) does not take the trade dimension into account. If de-intensification within Europe goes along with intensification of agricultural production in other world regions, overall environmental impacts might not be reduced or even increased (due to the use of less eco-efficient technologies and production practices).

LEAC provides a very detailed information base to address a number of policy issues related to agricultural and forestry production. One major issue is the loss of agricultural land through increase of artificial surfaces (in particular, urban areas, see below). Other policy issues concern changes in land cover between artificial land, arable land and forests. For example, in many Mediterranean countries, growth in built-up land is highest across Europe, but total agricultural area is not decreasing due to transformation of forest into agriculture areas. Such a pattern increases environmental pressures, for example on scarce water resources in this region.

5.5.1.4 Material policies

Decreasing the environmental impacts related to the use of products is at the core of the Resource Strategy as well as other policy processes, e.g. Integrated Product Policy (IPP) or the up-coming EU Action Plan on Sustainable Consumption and Production. So far, EU policies in terms of substances and materials focused on specific groups of environmentally harmful substances, such as chemicals and fertilizers.

In the basket of tools, the EMC allows determining the life-cycle wide environmental impacts of the use of various materials and substances in a large number of products and thus allows identifying those materials, which contribute most to different types of environmental impacts (e.g. global warming, ecotoxicity, acidification, etc.).

It shall be emphasised that an evaluation of the overall impact of materials should include both the production of the material as well as its use in products. For example, regarding production, aluminium has a much higher environmental impact than steel. However, if policies would be specifically targeted towards reducing aluminium, products, which used aluminium before (such as certain cars) would start employing steel. As steel is heavier than aluminium, this would – in the example of the car – increase the weight of a car and thus the fuel consumption. The overall evaluation could thus deliver a different result. Material policies should therefore define overall targets for the reduction of environmental impacts of both the production and the use stage of the life-cycle and should avoid shifting of burden between different materials.

This issue is also closely linked to the discussion on consumer versus producer responsibility (see, for example, Lenzen et al., 2007a). It is frequently argued that basic material industries would oppose indicators such as the EMC, as the indicator would reveal that only a handful of certain materials (metals, concrete, cement, etc.) would contribute a large share to the overall environmental impact. Producers of these materials argue that it is the demand of up-stream industrial sectors (manufacturing, services), which drives the production of these materials and it would be particular the use phase of the product, which determines the environmental impact.

A conclusion for future material policies in the EU therefore is that policies should address both the production and use/consumption aspect of the material and product life-cycle.

5.5.1.5 Spatial planning / Urban planning

The European Spatial Development Perspective (1999) emphasised that present patterns of economic development are too concentrated and policies such as the Regional and Structural Funds should aim at spread prosperous regions more evenly across Europe. In addition, residential and industrial areas as well as land used for transportation (roads, rail, and airports) are expanding across Europe, in particular on the expense of arable land and pastures (EEA, 2006).

The LEAC system is a suitable tool to monitor the impacts of policies for regional development and urban planning on land cover and land use changes. LEAC allows illustrating changes in land cover and land use on different geographical scales (the basic data are available on a 100 m x 100 m grid) and monitor the flow of land cover between different categories. With the help of LEAC data, policy makers can test, whether policies to halt the sprawl of urban areas are effective. LEAC can also reveal to what extent policies to homogenise European spatial development patterns get in conflict with ecological protection efforts, for example, the Natura 2000 network of ecological areas.

The Ecological Footprint adds value to this debate as well as it shows also what kind of land is being used by urban structures. Typically it is the most productive land that becomes urbanized first.

5.5.1.6 Policies to protect biodiversity

As emphasised in earlier sections, none of the four tools selected for the basket is directly able to monitor the impacts of natural resource use on biodiversity.

However, HANPP, the Ecological Footprint and LEAC can provide indirect information on pressures on local biodiversity and can thus be regarded as tools, which indirectly can monitor the likely consequences of policies on local and global biodiversity.

HANPP is a measure of the intensity an economy uses the ecosystems of its territory. The indicator demonstrates how much of the trophic energy for wild-living animals is still in place after the extraction of biomass by humans, compared to the energy that would be available in the absence of human activities (Haberl et al, 2007). The direct links between increasing HANPP and growing pressures on biodiversity still need to be explored. However, in general it can be stated that intensified agricultural production (food, feed, biofuels, etc.) as well as increasing conversions of ecosystems (in particular, forests) to infrastructure, cropland or grazing land have a detrimental effect on biodiversity and typically correlate with biodiversity loss. These developments of intensified exploitation of ecosystems can be illustrated by HANPP.

The Ecological Footprint measures human pressure on local and the world's ecosystems and the Footprint correlates with the five key drivers of biodiversity loss: landscape fragmentation, overexploitation, invasive species (correlated with volume of trade), climate change, and toxic substances (typically correlated with high usage level of resources).

Also the LEAC data system provides valuable background information with regard to pressures on biodiversity. LEAC data illustrate the expansion of artificial surfaces (built-up land for residential and commercial purposes, transport infrastructure) to the expense of mostly agricultural areas (across Europe) and the expansion of agricultural and pasture areas on the expense of forest areas (mostly Mediterranean countries). LEAC data also illustrate pressures on Habitat 2000 sites, which play an important role for biodiversity conservation. As with HANPP, these data provide indirect information on human pressures on biodiversity.

5.5.2 Regional and local impacts not covered by the basket

Although a large number of policy areas are addressed by the basket, some limitations also occur with regard to the monitoring of environmental impacts. These concern in particular the links between the potentials of environmental impacts measured by the EMC (e.g. greenhouse gas potentials, potential for ozone depletion, for eutrophication, etc.) and the actual geographical distribution of these impacts on sub-national levels. The indicators of the basket are basically macro indicators. Thus, e.g. the EMC cannot inform where the environmental impacts actually occur. In order to illustrate these links, the data on potential environmental impact of different materials must be cross-balances with data on the exposure to certain substances in specific cities or regions or the actual health impacts on humans (e.g. from local/regional health statistics)

5.5.3 Suggestions for reporting and communication

In order to monitor progress towards the achievement of the objectives of the Resource Strategy, the basket of indicators should be communicated to policy makers and the public in policy-oriented monitoring reports.

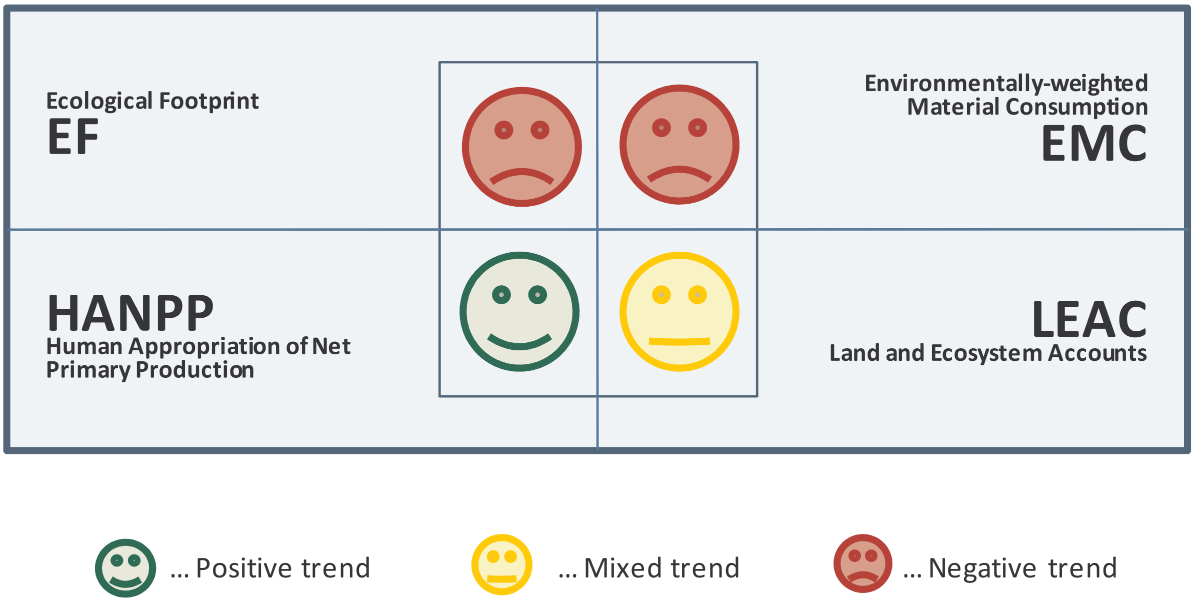
5.5.3.1 Illustrative presentation of the basket

The following figures illustrate how the four different tools in the basket could be visually presented. We suggest presenting each of the four indicators separately instead of aggregating them into one overall number or figure. On the one hand, this form of illustration avoids weighting of the different indicators of the basket against each other. If desired by the

Commission, establishing such a weighting scheme would need to be performed in a large forum including academic experts, policy makers and civil society organisations. Creating an ad-hoc weighting scheme by the project team would be beyond the scope of this project and not deliver a broadly accepted result. On the other hand, the disaggregated form of presentation allows keeping important detail information that would be lost when aggregating to one overall figure.

The results could be communicated in a two-step approach. As summary information, for example for overall country comparisons, the following overview could be applied (see Figure 9). The square with the smiley symbols in green, yellow or red provides an overall assessment of the respective indicators.

Figure 9: Summary presentation of the basket



As corresponding detailed figures, we suggest two alternative formats, which include the summary information and additionally provide key information on trends in all four selected tools by presenting one graph (or map) per indicator. Please note that the numbers underlying the graphs as well as the selection of the smiley colour are hypothetical and should only serve illustrative purposes. Also the text provided in alternative 2 should only illustrate the kind of text, which could be included in the respective box. We also assume that data regarding all four tools are available for the period of 1990 to 2005.

The following four graphs representing indicators on the national level are suggested for presentation in the respective corners of the illustration:

- Ecological Footprint per capita, by main land categories
- EMC in absolute numbers, by main resource categories
- HANPP (map), by geographical areas
- Land cover changes, by main land cover categories

Alternative 1 (Figure 10) provides the overall assessment plus the four graphs without explaining text. Alternative 2 (Figure 11) additionally includes a short description of each of the graphs.

Figure 10: Detailed presentation of the basket (Alternative 1)

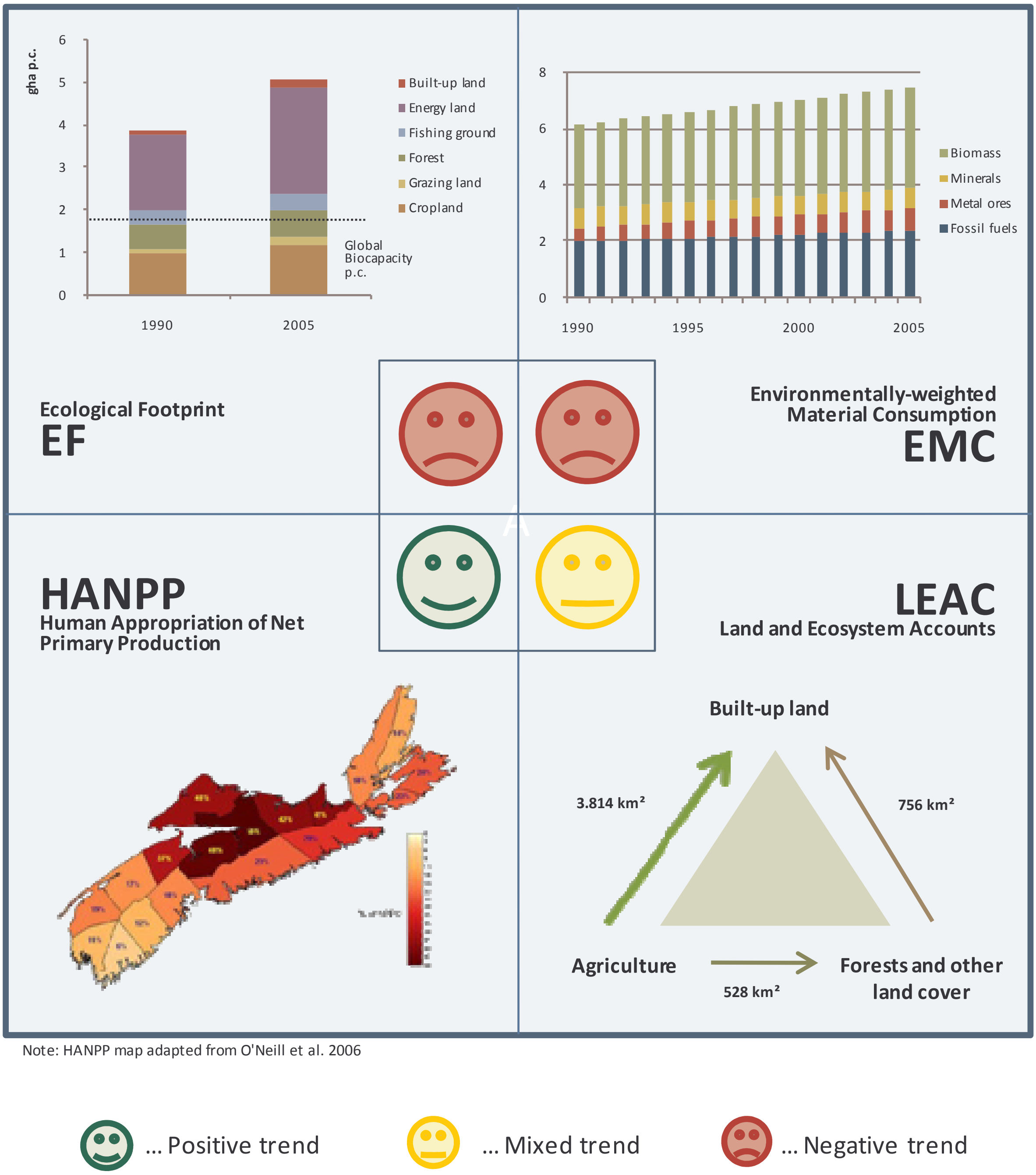
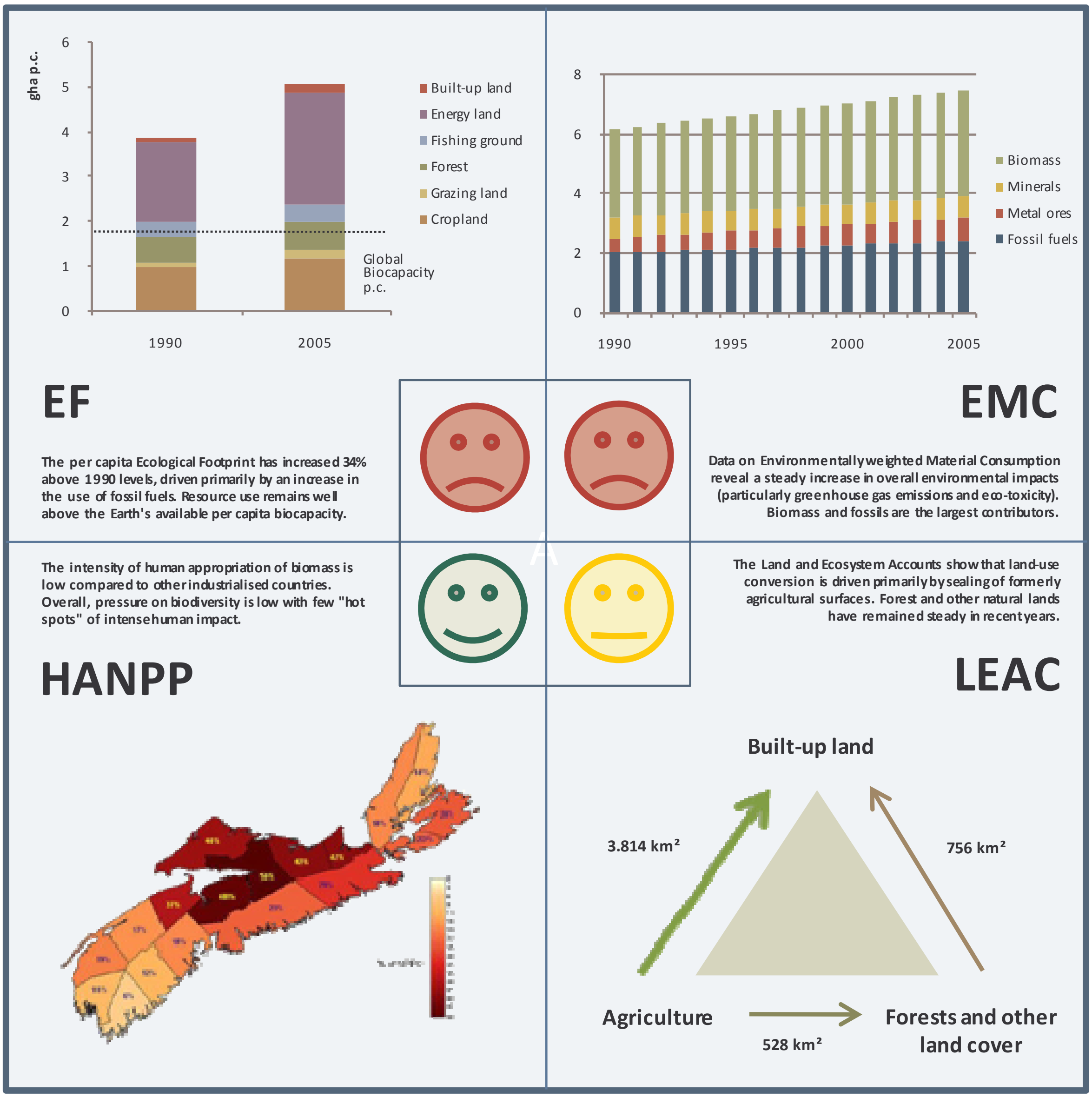
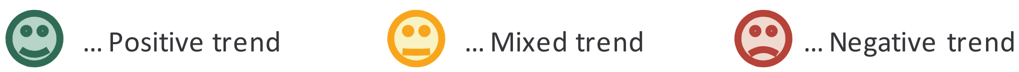


Figure 11: Detailed presentation of the basket (Alternative 2)



Note: HANPP map adapted from O'Neill et al. 2006



5.5.4 Data sources

The following table provides a summary of the different categories and respective sources necessary to calculate the different indicators included in the basket.

Table 13: Main data sources for the calculation of the tools in the basket

Tool	Data category	Data source
EF	Crop products, animal products, fisheries	The main data source for these categories are FAO data http://faostat.fao.org/default.aspx
	Forest products	Main data source: FAOSTAT forestry data http://faostat.fao.org/default.aspx
	Energy consumption / CO2 emissions	Three components are considered in this data area: • CO_2-consumption: IEA CO_2 emissions from fuel combustion • Embodied energy of imported goods: studies from literature • CO_2-Sequestration: IPPC approach
	Built-up land	For European countries: Corine land cover data, provided by EEA http://dataservice.eea.europa.eu/dataservice/metadetails.asp?id=667
	International trade	UN COMTRADE data base http://comtrade.un.org/
EMC	Consumption of different materials	One starting point are data from national material flow accounts: • Data on economy-wide material flows: Eurostat MFA data for EU-15 (1994-2005) http://epp.eurostat.ec.europa.eu -> Sustainable Development Indicators -> Production and consumption patterns • Data on material extraction of all countries: www.materialflows.net -> Data As economy-wide MFA in most cases is too aggregated, additional production data must be collected from other sources: • FAOSTAT data on production of agricultural and forestry products (http://faostat.fao.org/default.aspx) • Data from geological institutes on production of metal and mineral products, such as United States Geological Survey (http://www.usgs.gov) or British Geological Survey (http://www.bgs.ac.uk) • Other (national or international) industrial statistics In order to consider the imported and exported materials, additional trade statistics might be required, for example: • Eurostat COMEXT data base (http://epp.eurostat.ec.europa.eu -> External trade) • UN Comtrade data base (http://comtrade.un.org/)
	Life-cycle wide impact factors	To calculate the environmental impacts of different materials, life-cycle wide impacts factors are required. • Ecoinvent Database (applied for existing EMC calculations): http://www.ecoinvent.org • European Platform on Life Cycle Assessment (recommended as future source for LCA factors): http://lca.jrc.ec.europa.eu

<table>
<tr><th>Tool</th><th>Data category</th><th>Data source</th></tr>
<tr><td rowspan="3">HANPP</td><td>Harvest of biomass</td><td>Agriculture:
• FAOSTAT (rated as generally good quality): http://faostat.fao.org/default.aspx
Forestry:
• FAOSTAT (rated as problematic for some countries; problems of underreporting of illegal logging and missing data on fuel wood consumption) : http://faostat.fao.org/default.aspx
Grazing:
• Most problematic category as not reported in official statistics. Most reliable approach to calculate the “grazing gap”, i.e. the amount of biomass required for feeding the life-stock after considering other market feed products. Recommended: use of livestock feed balances.</td></tr>
<tr><td>Net primary production of the potential vegetation</td><td>Different approaches to calculate potential net primary production
• Use of Dynamic Global Vegetation Models
• Extrapolation of typical net primary production reported in literature
• Simple models, which calculate potential vegetation based on data on mean annual temperature and precipitation
• If map shall be produced, these data must be spatially explicit (i.e. GIS data)</td></tr>
<tr><td>Net primary production of the actual vegetation</td><td>Several components must be covered:
• Agricultural production can be covered through extrapolating total NPP from the amount of harvested crop (taken from agricultural statistics)
• Forestry production is mostly covered using the assumption that NPP of managed forests equals NPP of unmanaged forests
• Grazing land is the most problematic category, as (a) data on grazing areas is relatively poor and (b) effects of grazing on actual primary production
• Again, the availability o f a reliable data set on land cover and related land use is of high priority for the preparation of spatially explicit maps.</td></tr>
<tr><td rowspan="2">LEAC</td><td>Land cover data</td><td>Corine land cover data, provided by EEA
http://dataservice.eea.europa.eu/dataservice/metadetails.asp?id=667</td></tr>
<tr><td>Additional data to calculate aggregated indicators on the macro level</td><td>EEA is currently working on the development of aggregated indicators on the macro level, which combine land cover data with additional information. An example is Net Landscape Ecological Potential / LEP (see research agenda part of this report). Examples for such additional data:
• Data on Natura 2000 ecological protection areas
• Data on fragmentation of landscapes through transport infrastructure, using information e.g. from the UMZ (Urban Morphological Zones) model, an agglomeration of Corine land cover neighbouring urban and other artificial land cover units for mapping towns.</td></tr>
</table>

5.6 Communicating uncertainties and reducing risks

To ensure the basket of indicators is credible and effective, it is important to communicate the uncertainties and reduce the risks associated with each of the indicators. This short section describes key issues regarding uncertainties and risks, and provides guidance on how these aspects should be communicated to policymakers and the public. Because a related set of uncertainties and risks faces all the indicators, we cover these topics in general terms, using examples from the individual indicators to illustrate the key points.

5.6.1 Key uncertainties and risks associated with the indicators

Uncertainty and risk are related concepts. Each indicator has associated uncertainties related to issues such as data quality, status of scientific understanding, methodological issues, and underlying assumptions. The existence of these uncertainties generates an associated set of risks when using the indicator to inform decision makers and the public. Additional risks stem from poor practice in interpreting or communicating results.

5.6.1.1 Key uncertainties

Uncertainty affects all efforts to collect, manage and communicate data. These uncertainties may have known or unknown boundaries, and can stem from a fundamental lack of knowledge, or even in cases where the necessary knowledge exists, can stem from a lack of resources to reduce uncertainty (e.g. through better data or better models). Four key types of uncertainties are:

Quality of data. Data vary in accuracy, timeliness and level of detail. Each of these aspects affect how well data reflect what is currently happening in natural and socio-economic systems. Incorrect data are the most problematic, as it simply provides wrong information. Data that are old or not detailed enough loses relevance.

Scientific understanding. Useful indicators on resource use and related environmental impacts are usually driven by a causal model, where a resource-related change (as measured by an indicator) relates to some sort of outcome of concern (the so-called “safeguard object” of the indicator). Scientific uncertainty regarding causal models can exist (e.g. it may not be established that a relationship exists, or the relationship may exist but its exact nature remains vague or disputed).

Methodological validity. Even in situations where good data exist and the concept is scientifically robust, methodologies for collecting data, combining and processing them, and communicating them as an indicator may remain undeveloped or disputed.

Assumptions. When any of the above uncertainties exist, then assumptions can be made to ‘plug the gaps’. Assumptions are educated guesses or simplifications that enable a working model to function. By their nature, of course, they are uncertain.

5.6.1.2 Key risks

The risks related to indicators stem from people’s expectations of what the indicators convey, what they include, how they are communicated and how they should be used. It is important to understand that these expectations can differ based on who is the author of the indicator (e.g. NGO authors versus public sector agencies). The presence of the above uncertainties generates risks but is by no means the only source. Six key types of risks are:

Inaccurate results. Bad primary data, use of inaccurate parameters to process primary data, poorly conceived models, and human error can all generate inaccurate results.

False interpretations of data. Even in cases where data are of good quality and the indicator is transparently calculated, it is possible to falsely interpret its meaning. These false interpretations can be made by those producing the indicators, and can also be made by members of the target audience.

Bias (overstatement and understatement). It is possible that data, methods or assumptions introduce bias into the results. This bias may also be intentionally introduced due to uncertainties, where a lack of this bias would reduce the usability of the indicator.

Misguided policy. Misinformation leads to poorly based decision-making. The fundamental risk to use of an indicator is that it misguides policy.

Irrelevance. Uninteresting, non-actionable or poorly communicated indicators—even if low in uncertainty—risk being irrelevant.

Lack or loss of credibility. A risk that stems from each of the above risks is a lack or loss of credibility. Generally, indicators must earn their credibility by “proving themselves” to experts, policymakers and the public. Once credibility is lost, it is difficult to regain.

5.6.2 Guidelines for communicating uncertainties and reducing risks

The resource issues covered by the basket of indicators are complex. This fact, combined with the early state of the methodologies and the lack of comprehensive, detailed data makes uncertainty and risk inherent to using these indicators to guide policy. Also, as mentioned above, risks stem from expectations. The expectations of detail, accuracy and neutrality are generally higher for public statistical agencies than they are for academics and NGOs.

5.6.2.1 Communicating uncertainty

Communicating the uncertainties related to the calculation and interpretation of the indicators included in the basket is of key importance in order to avoid misinterpretation of the strengths and limits of each of the tools and to ensure focused application of single tools to specific aspects in the broad spectrum of different environmental impacts.

Reduce uncertainty. The first step to dealing with the problem of uncertainty is to reduce it and effectively communicate that uncertainty has been reduced. Means for reducing uncertainty include improving data quality, improving and standardising methodologies. Involving stakeholders in that process both helps to address the problems causing uncertainty and also helps to effectively communicate that uncertainty has been reduced. Compared to the other indicators, work on the Ecological Footprint is advanced in this respect, with the formation of the National Accounts and Standards committees—fora for international experts working on improving the National Footprint Accounts and creating standards for subnational applications. Such efforts have not been established for the other indicators to the same extent. For example, with regard to the EMC, no standard calculation procedures have been developed, neither with regard to the assessment of consumption of materials on the national level, nor with regard to the applied LCA-based impact factors. The shift towards using an increasing number of (quality-checked) life-cycle impact factors from the currently established "European Platform on Life Cycle Assessment" would be an important step to reduce uncertainty and lack of transparency in the calculation of this indicator.

Effectively acknowledge uncertainty. The uncertainties regarding primary data and processing steps to calculate the indicators should be openly acknowledged. In doing this, a balance must be struck between clarity of communication (which calls for limiting caveats and additional notation) and presentation of uncertainty. This balance is often struck through providing a generalist publication along with technical annexes for specialist audiences, with the latter containing detailed information on uncertainty. For example, with regard to current EMC, it should be clearly communicated that both data on consumption of different materials on the national level is incomplete and specific LCA impact factors only exist for a limited number of countries.

Estimate uncertainty and its effects. Some uncertainties can be quantified (e.g. by providing likely ranges, or conducting sensitivity analysis to show how variation in underlying data affects results). When it is possible to make quantitative estimates of uncertainty, it is good practice to do so. For example, in the calculation of HANPP, different methodological approaches exist to estimate the potential and actual net primary production of biomass in different ecosystems. It would be desirable to compare the results for HANPP based on different approaches and to provide a range for the overall results of HANPP when communicating the overall results. Regarding the Ecological Footprint, there have been no comprehensive quantitative estimates of uncertainty conducted, though Global Footprint Network is seeking to allocate resources to this.

5.6.2.2 Reducing risks

Certain strategies can be undertaken to reduce the risks associated with uncertainty and communication.

Publicise methods, data and sources. One key issue for all tools included in the basket concerns the clear communication on sources for basic data and methods for the processing of basic data into the indicator. It would be desirable, if in-depth technical reports with detailed descriptions of the used data and methods would be available for free download in the Internet. In this respect, the Ecological Footprint provides a good example, with methodological updates being published on the website of the Global Footprint Network on a yearly basis.

Communicate well. The key task here is to avoid misinterpretations by policymakers and the general public regarding what an indicator measures and how it should be interpreted. For example, the Ecological Footprint is designed to illustrate the impacts of anthropogenic resource use on the biological capacity of the planet's ecosystems. It follows from this principle decision regarding the design of the indicator that abiotic resources are only indirectly covered (i.e. through their impacts on biocapacity, e.g. due to CO2 emissions related to energy use in the processing stage). The frequently stressed argument that the Footprint does not cover the use of abiotic resources well stems from a miscommunication regarding the principle function of this indicator. This fact illustrates that a basket of tools is required in order to monitor the large spectrum of natural resource use and related environmental impacts. It is also important that the names of indicators and the language used to describe what they measure does not lead to misinterpretation. The term “ecological” in the title of the Ecological Footprint leads to misunderstandings regarding to what extent the indicator assesses impacts on ecological systems, when in fact it does so only in a highly aggregated, indirect way.

Reduce or manage bias. A general aim in statistical work is to be as neutral and accurate as possible (i.e. minimise bias). To the extent that uncertainty exists, however, it can be advisable to deliberately introduce a bias, if the overall quality of the indicator is increased. In the case of the Ecological Footprint, such a strategy has been pursued through deliberately underestimating the Ecological Footprint by leaving out certain categories where data or methodology remain uncertain. Flexibility to introduce bias in this way is greater for NGOs than it is for governments. The treatment of nuclear energy in the Ecological Footprint remains a source of criticism regarding a bias in the methodology and this issue is being revisited

Involve stakeholders and pool expertise. For further development and improvement of the indicators in the basket it is of key importance to involve different stakeholders and to bring together the expertise of different communities in academia and policy making. For example, it would be desirable for the European Commission to involve key experts from the LCA community in the further extension and improvement of the currently established *European Platform on Life Cycle Assessment*. This would create synergies with other existing LCA databases and reduce double work.

Box 4: Example Case: Communication Guidelines for the Ecological Footprint

There are significant efforts underway by Global Footprint Network to make the calculation of the Ecological Footprint more transparent, as described in the Ecological Footprint Standards (GFN 2006b). This document defines and describes 18 standards that have been identified and agreed upon by Global Footprint Network and its partners. These standards—developed to guide subnational applications of the Ecological Footprint—are grouped into two categories: application standards (Standards 1-9; related to transparency, consistency and reproducibility) and communication standards (Standards 10-18). The communication standards relate to how EF practitioners should communicate findings to policy makers and the public in order to clearly state results and strengthen the overall credibility and impact of EF reports.

Selected Communication Standards in the Ecological Footprint Standards 2006

Standard 10:	Traceability to National Footprint Accounts (Footprint must match most recent National Footprint Account)
Standard 11:	Glossary, Definitions and Versions (Reference information for auditing results and defining terms)
Standard 12:	Separation of Analytical Footprint Results from Normative or Values-based Interpretations (Separation of science-based results from recommendations for policy, planning, or practice)
Standard 13:	Footprint Scenarios (Scenario results can be applied for predictive modelling, although no commonly agreed methods yet)
Standard 14:	Footprint Study Limitations (Limitations must be clear so results are not misinterpreted)
Standard 15:	Explanation of Link between Sustainability and Footprint (Footprint is not absolute indicator of sustainability, just one necessary part)
Standard 16:	Citation of sources and description of methodologies

	(Cite sources and describe methodologies)
Standard 17:	Reference to Standards and Certifying Bodies (To ensure transparency and allow independent review)
Standard 18:	Communication style (GUIDELINE) (To strengthen effectiveness by using consistent tone, style and message)

Standards 12, 14, 15, and 18 provide the most guidance on the policy-related messages. Standard 12 states that analytical results need to be clearly distinguished from normative results to ensure objectivity. Standard 14 is specifically related to the issue of providing information on the limitations of the indicator, so that findings are understood. Within the description of this standard, GFN states that the National EF Accounts are deliberately constructed to be sure not to exaggerate resource use. Standard 15 addresses the fact that the EF can not measure all aspects of sustainability. The standard specifically identifies “biodiversity, resource management, social well-being and other sustainability dimensions” as outside the scope of the Footprint. Finally, Standard 18 specifically addresses the language used to discuss the overall findings of the Footprint, to ensure that the message is positive and not judgmental, while also being simple and accessible.

It is important that the results and implications of these results be presented clearly to avoid unintended policies. For example, although the Ecological Footprint of exports is attributed to the country where these goods and services are finally consumed, localised impacts to the producer country need to be accounted for as well. Policies that ignore damage caused by production are not intended consequences of the principle of focusing on final consumption. Similarly, increasing land use intensity, such as forest plantation instead of natural forests may increase forest product yield (or carbon absorption), but may at the same time degrade ecosystems, biodiversity and water quality.

Normative results also need to be clearly stated, such as the calculation of nuclear energy as equivalent to fossil fuel emissions (a choice which is currently being re-evaluated). Obviously, all trade-offs inherent in land use and energy decision-making cannot be adequately reflected in one indicator, thus it is important that it be clearly stated in the EF accounting results which impact dimensions are covered by the indicator and which are not.

5.7 Research agenda for the basket

This chapter illustrates the key priorities for further development of the single tools included in the basket in the form of an outlined research agenda. We separate those tasks, which could be realised in the short term (maximum of 2 years) from those areas of improvements, which require a medium-term (3-6 years) perspective. In addition, we discuss potential synergies that could be used in the application of the different tools.

The following table provides an overview of the suggested tasks in the research agenda.

Table 14: Suggested tasks in the research agenda of the basket of tools

Tool	Tasks	Time frame
EF	1. Accounting anthropogenic carbon and other greenhouse gas emissions with the Ecological Footprint	short to medium term
	2. Accounting traded goods and services with the Ecological Footprint, instead of using sector data alone.	
	3. Documenting the Ecological Footprint methodology	
	4. Development and calculation of Ecological Footprint equivalence factors	
	5. Improving the utility of the Ecological Footprint for policy-makers	
	6. Evaluating the robustness, validity and accuracy of source data used to derive the National Ecological Footprint Accounts	
	7. Accounting sustainable land use with the Ecological Footprint	
	8. Evaluating and testing the key constant assumptions of the National Ecological Footprint Accounts	
	9. Testing the sensitivity of the National Ecological Footprint Accounts	
EMC	1. Improvement of material consumption data	short term
	2. Validating EMC results against national statistical data	short term
	3. Increasing transparency and robustness of life-cycle inventory data	short to medium term
	4. Geographical expansion and regular update of the life-cycle inventory data	medium term and beyond
	5. Improving methods to calculate the overall environmental impact (incl. weighting schemes)	medium term
HANPP	1. Improving the data base for HANPP calculations	short to medium term
	2. Calculation of HANPP embodied in traded products	short term
LEAC	1. Further development of aggregated indicators based on LEAC data	short to medium term
	2. Specification of the relations between land cover and land use	medium term
	3. Further development towards integrated ecosystem accounts (physical and monetary)	medium term

5.7.1 Ecological Footprint

As part of this study, a thorough analysis was done to identify a research agenda for short- and medium-term improvements to the Ecological Footprint. The results of this work are summarised in Annex I. The annex describes the analytical process behind the development of the research agenda and puts forward nine research proposals for how to improve the Ecological Footprint. The research agenda is based on a comprehensive literature review of the Ecological Footprint (EF) that revealed 43 issues and concerns (covering data, accounting methodology, documentation, sensitivity, etc). Nine leading researchers and commentators were then consulted to agree and prioritise the issues raised. Using a simple weighting scheme, each issue was ranked for its perceived importance. This process resulted in all issues being categorised in 28 priority groupings. Carbon dioxide (CO_2) sequestration was rated as the most important issue.

Nine key research proposals were then developed as part of a future 'roadmap'—a medium-term five year research agenda for the Ecological Footprint (National Footprint Accounts methodology). The nine research proposals are:

- Accounting Anthropogenic Carbon and Other Greenhouse Gas Emissions with the Ecological Footprint
- Accounting Traded Goods and Services with the Ecological Footprint
- Documenting the Ecological Footprint Methodology
- Development and Calculation of Ecological Footprint Equivalence Factors
- Improving the Utility of the Ecological Footprint for Policy-Makers
- Evaluating the Robustness, Validity and Accuracy of Source data used to derive the National Ecological Footprint Accounts
- Accounting Sustainable Land Use with the Ecological Footprint
- Evaluating and Testing the Key Constant Assumptions of the National Ecological Footprint Accounts
- Testing the Sensitivity of the National Ecological Footprint Accounts

5.7.2 EMC and related LCA approaches

As the EMC is the tool that covers the largest number of different environmental impacts, further improvement of this approach should receive particular importance. The research agenda for EMC contains improvements both for the short and medium term. Short term improvements concern the harmonisation of material consumption data used for EMC with economy-wide material flow-based indicators and the validation of EMC results against national environmental statistics. Medium-term issues include increasing transparency, extended geographical coverage and more regular updates of the applied life-cycle inventory data.

5.7.2.1 Improvement of material consumption data (short term)

Problem definition

In an economic system, products are the results of a stepwise transformation and processing of virgin material. Several stages of this production chain generate different types of products. In economic statistics, three types are generally distinguished: raw materials (e.g. concentrated ore), semi-manufactures (e.g. steel, cement) and finished products (e.g. car).

For the calculation of the EMC as presented so far in the literature, the list of chosen 'materials' is not fully consistent, containing materials from several production stages. For example, construction materials contain 'clay' and 'ceramics', where 'clay' is a raw material which is used to produce the semi-manufacture 'ceramics'. The issue is to choose an adequate process stage on which all materials used by an economy are accounted for without double counting, as the currently selected materials show considerable overlaps in their process chains (process trees). The authors of the existing EMC studies argue that the selection of the process stage, for which consumption data were generated, was also determined by the need to harmonise with impact factors from the LCA data base, which are in most cases available for processed materials rather than for resource extraction or finished products.

In addition, the list of materials considered in the EMC is incomplete. Analysing the materials used for the EMC reveals that some important materials are so far missing: e.g. precious metals, limestone etc.

As indicators derived from economy-wide material flow accounts follow a clear definition, namely that the total of all materials crossing the system boundary between environment and economy are recorded (i.e. no double counting, and completeness), the sum of all apparent consumption of 'materials' used in the EMC should be closely related to the numbers of the related material consumption indicators on the economy-wide level. However, so far these numbers have no direct relation to the comparable material flow-based indicator (Domestic Material Consumption, DMC) and aggregated material consumption in the EMC is significantly lower than total DMC.

Task

When calculating the amounts of material consumption as the basis for EMC, the following criteria should be considered: materials should all cover the same process stage (i.e. point of extraction versus further processing) and the list of materials should be completed compared to the presently used, e.g. adding precious metals. Generally, if the list is complete, the sum of all of materials consumed in a country should equal total DMC.

Concerning the aggregation of material groups, it seems that this is basically a matter of convention, as adding more materials is rather additional work load than a principal conceptual issue. One could start for example at a lower level of aggregation, and then, investing more work, reach a higher level of aggregation.

Furthermore, the basis for further developed EMC should be to better integrate existing data on material consumption. Here, referring to the authors' experiences, the crucial point is that economy-wide MFA data is in some respects not detailed enough (e.g. what is actually being produced from the extracted materials). Further information and analysis, e.g. towards a physical input-output (PIOT) accounting scheme, are necessary.

Output

The results of this task would be a more consistent and more complete methodological concept, how consumption data of different material could be compiled as the basis for the calculation of an environmentally-weighted indicator on material consumption.

5.7.2.2 Validating EMC results against national statistical data (short term)

Problem definition

Results generated with the EMC differ from results obtained through national environmental statistics. It would be necessary to compare the results of the EMC with existing environmental statistics. For a given national economy, the environmental impacts related to the use of resources should be at least equal to the national totals as reported in environmental statistics. For instance, all greenhouse gas emissions in a national economy are related to the use of resources. It would be interesting to see, whether the total of assumed/estimated greenhouse gas emissions underpinning the EMC are the same order of magnitude as officially reported (for such a cross-check also the embodied emissions of foreign trade would need to be considered).

Task

In order to calibrate and validate the results from EMC calculations, the different results of the sub-categories considered in the EMC (e.g. global warming, ozone depletion, etc.) need to be compared with national environmental statistics.

Output

The result would be a comparison of EMC results with statistical information on the national level, which would help calibrating and validating the results of the EMC calculations.

5.7.2.3 Increasing transparency and robustness of life-cycle inventory data (short to medium term)

Problem definition

To determine the specific impacts of selected ‘materials’, life-cycle inventories are used, and for each considered ‘material’, a process tree is composed, which illustrates the supply and use of a specific material in different production processes. Before using the EMC on a broader level, the following issues regarding transparency of the used LCA data need to be resolved:

- In the current calculation of EMC, it is not clear whether only ‘up-stream’ or also ‘down-stream’ processes are considered in the grouping of the process tree of a given ‘material’.
- It is not sufficiently described, whether all environmental interventions are available for all the considered processes. For instance, the emission of certain toxic pollutants might be available only for some of the analysed processes.
- The majority of the characterisation methods/models for the around dozen impact categories are still subject to scientific debates. Only the characterisation methods for global warming, acidification, ground level ozone, and eventually eutrophication are well established in the scientific community.

In addition, the impact of a certain material depends on the weighting chosen for the 13 different categories. In an initial step all the weights were decided to be equal, but this approach is arguable.

Task:

If the EMC is selected for regular reporting in a basket of indicators, it would be essential to increase the level of transparency regarding the methodology applied in the LCA part of the calculation. It has to be clarified and transparently communicated, how the cradle-to-grave approach is realized – namely through a detailed cradle-to-gate LCA impact analysis and estimations on waste generation and management, land use, etc.

With this regard, it would be preferable not to use any individual databases, but the switch to applying data from the European Reference Life Cycle Data System (ELCD) core database, which is currently established by the European Commission's JRC. In the ELCD core database LCI data sets for most materials and energy carriers are available cost-free.

It is also required to improve scientific base of the selected impact categories, which, according to the interviewed experts, are still under scientific debate. Focus should be put especially on the impacts on biotic resources and resource depletion. In the case of land use, it is even thought about keeping this section out of the EMC and treating it in a separate calculation. The task is to clarify to what extent land-use aspects can and should be considered in the LCA impact factors and how this information would complement HANPP and LEAC data and indicators.

Output

The output of this step would be an improved basic data set concerning the LCA factors used in the calculation, with particular focus on applying the newly created European life-cycle inventory data base.

5.7.2.4 Geographical expansion and regular update of the life-cycle inventory data (medium term and beyond)

Problem definition

Uncertainties in the EMC results arise from the fact that the LCA process data are averages for Western Europe, impeding the consideration of efficiency improvements or country peculiarities. Specified data exist for some countries in the area of energy, but are missing in many categories.

The ETH database and its successor, the Ecoinvent database, which have been applied for the calculations of EMC, require a high degree of expert knowledge and, in addition to that, are updated on an irregular basis (so far around eight years). Especially the latter of these two aspects would have to be improved, if the EMC was selected by the Commission as a regularly reported indicator. Also referring to comments of the developers of EMC themselves, this is one of the main difficulties with respect to a broader application of EMC.

Task:

In the further development of the EMC indicator a number of institutions and stakeholders should be involved. Concerning the delivery of LCA data, a focus would have to be set on the incorporation of the different industry sectors which are producing the materials, as they dispose of data on national, regional, and worldwide demand.

In order to reflect specific patterns of environmental impacts due to application of different technologies, life-cycle inventory data should be collected also for Eastern European countries. The above mentioned European initiative could play a key role in this regard.

The second task concerns the regular update of the LCA factors. So far, the “Ecoinvent” database used for the EMC calculations has been updated (or is in the process of being updated) once to the level of 2004. Sometimes particular sectors are added also in-between updates, but in order to function as a readily applicable tool, a regular update is essential. It would be highly desirable, if the European ELCD database would be regularly updated, in order to ensure that results of the EMC calculations reflect technological changes and restructuring of production chains within Europe and beyond.

Output:

The output of this proposed improvement would by a LCA data set, which is geographically expanded to specifically cover a larger number of EU countries and more regularly updated than current available life-cycle inventory data bases.

5.7.2.5 Improving methods to calculate the overall environmental impact (incl. weighting schemes) (medium term)

Problem definition

Within LCA, there exist a number of different procedures to weight and aggregate different types of environmental impacts, in order to come up with a single-score number. The simplest procedure allocates equal weights to each of the single impact categories. Other approaches are based on policy priorities, expert opinions or economic reasoning (e.g. shadow prices or data on "willingness to pay").

As Oers et al. (2005) illustrate taking the example of the EMC for the EU-15, the final results based on these different weighting schemes differ significantly and can lead to very different policy conclusions.

Task:

The mid-term objective for the calculation of one aggregated indicator on environmental impacts is to achieve consensus on the weighting factors applied in the aggregation procedure. This would require setting up a consensus process, where all relevant stakeholders (policy makers from the European institutions, academia (environmental scientists, economists, etc.), representatives from NGOs, etc.) are involved, in order to develop one set of weighting factors. This set could then be applied to arrive at overall figures illustrating the environmental impacts related to resource use and would allow maintaining consistency across countries and over time.

Output

The outcome of such a process would be a recommendation for a standard weighting procedure applied to aggregate different categories of environmental impacts into one overall number.

5.7.3 HANPP

After interviews with some of the leading experts in the calculation of HANPP (see acknowledgements section), two main areas for improving HANPP could be identified: advances in the underlying data base, to be realized in the short to medium term, and advances in the methodology, which could be achieved in the short term.

5.7.3.1 Improving the data base for HANPP calculations (short to medium term)

Problem definition

Several issues regarding the data base were mentioned by the interviewed experts. First, some basic data used for HANPP calculations, in particular data from the FAO are sometimes of insufficient quality. This applies in particular to forestry statistics, sometimes also to agricultural statistics. The statistical numbers countries report to the FAO are sometimes influenced by political decisions, but the FAO reports, what they receive as data input from the member countries.

Second, data resolution used for global assessments of HANPP is too high to directly link to local developments, in particular regarding links to biodiversity. HANPP calculations on the global level exist, but are currently based on a 10 km x 10 km grid, which is several orders of magnitude more aggregated than the European data on land cover provided by the EEA (which uses a 100 m x 100 m grid system in the Corine data set; see sections on LEAC in this report).

Third, data on (potential and actual) NPP are regarded as insufficient on the European level. Generating data on potential vegetation requires application of more detailed modelling approaches (e.g. Dynamic Global Vegetation Models). Particular focus should be put on the issue of biomass uptake by grazing animals.

Task

In order to calculate HANPP of European countries on a detailed level, it would be necessary (and possible) to apply data from the Corine data base. The major task in this regard is to transform the Corine land cover data into land use data necessary for the HANPP calculation. The EEA (in cooperation with the Topic Centre on Land Use and Spatial Information) is currently putting effort into further developing their system of Land and Ecosystem Account (LEAC) towards integrating land cover data with information on land use. Pilot studies are also calculated on the national level, for example, a study on the application of Corine data for the Czech Republic is currently ongoing. These country experiences should be the basis for calculating European HANPP based on detailed LEAC data.

Outcome

The outcome of this effort would be highly disaggregated calculations of HANPP, which could be applied for national, regional and local studies and would form a more suitable pressure indicator for assessing trends in biodiversity.

5.7.3.2 Calculation of HANPP embodied in traded products (short term)

Problem definition

HANPP calculations so far did not consider the dislocation of HANPP through international trade. Increasing European imports of biomass are connected with appropriation of net primary production in other world regions. In order to calculate indicators of HANPP on the national and regional level, the trade dimension needs to be taken into account.

Task

The task is to develop methodologies how to calculate HANPP embodied in internationally traded products. A first methodological approach has been developed by researchers from the Institute of Social Ecology at the University of Klagenfurt, Austria. The respective study will be published in 2008. Based on this pilot study, further improvement and international harmonization of this methodological extension should be achieved.

Outcome

The results of these efforts would be a HANPP-based indicator, which considers the import and export of primary production through trade and thus would be better connectable to other environmental accounting approaches, which report both the use of domestic natural resources as well as resources associated with imports and exports.

5.7.4 LEAC

The research agenda for the Land and Ecosystem Accounts (LEAC) comprises three tasks: further development of aggregated indicators based on LEAC data (to be realised in the short to medium term), specification of the relations between land cover and land use (medium term) and further development towards integrated ecosystem accounts, able to illustrate the state of ecosystems and their potential to provide ecosystem services (medium term and beyond).

5.7.4.1 Further development of aggregated indicators based on LEAC data (short to medium term)

Problem definition

LEAC and its underlying main data system, the Corine data base on land cover, can be applied to a large number of assessments regarding changes in land cover within and between different land categories (agriculture, forestry, built-up land, etc.). However, aggregated indicators on the macro level are only currently being developed. Therefore, also in the suggested basket of indicators in this report, total land cover by aggregated type is introduced as the LEAC-based indicator (see sections on the basket in this report). It would be desirable to replace this basic indicator by other macro-indicators in the future, which better inform about the quality of the European ecosystems and the pressures on land cover change by human activities.

One indicator very recently suggested by the EEA is the so-called “Landscape net Ecological Potential (LEP)”. LEP is a landscape-based indicator, which informs about the value and integrity of ecosystems considering 3 dimensions: (1) Land use intensity/naturalness captured by the types of land cover. At the macro level, a distinction is made between intensive land covers (artificial and intensive agriculture) and the less intensive and natural land cover types. (2) Value given by society to natural features captured via the designation of protected areas for nature. (3) Fragmentation by roads, railways and other artificial features.

Task

The task is to further develop macro indicators based on LEAC data (such as LEP), which would be better suited in the basket of tools than the currently included land cover indicator. Therefore, it is necessary to test the validity of some of the additional data used for the calculation of the LEP indicator, in particular the fragmentation data regarding roads. Furthermore, it would be desirable, if the LEP indicator would not only be computed by 1km² grid cells (as it is currently done), but also with more detailed data, in order to link LEP to local problems. LEP could also be decomposed according to specific policy issues, for example a LEP “forest” could be computed.

Output

The output would be improved macro-indicators, which use the LEAC data in combination with other data sets to deliver robust indicators, which inform about human pressures on land and the integrity of European ecosystems. In addition to LEP, main physical macro-indicators derived from LEAC are Net Change in Land Cover, Change of Urban temperature and Intensive Agriculture temperature over protected areas. In the medium term, other physical indicators (biodiversity, HANPP, EF…) could be progressively harmonised and connected with the European land cover database and the LEAC framework.

5.7.4.2 Specification of the relations between land cover and land use (medium term)

Problem definition

The LEAC system as developed so far mainly includes land cover data derived from the remotely sensed imagery. Land cover reflects the biophysical characteristics of the earth's surface and includes categories such as built-up areas, grassland, forests, rivers and lakes. Land use, on the other hand, describes the purposes (economic activities) associated with a certain land area. Land use categories include industrial use, transport, agriculture, forestry, recreational use and nature protection (EEA, 2006). Land use is often more complex to describe than land cover, as single land cover types can fulfil multiple purposes (in particular, in regions outside Europe, e.g. agro-forestry systems, which fulfil also other purposes, such as the provision of habitats).

So far, it has not been possible to fully integrate land cover data with information on land use and provide the links to the economic sectors, which drive developments in different uses of land. This is particularly the case for the separation of economic sectors beyond the broad category of "industrial and commercial use". The clear and explicit link between land cover and economic activities through the concept of land use remains a key objective with regard to the further development of the LEAC data system.

Task

The major task here is to improve the information base for establishing matrices, which connect the core land cover accounts to functions of land use. Some countries (see, for example, Umweltbundesamt, 2004, for data on Germany) publish statistics on land use by main economic activities, with data collected through a direct assessment of area use instead of using satellite data. It needs to be tested whether this country information can be used to develop general algorithms for linking land cover with land use data, which might be valid also for other European countries (for example, based on the assumption that different service sectors have a comparable land intensity per € output across Europe).

Output

The output of this task is an improved methodology to link the basic land cover data to information on land use disaggregated by a larger number of economic sectors.

Further development of LEAC towards integrated ecosystem accounts (medium term and beyond)

Problem definition

The development of land cover accounts is just the starting point for the construction of more detailed ecosystem accounts, which should be able to inform about the ecosystem integrity and health and the quality of the ecosystem functions. Weber (2007) from the EEA outlines a system of several modules, which could form such integrated ecosystem accounts: core accounts of land cover stocks and flows by ecosystem types (this module is the core module of the current LEAC system); counts of stock diversity and integrity; and finally, information on the ecosystem state, including health diagnoses of the ecosystems.

In addition, the EEA aims to quantify ecosystem services and the costs of maintenance of ecosystems, in order to include these costs in an Inclusive Domestic Product, which better measures well-being of a society.

Task

The task is first to further develop approaches for measuring and illustrating the integrity and diversity of ecosystems and to improve the accounts of ecosystem state and ecosystem services. Second, monetary valuation of ecosystem services and ecosystem maintenance costs have to be carried out. This task is very challenging and resource intensive and will require further institutional cooperation between EEA, Eurostat, JRC and national institutions and agencies.

Output

The final output of this improvement would be a stepwise implementation of the ecosystem accounts including integrity/resilience, values and cost calculation. Key aggregates would be physical (Net Landscape Ecological Potential) and monetary (Inclusive GDP and Full Cost of Goods and Services). The action should support/liaise/build upon current programmes started in response to policy demands, such as Beyond GDP, the "Potsdam initiative" on the economic value of biodiversity or the Second Millennium Ecosystem Assessment as well as the implementation of the EU SDS.

5.7.5 Creation of a joint data infrastructure

The four tools suggested for the basket could significantly profit from the creation of joint databases on the European level. The following table illustrates the data requirements necessary for the calculation of the four tools.

Table 15: Data requirements for calculating the different indicators in the basket

Data	EF	EMC	HANPP	LEAC
Production and consumption of materials and products	X	X	X	
Life-cycle wide environmental impacts of materials and products		X		
Generation of emissions and waste	X	X		
Land cover / Land use	X	X	X	X
Productivity of ecosystems / Biocapacity	X		X	X

Except for the part of the LEAC system which is built upon the data base of European land cover, all the tools/indicators require new collections of information on the physical production and consumption of materials and products. One major need therefore is to create a harmonised data base for the different indicators in the field of material and product use. This data base should build on the methodological recommendations for material flow accounting as published by Eurostat (2001a; 2007). However, in addition to the economy-wide material flow accounts, which regard the economic systems as a “black box”, data should allow calculating the production and consumption of specific materials and products, in order to enable linking this information to LCA impact factors.

The recent developments towards the creation of joint data centres on the European level are of key importance with this respect. Eurostat will host three related data centres, all of key relevance for the indicators being developed in the framework of the Resource Strategy: natural resources, waste and products. The medium-term objective should be that this data centre provides consistent information on extraction, production, trade and consumption of different materials and products as the basic data for calculating combined material consumption impact indicators.

Another important initiative in this direction was started in 2006 by academic and consulting institutions, who underscored the importance of standardisation of basic data of the National Footprint Accounts and MFA at the national level. This initiative, led by SERI, includes Global Footprint Network, Best Food Forward, the Wuppertal Institute for Climate, Environment, Energy and a number of other organisations (see www.materialflow-consensus.net). Supporters of this initiative encourage government agencies to strengthen material flow accounting (MFA) as the core information base for research and policy analysis related to natural resource use and resource productivity, as it is vital for sustainability policy, research and communication. They underline that a robust and well documented statistical basis on material flows is essential for many core areas of sustainability science (e.g. carbon and greenhouse gas accounting, Ecological Footprinting, calculations of Environmental Space and assessments on the product level). Such a joint data base for the calculation of different indicators of resource use should be as transparent and freely accessible as possible.

With regard to the generation of life-cycle wide environmental impacts of materials and products, the Commission (DG JRC in cooperation with DG ENV) is setting up a European Reference Life Cycle Data System and an LCA guidance handbook along with recommended impact factors for all impact categories (European Commission, 2007). This initiative has the explicit mandate to support the Resource Strategy with life cycle data and methods. Further expansion of this European LCA data system is highly desirable, as this system – in contrast to other LCA data inventories – provides quality-tested LCA data for free use.

With regard to the third major area of data requirements, i.e. data on land cover, land use and productivity of ecosystems, the EEA (and the related European Topic Centres (ETC) on Land Use and Spatial Information) has set up the most comprehensive data base (Corine land cover system, currently being extended to more comprehensive Land and Ecosystem Accounts/LEAC). Given the expertise and infrastructure available at EEA and ETC, it is recommended that the EEA continues to play a key role in the process of gathering and improving land-related data.

5.8 Conclusions and recommendations

This final section of the report contains the summary of the key results and recommendations.

5.8.1 Key results

The main objective of Task 2 was to analyse a number of alternative assessment tools, in order to identify those methods and indicators which could best complement the Ecological Footprint in assessing and monitoring the environmental impacts of natural resource use.

RACER evaluation performed for 13 potential tools and indicators. Out of a list of 25 methodological approaches, which were initially identified as potentially relevant for the purpose of this study, the project team selected 13 approaches, for which a detailed RACER evaluation was performed. Results of the RACER evaluation, which were summarised through indicative numerical scores, revealed significant differences in the overall quality and suitability of the different approaches for the respective purpose.

The suggested basket contains four complementary tools. The tools included in the basket were selected through a set of three main criteria: policy relevance, high ranking in the RACER evaluation and completeness/complementarity. Four tools and related indicators passed all criteria and were therefore suggested to form the basket of indicators: Ecological Footprint (EF), Environmentally-weighted Material Consumption (EMC), Human Appropriation of Net Primary Production (HANPP) and Land and Ecosystem Accounts (LEAC). These four tools and related indicators all scored high in the RACER evaluation, in particular with regard to the criterion of policy relevance. Applied as a basket, these four tools are comprehensive regarding the coverage of a large number of different environmental impacts. At the same time, they are complementary and each impact category is well covered by (at least) one of the tools. (Impacts on biodiversity and ecosystems are the only category, which is only indirectly covered. For this impact category, development of robust indicators is still ongoing.). Therefore, the RACER evaluation of the whole basket of tools delivered higher scores for the basket than for any single approaches.

The basket allows monitoring the impacts of a wide range of policies. The identified basket of tools can be applied to monitor de-coupling of economic growth from environmental impacts as well as illustrating the effectiveness of a number of specific policies aiming at a more sustainable use of natural resources. Main policy fields covered by the basket are energy and climate policies, agriculture and forestry policies, material policies and spatial planning/urban planning. The main deficits regard the missing information about the geographical distribution of pollution impacts as well as the impacts on ecosystems and biodiversity. To capture the regional and local impacts, indicators from the basket (in particular, EMC) must be combined with other data, for example on the exposure to pollutants in cities and industrial regions or with data from health statistics.

5.8.2 Key recommendations

Apply basket instead of single indicators. The use of natural resources entails a large number of different environmental impacts. These range from pressures on the planet's overall biocapacity, impacts on land, ecosystem functions and biodiversity, impacts on climate, to the release of different forms of emissions and pollutants, which effect health of humans and ecosystems. One single tool or indicator is unable to illustrate the complexity of these impacts and their interrelations, in particular, regarding burden shifting between different types of impacts. Applying a basket of tools allows monitoring the spectrum of environmental impacts from different perspectives. Each tool is constructed to illustrate particular environmental impacts in a consistent and robust manner. A basket of tools and related indicators thus produces results of higher quality than one single aggregated indicator, which aims at covering all impact categories.

Dedicate resources to further improve the basket. All four tools suggested for the basket are of high relevance for the objectives of the Resource Strategy and improvement of the quality of results is one key task. The main priorities for improving the Footprint are detailed in Annex I. As the EMC is the tool in the basket, which covers the largest number of impact categories and applies life-cycle assessment (LCA) as one key approach to measure environmental impacts of products, further improvement of EMC and related LCA approaches should receive high priority. EMC requires particular improvement regarding the calculation of the amounts of different materials being consumed in a national economy as well as increasing the transparency and quality of the factors representing the life-cycle wide impacts of different materials. Priority focus in improvement of HANPP should be put on increasing data quality regarding potential and actual net primary production as well as application of land cover and land use data from LEAC to calculate a detailed HANPP indicator for Europe. The main objectives for future improvement of the LEAC system are to increase availability of data on land use for socio-economic purposes corresponding to certain types of land cover as well as to further develop macro-indicators regarding human pressures on land cover change and ecosystem integrity. Further development of the different tools and indicators could allow integrating some of the suggested tools in the basket and thus reduce the number of considered tools.

Create joint data infrastructure on the European level. The four tools suggested for the basket could significantly profit from the creation of joint and harmonised European databases. The three currently established data centres on natural resources, waste and products at Eurostat will play a key role with this regard. These data centres should develop into the core data provider on extraction, production, trade and consumption of different materials and products for the calculation of combined indicators on the impacts of material consumption.

Cooperate closely with the LCA community. It is recommended to carry out all future efforts to improve the LCA-oriented indicators in the basket in close cooperation with the Joint Research Centres' *European Platform on Life Cycle Assessment* and other institutions in the LCA community. In particular, the currently established European Reference Life Cycle Data System at the JRC should be developed into the main provider of consistent and quality-proved information on life-cycle wide impacts of different materials and products.

Feed in project results into Eurostat Task Force on Impacts. In 2007, Eurostat initiated a Task Force on Impacts, with the explicit objective to develop indicators for monitoring the objectives of the Resource Strategy. Apart from defining long-term, strategic objectives for further research and data compilation, the Task Force has the mandate to quickly conclude on recommendations for indicators, which could already be applied in 2008. It is recommended that the results of this project are fed into ongoing discussions in the Task Force as one suggestion, how existing indicators informing about environmental impacts could be applied in the short run.

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Please see the end of this section for a summary of key Ecological Footprint studies grouped by topic

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Annex 1: Agenda for short/medium term improvements to the basket and its individual indicators: The Ecological Footprint

Annex 1a: Summary of the analysis and findings

- A literature review of the Ecological Footprint (EF), focusing specifically on critiques of the National Footprint Accounts methodology published by the Global Footprint Network, revealed 43 issues and concerns covering data, accounting methodology, documentation, sensitivity and so on.
- Nine leading researchers and commentators were consulted to agree and prioritise the issues raised. Using a simple weighting scheme, each issue was ranked for its perceived importance. This process resulted in all issues being categorised in 28 priority groupings. Carbon dioxide (CO_2) sequestration was rated as the most important issue.
- The Top 10 ranked issues were elaborated further to formulate nine key research proposals (two related issues were grouped together). These were then developed into a future 'roadmap', a medium-term five year research agenda for the Ecological Footprint (National Footprint Accounts methodology).
- The nine research proposals are:
  1. Accounting Anthropogenic Carbon and Other Greenhouse Gas Emissions with the Ecological Footprint
  2. Accounting Traded Goods and Services with the Ecological Footprint
  3. Documenting the Ecological Footprint Methodology
  4. Development and Calculation of Ecological Footprint Equivalence Factors
  5. Improving the Utility of the Ecological Footprint for Policy-Makers
  6. Evaluating the Robustness, Validity and Accuracy of Source data used to derive the National Ecological Footprint Accounts
  7. Accounting Sustainable Land Use with the Ecological Footprint
  8. Evaluating and Testing the Key Constant Assumptions of the National Ecological Footprint Accounts
  9. Testing the Sensitivity of the National Ecological Footprint Accounts
- All 43 'micro' issues are covered by the nine 'macro' research proposals. Issues outside of the Top 10 were associated with the most relevant research proposal using the judgement of the project team in consultation with Justin Kitzes of the Global Footprint Network.
- It is strongly recommended that the research proposals be taken forward with the involvement of Eurostat, EEA and the life cycle methodological expertise of DG

JRC. Ecological Footprint expertise can be drawn from the membership of the Global Footprint Network.

- In the absence of competing footprint accounting methods, this report takes as its starting point the Ecological Footprint methodology used within the current National Footprint Accounts (which provides an analysis of more than 150 nations annually). The NFA are currently supported by voluntary Footprint Standards and an organisation of supporters and practitioners (including policy-makers, not-for-profits and commercial organisations).

Objectives

The key objective of this task is to produce a 5-year 'roadmap' in the form of a research agenda for improving those indicators identified in Task 2. This 'basket' of indicators, no more than five including the Ecological Footprint, will be treated similarly although the effort will be weighted in favour of the Ecological Footprint, as it forms the major focus of this research. Although the inclusion of the Ecological Footprint is guaranteed, it is important to note that great efforts have been made to ensure that this study is unbiased and balanced. The broad nature of the literature review and engagement of a wide range of experts has meant that the study results are critical of the Footprint where necessary.

In consultation with DG Environment, primary responsibility for work on 'basket' indicators other than the Ecological Footprint was transferred to SERI. This part of Task 3 is specifically focused on the Ecological Footprint.

Task 3 was divided into six sub-tasks.

- Task 3.1. Literature review of ongoing research
- Task 3.2. Consultation with leading practitioners
- Task 3.3. Drafting of research objectives based on outputs from 1 and 2
- Task 3.4. Consultation with selected practitioner group to agree, prioritise and scope objectives
- Task 3.5. Drafting of research agenda based on output from 4.

Subtask 1: Literature review

This literature review was focused specifically on the methodology used in the National Footprint Accounts (GFN 2006). The National Footprint Accounts (currently authored by the Global Footprint Network and published in summary form in WWF's Living Planet Report every two years) report the national Ecological Footprints of more than 150 countries.

Original academic sources and review papers citing more than 240 references were reviewed to identify key issues and concerns with the Ecological Footprint methodology. Included in this review are papers presented at the most recent , relevant international gathering - the 2nd International Footprint Conference, held in Cardiff (May 2007).

This review identified 43 key issues relating to the National Footprint Accounts methodology. Each issue was classified according to one of the six categories;

- Data/Calculations and Method Communication
- Current NFA Methodology
- Methodology Change
- Boundary and Philosophical
- EF Integration
- Central Metrics and Messages

Each issue was cross-referenced to the related literature. It is worth commenting that the number of issues raised was well in excess of that expected (based on previous reviews). This is a testament to both the thoroughness of the review and the extent of the literature – in particular the most recent literature – which more closely scrutinises the Ecological Footprint.

Subtask 2: Consultation with leading practitioners

Twenty-four practitioners - drawn from the membership of the Global Footprint Network (representing 21 international organisations) - were contacted (this activity was carried out prior to the completion of the literature review) to identify their broader views of research priorities.

Respondents were also asked about where they would prioritise limited research resources. They were asked to allocate between;

(1) improving the accessibility and transparency of calculations,

(2) improvements to data and methods, or

(3) Extensibility to other policy or accounting frameworks.

Average allocation of resources to (1) was 41%, second was (2) at 36% with the remaining 23% allocated to (3). See Figure 1 below.

Each respondent was also asked to rate the importance of tackling 15 specific issues relating to the quality and accessibility of the National Footprint Accounts (GFN 2006). These issues had previously been identified by the members of the Network – raised either directly with them, in the review process by the National Accounts Committee, or in the course of various recent reviews of the accounts (Swiss (von Stokar et al. 2006), Irish (Curry et al. in press) and German (Giljum et al. 2007). Summary results are given in Figure 2 below. The large white numbers indicate the final priority rating (1 (highest priority), 2 or 3) given to the item.

Two further open questions were posed to respondents to enable them to raise issues or provide general comment on the future development of the Ecological Footprint.

Figure 1: Allocation of resources to broad research areas.

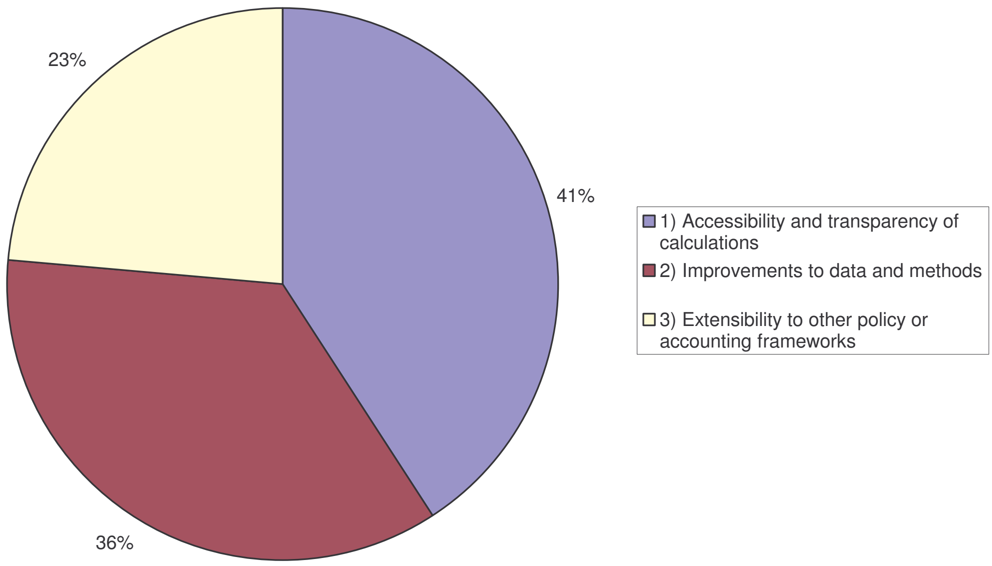
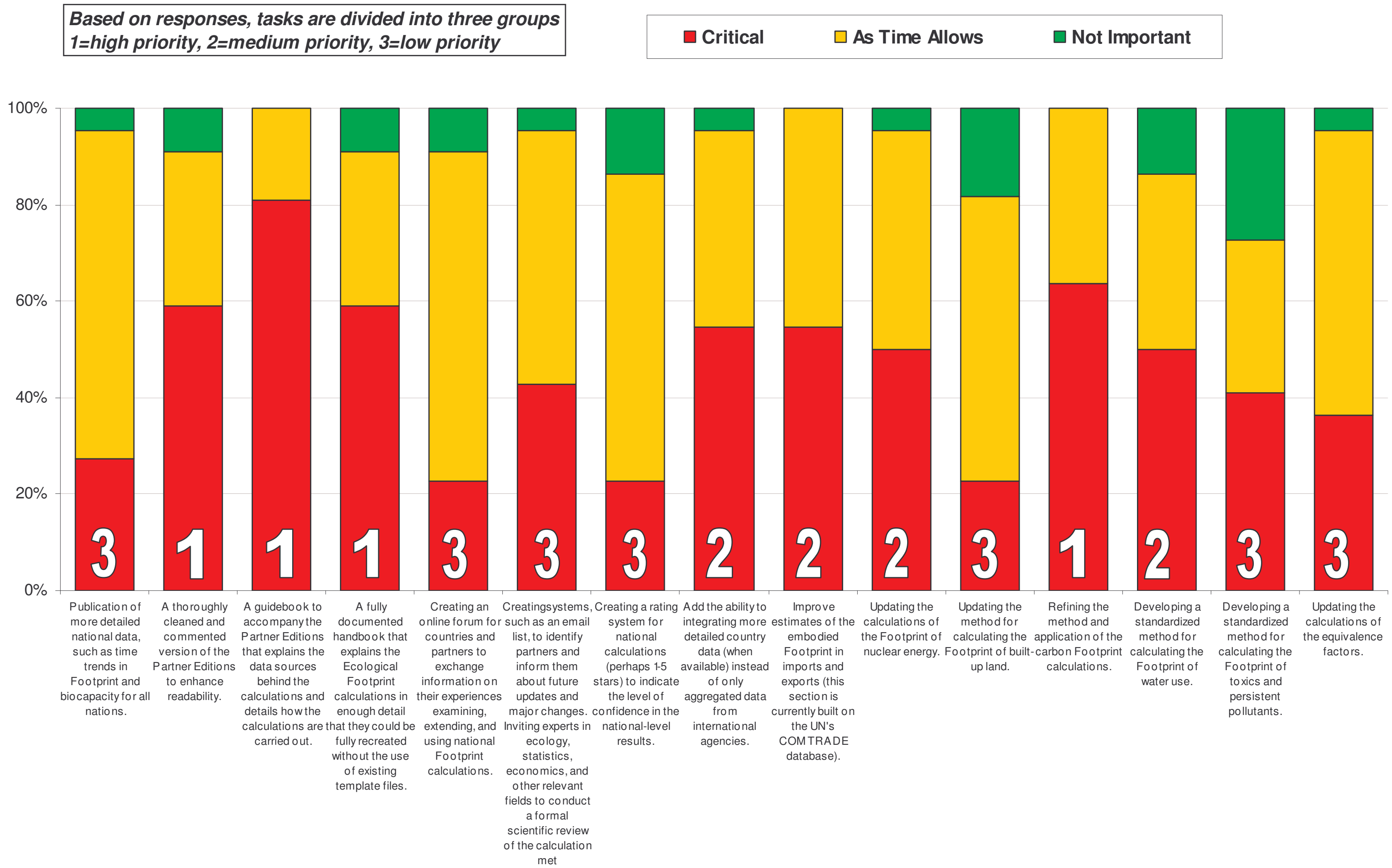


Figure 2: Summary responses from the first phase survey



Subtask 3: Drafting of research objectives based on outputs of subtasks 1 and 2

Perhaps not surprisingly, the expert responses – though useful in terms of identifying broad research priorities – did not raise any novel issues that had not already been picked up in the literature review. This is no doubt due to the fact that Global Footprint Network members (including some of the project team) had recently collected and collated the views of the wider practitioner community and used the opportunity presented by the 2nd International Footprint Conference to publish the results. All issues had therefore already been included (along with other matters presented at the May conference) in the Subtask 1 literature review.

The 43 issues arising from the literature review were each described in no more than a paragraph of text (see Annex 1a).

Subtask 4: Consultation with selected practitioner group to agree, prioritise and scope objectives

The consultation process asked 10 leading practitioners to express their expert opinion and personal judgement on a number of critical issues relating to the National Footprint Accounts (NFA). The issues included in the consultation were generated by a literature review (Task 3 subtasks 1-3). This project extends and builds on the work published by Kitzes et al. (2007a) by adding to the 26 issues originally identified and ranking their importance.

The nine leading practitioners (representing nine different organisations) that responded to the consultation process were:

- Craig Simmons, Best Foot Forward
- Justin Kitzes, Global Footprint Network
- Manfred Lenzen, The University of Sydney
- Richard Moles, Bernadette O'Regan & Conor Walsh, University of Limerick
- Bill Rees, University of British Columbia
- Ian Moffat, University of Stirling
- Jonathon Loh, Editor of WWF Living Planet Report
- John Barrett, Stockholm Environment Institute - York
- Andrew Ferguson, Optimum Population Trust

Given the unexpectedly high number of issues that arose, practitioners were simply asked to rank order the objectives – based on a simple paragraph description of each – rather than undertake a more complex multi-criterion analysis. The responses were then further divided into high (3 points), medium (2 points), low (1 point) and unranked (0 points) to help discern any consistent pattern (Table 1). The consultation process yielded nine responses and importance rankings for each of the 43 NFA issues identified[58].

Issues were ranked by the total number of points first, then the number of high importance responses and then the number of medium importance responses. Several issues had equal ranking after this process and the 43 issues therefore reduced to 28 importance categories (Table 2).

Note that despite the large number of issues and incomplete responses, clear priorities emerged including:

- Carbon sequestration
- Trade
- Documentation
- Equivalence factors
- Accuracy of source data
- Calculation errors
- Fish yields

Subtask 5: Drafting of research agenda based on output from subtasks 3 & 4

The research agenda was reduced to nine research proposals based on key themes. Initially, it was planned to define 10 research proposals based around the Top 10 issues (Table 2). However, when combining these with other 'micro' issues there was felt to be some overlap. It was concluded that it was more logical, and provided a stronger and more efficient research focus, if issues were slightly realigned. Therefore, Input-Output Analysis (Rank 4) was integrated with Trade (Rank 2) and the single most notable issues from Ranks 7 & 8 were taken as the key focal points for the respective proposals.

The recently published research agenda (Kitzes et al. 2007a) represented the most thorough review to date of the Ecological Footprint and specifically the National Footprint Accounts. Although Justin Kitzes is the lead author, the published paper is a collaborative effort and so reflects a broad range of opinion. Nonetheless, as someone with a good overview of the issues, it was felt that Mr. Kitzes' commentary on the proposed research roadmap would provide a valuable 'second opinion'. Table 3 shows how the issues grouped first by rank and then by theme to derive the nine research proposals. The research proposals are attached in Annex 1b. A Gantt chart showing the dependencies between proposals and associated timescales is attached in Annex 1c

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[58] An additional issue regarding the linkages of the Ecological Footprint to other analyses was highlighted by multiple authors (Kitzes *et al.* 2007, Giljum *et al.* 2007, Schaefer *et al.* 2006, Sherrington & Moran 2007, Hoekstra 2007, Xiao-dong *et al.* 2007, Tukker 2007, Demenge 2007, Wiedmann *et al.* 2007, Herva *et al.* 2007, Hannigan Popp *et al.* 2007 and Van Vuuren & Bouwman 2005) in the literature review. However, due to Task 2 and part of Task 3 of this project addressing this issue it has been excluded from this section of the report.

Table 1: Number and importance of responses for the 43 identified NFA issues

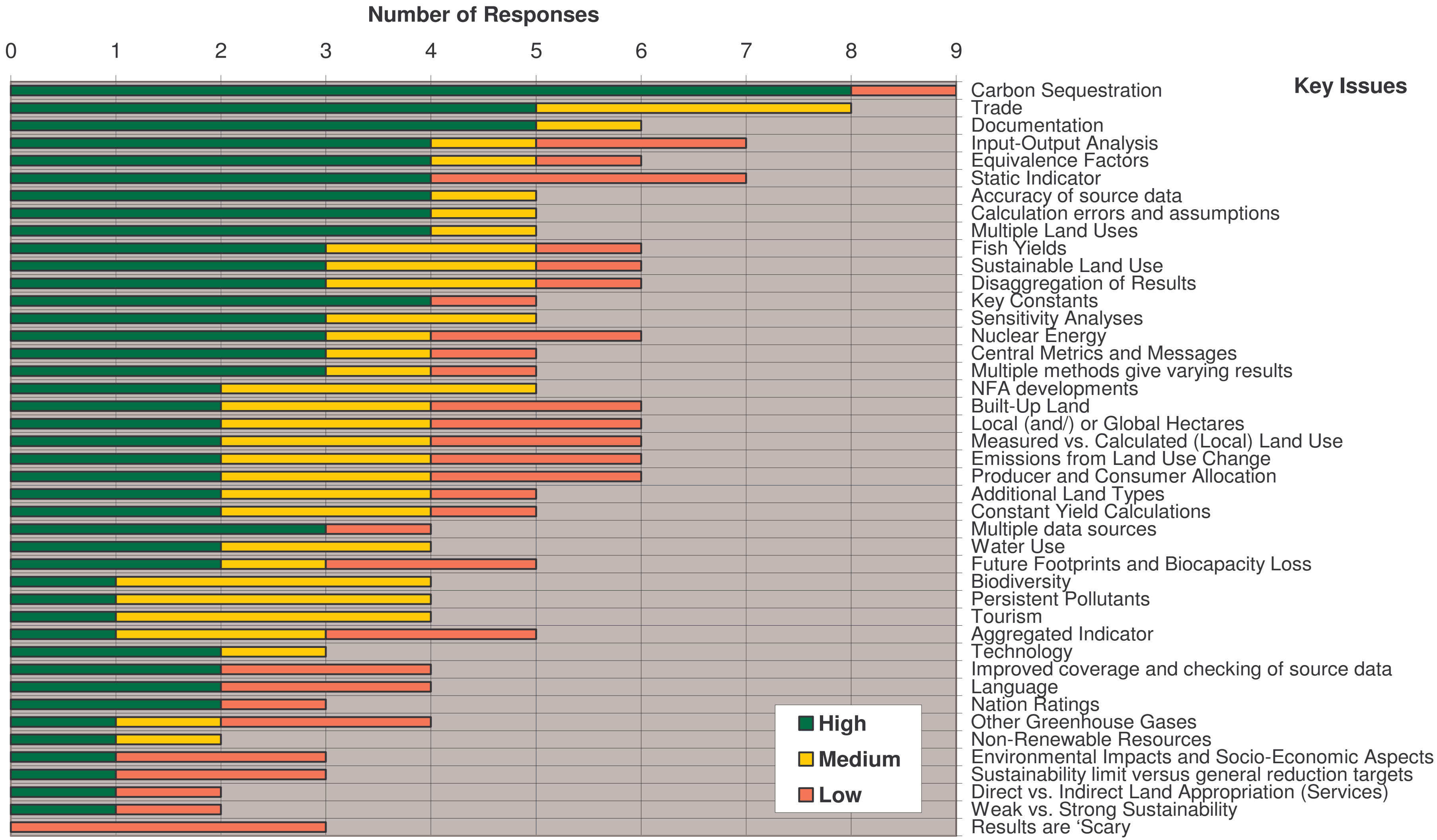

Table 2: The 43 Ecological Footprint issues ranked, shown with number of responses. Marked (✓) if included within Kitzes et al. (2007a)

Issue Description	Rank	No. of responses	Kitzes *et al* ?
Carbon Sequestration	1	9	✓
Trade	2	8	✓
Documentation	3	6	✓
Input-Output Analysis	4	7	
Equivalence Factors	5	6	✓
Static Indicator	6	7	
Accuracy of source data	7	5	✓
Calculation errors and assumptions	7	5	✓
Multiple Land Uses	7	5	✓
Fish Yields	8	6	✓
Sustainable Land Use	8	6	
Disaggregation of Results	8	6	
Key Constants	9	5	✓
Sensitivity Analyses	10	5	✓
Nuclear Energy	11	6	✓
Central Metrics and Messages	12	5	
Multiple methods give varying results	12	5	
NFA developments	13	5	
Built-Up Land	14	6	✓
Local (and/) or Global Hectares	14	6	✓
Measured (local, weighted) vs. Calculated (global) Land Use	14	6	✓
Emissions from Land Use Change	14	6	✓
Producer and Consumer Allocation	14	6	✓
Additional Land Types	15	5	✓
Constant Yield Calculations	15	5	✓
Multiple data sources	16	4	✓
Water Use	17	4	✓

Table 2: The 43 Ecological Footprint issues ranked, shown with number of responses. Marked (✓) if included within Kitzes et al. (2007a) (continued)

Issue Description	Rank	No. of responses	Kitzes *et al* ?
Future Footprints and Biocapacity Loss	18	5	✓
Biodiversity	19	4	✓
Persistent Pollutants	19	4	✓
Tourism	19	4	✓
Aggregated Indicator	20	5	
Technology	21	3	
Improved coverage and checking of source data	22	4	
Language	22	4	
Nation Ratings	23	3	
Other Greenhouse Gases	24	4	✓
Non-Renewable Resources	25	2	
Environmental Impacts and Socio-Economic Aspects	26	3	
Sustainability limit versus general reduction targets	26	3	
Direct vs. Indirect Land Appropriation (Services)	27	2	
Weak vs. Strong Sustainability	27	2	
Results are ‘Scary'	28	3	

Table 3: Ecological Footprint issues ranked and grouped to form the 9 proposals, which constitute the proposed research agenda

Research Proposal	Main Issues	Rank	Responses[1]	Associated Issues	Rank
1	Carbon Sequestration	1	9	Emissions from land use change	=14
				Other greenhouse gases	24
2	Trade	2	8	Input-Output Analysis	4
				Producer consumer allocation	=14
				Tourism	=19
				Direct vs. indirect land appropriation (services)	=27
3	Documentation	3	6	Disaggregation of results	=8
				Central metrics and messages	=12
				NFA developments	13
				Aggregated indicator	20
				Language	=22
				Non-renewable resources	25
				Environmental impacts and socio-economic aspects	=26
				Sustainability limit versus general reduction targets	=26
				Weak vs. strong sustainability	=27
				Results are ‘scary’	28
4	Equivalence Factors	5	6	Local and/or global hectares	=14
				Constant yield calculations	=15
5	Static Indicator	6	7	Future footprints and biocapacity loss	18
				Technology	21
6	Accuracy of Source Data	7	5	Calculation errors and assumptions	=7
				Multiple data sources	16
				Improved coverage and checking of source data	=22
				Nation ratings	23

Research Proposal	Main Issues	Rank	Responses[1]	Associated Issues	Rank
7	Sustainable Land Use	8	6	Multiple land uses	=7
				Measured (local weighted) vs. calculated (global) land use	=14
				Additional land types	=15
				Water use	17
				Persistent pollutants	=19
				Biodiversity	=19
8	Key Constants	9	5	Fish yields	=8
				Nuclear energy	11
				Built-up land	=14
9	Sensitivity Analysis	10	5	Multiple methods give varying results	=12

Annex 1b: National Footprint Accounts: issues grid and references

Introduction

This grid has been constructed to allow National Footprint Account methodological issues to be collated alongside published references. It has been assumed that Kitzes et al. (2007a) (144 cited references), Giljum et al. (2007) (74 cited references) and George (2007) (23 cited references) collate older issues from past papers (published before and including 2000). The focus of this literature review concentrated mainly on recent papers, primarily presented at the International Ecological Footprint Conference in Cardiff, 8-10th May 2007. The output of this consultation is a research agenda for the National Footprint Accounts.

The Issues

In total, 43 issues have been identified as part of this project. These issues have been grouped into 6 categories:

- Data/Calculations and Method Communication Issues
- Current NFA Methodology Issues
- Methodology Change Issues
- Boundary and Philosophical Issues
- EF Integration Issues
- Central Metrics and Messages Issues

Issues have been grouped in these categories, not to influence, but to try and aid consultees' responses. The categories have been chosen as loose groupings to purely ease reading and no greater importance is attached to them.

The Consultation

Within each of the 6 categories are a number of related issues. The issues are presented in table format. Each table consists of 3 columns, Priority, Issue Description and Papers which highlight issue.

***Priority: For each respondent to rank the issues in order, from 1 (highest) to 43 (lowest). You do not have to rank ALL issues, as some you may not consider relevant, valid or of any importance. However, do please rank ALL relevant issues.

Issue Description: A title (bold) for the issue is briefly followed by examples of supporting evidence from selected references. If you require further information regarding any issue, please e-mail: kevin@bestfootforward.com.

References: References which highlight, discuss and/or investigate the issue. All the references included in this review are listed.

Section 1: Data/Calculations and Method Communication Issues

Data/Calculations:

Priority	Issue Description	References
	Accuracy of source data e.g. Incomparable data for nations Systematic distortions 'Grey economy' excluded Nomenclature correlation errors (Kitzes et al., 2007a).	Kitzes et al. (2007a) Curry et al. (in press) Giljum et al. (2007) Version 1 RPA, 2005 George (2007) Schaefer et al., (2006) von Stokar et al. (2006) Moran et al. (2007) Walsh et al (2007) Druckman et al., 2007 Demenge, 2007
	Improved coverage and checking of source data e.g. Certain crops are excluded from the German accounts due to "duplication or insufficient data" (Giljum et al., 2007).	Giljum et al. (2007) Version 1 Moran et al. (2007) IAEA, 2007 GFN 2005, 2006
	Calculation errors and assumptions e.g. Data discrepancies within the categories Cropland, Pasture and Fisheries are mostly attributed to methodical differences (von Stokar et al., 2006).	Giljum et al. (2007) Version 1 Curry et al. (in press) von Stokar et al. (2006)
	Multiple data sources Use of detailed regional data, where available, instead of international sources (Kitzes et al., 2007a).	Kitzes et al. (2007a) Curry et al. (in press) Schaefer et al., (2006)
	Key Constants e.g. Review of key constant assumptions, e.g. tCO2/ha.	Kitzes et al. (2007a)
	Sensitivity Analyses e.g. Lack of uncertainty can significantly affect sub-national target setting (George 2007 citing Curry et al., 2006)	Kitzes et al. (2007a) Giljum et al. (2007) Version 1 Curry et al. (in press) George (2007) Schaefer et al., (2006) Niccolucci et al., 2007

Method Communication:

Priority	Issue Description	References
	Documentation e.g. Scientific basis of the weighting factors are not adequately documented to allow external review (Schaefer et al., 2006).	Kitzes et al. (2007a) Giljum et al. (2007) Version 1 RPA, 2005 George (2007) Schaefer et al., (2006)
	Language e.g. Current documentation is only available in English.	Kitzes et al. (2007a)
	Nation Ratings e.g. Variations in data quality and analysis could be made visible by a quality rating criteria (Giljum et al., 2007).	Kitzes et al. (2007a) Giljum et al. (2007) Version 1
	Multiple methods give varying results e.g. Local Authorities in the UK see that different methods give different results (even when Footprint Standards are compliant).	George (2007)
	NFA developments e.g. Constant method developments of the NFA can vary the EF of local authorities in the UK, whilst consumption may not have changed.	George (2007 citing Curry et al. (2006) as evidence

Section 2: Current NFA Methodology Issues

Priority	Issue Description	References
	Local (and/) or Global Hectares e.g. The use of 'actual' or measured hectares can be used instead of the default global hectares to answer different questions (Kitzes et al., 2007a).	Kitzes et al. (2007a) Giljum et al. (2007) Version 1 Wackernagel et al., 2004b Wiedmann & Lenzen (2007) Sherrington & Moran (2007) Hoekstra, (2007a) Demenge, 2007 Van Vuuren & Bouwman 2005
	Trade e.g. Trade accounts are imperfect in the current NFA (Kitzes et al., 2007a).	Kitzes et al. (2007a) Giljum et al. (2007) Version 1 Curry et al. (in press) Lenzen & Murray (2003) Huijbregts et al. (2007) Moran et al. (2007) Hoekstra, (2007) Demenge, 2007 Rees, 2006
	Tourism e.g. Impacts of Tourism are currently allocated to the destination country, not the home country of the tourist (Kitzes et al., 2007a).	Kitzes et al. (2007a) Giljum et al. (2007) Version 1
	Equivalence Factors e.g. Siche et al. 2007 use Emergy to calculate alternative equivalence factors, as well as including all area types and carbon emissions for treatment collection and supply of water and apply to Peru where there analysis shows Peru's ratio of BC/EF = 2.2, compared to NFA where BC/EF = 4.	Kitzes et al. (2007a) Haberl et al. (2003) Zhao et al. (2005) Siche et al. (2007) RP EF 2.0 (http://www.ecologicalfootprint.org/FAQ.html 20th June 2007) Huijbregts et al. (2007) Van Vuuren & Bouwman 2005
	Nuclear Energy e.g. In the WWF (2005) study, a unit of nuclear energy is considered as equal to one unit of fossil energy. This politically-wanted transfer coefficient does not reflect the environmental pressure from nuclear power activities. (Schaefer et al., 2006).	Kitzes et al. (2007a) Giljum et al. (2007) Version 1 Schaefer et al., (2006) Comment to reviewers: Please note that the National Accounts Committee agreed to exclude Nuclear Energy from the NFA.

Priority	Issue Description	References
	Carbon Sequestration e.g. A major EF assumption. Four alternative calculation approaches are presented (Kitzes et al., 2007a) e.g. "incorporates a new carbon sequestration approach that changes the corresponding Footprint from about 1 global hectare (gha) per tonne of carbon to about 16 gha/tC and adds over 8 gha of biocapacity to the energy land category, where EF 1.0 reported none. The basis for this change is shifting the focus from forest to the entire carbon cycle thus reducing the sequestration rate per hectare and adding biocapacity." (RP EF 2.0).	Kitzes et al. (2007a) Giljum et al. (2007) Version 1 RPA, 2005 Schaefer et al., (2006) Lenzen & Murray (2001, 2003) RP EF 2.0 (http://www.ecologicalfootprint.org/FAQ.html 20th June 2007) Hoekstra, (2007a) Collins, (2007) Rees, 2006
	Fish Yields e.g. Current methods use primary production requirements and a single estimate of sustainable yield. This ignores "quality" and availability of stocks in determining actual regenerative capacity in a given year (Kitzes et al., 2007a).	Kitzes et al. (2007a) Giljum et al. (2007) Version 1
	Built-Up Land e.g. Currently assumed as crop land. This varies per region and some data sources may give actual bioproductivity of built over land. Some argue this component should be removed as it is non-bioproductive land (Kitzes et al., 2007a).	Kitzes et al. (2007a) Giljum et al. (2007) Version 1
	Non-Renewable Resources e.g. The EF only includes renewable resources (Giljum et al., 2007).	Giljum et al. (2007) Version 1 Rees, 2006 GFN, 2006 Comment to reviewers: Please note that this issue is false.
	Direct vs. Indirect Land Appropriation (Services) e.g. The NFA land areas are referred to as "directly used by households or directly required by producers". This ignores the indirect uses, by the service sector for example, which is supplied from other sectors (Giljum et al., 2007).	Giljum et al. (2007) Version 1 Comment to reviewers: Please note that this issue is false. The NFA account total resource use, thus they do include indirect resource use, but do not identify it. This is due to the NFA not disaggregating results below the nation level, e.g. into economic sectors.

Priority	Issue Description	References
	Technology e.g. Energy efficient and CO_2-reducing technologies are not taken into account (Giljum et al., 2007). e.g. (EF) “represent what is, not what should be or what could be. EFA analysis is fully responsive to technological changes or substitutions that might significantly affect a population’s eco-footprint” (Rees 2006).	Giljum et al. (2007) Version 1 Rees, 2006 Comment to reviewers: Please note that this issue is false.

Section 3: Methodology Change Issues

Priority	Issue Description	References
	Measured vs. Calculated (Local) Land Use e.g. "EFA assumes that 'land' is being used sustainably: This charge is true and bothersome" (Rees, 2006). e.g. Measured hectares are 'actual' hectares adjusted by a disturbance factor (Lenzen and Murray, 2003) to reflect the qualitative conditions of land use (Kitzes et al., 2007a).	Kitzes et al. (2007a) Giljum et al. (2007) Version 1 Lenzen & Murray (2003) Lenzen et al. (2006a) Rees, 2006
	Other Greenhouse Gases e.g. Non-CO_2 emissions are left out of the EF. This exclusion requires caution if policies led to excluded emissions worsening, whilst, for example, CO_2 emissions fell. (RPA 2005 cited by Giljum et al., 2007). e.g. Substances without a significant absorption or Regenerative capacity cannot be covered by the EF/BC accounts. Schaefer et al., (2006).	Kitzes et al. (2007a) Giljum et al. (2007) Version 1 RPA, 2005 Schaefer et al., (2006) Lenzen & Murray (2003) Lenzen et al. (2006a) Huijbregts et al. (2007) Walsh et al (2007) Herva et al., 2007 Comment to reviewers: Please note that the National Accounts Committee rejected the inclusion of Other Greenhouse Gases into the NFA.
	Emissions from Land Use Change e.g. Currently excluded from EF, but may be 30% of fuel related CO_2 (IPCC 2001) (Kitzes et al., 2007a).	Kitzes et al. (2007a) Lenzen & Murray (2003)
	Additional Land Types e.g. Certain productive land types, e.g. wetlands are not included in current accounts. This is likely to not add significant amounts to the accounts (Kitzes et al., 2007a) e.g. According to RPA (2005) this exclusion of areas could lead to an underestimation of the global available biocapacity by 10-20%.	Kitzes et al. (2007a) Giljum et al. (2007) Version 1 RPA (2005) Siche et al. (2007) Lenzen & Murray (2003)
	Constant Yield Calculations e.g. Time series trends using annual studies vary both consumption and bioproductivity. These are difficult to disentangle. Using a constant yield can show the changes in resource consumption only (Kitzes et al., 2007a).	Kitzes et al. (2007a) George (2007 citing Curry et al. (2006 – Northern Limits II)

Priority	Issue Description	References
	Disaggregation of Results e.g. The NFA do not present disaggregated results aligned to either economic sectors, or policy-relevant components.	Giljum et al. (2007) Version 1
	Input-Output Analysis e.g. Intensified use of input-output-analysis (IOA) with data from the National Footprint Accounts could strengthen the policy-orientated applications of Footprint calculations. This already occurs with energy and materials data in Germany (Schoer and Schweinert 2005) (Giljum et al., 2007).	Giljum et al. (2007) Version 1 Simmons et al., 2006b Wiedmann et al., 2006c George (2007) Lenzen & Murray (2003) Weidmann et al., 2007 Tukker, A., 2007 Druckman et al., 2007

Section 4: Boundary and Philosophical Issues

Priority	Issue Description	References
	Producer and Consumer Allocation/ Consumption and/or Production Footprints? e.g. Methods using I-O (Lenzen et al., 2006a) can be used to allocate resource use to both producers and consumers (Giljum et al., 2007).	Kitzes et al. (2007a) Giljum et al. (2007) Version 1 Lenzen et al., 2006a Weidmann et al., 2007 Burdick, 2007
	Multiple Land Uses e.g. EF assumes a single land use per hectare. This has been found to "accurately calculate demand and supply" (Millennium Ecosystem Assessment 2005 cited in Kitzes et al., 2007a). Yet, RPA 2005 state that this assumption could overestimate the EF or underestimate biocapacity (Giljum et al., 2007).	Kitzes et al. (2007a) Giljum et al. (2007) Version 1 MEA 2005 RPA 2005
	Sustainable Land Use e.g. No account of land use intensity is taken and only shows up as a loss of bioproductivity (Giljum et al., 2007) e.g. "This charge is true and bothersome" (Rees, 2006).	Giljum et al. (2007) Version 1 Lenzen & Murray (2001, 2003) Lenzen et al. (2006a) Rees, 2006
	Future Footprints and Biocapacity Loss e.g. Current accounts are historical and exclude 'future' resource demands.	Kitzes et al. (2007a)
	Weak vs. Strong Sustainability e.g. Implicit assumption of strong sustainability assumes natural and man-made capital is not interchangeable. Weak Sustainability states it is, to a certain degree, and this would lower the EF (Giljum et al., 2007). e.g. "…eco-footprint analysis per se makes no assumptions whatever about material substitutions or technological change" (Rees, 2006).	Giljum et al. (2007) Version 1 Rees, 2006 Please Note that this issue is false.

Priority	Issue Description	References
	Aggregated Indicator e.g. By referring to the production area, which forms the basis for resource use, the physical amounts of consumption can be compared and added up. Thereby, yield data fulfils the function of weighting and standardisation. However, the direct link to environmental impacts is lost; this is a basic problem with all aggregated indicators of resource use (van der Voet et al., 2005a cited in Giljum et al., 2007).	Giljum et al. (2007) Version 1 van der Voet et al., 2005a
	Static Indicator e.g. "Typical EFA studies lack predictive power: This seeming 'criticism' is true but irrelevant. Many useful indices are based on static analyses" (Rees, 2006).	Giljum et al. (2007) Version 1 Rees, 2006

Section 5: EF Integration Issues

Priority	Issue Description	References
	Water Use e.g. Water not included as not a product of the biosphere. Can be included as resources consumed to supply and treat water (Lenzen et al., 2003), or as an estimate of catchment area (e.g., Luck et al 2001), which includes double counting of area. WWF (2006) present as a separate indicator (litres consumed/available) (Kitzes et al., 2007a). e.g. The water footprint concept introduced in 2002 is an analogue of the ecological footprint concept (Hoekstra 2007a).	Kitzes et al. (2007a) Giljum et al. (2007) Version 1 Siche et al. (2007) Hoekstra, (2007a) Taniguchi et al. 2007
	Persistent Pollutants e.g. Substances without a significant absorption or Regenerative capacity cannot be covered by the EF/BC accounts (Schaefer et al., 2006).	Kitzes et al. (2007a) Schaefer et al., (2006) Herva et al., 2007
	Biodiversity e.g. Not included in Biocapacity, though has been in the past. At the large scale, EF has been used as an indicator of a driver for Biodiversity loss. At the smaller scale, the usefulness is not clear. Other methods claim to address this, but paper suggests it is best to use alternative indicators for smaller scale management decisions (Kitzes et al, 2007a).	Kitzes et al. (2007a) RP EF 2.0 (http://www.ecologicalfootprint.org/FAQ.html 20th June 2007) Lenzen et al. (2006a)
	Environmental Impacts and Socio-Economic Aspects e.g. The quantitative use of land neglects the qualitative aspects, such as erosion, landslides, and pollution. Weighting factors neither reflect relative scarcity over time nor spatial differences (van den Bergh and Verbruggen, 1999 cited in Giljum et al., 2007).	Giljum et al. (2007) Version 1 Weidmann et al., 2007 Rees, 2006
	Sustainability limit versus general reduction targets e.g. The EF produces a global sustainability limit: That the Footprint of humanity must be smaller than the global available biocapacity is a necessary, but not sufficient condition for sustainability (GFN 2006b).	Giljum et al. (2007) Version 1 GFN 2006b Lenzen & Murray (2003)

Priority	Issue Description	References
	e.g. Other concepts of sustainable resource management (such as Factor 4/10) claim that it would not be possible to determine an exact level of sustainable resource use. They emphasise that the key issue is the reduction of resource consumption and associated negative environmental impacts (for instance Spangenberg et al., 1998 cited in Giljum et al., 2007).	

Section 6: Central Metrics and Messages Issues

Priority	Issue Description	References
	Results are 'Scary'/ questioned if they are 'politically acceptable' e.g. "EFA results are depressing: To quote one critic, '[EFA] is becoming a global aggregated indicator of ecological overshoot and doom.' As shown in a previous section, EFA suggests that the world economy is, in fact, in a state of overshoot… If this suggests 'doom' to our critics it may once again reflect their own subjective fears that the findings may actually be accurate" (Rees, 2006).	Personal comment from unspecified source (Footprint Forum 2006). Giljum et al. (2007) Version 1 George (2007) Ayres, 2000 EAI, 2002 Haberl et al. (2001) Rees, 2006
	Central Metrics and Messages e.g. Heterogeneous ingredients: The fact that a single figure is obtained does not guarantee that its Interpretation is straightforward (Schaefer et al., 2006). e.g. Increasing bioproductivity can actually be accompanied by increasing disturbance, leading in turn to decreasing future biodiversity, biocapacity and bioproductivity (Pimentel et al. 1976). If used in isolation, the bioproductivity metric not only provides no "early-warning signal" for looming future problems, it may actually provide incentives that lead to future problems." (Lenzen et al., 2006a). e.g. It would appear that the focus on equality of outcome eclipses any consideration of economic efficiency and therefore precludes widespread adoption of the Ecological Footprint approach by policy makers. This paper will argue that equality of opportunity, i.e. rights to fair shares of the planet's renewable resources, is more important than equality of outcome in the consumption of those resources in making progress towards One Planet Living." (Sherrington & Moran 2007).	Giljum et al. (2007) Version 1 Schaefer et al., (2006) Lenzen & Murray (2003) Lenzen et al. (2006a) Sherrington & Moran (2007) Demenge, 2007 Rees, 2006 Van Vuuren & Bouwman 2005

Annex 1c: The research agenda in nine research proposals

Outline proposal for the project

„Further Development and Application of the Ecological Footprint for monitoring sustainable use of natural resources“

Introduction and Context

This research proposal follows on from the European Commission DG Environment project „Potential of the Ecological Footprint for monitoring environmental impact from natural resource use“. This project identified the need for additional research to improve the accuracy and robustness of the Ecological Footprint.

A literature review followed by expert evaluation identified 43 distinct issues – which were ranked for importance and then grouped together based on similarity. As a result, nine core themes were identified. Each of these is formulated into a research brief.

The nine core themes are:

1. Accounting Anthropogenic Carbon and Other Greenhouse Gas Emissions with the Ecological Footprint,
2. Accounting Traded Goods and Services with the Ecological Footprint,
3. Documenting the Ecological Footprint Methodology,
4. Development and Calculation of Ecological Footprint Equivalence Factors,
5. Improving the Utility of the Ecological Footprint for Policy-Makers,
6. Evaluating the Robustness, Validity and Accuracy of Source data used to derive the National Ecological Footprint Accounts,
7. Accounting Sustainable Land Use with the Ecological Footprint,
8. Evaluating and Testing the Key Constant Assumptions of the National Ecological Footprint Accounts, and
9. Testing the Sensitivity of the National Ecological Footprint Accounts.

Each of these is described below.

Sub-proposal 1:

„ACCOUNTING ANTHROPOGENIC CARBON AND OTHER GREENHOUSE GAS EMISSIONS WITH THE ECOLOGICAL FOOTPRINT"

1. Key Source Data and Methodology Stakeholders

IPCC, FAO

2. Context and Problem Definition

The current method of carbon accounting in the National Footprint Accounts (currently authored by the Global Footprint Network and published in summary form in WWF's Living Planet Report) was ranked as the most important issue (Rank 1) in the previous project.

Currently, the Ecological Footprint of one tonne of carbon emission is calculated as the amount of forest area required to sequester 0.75 tonnes of carbon (the additional 0.25 tonnes of the emission is assumed to absorb, with no Footprint, into the surface ocean) Kitzes et al. (2007a).

In the UK, where the Ecological Footprint has been developed and applied at various sub-national scales for over 10 years, RPA undertook a review of the Ecological Footprint for DEFRA and found that "concern over including energy and its method of calculation" was the biggest source of criticism (RPA, 2005). Indeed, Global Footprint Network's own Kitzes et al. (2007a) state that "(Ecological) Footprint estimates are extremely sensitive to methodological decisions about how to calculate the carbon Footprint". The importance of this issue is reinforced by the observation that the carbon element of the Footprint commonly "represents more than 50% of the overall (Ecological) Footprint for most industrial countries" (RPA, 2005; van den Bergh and Verbruggen, 1999).

Eurostat have reviewed the Ecological Footprint and regarding carbon accounting noted, "regeneration of 'burnt' fuel stocks (is) not included" (Schaefer et al. 2006). Though a simple methodological observation, if implemented, this potentially complex change would align carbon accounting with the other components of the Ecological Footprint.

In addition, misunderstandings of the Ecological Footprint have arisen around the way in which carbon is accounted. These are often expressed in the literature as observations, concerns or are identified by peers as erroneous statements. For example, the "CO2 component – influences the overall result to a too large extent" (Giljum et al. 2007 citing Ayres, 2000 and EAI, 2002). This is clearly refuted by Bill Rees (2006) who has stated that "Energy-use creates a large (Ecological Footprint) EF primarily because of thermodynamic laws, not because of methodological flaws".

3. Task: Evaluate methodological options and recommend a robust method for accounting anthropogenic carbon emissions for inclusion within the Ecological Footprint

Kitzes et al. (2007a) recently published a research agenda for the National Footprint Accounts. This thorough evaluation of the Footprint methodology used to construct the National Footprint Accounts also highlighted the issue of carbon accounting. Kitzes et al. (2007a) went further and discussed four methodological options for carbon accounting with the Ecological Footprint:

- the amount of world-average bioproductive land of all types needed to sequester anthropogenic carbon emissions,
- changes in the extent and production of bioproductive land under climate change scenarios, with an allocation of a portion of this decrease in productivity to current carbon emissions (Lenzen and Murray 2001),
- the number of global hectares that would be required to produce a quantity of biofuels equal in energy potential to the fossil fuels being combusted, consistent with a thermodynamic equivalency framework (Wackernagel and Rees 1996), and
- the number of global hectares originally needed to produce the living matter embodied in a given quantity of fossil fuel.

Collins (2007) used five alternative sequestration based methods to illustrate the variance between approaches within just the first of the four methods suggested by Kitzes et al. (2007a). As carbon sequestration alternatives, Collins (2007) used:

- global average ocean,
- global average land,
- global average forest (current NFA method),
- average Irish forest, and
- average Irish willow short rotation coppice plantation.

Most recently, the National Accounts Review committee discussed issues affecting carbon accounting. In a committee document (GFN 2007a) it was suggested that "the amount of carbon absorbed by the surface ocean will not be subtracted from carbon emissions when calculating the carbon Footprint". This was based on an understanding that the role of the ocean as a carbon sink was most likely changing. A follow-on discussion document (GFN 2007d) outlined some of the inconclusive science surrounding the role of the ocean as a carbon-sink. However, it has been decided that no action will be taken at this time, pending additional review (GFN, June 2007).

4. Associated Issues:

Emissions from Land Use Change (Rank 14): Carbon emissions from land use change are currently excluded from the Ecological Footprint, but may be 30% of fuel related CO2 (IPCC 2001 cited in Kitzes et al. 2007a). The National Accounts Review committee has recommended that these be added to the global total, but not allocated to individual countries at this time due to the lack of a robust method for allocation, for next National Footprint Accounts Edition (2008) (GFN, June 2007).

Other Greenhouse Gases (Rank 24): Other greenhouse gases, such as methane, nitrous oxide, fluorocarbons and sulphur hexafluoride, are currently not included in the National Footprint Accounts.

5. Outputs:

It is important that the outputs from this research do not duplicate existing or planned work but build upon the extensive carbon and greenhouse gas literature that already exists.

The proposed project outputs are:

- Identify and Evaluate methodological options and associated issues for carbon accounting with the Ecological Footprint, including:
  - the amount of world-average bioproductive land of all types, world-average bioproductive ocean and world-average bioproductive forest (current method) needed to sequester anthropogenic carbon emissions,
  - changes in the extent and production of bioproductive land under climate change scenarios, with an allocation of a portion of this decrease in productivity to current carbon emissions (Lenzen and Murray 2001),
  - the number of global hectares that would be required to produce a quantity of biofuels equal in energy potential to the fossil fuels being combusted, consistent with a thermodynamic equivalency framework (Wackernagel and Rees 1996), and
  - the number of global hectares originally needed to produce the living matter embodied in a given quantity of fossil fuel.
- Conduct a thorough review and consultation with leading practitioners of best practices (including IPCC),
- Ensure any research takes account of the ‘best practice’ standards and guidelines contained with the Footprint Standards (GFN 2006b).
- Assess the implications for the current Footprint Standards of any proposed revisions to the Ecological Footprint methodology
- Draft methodological recommendations to address identified and associated issues,
- Consultation with leading practitioners to agree, prioritise and scope recommendations,
- Consultation with project team to finalise recommendations, and
- Final recommendations report.

6. Timeline & Budget:

Global Footprint Network, the current authors of the National Footprint Accounts, estimate that this research could be completed and ready for implementation in the 2010 edition of the National Footprint Accounts, published in summary in WWF's Living Planet Report (WWF, 2006).

Method Description	Estimated Days
Carbon sequestration via global average forest and global average ocean, comply w/ IPCC & Associated Issues	**70**
Carbon sequestration via all global average land types	**35**
Alternate Methods – Biofuels & Bioproductive area required to produce fossil fuels	**35**
Alternate Methods – A future bioproductive land change under climate change scenario	**85**

Sub-proposal 2:

„ACCOUNTING TRADED GOODS AND SERVICES WITHIN THE ECOLOGICAL FOOTPRINT“

1. Key Source Data and Methodology Stakeholders

UN Comtrade, OECD, National Statistical Agencies

2. Context and Problem Definition

The current method of trade accounting in the National Footprint Accounts (currently authored by the Global Footprint Network and published in summary form in WWF's Living Planet Report) was ranked as the second most important issue (Rank 2) in the previous project.

Currently, the trade accounts in the National Footprint Accounts use a mass balance approach, which "multiplies the reported weights of product flows between nations by (Ecological) Footprint intensities in global hectares per tonne to arrive at an estimate of total global hectares imported and exported" (e.g., Monfreda et al. 2004 cited in Kitzes et al. 2007a). The Ecological Footprint adopts a 'consumer responsibility' approach where apparent consumption is derived from the simple formula 'Production + Imports + Stock Changes – Exports' (GFN, 2006).

Problems with the current method of accounting trade in the National Footprint Accounts have received more attention in recent times (e.g. Bicknell et al. 1998, Lenzen and Murray, 2003, Curry et al. 2006, von Stokar et al. 2006 and Giljum et al. 2007). The issues identified are of two types: those that refer to the current calculation method and those that refer to the current trade accounting boundaries and data gaps.

Curry et al. 2006, von Stokar et al. 2006 and Giljum et al. 2007 refer to errors in the current calculation method. The Global Footprint Network has already addressed the main error identified by Curry et al. in the 2006 edition of the National Footprint Accounts . Giljum et al. 2007 state how "in conventional (National) Footprint Accounts, the embodied (Ecological) Footprint of traded goods is calculated by multiplying the physical quantity of imports by a coefficient (gha/tonne), which reflects energy requirements and emission intensities along the whole production life cycle, determined with the help of life cycle assessments. Currently, only a single data set related to these coefficients exists in the (National) Footprint Accounts for all countries".

Bicknell et al. 1998, Lenzen and Murray, 2003 and Giljum et al. 2007 refer to boundary limits and data gaps in the current trade accounting methodology. Lenzen & Murray, 2003 state, "current practice is to assume that industry sectors in the countries of imports origin apply the same production structure...as the respective domestic sectors. This is obviously not necessarily the case. Moreover, this assumption makes it impossible to identify opportunities where trade structures may be altered to reduce national Ecological Footprints (Bicknell et al. 1998)". Giljum et al. 2007 state "in order to comprehensively consider the interrelations of international production chains in the calculations, the use of a multi-regional economy-environment model is necessary, which could calculate the indirect (or embodied) environmental requirements of traded goods (Giljum, 2005; Wiedmann et al., 2006a[59])".

3. Task: Evaluate methodological options and recommend a robust method for accounting internationally traded goods and services within the Ecological Footprint

Kitzes et al. (2007a) recently published a research agenda for the National Footprint Accounts.. This thorough evaluation of the Footprint methodology used to construct the National Footprint Accounts also highlighted the issue of trade. This study gave two methodological options for accounting trade with the Ecological Footprint:

- For the mass balance approach: "locate more robust country (and sector) - specific embodied energy figures to more accurately capture the carbon embodied in traded goods", and
- For the Input-Output approach: The currently theoretical multi-sector, multi-region input-output analyses (Turner et al. in press, Wiedmann et al. 2007) could be applied to Ecological Footprint analysis. "Monetary input-output based frameworks also may provide the additional benefit of accounting for international trade in services in addition to goods".

Kitzes et al. 2007a states, "as many services traded across borders require biological capacity to support but have no physical product associated with them (e.g., insurance, banking, customer service, etc.), trade in these services could only be captured by non-physical accounts. The current omission of trade in services has the potential to bias upward the Footprint of service exporting nations, such as those with large telecommunications sectors, research and development, or knowledge-based industries".

In respect of the mass balance approach and a possible path forward, Kitzes et al. 2007a add, "many newer LCA databases derive their estimates using input-output frameworks". This, "may lead to convergence between these two methods (Hendrickson et al. 1998, Joshi 1999, Treloar et al. 2000, Lenzen 2002, Suh and Huppes 2002, Nijdam et al. 2005, Heijungs et al. 2006, Tukker et al. 2006, Weidema et al. 2005, Wiedmann et al. 2006a[60])". On the other hand, emerging standards (for example PAS 2050 (BSI, 2007)) are likely to require high levels of primary data which effectively excludes IO approaches.

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59 Cited as "Wiedmann et al. 2006 c" in this report.

60 Cited as "Wiedmann et al. 2006 c" in this report.

4. Associated Issues:

Input-Output Analysis (Rank 4): Projects are currently underway to assess the use of monetary Input-Output tables (MIOT) in environmental assessments (e.g. Tukker, 2007). Most relevant to the Ecological Footprint is the work by Wiedmann et al. 2007a:

> *"The aim of the ongoing work is to develop a data optimisation procedure that allows the construction of integrated national input-output and environmental databases that can be used for an environmental MRIO (multi-regional IO) model in the future. Thus the work will set the basis for numerous analyses of environmental impacts associated with UK trade flows, including detailed accounts of emissions embedded in trade flows to and from the UK over a period of time. [...] In order to derive reliable and robust estimates for embedded emissions, it is important to explicitly consider the production efficiency and emissions intensity of a number of trading countries and world regions in an international trade model, which is globally closed and sectorally deeply disaggregated (Wiedmann et al. 2007[61])."*

Wiedmann et al. (2007a) are also very clear as to the limitations of IO analysis within Footprint accounting: Input Output models: "are not well suited to describe change in a predictive (ex-ante) way, because they usually do not contain any realistic description of agent behaviour (e.g. producer and consumer demand). Input-output coefficients (the Leontief production function) provide an indication of average factor use, but should not be assumed to give information on marginal factor use, as a function of price or other determinants."

In summary, the suitability of IO may well depend on the question(s) to be answered.

The outcomes of such research would need to be assessed for application to the Ecological Footprint. In particular, it is important to consider the potential role of the Ecological Footprint as an eco-efficiency indicator as part of the EC Resources Strategy when using MIOT.

Producer and Consumer Allocation (Rank 14): "A framework in which the (Ecological) Footprint of a processed product is divided between all of the various sectors that extract and process a product and its final consumer" (Gallego and Lenzen 2005, Lenzen et al. 2007a, cited in Kitzes et al. 2007a). In other words, how can responsibility for the Ecological Footprint of goods and services (whether internationally traded or not) be best allocated to various agents along the supply chain with a view to setting clear targets and goals.

Tourism (Rank 19): "Currently, the Footprint of international tourism is allocated to the country in which the tourist is travelling…Since tourism is generally regarded as an export sector of the economy, this represents a methodological inconsistency...the (Ecological) Footprint of tourist activities should be allocated instead to the home country of the tourist. This inconsistency could prove significant for small nations with well-developed tourism infrastructure" (Kitzes et al. 2007a).

[61] Cited as "Wiedmann et al. 2007b" in this report.

5. Outputs

It is important that the outputs from this research do not duplicate existing or planned work but build upon the extensive literature that already exists. Outputs include:

- Document, review and critique current methods used to incorporate trade within national environmental accounts
- Identify and Evaluate methodological options and associated issues for accounting trade within the Ecological Footprint, including:
  - For the mass balance approach: "locate more robust country (and sector) -specific embodied energy figures to more accurately capture the carbon embodied in traded goods", and
  - For the Input-Output approach: How the currently theoretical multi-sector, multi-region input-output analyses (Turner et al. in press, Wiedmann et al. 2007) could be applied to Ecological Footprint analysis. "Monetary input-output based frameworks also may provide the additional benefit of accounting for international trade in services in addition to goods".
- Conduct a thorough review and consultation with leading practitioners of best practices,
- Ensure any research takes account of the 'best practice' standards and guidelines contained with the Footprint Standards (GFN 2006b).
- Assess the implications for the current Footprint Standards of any proposed revisions to the Ecological Footprint methodology
- Drafting of methodological recommendations to address identified and associated issues,
- Consultation with leading practitioners to agree, prioritise and scope recommendations,
- Consultation with project team to finalise recommendations, and
- Final recommendations report.

6. Timeline & Budget:

Global Footprint Network, the current authors of the National Footprint Accounts, estimate that this research could be completed and ready for implementation in the 2012 edition of the National Footprint Accounts, published in summary in WWF's Living Planet Report (WWF et al., 2006).

Method Description	Estimated Days
Testing and implementing a global Input-Output model in the National Footprint Accounts, including producer and consumer allocation methods, allocating the Ecological Footprint of tourism to the tourist's home nation, and accounting trade in services.	**80**
Develop multi-region Input-Output (MRIO) global model	**To Be Defined***
Testing and implementing national and sectoral lifecycle-based embodied energy and resources data in a mass-balance trade methodology	**50**

*The work by Lenzen et al. (2007) is recent and details are not specific enough to draft a proposal. At least one project (Wiedmann et al. 2007a) is already funded by the UK Department for Environment, Food and Rural Affairs (DEFRA).

Sub-proposal 3:

„DOCUMENTING THE ECOLOGICAL FOOTPRINT METHODOLOGY“

1. Key Source Data and Methodology Stakeholders

Global Footprint Network (National Footprint Account current authors)

2. Context and Problem Definition

The current method of documenting National Footprint Accounts (currently authored by the Global Footprint Network and published in summary form in WWF's Living Planet Report) was ranked as the third most important issue (Rank 3) in the previous project.

Currently, there exists no detailed documentation to accompany the National Footprint Accounts spreadsheets. Yet, Kitzes et al. 2007a points to the existence of "published methods papers (e.g., Lenzen and Murray 2001, Monfreda et al. 2004, Wiedmann et al. 2006, Kitzes et al. 2007a[62]) (that) are generally the most detailed current guides to understanding the overall framework of national Footprint calculations". However, even Kitzes et al. 2007 accept that "many complexities of the implementation of these calculations, however, remain undocumented in written publications. In addition, no documentation exists to "describe, and justify where necessary, differences between current calculation methods and previous methods. The past three annual editions of the National Footprint Accounts, for example, have all included revisions to previous methodologies as new data sets and scientific understanding have become available". Similar observations are echoed by RPA, 2005, George, 2007 and Giljum et al. 2007 for example.
In June 2006, the first Ecological Footprint Standards were launched (GFN 2006b). The www.footprintstandards.org website states that "the value of the Footprint as a trusted sustainability metric…depends not only on the scientific integrity of the methodology, but also on consistent application of the methodology across analyses. It also depends on communicating results of analyses in a manner that does not distort or misrepresent findings. These Standards are voluntary and address both Ecological Footprint applications and communications. In particular, Standard 14: Footprint Study Limitations, is intended "to ensure that Footprint analyses clearly identify the research question, the study's limitations, the method used, and the method's limitations, so that results are not misinterpreted". Currently, the National Footprint Accounts (GFN 2006b) do not meet this Standard.

The most specific critique of this issue comes from Schaefer et al. 2006, "In-transparency of the assumptions and selections: The construction of the composite indicator involves a number of stages at which the analyst has to make judgments. For example, the selection of input variable (consumption of resources and generation of waste), the choice of

[62] Cited as "Kitzes et al. 2007b" in this report.

weighting factors and the treatment of missing values (imputation technique) requires a number of decisions which are not transparent due to lacking detailed documentation...At the moment the selection of variables, the origin of the data and the weighting factors that are used can be perceived as being of an arbitrary nature and based on in-transparent assumptions. Additionally, to improve the transparency of the methodology all used data sources and the date of extraction have to be specified. Moreover, the handling of missing values and estimation procedures has to be specified. A high transparency of all procedures and clear standards for the quality assessment, together with independent reviews, are essential to give the EF/BC (Ecological Footprint/BioCapacity) accounting the status of a science-based tool".

3. Task: Evaluate options and recommend a robust method for documenting the Ecological Footprint methodology

Kitzes et al. (2007a) recently published a research agenda for the National Footprint Accounts.. This thorough evaluation of the Footprint methodology used to construct the National Footprint Accounts also highlighted the issue of documentation (the lack of). This study gave a decisive way forward. This path builds on the recommendation of Schaefer et al. 2006:

- A guidebook with clear standards could help to solve some of the problems, e.g. the "lack of international standards and lack of transparency"…Moreover, a guidebook should give clear guidelines to the issues of "validation techniques" and "quality assessment". The Global Footprint Network is preparing a first draft of a Standardization Guide. However, not all weaknesses are addressed for the time being and it is still not clear if the standards therein are widely accepted (Schaefer et al. 2006),
- When annual editions are not directly comparable, guidebooks and release notes should specifically address the rationale and method behind any major changes (Kitzes et al. 2007a), and
- The increase in transparency of the basic assumptions and of the documentation is one of the main objectives, and activities aiming for this purpose should receive full support. These include:
- the publishing of a detailed methodological guide, which should enable users to fully reconstruct all calculation steps in order to verify the results; the development of the Footprint Standards is the first step in this direction,
- the translation of the Footprint Standards in several languages (at the moment only available in English),
- a description of the background for methodological decisions (for example why CO_2 emissions are accounted through sequestration in forests) and
- the creation of a evaluation and rating system for the National Accounts which should communicate the quality of the results to the users (a draft version of Kitzes et al. 2007a cited by Giljum et al. 2007).

The current authors of the National Footprint Accounts have produced a draft of a detailed methodological guidebook for the Japanese Ministry of the Environment (pers.comm. Justin Kitzes, Senior Manager National Footprint Program, Global Footprint Network, 25th October, 2007).

4. Associated Issues:

Disaggregation of Results (Rank:8): "The Footprint at the national level is normally not disaggregated into economic sectors" (Giljum et al. 2007) or policy-relevant components. The National Footprint Accounts are only disaggregated by area-type (carbon sequestration land, nuclear energy land, built-up land, crop land, grazing land, forest, and fishing grounds) (WWF et al. 2006 cited in Kitzes et al. 2007a).

Central Metrics and Messages (Rank:12): "The fact that a single figure is obtained does not guarantee that its interpretation is straightforward" (Schaefer et al. 2006). This issue is detailed by authors at several levels. For example, Lenzen and Murray (2003) highlight how "the sustainability of regional land use… cannot be addressed by ecological footprints as currently calculated (van den Bergh and Verbruggen 1999, Opschoor 2000, van Kooten and Bulte 2000). This is because productivity and land use are not directly related to sustainability. Ecosystems, climates, farming and forestry methods differ regionally". In 2006, Lenzen et al. (2006a) stated that "one could argue that an increase in biocapacity due to increased yield and equivalence factors is generally accompanied with an increase in the Ecological Footprint, since the products from intensive production are consumed somewhere. However, when moving to intensive production, both global biocapacity and the global Footprint will experience the same increase, while the global ecological deficit – the difference between biocapacity and Footprint – stays constant. There is hence at least no penalty in the bioproductivity metric for intensifying production. These undesired effects are a direct consequence of the definition of bioproductivity in global hectares in the Ecological Footprint".

At the practical level, "it should be noted that the Ecological Footprint method does not state which conclusions shall be drawn from the calculation of Footprints…The central issue here is to what extent it makes sense to compare the consumption of a country with the biocapacity available in that country. According to the Ecological Footprint, high-consumption countries that are endowed with large quantities of biological resources (such as Canada or Finland) seemingly do not have problems with their resource consumption, as it remains below their biocapacity. On the contrary, some countries with very low Ecological Footprints per capita may still run a significant ecological deficit (e.g. Bangladesh)" (Giljum et al. 2007).

Practical interpretations from Ecological Footprint studies have been investigated by others. For example, "a third kind of biocapacity is considered – the potential biocapacity – based on a potential scenario for Ladakh. It accounts for the biocapacity of Ladakh if agriculture were extended to 1% of the territory, as is theoretically possible"..."There exist several historical and innovative examples in the North and in the South that show how Ecological Footprints can be reduced, but also how the biocapacity can be increased. More longitudinal studies on such examples using the Ecological Footprint are needed, in order to contribute to bringing solutions to the crisis the Ecological Footprint has so far been pointing at" (Demenge 2007).

On a philosophical level, Sherrington & Moran (2007) "...question whether One Planet Living by 2050 for an individual country, such as Scotland, is a reasonable policy objective? Does it really matter if Scotland continues to consume more than its fair share as long as the global ecological footprint can be reduced to a sustainable level? Should we really be aiming for equal levels of per capita consumption in all countries? It would appear that the focus on equality of outcome eclipses any consideration of economic efficiency and therefore precludes widespread adoption of the Ecological Footprint approach by policy makers".

Others have assessed how the Ecological Footprint has been interpreted. Van Vuuren and Bouwman (2005) found that "it should be noted that, in addition to support, the EF concept has also repeatedly been criticized (e.g., van den Bergh and Verbruggen, 1999; Ayres, 2000; Jorgensen et al., 2002). Some of this criticism seems to be related to fundamentally different world views [this, for instance, concerns discussions on the focus to the limits to earth's carrying capacity or the possible (negative) bias towards international trade]".

NFA developments (Rank:13): RPA (2005) and more recently George (2007) have undertaken reviews of the Ecological Footprint for the UK Department for Environment, Food and Rural Affairs (DEFRA). George (2007) found that "the National Footprint Accounts (NFA) are subject to constant refinement, as better data become available and methodological issues are resolved. Therefore, it is possible that a nation's (Ecological) Footprint can increase or decrease according to changes in the methodology, separately from actual changes in consumption".

Aggregated Indicator (Rank:20): "By referring to the production area, which forms the basis for resource use, the physical amounts of consumption can be compared and added up. Thereby, yield data fulfils the function of weighting and standardisation. However, the direct link to environmental impacts is lost; this is a basic problem with all aggregated indicators of resource use" (van der Voet et al. 2005a cited by Giljum et al. 2007).

Language (Rank:22): Giljum et al. 2007 highlighted the need for "the translation of the Footprint Standards (and Ecological Footprint documentation generally) in several languages (at the moment only available in English)".

Non-Renewable Resources (Rank:25): "The Ecological Footprint only captures the use of renewable resources, while the physical use of non-renewable resources (minerals, ores, and fossil fuels) is not directly incorporated in the calculation. Therefore, the Ecological Footprint has a different focus than other resource indicators such as those based on material flow analysis, as in latter case the largest share of total resource consumption is determined by non-renewable resources" (Giljum et al. 2007). This point can be further clarified by stating that the Ecological Footprint does include the consumption of non-renewable resources, but these are assessed by their use of renewable resources (e.g. physical land areas and CO2 emissions). This issue refers to "resource depletion", i.e. the declining of stocks of ores and fossil fuels, which are excluded from the Ecological Footprint (National Footprint Account methodology).

Environmental Impacts and Socio-Economic Aspects (Rank:26): "A number of important sustainability issues exist, where the Footprint is inadequate as a measure...These issues include biodiversity and conservation of ecosystems, resource management (in particular non-renewable resources), concrete environmental impacts of resource consumption (such as climate change, acidification, loss of fertile soil, etc.) as well as key aspects of other sustainability dimensions, such as social equity, health and quality of live" (Giljum et al. 2007).

Sustainability limit versus general reduction targets (Rank:26): The Global Footprint Network Standards Committees (GFN 2006b) state that "global sustainability requires that the global Footprint be less than or equal to the global biocapacity". Yet "other concepts of sustainable resource management (such as Factor 4/10) claim that it would not be possible to determine an exact level of sustainable resource use. They emphasise that the key issue is the reduction of resource consumption and associated negative environmental impacts (for instance Spangenberg et al., 1998)" (Giljum et al. 2007).

Weak vs. Strong Sustainability (Rank:27): An issue clearly in need of documentary clarification: "The Ecological Footprint is based on the concept of strong sustainability" (Giljum et al. 2007). Yet, Rees (2006) returns that "these assertions are erroneous because eco-footprint analysis per se makes no assumptions whatever about material substitutions or technological change".

Results are 'Scary' (Rank:28): "EFA (Ecological Footprint Analysis) certainly remains an imperfect tool. However, its major weakness may be the inherent conservatism of the method rather than the concerns expressed by economists and techno-optimists. EFA findings, already alarming enough, likely under-estimate rather than over-estimate the total human load. In this light the real sustainability problem is that the official world remains in the thrall of the perpetual growth myth" (Rees, 2006).

5. Outputs

It is important to note that this research proposal is not intended to duplicate the documentation being produced by the Global Footprint Network but to evaluate this in the light of the various criticisms made (including the lack of coverage of the more qualitative Associated Issues) making clear and concise recommendations for improvement. This should go as far as suggesting specific textual amendments and additional copy.

Outputs to this research proposal should also explore methods by which future documentation could be delivered reliably, their form and structure, language options, and how they might be updated to keep pace with method changes and in response to questions from Accounts users. Main output is a report which:

- Identifies and evaluates existing documentation, options for improvement and how best to deal with the Associated Issues, including:
- proposed text for a 'guidebook' to address some of the problems identified e.g. the "lack of international standards and lack of transparency"…Moreover, a guidebook should give clear guidelines to the issues of "validation techniques" and "quality assessment". The Global

Footprint Network is preparing a first draft of a Standardization Guide. However, not all weaknesses are addressed for the time being and it is still not clear if the standards therein are widely accepted (Schaefer et al. 2006),

- means of documenting new releases of the Accounts paying special attention to how best to deal with changes in data and methodology and the rationale behind these (Kitzes et al. 2007a), and
- how to improve the transparency of the calculations and basic assumptions underlying them. Issues to address include:
- how to explain and present, in an accessible manner, all the information a user of the Accounts would need to fully reconstruct all calculation steps in order to, for example, verify the results;
- the translation of the Footprint Standards in several languages (at the moment only available in English),
- a description of the background reasons for certain methodological decisions (for example why CO2 emissions are accounted through sequestration in forests and oceans) and
- the creation of a evaluation and rating system for the National Accounts which should communicate the quality of the results to the users (a draft version of Kitzes et al. 2007a cited by Giljum et al. 2007).
- An exploration of multimedia options for explaining the Accounts and Associated Issues (for example, web streamed video, wiki, interactive seminars and so on)
- What pre-existing documentation, for example text books and educational resources would benefit from being updated
- Examples (including sample text) demonstrating how the various options for documenting the Accounts would appear.
- Text (suitable for inclusion in a User Manual) which addresses the qualitative issues surrounding use and interpretation of the Accounts. This should address the Associated Issues above and any other issues which the researcher feels are important, but which would not be covered by technical documentation.
- Ensure any research takes account of the 'best practice' standards and guidelines contained with the Footprint Standards (GFN 2006b).
- Assess the implications for the current Footprint Standards of any proposed revisions to the Ecological Footprint methodology
- Align Ecological Footprint documentation with educational best practice,
- Drafting of recommendations to address identified and associated issues,

Other Outputs include:

- A thorough review and consultation exercise with leading practitioners to advise on the main Outputs and try and reach agreement on any recommendations,

Note that, at this time, Outputs are only required in English. However, the researcher would be expected to address any issues that might affect the later translation of the Outputs.

6. Timeline & Budget:

Global Footprint Network, the current authors of the National Footprint Accounts, estimate that this research could be completed and ready for implementation in the 2010 edition of the National Footprint Accounts, published in summary in WWF's Living Planet Report (WWF, 2006).

Method Description	Estimated Days
Detailed National Footprint Accounts handbook	**To Be Defined**
Series of methodological papers (3) documenting calculations	**60**
Methodology book written by technical experts in community	**80**

Sub-proposal 4:

„DEVELOPMENT AND CALCULATION OF ECOLOGICAL FOOTPRINT EQUIVALENCE FACTORS“

1. Key Source Data and Methodology Stakeholders

FAO and Institute for Interdisciplinary Studies of Austrian Universities

2. Context and Problem Definition

The current method of calculating the equivalence factors in the National Footprint Accounts (currently authored by the Global Footprint Network and published in summary form in WWF's Living Planet Report) was ranked as the fifth most important issue (Rank 5) in the previous project.

Currently, the equivalence factors used in the 2006 edition of the National Footprint Accounts are "based on estimates of achievable crop yields as compared to maximum potential crop yields from the Global Agro-Ecological Zones (GAEZ) assessment (FAO/IIASA 2000)" (Kitzes et al. 2007a). Van Vuuren & Bouwman (2005) found "a final criticism category relates to actual calculation methods, the most important being the aggregation method of land and energy use, which involves a rather arbitrary weighting". Evidence to support this observation was supplied by Giljum et al. (2007) who "found the forest equivalence factor to be the 6th most significant single cell in the German NFA (National Footprint Accounts) 2006 (2003 data) using Monte Carlo simulation".

"Alternate approaches include basing equivalence factors on total NPP (Venetoulis and Talberth 2007), or on usable NPP, as defined by the NPP embodied in extractable products from a given land type" (Kitzes et al. 2007a). Venetoulis and Talberth (2007) explain how "…the basis of the EFA (Ecological Footprint Analysis) equivalence factors are changed from potential of land to provide food for humans to the relative Net Primary Productivity of various ecosystem/biomes". A practical outcome of this conversion process, as enacted by Venetoulis and Talberth, is that it "incorporates a new carbon sequestration approach that changes the corresponding Footprint from about 1 global hectare (gha) per tonne of carbon to about 16 gha/tC" (Redefining Progress, 2007). Another finding from this kind of equivalence factor calculation was provided by Siche et al. (2007), who report that "according to calculations based on emergy analysis, the indicators of EF (Ecological Footprint) could underestimate the problem of human carrying support. EF does not consider the work of untouched nature in productivity and ecosystems services. To improve this, we propos…to consider the value of NPP (in emergy units: seJ/m2/yr) as the base for calculation of Equivalent Factors (EQF)… Introducing these changes to conventional EF and taking as reference the Peruvian economy (during 2004) the Biocapacity was 14.6 gha/capita and the Footprint 6.6 gha/capita. It means that Peru can support 2.2 times its population if present life style is maintained, in opposition to the 4 times ratio obtained with conventional EF. The results obtained with improved approach show a worse situation of than that revealed by conventional EF".

3. Task: Evaluate methodological options and recommend a robust method for development and calculation of equivalence factors for the National Ecological Footprint Accounts

Kitzes et al. (2007a) recently published a research agenda for the National Footprint Accounts. This thorough evaluation of the Footprint methodology used to construct the National Footprint Accounts also highlighted the issue of the development and calculation of equivalence factors. Kitzes et al. (2007a) gave two methodological options for calculating the equivalence factors for the Ecological Footprint:

- The GAEZ assessment model has the advantage of reflecting land quality using a single measurement unit, crop yields, that is highly relevant to human activities. Total NPP measurements have been criticized for reflecting relative levels of total production rather than those useful for humans. As NPP may also depend heavily on the degree of human management, the use of NPP-based equivalence factors may strongly reflect the current extent and distribution of human intervention (i.e., poor quality land that is intensively managed may be calculated to have a higher equivalence factor than high quality, unmanaged land), and
- Conversely, equivalence factors based on a form of NPP would be more closely linked to the central unit of ecosystem functioning and would allow closer comparisons between Footprint result sets and other ecological indicators. The use of "usable" NPP as an equivalence factor basis has the potential to combine the benefits of both approaches while taking advantage of the most current remote sensing and ecosystem modeling data sets. Definitions of "usability" will need to be defined carefully, as usability is not an intrinsic function of ecosystems but rather depends on either present human behavior or assumptions about value. Under any approach, GIS models should be strongly considered for their ability to provide better estimates than low-resolution tables and aggregate estimates.

Huijbregts et al. (2007) suggest the Ecological Footprint "provide equivalence factors on an ecological basis". Kitzes et al.'s (2007a) "useable" NPP could be further defined as the Human Appropriation of NPP (HANPP). Haberl et al. (2004) explain how, "In contrast to EF, which accounts for a population's demand for and supply of mutually exclusive areas, HANPP measures how intensively these areas are used (Haberl, 1997; Haberl et al., 2001b). Unlike EF, which refers to a defined socio-economic system or production process, HANPP refers to a defined land area. If applied on a national scale, HANPP evaluates the effects of people's activities on the energetics of terrestrial ecosystems on a nation's territory".

Similar to Siche et al. (2007), Zhao et al. (2005) developed “a modified form of ecological footprint calculation by combining emergy analysis with conventional ecological footprint form of calculations. Our new method starts from the energy flows of a system in calculating ecological footprint and carrying capacity. Through a study of the energy flows, and using the method of emergy analysis, the energy flows of a system are translated into corresponding biological productive units. To demonstrate the mechanics of this new method, we compared our calculations with that of an original calculation of ecological footprint of a regional case. We select Gansu province in western China, as an example for application of our study. In this case the same conclusions were drawn using both methods: that Gansu province runs an ecological deficit”. Zhao et al.’s (2005) analysis showed the Gansu comparison of Ecological Footprint / local Biocapacity to be 105%, whereas the ‘emergy footprint’ / local emergy capacity was 134%. In agreement with Siche et al. (2007), the Zhao et al. (2005) emergy analysis shows a worse picture than conventional Ecological Footprint analysis, yet applies emergy to all Ecological Footprint components, whereas Siche et al. (2007) apply emergy to the equivalence factors only.

4. Associated Issues:

Local (and/) or Global Hectares (Rank 14): Van Vuuren and Bouwman (2005) found that, “assumptions on yields are shown to have very important consequences for EF calculations. The EF based on local yields gives insight into the actual land use of a region, while that based on global average yields (the current National Footprint Accounts (GFN 2006)) shows differences in consumption patterns and improves the comparability of results for different regions. Wackernagel et al. (2004a) reported that “both methods have been shown to produce trends with similar directions”. A possible integration path is demonstrated by the concept and method of water footprints. "In WF (water footprint) analysis the dominant approach is to work with local productivities. This choice has been driven by the research questions addressed by the various authors in the field of water footprint and virtual water trade analysis. An important question all the time is where and how nations or the global society as a whole can save water (Hoekstra, 2003; Oki and Kanae, 2004; De Fraiture et al. 2004; Wichelns, 2004; Hoekstra and Hung, 2005; Chapagain et al., 2006). For that reason it has been considered key to consider local productivities, because only local data on productivities can tell where water use per unit of product is relatively large and where small. The water need per unit of product depends on both climate and water-use efficiency. Reducing water footprints through adjusting consumption patterns is one option, but reducing water footprints by producing where the climate is most suitable and by using water more efficiently are two other important options to be considered (Hoekstra and Chapagain, 2007a, b). When water footprints were calculated based on global averages, the production circumstances (climate and water-use efficiency) would not be a variable in the equation anymore" (Hoekstra 2007).

Constant Yield Calculations (Rank 15): Van Vuuren and Bouwman (2005) highlight that “development of yields in time is a crucial factor for EF trends". This is acknowledged by Kitzes et al. (2007a): “Calculating and interpreting Ecological Footprint and biocapacity accounts in time series present additional challenges beyond those encountered in single year analyses (Haberl et al. 2001, Erb 2004, Wackernagel et al. 2004a[63])...An alternate method that could isolate changes in total consumption would be to calculate time series in Footprint and biocapacity using yields for a single reference year. Under this method, time trends will reflect changes in absolute consumption and material extraction (Ferguson 1999, Haberl et al. 2001, Wackernagel et al. 2004[64], Kitzes et al. in press)...The choice of constant or variable yields should be made on a case by case basis, and, as variable yields are the current norm, applications using constant yields should state this choice clearly. The accounts should provide users with the option of using either constant or annually varying yields".

5. Outputs

It is important that the outputs from this research do not duplicate existing or planned work but build upon the extensive literature that already exists. Outputs include:

- Identify and evaluate methodological options for the development and calculation of equivalence factors for the National Ecological Footprint Accounts, including:
- GAEZ
- NPP, HANPP
- Emergy
- Engage leading practitioners to review and, ideally, agree upon final outputs
- Drafting of methodological recommendations to address identified and associated issues,
- Ensure any research takes account of the 'best practice' standards and guidelines contained with the Footprint Standards (GFN 2006b).
- Assess the implications for the current Footprint Standards of any proposed revisions to the Ecological Footprint methodology
- Consultation with project team to finalise recommendations, and
- Final recommendations report.

[63] Cited as "Wackernagel et al. 2004b" in this report.

[64] Cited as "Wackernagel et al. 2004a" in this report.

6. Timeline & Budget:

Global Footprint Network, the current authors of the National Footprint Accounts, estimate that this research could be completed and ready for implementation in the 2010 edition of the National Footprint Accounts, published in summary in WWF's Living Planet Report (WWF, 2006).

Method Description	Estimated Days
Review and recalculation of GAEZ equivalence factors	**20**
Evaluate HANPP and Emergy options as alternatives to GAEZ	**50**

Sub-proposal 5:

„IMPROVING THE UTILITY OF THE ECOLOGICAL FOOTPRINT FOR POLICY-MAKERS “

1. Context and Problem Definition

That the Ecological Footprint, as reported in the National Footprint Accounts (currently authored by the Global Footprint Network and published in summary form in WWF’s Living Planet Report) is a static indicator and of limited value to policy-makers was ranked as the sixth most important issue (Rank 6) in the previous project.

Currently, the National Footprint Accounts (GFN, 2006b) present the Ecological Footprints of nations as static, annual and historical (backcast) results. To provide some context for the latest results, a time series from 1961 to the most recent year is also given. GFN (2006c) currently present these time series in two graphs for each nation and the world as a whole, which show the Ecological Footprint of consumption and production against the national (or global for the world) Biocapacity, on a per capita and total basis. No further documentation or a summary for policymakers (see IPCC (2007) for example) accompanies the large spreadsheets of the National Footprint Accounts.

Giljum et al. (2007) report a historical observation that "...a static indicator cannot provide a foundation for political measures and strategies (Ayres, 2000; EAI, 2002)”. Yet, Giljum et al. (2007) respond with their own observation how “the Footprint is explicitly an instrument to measure the consumption of nature at a given point of time and is able to reflect technological changes in the future. Similar critique could be formulated for any indicator (environment indicators or also GDP), which measures the state of the society at a given time and with a defined method".

Rees (2006) expands Giljum et al.’s (2007) response to the apparent lack of value in a static indicator. Responding to a similar comment (“Typical EFA studies lack predictive power”), Rees (2006) plainly states how, “this seeming ‘criticism’ is true but irrelevant. Many useful indices are based on static analyses. For example, average ‘life-expectancy’ is not a predictive indicator but it is a good measure of population health; the ‘human development index’ is not a predictive tool but it is accepted as a good aggregate indicator of, well, relative ‘human development’; ‘GDP’ is not a predictive tool but it is generally regarded as a fair indicator of aggregate economic activity… One might criticize a dynamic model that fails to make good predictions but it is silly to reject static models and indicators (contemporary ‘snapshots’) on the same grounds”.

This response may be expected from Ecological Footprint supporters, yet something of the original observations remains. Eurostat (Schaefer et al. 2006) published a brief review paper of the Ecological Footprint and Biocapacity (EF/BC) and observed that, "for discussions among policy makers’ current applications are too diverse and highly in-transparent... To be used for policymakers an appropriate quality management needs to be applied for EF/BC accounts as it is done for Economic Accounting or for the UN Framework Convention on Climate Change (UNFCCC) greenhouse gas inventories".

2. Task: Evaluate options and recommend methodological improvements to increase the utility of the Ecological Footprint for policy-makers

Kitzes et al. (2007a) recently published a research agenda for the National Footprint Accounts. This thorough evaluation of the Footprint methodology used to construct the National Footprint Accounts failed to mention the limitations inherent in the static nature of the Ecological Footprint and failed to mention how to address the needs of policy-makers. Suggestions and comments are therefore limited to other sources:

- "Analysts could use EFA (Ecological Footprint analysis) in simulation studies involving assumed life-style changes or advances in technology and thus predict the likely effect on ecological demand" Rees (2006).
- Best Foot Forward (BFF 2005a, 2005c and 2002) have conducted many scenario analyses targeted at policy-makers and have had some success at influencing policy. BFF (2005c) presented future scenarios for domestic waste, personal transport, domestic energy use and carbon dioxide emissions. Policy targets derived directly from these scenarios were officially adopted by the local authority. BFF (2005a) presented scenario analyses which combined the Ecological Footprint with other sustainability indicators for waste arisings and management. BFF (2002) was supported by the Mayor of London, Ken Livingstone, who stated, "This study of London's footprint is particularly important because it is the first such analysis of a major world city. For the first time we have an overall picture of London's metabolism, how resources are used and where action might be taken to increase our efficiency and become more sustainable...I welcome the publication of this study and commend it to everyone involved in achieving my vision of making London an exemplary, sustainable world city".
- Lenzen et al. (2007b) "…provides the theoretical base and an example for expanding the static Ecological Footprint accounting method into a dynamic forecasting framework which is forward looking to 2050, incorporating biodiversity amongst other factors, into a causal network of driving forces, and taking into account globalised trade with its complex supply chains". Further motivation for this development is based on the observation: "The static Ecological Footprint method measures the end-point of the causal chain… It is backward-looking accounting of what occurred, not an extrapolation of how it could affect the future. It thus does not contain an "earlywarning" signal: By the time bioproductivity has decreased because of biodiversity loss, habitat loss, and/or land and soil degradation due to unsustainable agricultural practices, it may be too late for abatement action. Therefore, policy needs models that deal with the pressure variables… and link them to the bioproductivity endpoint" (Lenzen et al. 2007b).

3. Associated Issues:

Future Footprints and Biocapacity Loss (Rank 18): Kitzes et al. (2007a) acknowledge, "One of the most potentially significant considerations not included in the current core National Footprint Accounts are activities that affect future Footprint or biocapacity. Because the accounts are purely historical in nature, capturing past demands on biological capacity and comparing these demands to available capacity in any given year, they cannot capture activities occurring today that will likely cause demands to be placed on ecosystems or will destroy ecosystem capacity in future years".

Technology (Rank 21): Giljum et al. (2007): "The calculation of the energy component is frequently criticised, because less CO_2-intensive forms of energy production, and technical progress, potentially resulting in the reduction of the Footprint, are not taken into account (Ayres, 2000; EAI, 2002)". Rees (2006) states however, "EFA (Ecological Footprint analysis) is fully responsive to technological changes or substitutions that might significantly affect a population's eco-footprint". Yet, the assertions of Rees (2006) can be disputed with regard to current trade accounts in the National Footprint Accounts (GFN, 2006). Barrett (pers.comm. 16th July 2007) states, "There is a clear need to be able to measure the change in technological efficiency on an annual basis".

4. Outputs

It is important that the outputs from this research do not duplicate existing or planned work but build upon the extensive literature that already exists. Outputs include:

- Identify and evaluate means of increasing the utility of the Ecological Footprint for policy-makers. Include:
- Approaches to simulation and modelling
- Methods for assisting scenario development; which should include demand management and efficiency improvements (through technology or otherwise)
- Means of making the structure and output of the Ecological Footprint Accounts more relevant for policy-makers
- Use of the Ecological Footprint to provide predictive, 'early warning' signals and
- Means of estimating and extrapolating future loss of bioproductivity and biodiversity from current consumption
- Conduct a thorough review and consultation with leading practitioners of best practices,
- Ensure any research takes account of the 'best practice' standards and guidelines contained with the Footprint Standards (GFN 2006b).
- Assess the implications for the current Footprint Standards of any proposed revisions to the Ecological Footprint methodology
- Drafting of recommendations to address identified and associated issues,

- Consultation with leading practitioners to agree, prioritise and scope recommendations,
- Consultation with project team to finalise recommendations, and
- Final recommendations report.

5. Timeline & Budget:

Global Footprint Network, the current authors of the National Footprint Accounts, estimate that this research could be completed and ready for implementation in the 2010 edition of the National Footprint Accounts, published in summary in WWF's Living Planet Report (WWF, 2006).

Method Description	Estimated Days
Development of non-static Ecological Footprint model for policy application	**To Be Defined***
Development of static Ecological Footprint best practice and application case studies	**50**

*The work by Lenzen et al. (2007) is recent and details are not specific enough to draft a proposal. At least one project (Wiedmann et al. 2007a) is already funded by the UK Department for Environment, Food and Rural Affairs (DEFRA).

Sub-proposal 6:

„EVALUATING THE ROBUSTNESS, VALIDITY AND ACCURACY OF SOURCE DATA USED TO DERIVE THE NATIONAL ECOLOGICAL FOOTPRINT ACCOUNTS“

1. Key Source Data and Methodology Stakeholders

International and National Statistical Agencies, including UN FAO and UN Comtrade

2. Context and Problem Definition

The robustness, validity and accuracy of source data used in the National Footprint Accounts (currently authored by the Global Footprint Network and published in summary form in WWF's Living Planet Report) was ranked as the seventh most important issue (Rank 7) in the previous project.

Currently, the source data used in the 2006 edition of the National Footprint Accounts is derived from multiple sources, "including databases from the United Nations Food and Agriculture Organization, the United Nations Statistics Division, and the International Energy Agency (FAOSTAT 2007, UN Comtrade 2007, IEA 2007). Other data are drawn from published scientific papers, satellite land use surveys, and national and regional databases. Much data is self reported, and metadata describing the methods of data collection, aggregation, and frequency of updates are commonly, though not always, publicly available" (Kitzes et al. 2007a).

Curry et al. (in press) and Kitzes et al. (2007a) note the following issues with the current data sources:

1. Incomparable data for nations: Kitzes et al. (2007a): "In the United Arab Emirates, for example, government agencies have expressed their opinion that the frequency of data reporting, the lack of reporting for certain commodities, and methods for measuring population may be significantly biasing the results for that nation (EAD 2006).

2. Systematic distortions: Kitzes et al. (2007a): "Systematic distortions in the marine fish catch reported by China may be large enough to affect estimates of the fishing grounds Footprint of not only that nation but the entire world (Watson and Pauly 2001)".

3. 'Grey economy' excluded: Curry et al. (in press): "Early investigations indicated that the trade data (and the associated Materials and Waste component footprint) warranted further analysis… Possible explanations which were initially explored – and dismissed – included…Influence of the informal economy (i.e. consumption of items which do not appear in official trade statistics)".

4. Nomenclature correlation errors: Curry et al. (in press): "To provide an additional data check and to test…sensitivity…the COMTRADE data used in the NFA (National Footprint Accounts) was supplemented with CSO (Ireland's Central Statistics Office) trade data…COMTRADE suffers from some reporting difficulties as CSO data reported in units

other than mass (kg or tonnes) are omitted from COMTRADE. Thus beer (reported by the CSO in litres) is recorded as zero in the equivalent COMTRADE category".

Switzerland (von Stokar et al. 2006) has undertaken an official review of their National Footprint Account (2006 edition). This largely consisted of comparing national Swiss data with that reported in the National Footprint Account. This should, of course be the same data as international datasets collate national datasets. Yet, "as far as Fossil Energy is concerned, differences are in the range of 2%. To guarantee international comparability it is justified to remain with IEA data as done by Global Footprint Network. A deepened data assessment for the category Embodied Energy would require additional research" (von Stokar et al. 2006).

Regarding national datasets (in the context of methane emissions) Walsh (2007) cautioned, "It should be noted that fugitive emission factors suffer from high degrees of uncertainty. Newer conversion factors published in the 2006 IPCC Guidelines also incur high degrees of uncertainty (in some cases +/- 100%). This is to be expected given the considerable variety in fuel production technologies and is inevitable when attempting to approximate data on a national scale". Druckman et al. (2007) adds observations regarding national greenhouse gas (GHG) inventories: "It is now recognised that these inventories already have high uncertainties, and in some cases the margins of uncertainty are of a similar magnitude to the change that we are attempting to measure. For example, the reported uncertainty in total GHG emissions has been found to range from ± 5% to ±20% for five industrialised countries with reputedly high standard GHG inventories; and, for the UK, uncertainties range from ±4% for carbon dioxide to ±200% for nitrogen dioxide (Rypdal and Winiwarter 2001)".

Schafer et al. (2006) found "the use of other data sources, modifications in the choice of input variables, and/or in the weighting system can change the message significantly". In terms of source data, this finding is evidenced by Turner (2006, cited in George, 2007): "Turner (2006)...suggests that the benefit of adopting a top down approach is that it is relatively cheap and gives regional accounts that are numerically consistent with existing national accounts. However, based on a study of Jersey (UK), Turner (2006) notes that the added precision from using good-quality region-specific data compared with adjusted national UK data results in different findings in terms of both absolute pollution levels and the relative contribution of different activities to the total emissions in the economy".

3. Task: Evaluate data source options and recommend a robust method for data source selection for use with the Ecological Footprint

Kitzes et al. (2007a) discuss several issues relating to the source data used to calculate the Ecological Footprint. In particular, they point to the need for independent scientific review of the underlying data sets used to calculate each nation's Ecological Footprint. Agencies within the governments of Switzerland (von Stokar et al. 2006), Finland (Väinämö et al. 2006), Ireland (Curry et al. in press), Germany (Giljum et al. 2007), and Japan have already sponsored complete or partial reviews of this nature (Kitzes et al. 2007a). This way forward is embedded in the current Global Footprint Network Ten-in-Ten campaign (GFN 2005).

Other authors have also highlighted specific data issues:

- von Stokar et al. (2006): concluded for Switzerland that, “A deepened data assessment for the category Embodied Energy would require additional research” but found that other inconsistencies between national statistical data and the sources used to calculate the National Footprint Accounts were relatively insignificant; “Inconsistencies or implausible data can be found in the categories fisheries (methodological switch) and built-up land (lack of meaningful time series). These two categories are however of minor importance. Inconsistencies do therefore not lead to wrong estimations and erroneous interpretation of the general Footprint figures… Main ambiguities can be found in the field of embodied energy.”
- Curry et al. (in press) in their study of Ireland made specific recommendations relating to trade data:

“ • That consideration is given to changing the trade data source for the National Footprint Accounts to SITC Rev. 3 or a similar recent edition of a trade statistics classification to increase data reliability.

- That consideration is given to the priority of data robustness (or/) and a time trend to 1961. SITC Rev. 3 is available from 1985.
- That a request is made to UNSD COMTRADE to consider publishing reliable correspondence tables for SITC Rev. 1 and SITC Rev. 3.
- That a request is made to UNSD COMTRADE to consider reporting “Quantity 2” data and units alongside $ and kg”.

4. Associated Issues:

Calculation errors and assumptions (Rank 7): Giljum et al. (2007) discuss, “The 150-Country National Accounts are necessarily ‘mass produced’ using automated data import and available international datasets. Where assumptions have to be made they are generally globally-derived. To individually tailor or audit individual Country Accounts would be a substantial undertaking and outside the capabilities of the Global Footprint Network. To overcome this, it has been proposed that National Accounts are individually audited by a partnership of National organisations, working together with the Global Footprint Network, to check for errors in the source data and refine the data and assumptions used where more accurate National data is available.”

Multiple data sources (Rank 16): Schaefer et al. (2006) found, "The use of other data sources, modifications in the choice of input variables, and/or in the weighting system can change the message significantly”. Kitzes et al. (2007a) suggest, “Where possible, Footprint accounts should make efforts to use the most detailed and accurate source data available for national calculations. High resolution data sets are available for many high-income countries, and are often available in a consistent regional format (Schaefer et al. 2007). When these more detailed data sets are available, Footprint accounts should provide the option to calculate national Footprints based on these data in addition to internationally available statistics...International statistical agencies are encouraged to publish, and researchers are encouraged to review, the compilers manuals and correspondence tables that are used to convert national statistical classifications to international systems in an effort to correct any errors or distortions".

Improved coverage and checking of source data (Rank 22): Giljum et al. (2007) reported on the German National Footprint Account (2006 edition), "Information on some crops is also excluded due to 'duplication or insufficient data'". Moran et al. (2007) also found, "In the COMTRADE dataset 13% of records, representing 26% of total trade value, had no weight values reported. Since all the Footprint yield coefficients are in units of weight, the missing weights were filled, using price ($/t) estimates".

Nation Ratings (Rank 23): Giljum et al. (2007) report, "...it has been proposed that National Accounts are individually audited by a partnership of National organisations, working together with the Global Footprint Network, to check for errors in the source data and refine the data and assumptions used where more accurate National data is available. This Quality Control system would result in 'star rated' Accounts whose results would be more robust".

5. Outputs

It is important that the outputs from this research do not duplicate existing or planned work but build upon the extensive literature, and in particular the evaluations of the National Footprint Accounts for individual countries, that have already been undertaken. Outputs should include:

- Identify and evaluate source data options for calculating national Ecological Footprints, including:
  - An evaluation of the sources currently used in the National Footprint Accounts and the identification of alternative, higher resolution, sources that may be used for EU countries.
  - Cataloguing of possible sources of bias, omissions and errors within those data sources used at the national level to calculate the National Footprint Accounts.
- A system for quality rating the current National Footprint Accounts that can be used to assess the robustness of any particular country's National Footprint Account.
- Specific examples should be provided which illustrate both problems with the existing datasets and recommended solutions.
- Issues covered should include all those raised by the national studies completed to date.
- Ensure any research takes account of the 'best practice' standards and guidelines contained with the Footprint Standards (GFN 2006b).
- Assess the implications for the current Footprint Standards of any proposed revisions to the Ecological Footprint methodology

- Conduct a thorough review and consultation with leading practitioners of best practices, particularly national statistical agencies.
- Drafting of recommendations to address identified and associated issues,
- Consultation with leading practitioners to agree, prioritise and scope recommendations,
- Consultation with project team to finalise recommendations, and
- Final recommendations report.

6. Timeline & Budget:

Global Footprint Network, the current authors of the National Footprint Accounts, estimate that this research could be completed and ready for implementation in the 2010 edition of the National Footprint Accounts, published in summary in WWF's Living Planet Report (WWF, 2006).

Method Description	Estimated Days
Establish evaluation and reporting system for source data quality in the National Footprint Accounts	**15**
Establish European national research collaborations to review the source data of National Footprint Accounts, in conjunction with national statistical agencies and leading practitioners.	**1,350**

Sub-proposal 7:

„ACCOUNTING SUSTAINABLE LAND USE WITH THE ECOLOGICAL FOOTPRINT“

1. Key Source Data and Methodology Stakeholders

Institute for Interdisciplinary Studies of Austrian Universities

2. Context and Problem Definition

The exclusion of sustainable land use accounting within the National Footprint Accounts (currently authored by the Global Footprint Network and published in summary form in WWF's Living Planet Report) was ranked as the eighth most important issue (Rank 8) in the previous project.

Currently, the accounting of sustainable land use is not included in the 2006 edition of the National Footprint Accounts. Rees (2006) considers, "EFA (Ecological Footprint analysis) assumes that 'land' is being used sustainably: This charge is true and bothersome". Giljum et al. (2007) elaborate: "The current accounts do not explicitly deal with issues of land use intensity. Hence whether land is currently over-grazed or unsustainably farmed is only noticeable in future accounts – when it would appear as a loss in bioproductivity". Lenzen and Murray (2003) add, "This is because productivity and land use are not directly related to sustainability".

This limit of the current National Footprint Account methodology is further illuminated by Lenzen et al. (2006a), "One could argue that an increase in biocapacity due to increased yield and equivalence factors is generally accompanied with an increase in the Ecological Footprint, since the products from intensive production are consumed somewhere. However, when moving to intensive production, both global biocapacity and the global Footprint will experience the same increase, while the global ecological deficit – the difference between biocapacity and Footprint – stays constant. There is hence at least no penalty in the bioproductivity metric for intensifying production... examples point to important global issues that are not covered in the bioproductivity research question and metric: landcover disturbance, soil degradation and biodiversity decline. Increasing bioproductivity can actually be accompanied by increasing disturbance, leading in turn to decreasing future biodiversity, biocapacity and bioproductivity (Pimentel et al. 1976). If used in isolation, the bioproductivity metric not only provides no "early-warning signal" for looming future problems, it may actually provide incentives that lead to future problems. For example, a time series of annual bioproductivity accounts for a country engaging in monoculture forest expansion could initially show a continuous biocapacity increase, but would reveal biocapacity declines only after they have already occurred".

3. Task: Evaluate methodological options and recommend if the Ecological Footprint can account sustainable use of bioproductive areas and if so, a robust method for accounting sustainable use of bioproductive areas with the Ecological Footprint

Kitzes et al. (2007a) recently published a research agenda for the National Footprint Accounts. This thorough evaluation of the Footprint methodology used to construct the National Footprint Accounts failed to consider the exclusion of sustainable land use accounting as an issue. Observations on the current National Footprint Accounts and alternative methodological approaches are therefore based on other sources:

- Lenzen et al. (2006a) propose a different path, building on previous work (Lenzen and Murray 2001, Lenzen and Murray 2003), "The land disturbance metric is largely designed from practices within LCA, and – in the Australian case – based on field and satellite data. This metric represents a first cut at quantifying biodiversity, but can be further refined using more ecological survey data. At present, it uses as a proxy the species density of vascular plants, because they are most readily able to be surveyed, and provide habitat and food to other species. Land disturbance is thus directly related to biodiversity decline, for example because of substitution by intensive monocultures, land clearing and other habitat loss, salinisation and other types of degradation. These factors in turn are direct precursors to biocapacity and biodiversity decline, and thus indicate future problems without ambiguity and delay. The ISA group at the University of Sydney is currently undertaking research on developing a global database underpinning the land disturbance indicator. This research is motivated by the fact that only when land disturbance weights and benchmarks are available at the global level can we assess how national policy decisions affect biodiversity in other national territories".
- Kitzes et al. (2007a) under the section on Equivalence Factors (proposal 4) suggests, “Conversely, equivalence factors based on a form of NPP would be more closely linked to the central unit of ecosystem functioning and would allow closer comparisons between Footprint result sets and other ecological indicators. The use of “usable” NPP as an equivalence factor basis has the potential to combine the benefits of both approaches while taking advantage of the most current remote sensing and ecosystem modeling data sets. Definitions of “usability” will need to be defined carefully, as usability is not an intrinsic function of ecosystems but rather depends on either present human behavior or assumptions about value". The equivalence factors are used in every calculation of the National Footprint Accounts and will therefore have a significant influence on the boundary of the Ecological Footprint.

4. Associated Issues:

Multiple Land Uses (Rank 7): Kitzes et al. (2007a) give an overview of this issue, "Under present accounting methods, land and sea areas serve only a single, mutually-exclusive purpose. The current National Footprint Accounts, for example, allow a single hectare of forest to be used either for timber production, or for carbon sequestration, but not for both simultaneously, as counting both services would create double counting (Venetoulis and Talberth 2007). The consideration of only a single function per unit of area accurately reflects the mutually exclusive provisioning services and carbon dioxide absorption (MEA 2005) that the accounts are designed to include. This decision prevents the core accounts, however, from considering other ecosystem services, such water catchment or biodiversity services in a forest, that are not mutually exclusive with material production and waste absorption".

This issue is expanded by Giljum et al. (2007) and RPA (2005). The RPA (2005) review of the Ecological Footprint found, "A general criticism of eco-footprinting is that it takes no account of the possibilities of multi-functional land use. Critics argue that biodiversity, carbon sequestration and timber production are not mutually exclusive activities and so demand for land is overstated. However, Wackernagel et al. (1999) argue that recently reforested areas or immature forests are required for absorbing large quantities of CO2 and these 'new' forests do not have the same biodiversity value as 'old' forests. In addition, CO2 absorbing forests cannot be used for timber production, as harvesting trees removes the opportunity for carbon sequestration. Proponents of eco-footprinting do not disagree that the 'use' of natural resources, and specifically land, is more complex than can be represented by the eco-footprint method. However, it is generally accepted that certain uses are mutually exclusive; for example, animals cannot be grazed where there are buildings, arable crops cannot be grown where there are forests, and so on. Treating land uses as mutually exclusive is therefore a necessary simplification...One issue which would require this assumption to be reconsidered is if the supply of freshwater for human consumption were to be included in the eco-footprint. The complexities of accounting for this multiple land use is probably one of the main reasons that this is currently excluded".

Measured (local, weighted) vs. Calculated (global) Land Use (Rank 14): Kitzes et al. (2007a) summarises this debate, "The current National Footprint Accounts calculate Footprints in units of global hectares by dividing a nation's total extraction of a product by the world-average yield for that product and multiplying by the appropriate equivalence factor (Monfreda et al 2004). The accounts can also be configured to calculate Footprints in local or national-average hectares for a specific land type, by dividing a nation's extraction for a product by that nation's yield for the product, without the use of equivalence factors. This "calculated area" approach is widely applied (e.g., Monfreda et al 2004, Erb 2004a, WWF 2006). A second method is "measured area", which draws area occupied estimates directly from land use and land cover surveys, and often combines these areas with disturbance weightings (e.g., Bicknell et al 1998, Lenzen and Murray 2001). In this method, Footprints are generally measured in actual hectares. The measured area method gives a more accurate depiction of the physical area occupied within a nation to the extent that uncertainties within land cover surveys, field based or remote, are smaller than uncertainties in production and yield data sets. The calculated area approach, however, inherently addresses partial occupation of areas, while the additional disturbance or intensity multipliers are needed to account for the intensity of use in a measured area approach (Lenzen and Murray 2001, Lenzen and Murray 2003). The basis for disturbance and intensity multipliers continues to be debated, especially as they may show significant geographic variation (e.g., the disturbance caused by grazing in low-productivity arid regions may be of a different magnitude than that caused by grazing in high-productivity regions)".

Additional Land Types (Rank 15): Kitzes et al. (2007a) explains, "Since their inception, the accounts have excluded several land types that do no provide significant amounts of concentrated resources for human extraction or waste absorption services, including wetlands, tundra, and deserts. The distinction between what land types are considered bioproductive and not bioproductive has been criticized as not clearly demarcated and based on subjective judgment (Venetoulis and Talberth 2007). A response could be to expand the coverage of the National Footprint Accounts to include additional land types that provide other types of services to humans, such as wetlands, or to all land types on the planet. At the local level, at least one preliminary study (Bagliani et al. 2004) has focused attention on calculating the biocapacity of lagoons and other wetlands, finding that the biocapacity of the lagoon under analysis may be higher on a per hectare basis than open sea. The complexity of wetland and estuary systems may create significant analytical difficulties in choosing and measuring appropriate levels of biomass production and waste absorption services".

The inclusion of additional 'land' types was one modification in the Ecological Footprint analysis of Peru (Siche et al. 2007). Siche et al. (2007) considered, "EF (Ecological Footprint) does not consider the work of untouched nature in productivity and ecosystems services. To improve this, we propose…to include the ecosystems not considered in EF: tundra, deserts and zones covered by ice".

Water Use (Rank 17): Kitzes et al. (2007a), "Although freshwater is a natural resource cycled through the biosphere, and related to many of the biosphere's critical goods and services, it is not itself a creation of the biosphere. Similar to other nutrients, the water is an enabler of bioproductivity (e.g., photosynthesis), but largely not a product of ecosystems. As a result, the Footprint of a given quantity of water cannot be calculated with yield values in the same manner as a quantity of crop or wood product. When values for a "water footprint" are reported, these generally refer to either a measurement of total liters of water consumed, not any measure of land area (e.g., Hoekstra 2007), or a measurement of the Footprint required for a utility to provide a supply of water (Lenzen et al. 2003)...Currently, where an application requires that demand on water be tracked directly, water use accounts are often presented in tandem with Footprint assessments (e.g., WWF 2006). Future research into this area should recognize and build on the new United Nations SEEA water accounts (SEEAW)".

Water has been added to the Ecological Footprint in at least 3 different ways. The following methods of accounting water are not independent of each other. Sharing Nature's Interest (Chambers et al. (2000) refers to the first two methods for accounting water:

I. Embodied Energy:

To avoid double counting, the first way of accounting water is to identify the energy needed to collect, process, supply and treat water. This energy is already included in the National Footprint Account), but not identified.

II. Water ‘shadow’:

In line with the Ecological Footprint, the bioproductive area for the supply and treatment of water can also be accounted as Method 1 + water ‘shadow’. The water ‘shadow’ is the internal renewable water resource of a country divided by the land area of that country and converted to gha. The water ‘shadow’ is not additive to the conventional Ecological Footprint components.

The third method does not convert water into an Ecological Footprint, but aligns litres of water alongside the National Footprint Accounts’ components.

III. Water Footprints (Hoekstra, 2007):

Water ‘footprints’ is a method of calculating total water demand by activity and product, including both direct and indirect water and trade. It is not an Ecological Footprint, but reports the ‘footprint’ as litres or m3 of water. Water is divided between blue (treated), green (rain, river etc.) and grey (pollution abatement) water. Grey water is admittedly the weakest component but is still an indicative method. As water ‘footprints’ are not Ecological Footprints they could be presented as satellite accounts to the National Footprint Accounts.

Persistent Pollutants (Rank 19): Kitzes et al. (2007a) discuss this issue: Under current methods and frameworks, toxic materials for which the biosphere has no regenerative capacity for absorption are assigned Footprints associated with the amount of biological capacity required to create them (e.g., energy for processing, area for mining, etc.). There is no Footprint directly assigned to these materials based on the amount of area required to re-absorb them, however, as this area would be undefined or infinite. The total impacts on bioproductive land from materials for which the biosphere has no regenerative capacity are thus not fully reflected in Ecological Footprint accounts. Similar to the use of freshwater, however, any damages to productive ecosystems that result from the release of toxic materials are captured indirectly through decreases in biocapacity, if and when they occur. Similar to water use, methods for allocating this lost biocapacity to the materials that cause its loss could be developed. Other research could pursue methods for extending the theory of Footprint accounting to include physical cycles (e.g., geochemical processes that can remove pollutants from soils) in addition to biological cycles".

Yet, Holmberg, Lundquist, Karl-Henrik and Wackernagel (1999) suggest that waste substances other than CO_2 could be included. "A systematic inclusion of such wastes in EF (Ecological Footprint) calculations is difficult because the assimilation capacities in the ecosphere are known only for a few of the naturally occurring substances. In these cases, the anthropogenic flows of such a substance can be converted to an area needed for assimilating that substance...When assimilation capacities are not known, it can be possible to indirectly estimate them, for example, by considering some natural flows. The assimilation capacities of metals are usually not known, but can be assumed to be proportional to their natural flows, such as in their weathering and sedimentation rates...To avoid double counting of productive areas and erroneously large footprints, it is necessary to consider that the area needed for assimilation of substances can still be made applicable for other purposes, for instance, productive forests and crop land, provided that these areas are not destroyed because of high concentrations of the emitted compounds. Further, the same area can be applied for the assimilation of more than one compound. We define additive aspects as those that can be added to each other when calculating the total footprint without the risk of double counting of area, e.g. food and fibre production. In contrast to exclusive (primary or additive) aspects, the secondary (or non-additive) aspects should not be added to each other since the same area can be used for several of these aspects, e.g. assimilation of substances can be done on the same area as is used for fibre production. Note that built-up land is also an additive aspect but this area cannot be used for assimilation of substances. If none of the emissions of compounds exceed their assimilation capacities corresponding to the productive area needed for additive aspects, there is no need to add any productive area occupied by this function to the footprint area...if some of the emissions of compounds exceed their assimilation capacities of the productive area needed for additive aspects, the footprint should increase the more the assimilation is exceeded. The most appropriate strategy would then be to calculate how much the productive area for assimilation of the most dominant compound would need to be extended in order not to have accumulation of that compound...Substances for which it is not possible to estimate their assimilation capacities cannot be considered in the EF (Ecological Footprint) method and have to be accounted for in some other way".

Biodiversity (Rank 19): Kitzes et al. (2007a) set out the current National Footprint Accounts author's perspective, "When calculating a nation's ecological reserve or deficit, or local and global overshoot, the National Footprint Accounts do not specifically reduce the amount of available biocapacity to account for the needs of wild species. While quantitative set-asides of biocapacity based on a estimated percentage of land necessary for preserving biodiversity have been used in the past and continue to be suggested (Talberth and Venetoulis 2007), the historical position of the accounts has been to report only on total availability of capacity and demand and allow other decision making tools to address the desirability of leaving a certain amount of capacity aside for wild species".

An example of biodiversity accounting with the Ecological Footprint is given by Best Foot Forward (BFF 2005a), "In addition (to the other 'land' types) a fifth type – biodiversity – refers to the area of land and water that would need to be set-aside to preserve biodiversity. This area of land and water is allocated in proportion to the ecological footprint – for example, the larger the ecological footprint the larger the responsibility to maintain biodiversity. As biodiversity was not included in the headline National Footprint Accounts, it was not therefore presented in the main ecological footprint results. If biodiversity were included, a South West resident's ecological footprint would increase to 6.31 gha per person" (compared to 5.56 gha per person excl. biodiversity allocation). This calculation uses the Brundtland Commission (WCED, 1987) assumption of setting aside 12% of bioproductive area for non-human species.

5. Outputs

The outputs of this research proposal should build upon existing studies which address sustainable land use techniques and issues. The proposed project outputs are:

- Identify and evaluate sustainable land use accounting options and associated issues for the Ecological Footprint, including:
    - Alternatives to the ‘set aside’ method of accounting for the bio-productive area for non-human species
    - The possible incorporation of a ‘land disturbance’ metric – such as that suggested by Lenzen et al. (2006a) or HANPP.
    - The possible inclusion of additional area (land use) types into Ecological Footprint calculations
    - Alternatives to the current assumption of mutually exclusive area types
    - Methods for incorporating or aligning additional resources, such as water and persistent pollutants, into or alongside the National Footprint Accounts and
    - An assessment of the advantages and disadvantages of using local and/or global, hectares.
- Conduct a thorough review and consultation with leading practitioners
- Ensure any research takes account of the ‘best practice’ standards and guidelines contained with the Footprint Standards (GFN 2006b).
- Assess the implications for the current Footprint Standards of any proposed revisions to the Ecological Footprint methodology
- Drafting of recommendations to address identified and associated issues,
- Consultation with leading practitioners to agree, prioritise and scope recommendations,
- Consultation with project team to finalise recommendations, and
- Final recommendations report.

6. Timeline & Budget:

Global Footprint Network, the current authors of the National Footprint Accounts, estimate that this research could be completed and ready for implementation in the 2012 edition of the National Footprint Accounts, published in summary in WWF's Living Planet Report (WWF, 2006).

Method Description	Estimated Days
Alternative method development, based on the work of Lenzen & Murray (2001, 2003) and Lenzen et al. (2006a) using a sustainable land-use weighting system. Including evaluation and assessment of all associated issues	**To Be Defined[1]**
Incorporating Human Appropriated Net Primary Productivity (HANPP) into the Ecological Footprint may lead to indicators of sustainable land use and biodiversity. Including evaluation and assessment of all associated issues	**To Be Defined[2]**

Notes: 1 Insufficient detail is currently available to enable an estimate of days.

2 The use of HANPP for the calculation of equivalence factors is included as part of Proposal 4. Completion of Proposal 4 may lead to outcomes appropriate for this proposal. It may also be possible that further work with the concept of Net Primary Productivity (NPP) is required to account sustainable land use with this approach.

Sub-proposal 8:

„EVALUATING AND TESTING THE KEY CONSTANT ASSUMPTIONS OF THE NATIONAL ECOLOGICAL FOOTPRINT ACCOUNTS“

1. Key Source Data and Methodology Stakeholders

International and National Statistics Agencies

2. Context and Problem Definition

The relative importance of ‘key constant assumptions’ to influence the final results of the National Footprint Accounts (currently authored by the Global Footprint Network and published in summary form in WWF’s Living Planet Report) was ranked as the ninth most important issue (Rank 9) in the previous project.

Currently, the key constant assumptions of the 2006 edition of the National Footprint Accounts include examples, such as, “the amount of carbon sequestered per hectare of world-average forest (IPCC 2006), the total sustainable harvest of marine fish, invertebrate, and plant species, (FAO 1971, Pauly 1996), the feed conversion ratios and feed baskets of various livestock (Steinfeld et al. 2006), and others…The National Footprint Accounts rely on a number of key constants to translate material extraction and waste emissions into units of productive area" (Kitzes et al. 2007a).

Schafer et al. (2006) found as a result of the brief Eurostat review, “The use of other data sources, modifications in the choice of input variables, and/or in the weighting system can change the message significantly. Also, the margin of error of EF/BC accounts based on shortcomings of the data sources is hard to quantify". These concerns were further reinforced in the review of the German National Footprint Account (Giljum et al. 2007), which, “considered that a Monte Carlo Analysis could provide a valuable insight into the sensitivity of the National Footprint Account to variations in source data and the Account’s own in-built assumptions". The Accounts were found to be particularly sensitive to small changes in a relatively few constants.

3. Task: Evaluate methodological options and recommend a robust method for evaluating and testing the key constant assumptions of the Ecological Footprint

Kitzes et al. (2007a) recently published a research agenda for the National Footprint Accounts. This thorough evaluation of the Footprint methodology used to construct the National Footprint Accounts also highlighted the issue of key constant assumptions. They recognised that the values given to certain key constants could significantly influence the headline Ecological Footprint results:

- “Key constants…that are known to have a large influence on the overall Footprint calculations should be subject to specific additional scientific analysis. Where appropriate, likely ranges for these constants should be applied to generate a range or set of standard error estimates for Footprint result sets. This list of key constants should be selected by expert opinion coupled with formal sensitivity analysis" (Kitzes et al. 2007a).

Other authors have also commented on the sensitivity of the Accounts to changes in the values of key constant assumptions:

- Schafer et al. (2006) recommend, "External reviewers should be part of the applied quality management using independent data sources for comparison".
- Giljum et al. (2007) describe the tools and methods they used to review the German National Footprint Accounts. "Monte Carlo methods are a widely used class of computational algorithms for simulating the behaviour of various physical and mathematical systems. They are distinguished from other simulation methods (such as molecular dynamics) by being stochastic, that is nondeterministic in some manner - usually by using random numbers (or, more often, pseudo-random numbers) - as opposed to deterministic algorithms. Because of the repetition of algorithms and the large number of calculations involved, Monte Carlo is a method suited to calculation using a computer, utilizing many techniques of computer simulation. More broadly, Monte Carlo methods are useful for modelling phenomena with significant uncertainty in inputs…Here we present a preliminary Monte Carlo Analysis which attempts to model the impact of variations in the primary data and parameters on the final result, the total Ecological Footprint figure. The total number of cells studied in this project was 5,866... The undertaken research is a first tentative step towards a detailed sensitivity analysis of Ecological Footprint accounts".

4. Associated Issues:

Fish Yields (Rank 8): Kitzes et al. (2007a) explain how, "calculations of Footprint and biocapacity for fisheries based only on primary production requirements and a single estimate of sustainable yield ignore the importance of availability and quality of fishing stocks in determining actual regenerative capacity in a given year. Treating the availability of primary production as the only determinant of marine fisheries production might be compared to considering the availability of atmospheric carbon dioxide to be the only determinant of timber growth in forests. The current very small estimate of overshoot in global marine fisheries accounts may be due to exactly this problem, as the accounts are insensitive to any declining quality and yearly sustainable yield of fisheries over time.

A significant improvement to fisheries Footprints would be to calculate the yields for fisheries based on stock quality information for all, or at minimum the most significant, fish species. Data on the quality and reproduction rates of specific fisheries may be extremely difficult to locate, and difficult to compile. Even simple models, however, may represent a theoretical and practical improvement over current methods. These models should make a point of addressing the potential influence and importance to fisheries biocapacity of specific spawning grounds, an issue which has not yet been addressed by fisheries accounts".

Nuclear Energy (Rank 11): Schafer et al. (2006) observe, "It is unclear what kind of environmental pressure is included in the transfer coefficients and how this is scientifically justified. In the WWF (2005) study, a unit of nuclear energy is considered as equal to one unit of fossil energy. This politically-wanted transfer coefficient does not reflect the environmental pressure from nuclear power activities".

Kitzes et al. (2007a) acknowledge this point and discuss the issue further. "Many researchers now believe that the Footprint of nuclear land should not be calculated using the fossil fuel equivalent method, as this equivalency does not reflect any measurement of actual demand on the biosphere. One suggestion is that the nuclear Footprint would instead be defined as a type of consumption activity, similar to the Footprint of other activities. Under this method, the Footprint of nuclear electricity would be the amount of Footprint related to the consumption of those products necessary to produce nuclear electricity, such as forest land for creating infrastructure, built land for physical space, carbon sequestration land for carbon dioxide emissions (ISA 2006), and perhaps productive land already rendered unproductive by contamination. No additional equivalency-based calculation of "nuclear land" would be included.

Other impacts, such as the potential risk of a future nuclear accident or the Footprint required for future waste disposal, would be reflected in biocapacity and Footprint accounts only when they occurred, consistent with the existing accounting framework. This method of not including potential future impacts in the core National Footprint Accounts can lead those not familiar with the present-day focus of these accounts to conclude that activities, such as nuclear power, that place small current demands but high expected future demands, are better for the biosphere. In such cases, the use of extended accounts in tandem with the National Footprint Accounts may be the most appropriate means of addressing this misinterpretation, and this message should be communicated to the appropriate policy makers.

The amount of communication necessary to describe the appropriate use of multiple assessment tools in some decision making, such as the choice between nuclear and fossil fuel electricity, may prove more difficult in short, simple applications intended for the general public. These communication challenges will need to be addressed in tandem with any methodological changes".

The concern over the accounting of nuclear energy can be considered more broadly in terms of how best to account for future risk (addressed also in sub-proposal 5, Policy Applications of a Static Indicator, The Ecological Footprint - section 3).

Built-Up Land (Rank 14): Kitzes et al. (2007a) discuss this issue: "Because cropland is the most productive of all land types according to current equivalence factor calculations, the assumption that built space occupies cropland can create a counter-intuitive result when the infrastructure replaces other land types. In this instance, the estimated biocapacity of the nation will actually increase, even though the land itself is degraded

(Wackernagel et al. 2004)[65]...These calculations can be made more accurate by estimating more precisely what land type was replaced by built infrastructure. These data can be modeled based on remotely sensed data sets, such as the GLC, GLOBCOVER, or CORINE (JRC 2000, GOFC-GOLD 2007, LEAC 2007). Global NPP data sets could be used to calculate the actual biological production of areas under infrastructure (from gardens and parks, for example), and this production level could also be used as the basis for biocapacity and Footprint calculations for built-land (Venetoulis and Talberth 2007)...(Finally,) aggregated accounts will show no change in biocapacity as previously harvested cropland is covered with infrastructure".

5. Outputs

This particular research proposal is NOT seeking to determine a definitive method of accounting for nuclear energy, built land or fish yields. Instead these constants should be considered as exemplars – illustrations of some of the issues surrounding the assignment of values to constants within an Ecological Footprint accounting framework.

The focus of this research proposal is to identify key constants. That is, those likely to significantly affect the headline Ecological Footprint results. These may, or may not, include those constants discussed above. Outputs include:

- Identification, using a structured analysis, of all key constants within the National Footprint Accounts
- Determine the uncertainty in these 'constants' based on current scientific research
- As a result of the above, identify which are the key uncertainties. Those which – if altered – would impact on more than one key constant.
- Conduct a thorough review and consultation with leading practitioners
- Ensure any research takes account of the 'best practice' standards and guidelines contained with the Footprint Standards (GFN 2006b).
- Assess the implications for the current Footprint Standards of any proposed revisions to the Ecological Footprint methodology
- Drafting of recommendations to address the above
- Consultation with leading practitioners to agree, prioritise and scope recommendations,
- Consultation with project team to finalise recommendations, and
- Final recommendations report.

65 Cited as "Wackernagel et al. 2004a" in this report.

6. Timeline & Budget:

Global Footprint Network, the current authors of the National Footprint Accounts, estimate that this research could be completed and ready for implementation in the 2010 edition of the National Footprint Accounts, published in summary in WWF's Living Planet Report (WWF, 2006).

Method Description	Estimated Days
Determine, evaluate and test Ecological Footprint key constant assumptions, including all associated issues	**50**
Integrate as part of the European national research collaborations (Proposal 6, Accuracy of Source Data).	**To Be Defined***

*Included in Proposal 6: Accuracy of Source Data, is the proposal for European nations to review their National Footprint Accounts. If this occurred, this proposal could potentially form part of that project.

Sub-proposal 9:

„TESTING THE SENSITIVITY OF THE NATIONAL ECOLOGICAL FOOTPRINT ACCOUNTS“

1. Key Source Data and Methodology Stakeholders

International and National Statistical Agencies

2. Context and Problem Definition

The lack of sensitivity analyses within the National Footprint Accounts (currently authored by the Global Footprint Network and published in summary form in WWF's Living Planet Report) was ranked as the tenth most important issue (Rank 10) in the previous project.

Currently, the 2006 edition of the National Footprint Accounts does not report any sensitivity analyses or error estimates for its results. Kitzes et al. (2007a) addresses this issue, "Although many researchers have suggested that the standard error of national Footprint accounting remains fairly high, no major systematic analyses have yet been published to examine and test confidence levels of source data in the National Footprint Accounts (Giljum et al. 2007 and Lewis et al. 2007 represent perhaps the first)".

Eurostat's brief review highlight this issue also (Schafer et al. 2006), "The use of other data sources, modifications in the choice of input variables, and/or in the weighting system can change the message significantly. Also, the margin of error of EF/BC (Ecological Footprint/Biocapacity) accounts based on shortcomings of the data sources is hard to quantify. External reviewers should be part of the applied quality management using independent data sources for comparison".

George (2007) is the second review of the Ecological Footprint in the UK. George (2007) found, "Curry et al. (2006) applied the NFA (National Footprint Accounts) methodologies for 1999, 2001 and 2002 to 2001 (consumption) data for Northern Ireland, to calculate the change in the footprint which can be attributed to methodological developments alone. This suggested a decrease in the footprint of 4% between the 1999 methodology and that used in 2001, and a subsequent increase of 3% when using the 2002 methodology.

A number of countries have reviewed their national footprint, as calculated by the National Footprint Accounts. Completed studies in Switzerland (von Stokar et al., 2006), Ireland

(Curry et al., 2006) and Finland compared national data with that provided by international agencies. In general, there was good correlation between national and international data sets (which would be expected where the latter are based on the former). However, all three studies identified issues with trade data that affected their footprints, which varied the national footprints between -12% and +28%. While some of these issues have now been addressed, further national studies have the potential to raise new issues".

George (2007) also reports, "A related issue is that the NFA (National Footprint Accounts) do not identify the level of uncertainty associated with the footprints, as the data sources it uses do not publish such information. The Global Footprint Network maintains that the methodology is designed to overestimate biocapacity and underestimate the footprint, thus any uncertainty/changes in data and methodology are unlikely to change the general message (that human activities are using more resources than the Earth can regenerate). However, levels of uncertainty are more significant where the footprint is used as an indicator or target. Curry et al. (2006) note that the footprint for Northern Ireland 'grew between 2001 and 2002, but is estimated to have reduced slightly in 2003 even though it is not known if this change is within the error limits and therefore not a significant reduction'".

3. Task: Evaluate methodological options and recommend a robust method for testing and applying sensitivity analyses of the Ecological Footprint

Kitzes et al. (2007a) recently published a research agenda for the National Footprint Accounts. This thorough evaluation of the Footprint methodology used to construct the National Footprint Accounts recognised the importance of providing additional checks on the sensitivity of Ecological Footprint results, although no such sensitivity checks currently exist:

- Accounting methods and assumptions should be subject to additional formal analysis and "reality checks" using a range of published data sources (Kitzes et al. 2007a).
- In addition to purely mathematical simulations from within the existing calculation framework, a broad definition of sensitivity analysis would include investigations of alternative methods that may affect final Footprint results. These might include new techniques for calculating the Footprint embodied in traded goods, alternate methods for calculating equivalence factors, or a shift in the basis for calculating the carbon Footprint. These analyses of alternate methods should be compared to existing methods, with documentation of differences and their significance (Kitzes et al. 2007a).

Other authors have also identified the importance of being able to assess the robustness of the National Footprint Accounts:

- "It was considered that a Monte Carlo Analysis could provide a valuable insight into the sensitivity of the National Footprint Account to variations in source data and the Account's own in-built assumptions. Monte Carlo methods are a widely used class of computational algorithms for simulating the behaviour of various physical and mathematical systems. They are distinguished from other simulation methods (such as molecular dynamics) by being stochastic, that is nondeterministic in some manner - usually by using random numbers (or, more often, pseudo-random numbers) - as opposed to deterministic algorithms. Because of the repetition of algorithms and the large number of calculations involved, Monte Carlo is a method suited to calculation using a computer, utilizing many techniques of computer simulation. More broadly, Monte Carlo methods are useful for modelling phenomena with significant uncertainty in inputs… Here we present a preliminary Monte Carlo Analysis which attempts to model the impact of variations in the primary data and parameters on the final result, the total Ecological Footprint figure. The total number of cells studied in this project was 5866… The undertaken research is a first tentative step towards a detailed sensitivity analysis of Ecological Footprint accounts" (Giljum et al. 2007).

- “Results from the LPR (WWF’s Living Planet Report) series aggregate changes in methodology and consumption over time and (thus) give a false trend…Backcasting national results to 1961 using the latest method add value to the NFA. This gives a time trend altered only by consumption of resources. For Northern Ireland, 1999, 2001 and 2002 consumption data assessed using the Stepwise™ methodology, aligned to the UK NFA 2002, (was used) to illustrate the impact of consumption changes (only)… (Alternatively,) consumption data (2001) for Northern Ireland was assessed using the Stepwise™ methodology, aligned to the UK National Footprint Account (NFA) 1999, 2001 and 2002 to illustrate the impact of methodological changes. Error estimates rarely accompany consumption data. For Northern Ireland, consumption data was assumed to vary by 10%. Error can also occur within the methodology. The Footprint of Ireland’s trade was found to be highly sensitive. This example illustrates the scale of sensitivity in the NFA. The most sensitive assumption was corrected in the NFA 2006. Monte Carlo simulation was used to test sensitivity and could lead to a process to evaluate NFAs and the proposed grading of NFA" (Lewis et al. 2007).
- "The provision of error margins enables a more meaningful comparison between results. They allow a judgment whether differences in Ecological Footprints are real or only ostensible. An estimation of the precision should also increase the credibility of the Ecological Footprint. Unfortunately, National Footprint Accounts depend on data inputs that mostly lack information about error margins. Hence, the national results cannot be bracketed with error margins. It is important to recognize that this guideline addresses errors in the source data, or errors introduced as a result of analytical limitations (e.g., truncation errors or unavoidable double counting because information is lacking). It does not address methodological errors, such as double counting of demand or production elements when these are separable. Best practices call for a discussion of sources of error in the report and the availability of data on error margins, even if the quantitative estimates of the error are not available" (Footprint Standards 2006).

4. Associated Issues:

Multiple methods give varying results (Rank 12): Curry et al. (2006) reports, “The National Footprint Accounts also include methodology changes, such as the availability of new and improved data sources and improved methodology. Both of these changes have affected the Materials & Waste component Footprint between 2001 and 2002. For example, full trade data became available in the National Footprint Account 2002 in a format that enabled direct electronic use within the National Footprint Account calculations. Previous to this, data was entered by hand into the accounts and not all data was available. The introduction of full trade data has also lead to improved methodology within the National Footprint Accounts, to be published in the forthcoming 2006 edition...Although such changes occur and will continue to do so, the variation to the total Ecological Footprint of Northern Ireland residents does not vary significantly at the planet index scale". (Note: The planet index depicts the number of planets humanity would require if everyone lived like the average Northern Ireland resident).

5. Outputs

It is important that the outputs from this research do not duplicate existing or planned work but build upon existing sensitivity analysis techniques, and in particular collaborate with the authors who have undertaken evaluations of the National Footprint Accounts for individual countries. Outputs should include:

- Identification and literature review of methodological techniques for sensitivity analyses, including Monte Carlo simulation, applicable to the National Footprint Accounts
- Determine sensitivity by applying alternative data sources for national consumption data and key constant assumptions (integrates with sub-proposal 6).
- Apply alternative methods for the total Ecological Footprint calculation and/or specific sections (eg. CO2, trade) or assumptions (e.g. equivalence factors)
- Evaluate the use of sensitivity analysis techniques for the National Footprint Accounts (integrates with sub-proposals 8)
- Clear documentation of methods and assumptions used to perform sensitivity analysis and interpretation of the results. Include boundary definitions, as shown by Curry et al. (2006) for example
- Evaluation of error assessment techniques for source data and the Ecological Footprint calculations
- Conduct a thorough review and consultation with leading practitioners
- Ensure any research takes account of the ‘best practice’ standards and guidelines contained with the Footprint Standards (GFN 2006b).
- Assess the implications for the current Footprint Standards of any proposed revisions to the Ecological Footprint methodology
- Drafting of recommendations to address the above
- Consultation with leading practitioners to agree, prioritise and scope recommendations,
- Consultation with project team to finalise recommendations, and

- Final recommendations report.

6. Timeline & Budget:

Global Footprint Network, the current authors of the National Footprint Accounts, estimate that this research could be completed and ready for implementation in the 2010 edition of the National Footprint Accounts, published in summary in WWF's Living Planet Report (WWF, 2006).

Method Description	Estimated Days
Develop robust methods and processes for sensitivity analysis of the National Ecological Footprint Accounts, including all associated issues	**80***

Note: The use of sensitivity analysis overlaps with other sub-proposals, particularly sub-proposal 6 and 8. The duration of the sensitivity analysis project will be influenced by the output of both these sub-proposals. The dependencies of these issues are illustrated in the Gantt chart (Annex 1d).

Annex 1d: The research agenda Gantt chart

The Gantt chart presents an overview – a research 'road map' - of how the nine sub-proposals might be delivered within the 5-year time period. There are, of course, considerable uncertainties inherent in this schedule but it is nonetheless helpful in identifying key dependencies.

National Footprint Accounts - Projects and Goals

Year1

	Days
Documentation	
Series of methodological papers (3) documenting calculations	60
Methodology book written by technical experts in community	80
Full national accounting handbook for NFA	TBD
Accuracy of Source Data	
Establish evaluation and reporting system for source data quality in NFA	15
Establish European national research collaborations (26 nations)	1,300
Carbon Sequestration	
Review of global average forest/ocean method, comply w/ IPCC	70
Comparison to "all land" sequestration value	35
Alternates - Biofuel-substitution & Bioproductive area to produce fossil fuels	35
Alternate - Future loss of productive land due to climate change	85
Trade	
Updating LCA / mass balance trade approach	50
Construct global/regional MRIO model	TBD
Test/Implement global MRIO model in NFA	80
Equivalence Factors	
Review and recalculation of GAEZ equivalence factors	20
Evaluate HANPP and Emergy options as alternatives to GAEZ	50
Key Constants	
Examine and test confidence intervals for key constants	50
Sensitivity Analysis	
Implement sensitivity analysis in NFA	80
Utility of the Ecological Footprint for Policy-Makers	
Development of appropriate use case studies	50
Development of non-static extensions of indicator	TBD
Sustainable Land Use	TBD

National Footprint Accounts - Projects and Goals

	Days	Year2: J F M A M J J A S O N D
Documentation		
Series of methodological papers (3) documenting calculations	60	
Methodology book written by technical experts in community	80	
Full national accounting handbook for NFA	TBD	
Accuracy of Source Data		
Establish evaluation and reporting system for source data quality in NFA	15	
Establish European national research collaborations (26 nations)	1,300	
Carbon Sequestration		
Review of global average forest/ocean method, comply w/ IPCC	70	
Comparison to "all land" sequestration value	35	
Alternates - Biofuel-substitution & Bioproductive area to produce fossil fuels	35	
Alternate - Future loss of productive land due to climate change	85	
Trade		
Updating LCA / mass balance trade approach	50	
Construct global/regional MRIO model	TBD	
Test/Implement global MRIO model in NFA	80	
Equivalence Factors		
Review and recalculation of GAEZ equivalence factors	20	
Evaluate HANPP and Emergy options as alternatives to GAEZ	50	
Key Constants		
Examine and test confidence intervals for key constants	50	
Sensitivity Analysis		
Implement sensitivity analysis in NFA	80	
Utility of the Ecological Footprint for Policy-Makers		
Development of appropriate use case studies	50	
Development of non-static extensions of indicator	TBD	
Sustainable Land Use	TBD	

National Footprint Accounts - Projects and Goals

	Days (Year3: J F M A M J J A S O N D)
Documentation	
Series of methodological papers (3) documenting calculations	60
Methodology book written by technical experts in community	80
Full national accounting handbook for NFA	TBD
Accuracy of Source Data	
Establish evaluation and reporting system for source data quality in NFA	15
Establish European national research collaborations (26 nations)	1,300
Carbon Sequestration	
Review of global average forest/ocean method, comply w/ IPCC	70
Comparison to "all land" sequestration value	35
Alternates - Biofuel-substitution & Bioproductive area to produce fossil fuels	35
Alternate - Future loss of productive land due to climate change	85
Trade	
Updating LCA / mass balance trade approach	50
Construct global/regional MRIO model	TBD
Test/Implement global MRIO model in NFA	80
Equivalence Factors	
Review and recalculation of GAEZ equivalence factors	20
Evaluate HANPP and Emergy options as alternatives to GAEZ	50
Key Constants	
Examine and test confidence intervals for key constants	50
Sensitivity Analysis	
Implement sensitivity analysis in NFA	80
Utility of the Ecological Footprint for Policy-Makers	
Development of appropriate use case studies	50
Development of non-static extensions of indicator	TBD
Sustainable Land Use	TBD

National Footprint Accounts - Projects and Goals

	Days	Year4 J	F	M	A	M	J	J	A	S	O	N	D
Documentation													
Series of methodological papers (3) documenting calculations	60												
Methodology book written by technical experts in community	80												
Full national accounting handbook for NFA	TBD												
Accuracy of Source Data													
Establish evaluation and reporting system for source data quality in NFA	15												
Establish European national research collaborations (26 nations)	1,300												
Carbon Sequestration													
Review of global average forest/ocean method, comply w/ IPCC	70												
Comparison to "all land" sequestration value	35												
Alternates - Biofuel-substitution & Bioproductive area to produce fossil fuels	35												
Alternate - Future loss of productive land due to climate change	85												
Trade													
Updating LCA / mass balance trade approach	50												
Construct global/regional MRIO model	TBD												
Test/Implement global MRIO model in NFA	80												
Equivalence Factors													
Review and recalculation of GAEZ equivalence factors	20												
Evaluate HANPP and Emergy options as alternatives to GAEZ	50												
Key Constants													
Examine and test confidence intervals for key constants	50												
Sensitivity Analysis													
Implement sensitivity analysis in NFA	80												
Utility of the Ecological Footprint for Policy-Makers													
Development of appropriate use case studies	50												
Development of non-static extensions of indicator	TBD												
Sustainable Land Use	TBD												

National Footprint Accounts - Projects and Goals

	Days	Year5 J	F	M	A	M	J	J	A	S	O	N	D
Documentation													
Series of methodological papers (3) documenting calculations	60												
Methodology book written by technical experts in community	80												
Full national accounting handbook for NFA	TBD												
Accuracy of Source Data													
Establish evaluation and reporting system for source data quality in NFA	15												
Establish European national research collaborations (26 nations)	1,300												
Carbon Sequestration													
Review of global average forest/ocean method, comply w/ IPCC	70												
Comparison to "all land" sequestration value	35												
Alternates - Biofuel-substitution & Bioproductive area to produce fossil fuels	35												
Alternate - Future loss of productive land due to climate change	85												
Trade													
Updating LCA / mass balance trade approach	50												
Construct global/regional MRIO model	TBD												
Test/Implement global MRIO model in NFA	80												
Equivalence Factors													
Review and recalculation of GAEZ equivalence factors	20												
Evaluate HANPP and Emergy options as alternatives to GAEZ	50												
Key Constants													
Examine and test confidence intervals for key constants	50												
Sensitivity Analysis													
Implement sensitivity analysis in NFA	80												
Utility of the Ecological Footprint for Policy-Makers													
Development of appropriate use case studies	50												
Development of non-static extensions of indicator	TBD												
Sustainable Land Use	TBD												

Annex 2: Pre-selection of alternative approaches

Description of methods and indicators

Socio-economic-environmental indices:

Environmental Sustainability Index (ESI). The ESI was developed by Yale and Columbia Universities and sponsored by the World Economic Forum and the European Commission Joint Research Centre (Esty et al., 2005). The latest ESI report (2005) benchmarks the ability of nations to protect the environment over the next several decades. It does so by integrating 76 data sets (including the Ecological Footprint) tracking natural resource endowments, past and present pollution levels, environmental management efforts, and a society's capacity to improve its environmental performance into 21 indicators of environmental sustainability. These indicators permit comparison across the following five fundamental components of sustainability: Environmental Systems; Environmental Stresses; Human Vulnerability to Environmental Stresses; Societal Capacity to Respond to Environmental Challenges; and Global Stewardship.

Inclusive Wealth Accounting (Green GDP; Genuine Savings). Green GDP is the informal name given to national income measures that are adjusted for the depletion of natural resources and degradation of the environment. In terms of measuring the sustainability of development, the green accounting aggregate with the most policy relevance is Genuine Savings. Measures of Genuine Savings address a much broader conception of sustainability than net savings by valuing changes in the natural resource base and environmental quality in addition to produced assets (Hamilton and Clemens, 1999). Genuine Savings is complementary to the Ecological Footprint as together they measure how nations wealth is changing and what amount of biological capacity they are using (Wackernagel et al., 2002).

Index of Sustainable Economic Welfare (ISEW) and Genuine Progress Indicator (GPI). The ISEW has been developed by Daly and Cobb (1989) and provides a monetary correction of the GDP that includes defensive social and environmental costs and also recognises the distribution of work and labour between women and men. It has been developed further as GPI by including further long-term environmental damages, joblessness and changes in time for labour (Cobb and Halstead, 1994).

Human Development Index (HDI) / Sustainable HDI. The Human Development Index (HDI) has been initiated and refined by the United Nations Development Programme (UNDP) and is used for a world-wide country ranking in its annual *Human Development Report*. The HDI is a composite index that measures three basic aspects of human development: longevity, knowledge, and a decent standard of living. Longevity is measured by life expectancy at birth; knowledge is measured by a combination of the adult literacy rate and the combined primary, secondary, and tertiary gross enrolment ratio; and standard of living by GDP per capita (PPP US$). First attempts have been made to extend the HDI by a component of natural resource use for calculating a **Sustainable Human Development Index (SHDI)** (Hammer and Hinterberger, 2003). For natural resource use an indicator based on material flow analysis (MFA) has been used.

Environmental vulnerability index (EVI). Developed by the South Pacific Applied Geoscience Commission (SOPAC) and the United Nations Environment Programme (UNEP) and their partners in 1999, the EVI is a vulnerability index for the natural environment and is designed to be used with economic and social vulnerability indices to provide insights into the processes that can negatively influence the sustainable development of countries (Kaly et al., 1999). The EVI is based on 50 indicators and has been designed to reflect the extent to which the natural environment of a country is prone to damage and degradation. Each indicator is classified into a range of subindices including the three aspects of hazards; resistance and damage and into policy-relevant sub-indices including climate change, biodiversity and agriculture and fisheries. Indicators include natural and human induced damages and hazards. Many indicators describe the state of ecosystems.

Happy Planet Index. The Happy Planet Index is a "measure of the ecological efficiency of delivering human well-being" (Murphy, 2006). It measures the happiness (or life satisfaction) of humans of a given society and their life expectancy per unit of planetary resources consumed. For the latter the concept of the Ecological Footprint is used.

IPAT. IPAT is a model for the description of the influence of societies to nature (Ehrlich and Holdren 1971, Holdren and Ehrlich 1974). The model states that the impact to the environment (I) is a function of the size of a population (P), its affluence per capita (A) and the used technology (T) (I=P*A*T). Therefore, the combination of all three factors determines the impact. Indicators such as the Ecological Footprint operationalise IPAT and put it into the context of limited biocapacity.

<u>Integrated Accounting Systems</u> (including several sub-accounts plus indicators)

SEEA. The United Nations Handbook of National Accounting - Integrated Environmental and Economic Accounting (commonly referred to as SEEA), provides a common framework for economic and environmental information, permitting a consistent analysis of the contribution of the environment to the economy and of the impact of the economy on the environment (United Nation et al., 2003). The SEEA is a satellite account of the System of National Accounts (SNA) and its basic accounting structure is based on that of the SNA.

NAMEA. The National Accounting Matrix including Environmental Accounts (NAMEA), mainly used on the European level, extends the System of National Accounts (SNA) by physical flow accounts. NAMEA is a hybrid matrix where physical measures of environmental inputs and residual outputs are added to the flow accounts of the SNA (Eurostat, 2001b).

<u>Integrated environmental approaches:</u>

Environmental space. Environmental Space is the total amount of pollution, nonrenewable resources, agricultural land and forests that can be used globally without impinging on access by future generations to the same resources. The concept was further developed in the 1990s by Friends of the Earth and has been applied in studies such as “Towards Sustainable Europe” (Spangenberg, 1995) and “Tomorrow's World” (1998).

Sustainable Process Index (SPI). The SPI provides a measure of the land area appropriated by economic processes. While related to the Ecological Footprint, SPI adds up all the demand, independent of whether they could have been accommodated on the same piece of land or not. This has the advantage that the overall number becomes sensitive to improvements. But the disadvantage is that the results can no longer be compared to the area available per capita. Therefore, the SPI is more suited for comparing processes (Krotscheck and Narodoslawsky, 1996). Results and data from SPI analysis could be useful for Footprint analysis, however, this has not yet been tested widely.

Accounting systems focusing on one environmental dimension

Materials and substances.

Material flow accounting and analysis (MFA): Economy-wide indicators (DMI, DMC, TMR, TMC, DPO, TDO), ecological rucksacks. Material flow analysis (MFA) can be used to measure resource flows through countries, regions and industries. An economy-wide MFA provides a comprehensive description of the material flows between the environment and the economy. Economy-wide MFA’s are based on the concept of ‘industrial metabolism’ (Eurostat, 2001a). MFA provides an aggregated overview in tonnes of annual material inputs and outputs of an economy, including inputs from the national environment, outputs to the environment and the physical amounts of imports and exports. The net stock change (net accumulation) is equal to the difference between inputs and outputs. A number of indicators can be derived from economy-wide MFA accounts, which describe the material productivity and resource intensity of an economy and Eurostat has published a set of standard tables for indicators. The ecological rucksack of a good or service is the total material input minus the weight of the product itself. The total material input is defined as the life cycle wide total quantity (in kg) of natural material moved (physically displaced) by humans in order to produce a good. The ecological rucksack includes all hidden flows behind direct physical flows. MFA data is essential for many other materially based indicators such as the Ecological Footprint or EMC.

Physical IO tables (PIOT). A physical input-output table shows the physical flows (or the sub-set of materials) from the environment or rest of the world to the economy, within the economy and from the economy to the rest of the world or the environment in a condensed way (Giljum and Hubacek, forthcoming). IO tables (both monetary and physical) are either supply and use tables or symmetric IO tables, the latter showing interrelationships in an industry by industry or product by product matrix (United Nations et al., 2003). Such tables can be used for allocating material flows, for example, CO_2, Ecological Footprint or mass flow.

Substance flow analysis (SFA). As sub-set of Material Flow Analysis (MFA), Substance Flow Analysis (SFA) is the material flow analysis of specific substances. It enables the measurement of substance flows through complex supply chains and can be applied to industrial sectors, regions or national economies. SFA studies often focus on particular ‘problem’ substances such as heavy metals or hazardous substances (Klien et al., 1997; Tukker et al., 1997).

Carbon accounting. Carbon accounting encompasses the measurement of carbon equivalents (CO2-eq) emissions from economies, regions or organisations. Sometimes referred to as "carbon footprint", a range of methods are available for measuring both direct CO2-eq emissions and emissions that are indirectly linked to processes or activities, usually referred to as 'embodied' or 'associated' emissions. Recent methodological advances include the development of multi-regional input-output analysis as a means of estimating embedded emissions in imported products or services (Wiedmann et al., 2006a).

Energy

Energy flow accounting. Energy flow accounting (EFA) is based on the law of conservation of energy, and follows an Energy Balance approach, which aims at establishing a complete balance of energy inputs, internal transformations, and energy outputs of a society, or of a defined socio-economic component (Schandl et al., 2002).

Exergy accounting (EA). This concept tries to measure the amount of exergy resources to produce any good or service. EA attempts to integrate the principles of thermodynamics into economic thinking, to account for the degradation in the quality of energy when work takes place in the economy to produce goods or services.

Emergy accounting. Emergy accounting has an advantage over exergy of including ecosystem services (Han and Bhakshi, 2004). Its use is coupled with a systems theory of the organisation of economies and societies in relation to ecosystems (Odum, 1996), it has its own set of sustainability indicators (Brown and Ulgiati, 1996). Just recently, a consistent framework has been developed for analysis of nations and regions with a complete database of country energy use and indicators (Cohen, 2006). Active policy-related interest in using the methodology is demonstrated by a UNEP-funded project using emergy to evaluate sustainability in the Sahel region of Africa (http://sahel.ees.ufl.edu/), and use for state-wide environment-economy assessment by the US EPA (Campbell, 2005).

Land

Land use accounting (LUA). There are three core categories of environmental inputs – materials, energy and land (Spangenberg and Bonnoit, 1998). Land use statistics from national statistical agencies (for example, Statistisches Bundesamt, 2004) and from Geographical Information Systems (GIS) can be integrated with other geo-referenced data to provide statistics and information for different spatial reporting units such as regional and natural environment e.g. watersheds. Land use data can also be linked to material flow to analyse the relationship between the material intensity and intensity of land use of industrial sectors (Hinterberger et al., 2003).

Human appropriation of net primary productivity (HANPP). HANPP is a measure of human use of ecosystems and can be defined as the amount of terrestrial NPP required to derive food and fibre products consumed by humans, including the organic matter that is lost during the harvesting and processing of whole plants into end products (Haberl et al., 2007; Imhoff et al., 2004). HANPP is complementary to the Ecological Footprint as it measures how much bioproductivity is appropriated in a given territory, whereas the Footprint measures how biocapacity a country utilizes wherever that biocapacity is located in the world (Haberl et al., 2004). HANPP can measure the “depth” of the Footprint by tracking how intensively given ecosystems are being harvested.

Land and Ecosystem Accounts (LEAC): LEAC is a method use by the EEA to provide a detailed grid (1km x 1km) for land use and land cover changes within the European Union. It is based on CORINE land cover data and its goal is to provide information on the stock of available land cover classes changes. It is used for 44 CORINE land cover classes and describes one-to-one changes between these classes. Out of the possible number of 1892 change categories 50 are reported as land cover flows (Gómez and Páramo 2005).

Product-oriented methods / impact-oriented methods

Life Cycle Assessment (LCA) / Life Cycle Inventories (LCI) / Eco-Indicator. At its most basic level, LCA attempts to quantify the waste generation, emissions, and the consumption of resources associated with a product’s life cycle – from raw material extraction, energy acquisition, production and manufacturing, use, reuse, recycling, transport, through to ultimate disposal (UNEP, 2003). The stages of the Life Cycle process comprise goal scoping and definition (including the critical area of boundary-setting), data collection and inventory analysis and impact assessment. Areas of uncertainty within LCA include the choice and weighting of impact assessment parameters, one approach has been to normalise/weight the parameters into a common metric or index, one of which is the Eco-Indicator. Standardised ISO guidance has been developed for LCA Goal and Definition/Scope and Inventory Assessment, Impact Assessment and Improvement Assessment (ISO 14040 - ISO 14042). A range of development and standardisation actions are ongoing at a European level, including the European Commission European Platform on Life Cycle Assessment.

Material Input per Service Unit (MIPS). MIPS is an aggregated indicator of the material consumption associated with a product or service throughout its life cycle. Developed by the Wuppertal Institute, the indicator expresses all data in terms of tonnes of materials moved and/or used. Material inputs are expressed in terms of five input categories, abiotic raw materials, biotic raw materials, earth movements in agriculture and silviculture, water and air (Ritthoff et al., 2002).

Environmentally Weighted Material Consumption (EMC). EMC is a weighted indicator of material flows based on environmental impacts. It is usually applied in conjunction with a material flow indicator such as Direct Material Consumption (DMC) and the accompanying Material Flow Accounts (MFA) (Oers et al., 2005). EMC is based on a Life Cycle Impacts approach, to an estimate to be made of its contribution to environmental impacts throughout a products life cycle. As with LCA/Eco-Indicator, areas of uncertainty centre around the methodology/s used for weighting of impact assessment parameters.

Definition of evaluation criteria

The described methods have been assessed by the following set of criteria. The assessment has been based on literature research and knowledge from existing experience by the authors :

Coverage of one or several dimensions of sustainable development. Integrated indices, such as the Genuine Progress Indicator or the (Un)happy Planet Index, comprise both socioeconomic and environmental information and perform different methods of aggregation and weighting to derive these highly aggregated indices. Other accounting approaches and derived indicators (such as the Ecological Footprint) focus only on the environmental pillar of sustainable development.

Coverage of one or several environmental categories. Several approaches and derived indicators focus only on one environmental category (such as materials, energy, emissions or land), while other approaches integrate several environmental dimensions into one indicator, applying factors to transform information from one environmental category to another (such as the calculation of land area requirements based on mass flows in some components of the Ecological Footprint). The assessment has been made for the following environmental categories: energy, renewables, non-renewables, water, land, CO2 / GHG emissions, other air emissions, and waste.

Pressure vs. impact indicators / DPSIR. Approaches such as material flow accounting and energy flow accounting provide information on the socio-economic pressures on the environment, but have weak links to concrete environmental impacts. Some concepts (including the Ecological Footprint and EMC) aim at weighting specific mass flows according to their environmental impacts. On the product level, LCA / LCI methods are most popular to compare the environmental impacts of different products and technologies. In the proposal only pressure vs. impact has been mentioned. This has been broadened to all five categories of the DPSIR framework of the EEA.

Input- vs. output-oriented approaches. Some methods (such as land use accounting) and indicators (such as MIPS) focus on the input of natural resources for economic activities, while others trace the outflows from the socio-economic system back to the environment (output-oriented MFA, emissions accounting in the NAMEA framework). Several approaches include both inputs and outputs in one accounting framework (among them, the Ecological Footprint and physical IO tables).

Scale / levels of economic activity. Accounting approaches and indicators can focus on different levels of economic activities, ranging from micro levels (products/businesses/individuals) via the meso level (sectors/cities/sub-national regions) to the macro level (economywide/supranational). Some approaches and indicators are mainly applied on the product level (LCA; MIPS), while others, in particular aggregated indices (ISEW, HDI) and integrated accounting systems (such as SEEA or NAMEA, Environmental Space), mainly focus on the macro level.

Compatibility with the System of National Account (SNA). Some indicators are directly based on GDP numbers, which are then adjusted by environmental and social factors (ISEW, Green GDP). Some accounting frameworks (such as the environmental accounts in the SEEA-system, the NAMEA accounts, economy-wide MFA, etc.) are directly compatible and connectable with the economic System of National Accounts. Others (such as the physical IO table) are directly derived from monetary accounting frameworks (in this case, monetary IO tables). This integration can be helpful for establishing one consistent framework of analyses of the impacts of economic policy measures on the environment and vice versa.

Coverage of exported or imported environmental pressures. International trade has a large impact on raw material use. For example, as Europe's external trade has increased, materials extraction and the associated environmental effects have been shifted to other regions. In order to determine the global dimension of resources consumption in Europe, it is necessary to account for materials, energy inputs, emissions and waste that are used /generated abroad to produce imported products. Studies done in this field show that restricted access to data influences the design of the analyses carried out.

As can be seen in the assessment table (see below), a broad overlap between the Ecological Footprint and many other methods/indicators can be observed. As many methods could complement the Footprint in assessing different (environmental) impacts from natural resource use, mainly those methods have been selected for the further assessment steps within the project.

Assessment matrix

Criteria / Indicator	Coverage of sustainability dimensions			Coverage of one or several environmental categories								DPSIR Coverage					Input-output orientation		Scale/level of economic activity			Compatibility with the system of national accounts	Coverage of exported or imported environmental pressures	Comments
	Environmental	Economic	Social	Energy	Renewable res.	Non-renewable res.	Water	Land	CO2 / GHG emissions	Other air emissions	Waste	Driving force	Pressure	State	Impact	Response	Input	Output	Micro	Meso	Macro			The environmental category „energy" applies only if energy is measured in energy units (Joule), energy carriers are otherwise included in non-renewable resources.
Ecological Footprint	X				X	(X)		X	X				X				X	X	X	X	X		X	Fossil fuels are included in the EF as CO2 emissions from energy consumption and embodied energy.
Socio-economic-environmental indices																								
Environmental Sustainability Index (ESI)	X	X	X	X	X	X	X	X	X	X	X		X	X		(X)	X	X			X			
Inclusive Wealth Accounting, Green GDP, Genuine Savings	(X)	X			X	X								X							X	X		
Index of Sustainable Economic Welfare (ISEW), Genuine Progress Indicator (GPI)	(X)	X	X			(X)	(X)	(X)	(X)	(X)						X	(X)	(X)		(X)	X	X		Measures environmental dimension only in defensive costs; not yet applied on the meso level.
Human Development Index (HDI)		X	X																	(X)	X			Not yet applied on meso level.
Sustainable Human Development Index (SHDI)	X	X	X		X	X							X				X			(X)	X		(X)	Not applied yet, only tested; imported/exported pressures included in ecologic component of the indicator.
Environmental Vulnerability Index (EVI)	X			X	X	X	X	X		X	X	X	X	X	X		X	X			X			
Happy Planet Index	X		X		X	(X)		X	X				X				X	X		(X)	X		(X)	Not yet applied on meso level; imported/exported pressures included in footprint component of the indicator.
IPAT (Impact, Population, Affluence, Technology)	X	X	X	?	?	?	?	?	?	?	?		(X)		X		?	?	?	?	?		?	Fields with „?" depend on application and the indicator chosen for measuring impacts.
Integrated accounting systems																								
SEEA – UN Handbook of National Accounting – Integrated Environmental and Economic Accounting	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	Not yet applied on meso level.
NAMEA – National Accounting Matrix including Environmental Accounts	X	X			X	X	X		X	X		X	X	X	X	X	X	X		X	X	X	X	Not yet applied on meso level.
Integrated environmental approaches																								
Environmental space	X			X	X	X	X	X	X				X	X			X	X			X	(X)	(X)	The coverage of environmental categories follows Towards Sustainable Europe (1995).
Sustainable Process Index (SPI)	X				X	X		X	X	X			X				X	X	X				(X)	

Criteria / Indicator	Coverage of sustainability dimensions			Coverage of one or several environmental categories								DPSIR Coverage					Input-output orientation		Scale/level of economic activity			Compatibility with the system of national accounts	Coverage of exported or imported environmental pressures	Comments
	Environmental	Economic	Social	Energy	Renewable res.	Non-renewable res.	Water	Land	CO2 / GHG emissions	Other air emissions	Waste	Driving force	Pressure	State	Impact	Response	Input	Output	Micro	Meso	Macro			The environmental category „energy" applies only if energy is measured in energy units (Joule), energy carriers are otherwise included in non-renewable resources.
Accounting systems focussing on one environmental dimension																								
Materials and substances																								
Material Flow Analysis (MFA)	X				X	X	(X)		X	X	X		X				X	X	(X)	X	X	X	X	Could be applied on micro-level; similar methods have been applied (e.g. Environmental accounting systems for companies).
Physical input-output tables (PIOT)	X	(X)		X	X	X	X		X	X	X	X	X				X	X		X	X	X	X	Can be applied to different material environmental categories and materials (e.g. materials or energy).
Substance flow analysis (SFA)	X				X	X			X	X	X		X	X	X		X	X	X	X	X		X	Focuses normally on one substance / elemt but can be applied to all substances.
Carbon (GHG) accounting	X			(X)	(X)	X			X				X	(X)				X	X	X	X	X	X	State: If concentration of CO2 in the atmosphere is measured. Energy in brackets: This method is relevant for energy consumption but measures energy not in energy units but in mass of carbon. Renewables in brackets: Carbon accounting could include carbon in biotic sources.
Energy																								
Energy flow accounting (EFA)	X			X					(X)				X	(X)			X	X	X	X	X	X	X	
Exergy accounting (EA)	X			X					(X)				X	(X)			X	X	X	X	X	X	X	
Emergy accounting	X			X					(X)				X	(X)			X	X	X	X	X	X	X	
Land																								
Land use accounting (LUA)	X							X					X	X			X		X	X	X	(X)	X	Micro refers to land use of imported goods, comparability with SNA refers to land use by sectors.
Human appropriation of net primary production (HANPP)	X			X	X			(X)					X	X			X			X	X			Rate of HANPP depends on type of land use.
LEAC (Land Cover Accounts of the EEA)	X							X					X	X			X			X	X		X	
Product/impact oriented methods																								
Life Cycle Assessment (LCA), Life Cycle Inventories (LCI), Eco-Indicator	X			X	X	X	X	X	X	X	X		X	X	X		X	X	X				X	
Material Input per Service Unit (MIPS)	X				X	X	X						X				X		X				X	Could include several environmental categories if materials, water, air and erosion are seen as different categories.
Environmentally Weighted Material Consumption (EMC)	X				X	X	(X)		X	X			X		X		X	X		X	X	(X)	X	

List of pre-selected methods and indicators

Indicators/methods suggested for selection for the RACER analysis:

Ecological Footprint: The EF is the core concept of this project. The EF integrates all resource use in terms of demand on regenerative capacity and allows relating human demand to supply by nature and determining a clear sustainability target.

Environmental Sustainability Index (ESI): The ESI has been included as it covers a broad range of issues including many state and process indicators. The ESI seems to be too broad but maybe single indicators of the ESI could be used to cover specific missing aspects.

Genuine Savings, Inclusive Wealth Accounting, Green GDP: From this group genuine saving shall be included as it measures the stock / wealth of natural resources compared to annual flows of the Ecological Footprint and is therefore complementary.

Index of Sustainable Economic Welfare (ISEW), Genuine Process Indicator (GPI): ISEW is an indicator that measures impacts of resource use in monetary units. Furthermore, it is the only indicator, which covers the “response” category in the DPSIR framework, as it measure economic / social responses to resource use and damage to nature by including defensive costs.

Sustainable Human Development Indicator (SHDI): SHDI combines economic and social aspects of human development from the HDI with environmental aspects from MFA and could thus serve as a score card for countries on their performance in selected sustainability aspects. Data bases for the SHDI have not been compiled so far, but data bases for HDI and MFA indicators exist and could easily be combined. The method would have to be tested and further elaborated based on the existing initial work.

Environmental Vulnerability Index (EVI): With its 50 indicators the index is quite complex but it has been included as many indicators provide information on the state of the environment and impacts from resource use. Maybe single indicators of the EVI could be used to cover specific missing aspects and especially impact aspects.

Environmentally Weighted Material Consumption (EMC): EMC combines the material aspects of bulk-MFA from which it stems and impact aspects of the LCA.

Material Flow Analysis (MFA): MFA is suggested for further analysis. It is already partially included in EMC and as basis for PIOT it is method. But the MFA methodology is a step further in standardisation and MFA-derived indicators are already part of the EU SDI set, whereas PIOT's have not be compiled for many countries and the further assessment of EMC (with the incorporation of LCA) also means to discuss different boundary when assessing EMC for robustness.

Physical Input Output Tables (PIOT): PIOT is a further develop economy-wide MFA by providing a sectoral disaggregation and a separation of intermediate production and final consumption. PIOTs allow a parallel analysis of economic development on the sector level, resource requirements, and production of waste and emissions and enables modelling of policy measures.

Substance flow analysis (SFA): SFA focuses on substances of high concern (e.g. heavy metals) and connects directly to bulk MFA covering substances of special interest and specific environmental harm.

Energy Flow Accounting (EFA): EFA explicitly focuses on energy flows (measured in energy units). EFA is selected, although energy flows are also included (in mass units or CO2 emissions) in other indicators.

Land Use Accounting (LUA): LUA has been included as one of the core methods that directly measures land use and changes.

Human Appropriation of Net Primary Consumption (HANPP): HANPP directly measures the share of natural production appropriated by humans, with mostly negative consequences for ecosystems.

Land and Ecosystems Accounts (LEAC): This method / data base has been included as it is already in use by the EEA and provides a detailed grid land use and land cover changes within the EU.

Indicators/methods to be excluded:

- Human Development Indicator (HDI): HDI should be excluded as it does not include the environmental dimension.
- Happy Planet Index (HPI): HPI should not be included as it already includes the EF. It could add the happiness / well-being issue (but this doesn't directly measure "environmental impacts from natural resource use"—the core policy objective behind this indicator evaluation).
- IPAT: IPAT should be excluded as it lacks specific definitions, methods and data (for example on how the impacts should be measured).
- SEEA/NAMEA: These concepts cover a broad range of aspects but are general framework concepts for deriving other methods and indicators. Several of those have been selected for further elaboration (see above).
- Sustainable Process Index (SPI): The SPI accounts for the land area needed for technical processes. For practical application the processes would have to be defined and data might not be available or would have to be generated. It should be excluded as it is micro oriented and might be difficult to apply for the whole EU as it is process oriented.
- Environmental Space (ES): ES lacks specificity. It could be a good model for covering missing fields but would therefore require specific methods and indicators which would have to be defined.
- Carbon accounting: This should be excluded as fossil energy carries are already covered by various other methods (e.g. EF, MFA and EFA).
- Exergy accounting: Excluded as it could be part of a more detailed energy flow analysis.
- Emergy accounting: Excluded as it could be part of a more detailed energy flow analysis.

- Life Cycle Assessment: LCA focuses mainly on single products and does therefore not appear appropriate for this project, which is primarily aimed at national and EU level evaluation. However, LCA forms an important part of indicators, when combined with macro data on consumption of materials (EMC and related LCA-oriented tools).
- Material Inputs per Service Unit (MIPS): MIPS also focuses mainly on the product level.

Annex 3: Detailed results of RACER evaluation

The following 13 indicators and methods were selected for further evaluation with the RACER framework:

- Environmental Sustainability Index (ESI)
- Environmental Vulnerability Index (EVI)
- Genuine Savings (GS)
- Index of Sustainable Economic Welfare (ISEW) and Genuine Progress Indicator (GPI)
- Sustainable Human Development Index (SHDI)
- Material Flow Analysis (MFA)
- Environmentally Weighted Material Consumption (EMC)
- Environmental Impact Load (EVIL)
- Physical Input-Output Tables (PIOT)
- Substance Flow Analysis (SFA)
- Energy Flow Accounting (EFA)
- Land Use Accounting (LUA) / Land and Ecosystems Accounts (LEAC)
- Human Appropriation of Net Primary Production (HANPP)

The range of scores lies between 0 (criterion is not addressed) and 4 (criterion is fully addressed).

Environmental Sustainability Index (ESI)

The ESI was developed by Yale and Columbia Universities and sponsored by the World Economic Forum and the European Commission Joint Research Centre (Esty *et al.*, 2005). The latest ESI report (2005) benchmarks the ability of nations to protect the environment over the next several decades. It does so by integrating 76 data sets (including the Ecological Footprint) tracking natural resource endowments, past and present pollution levels, environmental management efforts, and a society's capacity to improve its environmental performance into 21 indicators of environmental sustainability. These indicators permit comparison across the following five fundamental components of sustainability: Environmental Systems; Environmental Stresses; Human Vulnerability to Environmental Stresses; Societal Capacity to Respond to Environmental Challenges; and Global Stewardship.

<u>RACER analysis of ESI:</u>

Criteria and Subcriteria	Analysis	Score
Relevant		**1**

Policy support, identification of targets and gaps	• *Is the indicator/methodology related to existing EU-specific policy objectives?* The ESI contains 21 indicators in 5 thematic categories, all relating to relevant EU policy objectives, in particular the Resource Strategy through the inclusion of several output-related indicators and other thematic strategies (e.g. waste, fertilizers). • *Does it provide guidance in monitoring, strategic policy making and/or target setting?* The ESI is a relatively new metric and provides a relative gauge of environmental stewardship between countries and identifies peer groups of countries, it identifies areas where a country is not performing as well as it could given its economic and institutional capacity. ESI cannot be used to set absolute targets for monitoring, therefore it fulfils this requirement partly. • *Does it quantify gaps between the current situation and specified targets?* It does not at present, but could do so if targets were set, so it fulfils this requirement partly. • *Does it provide adequate early warning to guide policy action?* ESI is calculated retrospectively so it inadequately addresses this requirement. • *Does it react to short-term changes that can (among other things) show whether policies are having an effect?* The component indicators of ESI can reflect short term changes and many of these indicators already form part of the EU SDI dataset. However the overall ESI value may not reflect short term changes as well as the components, the ESI reports by individual indicators as well as thematically, so it fulfils this requirement partially.	2
Identification of trends	The ESI has been calculated for 2000 (pilot), 2002 and 2005 and while the methodology is being refined and revised, it can be back calculated for countries and so could identify trends, although it is more of a snapshot measure at present.	1
Forecasting and modelling	• *Can the methodology/indicator be used in a predictive sense to forecast future environmental impacts from natural resource use or for more sophisticated modelling where the impact of different potential policies or of technology progress and/or change of consumption patterns can be simulated?* The ESI as an aggregated measure cannot be used for forecasting future impacts, but underlying single indicators can be used, in particular in combination with economic models (e.g. development of emission levels in the future). • *Can the indicator function as an early warning indicator?* The ESI is too aggregated an indicator to do so, although the component indicators may do so.	1
Scope/levels of	• *Does the indicator provide the required local information?*	0

application	The ESI is calculated at national level only • *Is industry-level data provided by the methodology/indicator?* The ESI does not fulfil this requirement	
Function- and needs related analysis	For the aggregate measure, it is very difficult to relate specific developments of sub-indicators to specific human needs. This could be better performed with single indicators of the overall index.	1
Accepted		**1**
Stakeholder acceptance	The methodology was developed with the involvement of stakeholder groups, including policy makers. However, many representatives from the environmental community are very critical of the weighting (equal weighting of all components), and also concerned that the focus on compliance/regulation biases the metric toward highly developed countries.	2
Credible		**2.5**
Unambiguous	• *Convey a clear, unambiguous message.* A clear overall message can be communicated, and the concept is understandable and the calculations are transparent. Although the index is highly aggregated, the reporting in themes and clustering of peer groups of countries provides a good explanation of why individual countries have particular scores. • *Allow for clear conclusions to guide political action.* The ESI approach of clustering peer groups of countries enables benchmarking of performance and analysis of where individual countries differ, is useful for comparative analysis and identification of areas for improvement, however the EU SDI set provides much of the same information. • *Interpretation by the general public.* The overall message is interpretable by the general public, however as the responses to the critiques of the ESI highlight the ESI is meant to be indicative rather than definitive and this distinction needs to be emphasised.	2
Transparency of the method	For the composite index, ESI fulfils this requirement and it highlights the level of uncertainty and data quality for each underlying indicator. In order to fulfil this criterion fully, one would need to test the transparency also for all sub-indicators.	3
Easy		**2.3**
Data availability	Data for some countries has been imputed where missing and the lack of data for some desirable indicators has been highlighted, and this has led to their exclusion.	2
Technical feasibility	The ESI methodology clearly defines the calculation which is relatively straightforward. However, easy aggregation to the overall	3

	index requires availability of all underlying data.	
Complementarity and integration	• *Are there potential complements between the methodology/indicator and the others being assessed?* Yes, the Ecological Footprint is included as a component indicator in the index, although many of the component indicators relate to governance and institutional mechanisms and do not relate to the use of natural resources. • *Is there the potential for further integration of the methodology/indicator with the others?* The ESI methodology has been correlated with the ecological footprint and EVI, although the ideal indicator set includes additional indicators on resource use.	2
Robust		**2.4**
Defensible theory	The ESI as an aggregated measure fulfils this criteria well and has reported on criticisms and responded to them. However, the theory of the underlying sub-indicators has not been evaluated.	3
Sensitivity	ESI may not respond rapidly to policy interventions however component indicators will do, so it fulfils this requirement partially.	2
Data quality	The ESI partially fulfils this requirement as issues with data quality remain although they are identified in a transparent manner.	2
Reliability	Given that the underlying data are reliable, this criterion is well fulfilled for the ESI.	3
Completeness	The component indicators of the ESI address a range of issues and give a comprehensive picture of environmental stewardship, although many issues could still be added (e.g. GHG emissions other than CO2, resource consumption indicator on the macro level, etc.).	2
Summary appraisal	+ Includes a large number of environmental issues; developed with stakeholders and policy makers. - Highly aggregated index (but can be split into components); method still being refined.	

<u>Analysis of impact categories for ESI:</u>

Criterion	Analysis	Score
Resource consumption	This is covered by the ecological footprint and other indicators	2
Land use	Only partly covered	1
Climate change	Covered by a number of indicators	2
Stratospheric ozone depletion	Not covered	0

Human health impacts	Not covered	0
Eco-toxicity	Not covered	0
Photo-oxidant formation	Not covered	0
Acidification	Not covered	0
Eutrophication	Not covered	0
Ionizing radiation	Not covered	0
Impact on ecosystems and biological diversity	Covered by a number of indicators	2
Summary appraisal		**7**

Environmental Vulnerability Index (EVI)

Developed by the South Pacific Applied Geoscience Commission (SOPAC) and the United Nations Environment Programme (UNEP) and their partners in 1999, the EVI is a vulnerability index for the natural environment and is designed to be used with economic and social vulnerability indices to provide insights into the processes that can negatively influence the sustainable development of countries (Kaly *et al*., 1999). The EVI is based on 50 indicators and has been designed to reflect the extent to which the natural environment of a country is prone to damage and degradation. Each indicator is classified into a range of subindices including the three aspects of hazards; resistance and damage and into policy-relevant sub-indices including climate change, biodiversity and agriculture and fisheries. Indicators include natural and human induced damages and hazards. Many indicators describe the state of ecosystems. The EVI was originally focused at informing sustainable development in small island states, but can be applied to any country and at different spatial levels as long as data are available (Pratt *et al*., 2004).

<u>RACER analysis of EVI:</u>

Criteria and Subcriteria	**Analysis**	**Score**
Relevant		**1**
Policy support, identification of targets and gaps	• *Is the indicator/methodology related to existing EU-specific policy objectives?* It is related to specific policy objectives on climate change mitigation and adaptation, biodiversity and agriculture and fisheries. • *Does it provide guidance in monitoring, strategic policy making and/or target setting?* There has been a difficulty in identifying a sustainability threshold for some component indicators and these have been estimated where knowledge was lacking. It could be used to set targets and inform strategic policy making aimed at reducing environmental vulnerability. • *Does it quantify gaps between the current situation and specified targets?*	2

	It could do so if targets were set so it fulfils this requirement partially. • *Does it provide adequate early warning to guide policy action?* EVI is calculated retrospectively but it does identify areas of greatest environmental vulnerability and greatest resilience so it can address this requirement partially. • *Does it react to short-term changes that can (among other things) show whether policies are having an effect?* Many of the component indicators cannot be directly influenced by human actions, those that can be are identified and areas of policy intervention. However many of the indicators are averaged over a five year period so the EVI would not adequately reflect short term changes or effect of policy interventions at this time scale.	
Identification of trends	The EVI has been calculated for 2004 and 2005 and further time series could be calculated and trends identified although this has not been done to date. The time period over which each component indicator is calculated is variable.	1
Forecasting and modelling	• *Can the methodology/indicator be used in a predictive sense to forecast future environmental impacts from natural resource use or for more sophisticated modelling where the impact of different potential policies or of technology progress and/or change of consumption patterns can be simulated?* The EVI does not fulfil this criteria adequately • *Can the indicator function as an early warning indicator?* The EVI identifies areas of greatest environmental vulnerability and so partially fulfils this requirement.	1
Scope/levels of application	• *Does the indicator provide the required local information?* The methodology can be used at different spatial levels if data are available, however the EVI is currently calculated at national level and many of the component indicators are not collected at a sub-national level or on a spatial basis so it addresses this requirement inadequately. • *Is industry-level data provided by the methodology/indicator?* This is not addressed by the EVI	1
Function- and needs related analysis	This is not addressed by the EVI.	0
Accepted		**1**
Stakeholder acceptance	The methodology is clear, but includes normative decisions, how to allocate score points to different values. Furthermore, reducing environmental vulnerability to underpin sustainable development is expected to be accepted by stakeholder groups.	1
Credible		**2.5**

Unambiguous	• *Convey a clear, unambiguous message.* A clear overall message can be communicated due to the understandable concept and transparent calculation of the EVI and its indicators. • *Allow for clear conclusions to guide political action.* However many aspects of vulnerability are not ones that can be directly influenced by human actions and policy interventions and the EVI identifies the areas of greatest vulnerability and resilience by country and this may lead to complex conclusions. • *Interpretation by the general public.* The relative scale and the lack of a clear threshold for sustainability will act as a barrier to interpretation by the public.	2
Transparency of the method	As an aggregated index, EVI fulfils this requirement completely, however, the quality of the sub-components remain questionable and difficult to assess due to the large number of different data sources.	3
Easy		**2**
Data availability	Data used to calculate EVI comprises of international and national statistics and is only supplemented with nationally sourced data when required.	3
Technical feasibility	The EVI methodology clearly defines the calculation which is straightforward. However, calculation procedures for underlying indicators can in many cases not be directly assessed.	2
Complementarity and integration	• *Are there potential complements between the methodology/indicator and the others being assessed?* The EVI includes some aspects of human use of natural resources and combines these with economic, social and environmental indicators. • *Is there the potential for further integration of the methodology/indicator with the others?* There is the potential to include additional or further refine the EVI component indicators and this is an ongoing process. It could include further information on resource use as an anthropogenic event that contributes to hazard and damage.	1
Robust		**1.6**
Defensible theory	The EVI fulfils the criteria for this aspect, however it is not yet a widely used index. The scoring method is based on subjective and normative decisions.	1
Sensitivity	EVI as an aggregate measure may not respond rapidly to policy interventions given that there are 50 component indicators some of which are not influenced by policy and some of which are calculated over long time periods. However the sub-indices may do so, so it	1

	partially fulfils this requirement.	
Data quality	It is very difficult to assess the quality of the underlying data, however, data sources are clearly communicated.	2
Reliability	The EVI fulfils this requirement well.	2
Completeness	The composite indicators of the EVI address a range of issues and give a comprehensive assessment of vulnerability but would not address burden shifting and so it fulfils this requirement only partially.	2
Summary appraisal	+ Focus on vulnerability issues. Comprehensive index covering many environmental issues. - Scoring and aggregation requires normative decisions. Difficult to evaluate quality of underlying indicators.	

<u>Analysis of impact categories for EVI:</u>

Criterion	Analysis	Score
Resource consumption	This is not covered fully, some biotic resources included	1
Land use	Covered by a number of land use related indicators	1
Climate change	Not completely covered	1
Stratospheric ozone depletion	Not covered	0
Human health impacts	Not covered	0
Eco-toxicity	Not covered	0
Photo-oxidant formation	Not covered	0
Acidification	Not covered	0
Eutrophication	Not covered	0
Ionizing radiation	Not covered	0
Impact on ecosystems and biological diversity	Covered by a number of indicators	2
Summary appraisal		**5**

Genuine Savings (GS)

Genuine savings measures the accumulation or depletion of a society's capital. It is based on assuming that different forms of capital are infinitely substitutable. The RACER assessment has mainly been based on the description of GS in Ditz and Neumayer (2006). In general GS is net investment in produced capital minus net depreciation of natural capital plus investment in human capital. The most comprehensive data set on GS has been set up by the World Bank for over 150 countries using the following calculation: GS =

Investment in man-made capital (obtained from national accounts)

– net foreign borrowing (obtained from national accounts)

+ net official transfers (obtained from national accounts)

– depreciation of man made capital (coming from estimates for produced capital formation)

– net depreciation of natural capital (Consisting of resource extraction and environmental pollution. Resource extraction is calculated for fossil fuels, various minerals and wood as the product of price minus average cost of extraction multiplied by volume of extraction. Pollution is calculated as estimated damage costs for carbon emissions and has recently been extended by damage costs for particulates in the air.)

+ current education expenditures

Ditz and Neumayer (2006) mention that positive GS is a necessary but not sufficient condition for sustainability. A comparison of GS data for different countries shows that mainly countries with large resource extraction tend to have a negative GS (e.g. Sub-Saharan Africa, North Africa and Middle East). These countries, while increasing their GDP, have actually become poorer as they depleted their natural resources and did not compensate this by either a reconstitution of their natural capital or an investment in human capital.

GS is not only an indicator for resource depletion, but for depletion of all forms of capital. Therefore it could add complementary information to most other indicators. This "holistic" approach is however derogated by some important points:

- The indicator is based on a concept of weak sustainability assuming substitutability of man-made, human and natural capital. This assumption is criticised by proponents of a concept of "strong sustainability". (Also the authors of this assessment do not share the view of infinite substitutability.)
- The calculation method is based on resource economics and seems too weak to reflect environmental sustainability. E.g. the calculation method of depletion of natural capital (multiplying extracted amounts of resources with resource price minus costs for extraction) could lead to the result that extraction is sustainable as long as resource prices are high and/or extraction costs are low. Environmental sustainability should better be focused on extracted (physical) amounts and on related environmental impacts. The use of resource prices also would change the sustainability status of extracting and resource exporting countries even if amounts of extracted resources do not change.
- The approach of accounting all forms of capital is in practice limited as the method focuses on single aspects (e.g. only a small number of resources for calculating natural capital depletion; focusing on carbon emissions and particulates for calculating environmental damage; using education expenditures for estimating development of human capital). The selection of single aspects ignores other relevant issues (e.g. resources and emissions not included in the calculation, other

aspects influencing human capital) although this might be unavoidable for practical reasons.

The method of GS seems to be very controversial and stakeholder acceptance can be divided between the proponents of strong and weak sustainability. Ditz and Neumayer (2006) also mention that the usefulness of the concept for policy applications will depend on the acceptance of weak sustainability. Apart from these critical points (which are shared by the view of the authors of this assessment), GS could add complementary information to other indicators as it focuses on the capital stock and is based on monetary calculations.

The fact that countries with large endowments of natural resources (and therefore large extraction for exports to world market) seems to be insufficient in reflecting global trade with resources and recognising resource consumption by countries.

A data set from the World Bank exists for over 150 countries. However the method is target of critique and different methods for calculating GS have been proposed and tested. Though a big database exists these facts seem to limit acceptance, credibility and robustness of the indicator.

Currently two environmental impacts are covered by the World Bank data set: carbon emissions and particulates in the air (though only for carbon emission exist long time series as particulates have only been added recently). In principle the method could be extended to other impact categories.

<u>RACER analysis of GS:</u>

Criteria and Subcriteria	**Analysis**	**Score**
Relevant		**1**
Policy support, identification of targets and gaps	• *Is the indicator/methodology related to existing EU-specific policy objectives?* GS is related to economic policies and to some extend to resource policy objectives. GS is not directly related to the objective of this study, i.e. monitoring the environmental impacts of resource use. • *Does it provide guidance in monitoring, strategic policy making and/or target setting?* As far as capital formation and depletion is concerned: yes. Help for detailed strategic policy making is however limited due to aggregated data. The assumption of GS that all forms of capital are substitutable and the fact that positive GS is only seen as a necessary but not as a sufficient condition to sustainability may limit its use for policy making. GS provides very limited guidance with regard to monitoring the specific environmental impacts related to resource use. • *Does it quantify gaps between the current situation and specified targets?* Yes. The target for GS would be to be increased or at least to not	1

	decline. However, as the targets set for monitoring environmental impacts would be set in physical terms, the monetary information provided by the GS could not be used in this regard. • *Does it provide adequate early warning to guide policy action?* No, as it measures current capital stocks and its changes. As it is a measure of weak sustainability (assuming substitutability of different forms of capital) it might even be a miss-leading early warning indicator if this assumption fails. • *Does it react to short-term changes that can (among other things) show whether policies are having an effect?* GS would show reactions with regard to selected aspects, i.e. depletion of non-renewable resources. However, as said above, this information is only provided in monetary terms.	
Identification of trends	Time series have been published by the World Bank. Trends in capital formation and depletion can be observed. However, this information is not of focal value for monitoring environmental impacts.	1
Forecasting and modelling	• *Can the methodology/indicator be used in a predictive sense to forecast future environmental impacts from natural resource use or for more sophisticated modelling where the impact of different potential policies or of technology progress and/or change of consumption patterns can be simulated?* Partly. As GS deals with investments and capital formation it should be possible to integrate it with macroeconomic modelling. • *Can the indicator function as an early warning indicator?* No, as it measures past trends and calculates current stocks of capital.	1
Scope/levels of application	• *Does the indicator provide the required local information?* So far GS has only been accounted nationally. Data could also be available regionally, but GS is generally seen as a measure to correct (national) GDP. • *Is industry-level data provided by the methodology/indicator?* No, it is only used as a macro indicator so far.	1
Function- and needs related analysis	GS could well show changes between economic, human and natural capital as it accounts for all three dimensions. The message of the indicator is however limited by the simplified way in which different capital forms are estimated and by the assumption of substitutability between all forms of capital.	1
Accepted		**2**
Stakeholder acceptance	With the World Bank, one of the major institutions on the global level applies this concept. However, as GS implements a concept of weak sustainability (with its assumption of capital substitutability)	2

	proponents of a concept of "strong sustainability" will oppose this kind of measuring capital changes.	
Credible		**1.5**
Unambiguous	• *Convey a clear, unambiguous message.* It does not provide a very clear message, as positive GS is only a necessary but not a sufficient condition for sustainability. Negatives values for some countries have also been criticised in the literature (see summary description of GS). Values and directions for GS change with different applied methodologies. • *Allow for clear conclusions to guide political action.* Due to the points mentioned in the point before conclusions for policy action are not very clear. • *Interpretation by the general public.* Interpretation by the general public is possible (similar to GDP) though details in the methodology and discussions about the method and strong and weak sustainability probably will not reach the broader public.	1
Transparency of the method	The method e.g. of the World Bank is transparent but in different studies, different methods have been applied so far. This fact has been repeatedly criticised. Parts of its economic calculation and valuation are subject to discussion and influence the results.	2
Easy		**1.6**
Data availability	Time series data on GS exist from the World Bank. Data availability for inclusion of corrections to GDP (e.g. damage costs) is not complete and subject to different methods to estimate these costs.	2
Technical feasibility	The calculation can be carried out with existing data from national accounts and resource data basis. However, the availability of correction costs (costs of resource extraction and pollution) is limited.	2
Complementarity and integration	• *Are there potential complements between the methodology/indicator and the others being assessed?* A main complementary component is that GS is a monetary indicator, presenting a correction of traditional GDP and accounts for different forms of capital (economic, human and natural). However, as the monetary information is not the focus of the Resource Strategy, complementarity is very limited. • *Is there the potential for further integration of the methodology/indicator with the others?* GS can be integrated with GDP and has some similarities with the ISEW (GDP correction, monetary).	1
Robust		**1.4**
Defensible theory	A main weak point is the assumption of substitutability of different forms of capital which follows the concept of weak sustainability and	1

	is not accepted by proponents of strong sustainability.	
Sensitivity	As the message of the indicator is debatable, its sensitivity is not very high.	1
Data quality	Quality of basic data needed for calculating GS is expected to be good. Some of the data is also used for GDP calculations or stems from there. Other data, in particular for resource prices and for estimating shadow prices is rated as to be of poorer quality.	1
Reliability	Details of calculation are clear, but partly controversial.	2
Completeness	GS covers different forms of capital and therefore is not focussed on a single issue related to natural resource use or environmental impacts. However, each capital form is estimated by a specific issue which neglects many other important facts for each capital form.	2
Summary appraisal	+ Economic indicator, measuring overall capital stock and depletion in monetary units. - Controversial method, concept of weak sustainability, assuming substitutability. - No information on physical impacts related to resource use.	

Analysis of impact categories for GS:

The following evaluation follows the method of the World Bank as described in Ditz and Neumayer (2006). It has to be mentioned that so far only damage costs from CO2 emissions and recently costs of air particulates have been included by the World Bank, but that the method could be open for including more impact categories.

Criterion	Analysis	Score
Resource consumption	Resource extraction is covered for some non-renewable resources and wood. Consumed amounts of resources are not included directly but as product of extracted amounts multiplied with product price minus costs of extraction.	1
Land use	Not covered.	0
Climate change	Included as damage costs of CO2 emissions. (Rated as partly as other emissions are left out and costs are calculated indirectly as “shadow prices”).	1
Stratospheric ozone depletion	Not covered.	0
Human health impacts	Could be partly covered by damage costs of particulates in the air if these costs include health costs.	0
Eco-toxicity	Not covered.	0
Photo-oxidant formation	Not covered.	0
Acidification	Not covered.	0

Eutrophication	Not covered.	0
Ionizing radiation	Not covered.	0
Impact on ecosystems and biological diversity	Not covered.	0
Summary appraisal		**2**

Index of Sustainable Economic Welfare (ISEW) and Genuine Progress Indicator (GPI)

The ISEW only partly considers issues of resource use and environmental impacts of resource use. It corrects GDP for defensive (environmental) costs and (unequal) income distribution and therefore refers more to economic and social impacts (of resource use) than to environmental impacts. It includes a broad range of sustainability issues for measuring welfare and welfare losses induced by resource use. The calculation method differs between available country studies, depending on the availability of data to estimate welfare losses. As an alternative measure of welfare it is highly relevant to policies, however, not directly to resource policies. Especially the correction of expenditures that positively influence GDP but are considered as negative corrections in the concept (as defensive costs) should be of high relevance and interest.

Policy measures, however, might only indirectly influence the ISEW as they will influence resource use which than influences reaction by the society. Therefore the ISEW is seen as a good indicator for correcting GDP as a measure of wealth and long-term development, but it's value for providing early warning information is very limited.

The ISEW does not only focus on resource use and environmental sustainability but also on a range of other sustainability issues (such as crime, unemployment, volunteer work, income distribution and others). Therefore it contributes well to measuring impacts of resource use but its trend is clearly also influenced by other aspects.

The ISEW covers a range of impact categories, basically by economic costs or reactions to impacts from resource use. Lawn (2003) argues that improvements are needed in the valuation methods for the following components of ISEW: the index of distributional inequality, the weighting of personal consumption expenditure, defensive and rehabilitative expenditures, the cost of resource depletion, and the cumulative cost of ozone depletion, long-term environmental damage, and lost old grown forests. As the components of ISEW cannot cover all welfare aspects, Lawn (2003) further suggests to replace some components with minor importance by others missing so far such as the disutility of certain forms of work and the existence values of natural capital. Some components dominate the indicator and could for a better analysis also be disaggregated (Neumayer 1999, cited in Lawn 2003). The ISEW uses all expenditure as influencing welfare positively. As Lawn argues this could be corrected for expenditures not contributing to welfare, such as junk food, tobacco products, alcohol, and guns. Future costs and benefits are not reflected in the ISEW. Lawn (2003) therefore also argues to use forecasting technologies to set improvements here. This could improve the use of ISEW as an early warning indicator.

RACER analysis of ISEW:

Criteria and Subcriteria	Analysis	Score
Relevant		**1.2**
Policy support, identification of targets and gaps	• *Is the indicator/methodology related to existing EU-specific policy objectives?* It is related to specific policy objectives concerning GDP, economic growth and welfare. It also includes income distribution and resource depletion. Basically it measures defensive costs. This fits well to the EU SDS which demands that "polluters pay". However, its links to the Resource Strategy and targets to reduce environmental impacts are very limited. • *Does it provide guidance in monitoring, strategic policy making and/or target setting?* The ISEW can be a good tool for monitoring, strategic policies making and target setting. However, targets are currently not set for ISEW development or defensive costs. Therefore the ISEW can be used in that way but doesn't necessarily relate directly to current policy making and target setting. Therefore it addresses this requirement only partly. • *Does it quantify gaps between the current situation and specified targets?* The ISEW could do that if targets were set for ISEW development (like closing the gap between ISEW and GDP) which is currently not the case. However, with regard to environmental impacts, the ISEW cannot quantify these targets. • *Does it provide adequate early warning to guide policy action?* The ISEW seems rather to be a tool for ex-post evaluations which doesn't provide early warning guidance. Therefore it only addresses this point inadequately. • *Does it react to short-term changes that can (among other things) show whether policies are having an effect?* This aspect is also addressed only partly. It reacts to short term changes (like for example in changes in defensive costs) but these changes might not only be induced and influenced by policy as e.g. money for defensive costs can be spent by companies and individuals though policies can also force companies and consumers to pay defensive costs.	1
Identification of trends	This is possible and time series have been calculated in existing ISEW studies. However, these trends provide very limited information on the issue of resource use and related environmental impacts.	2

Forecasting and modelling	• *Can the methodology/indicator be used in a predictive sense to forecast future environmental impacts from natural resource use or for more sophisticated modelling where the impact of different potential policies or of technology progress and/or change of consumption patterns can be simulated?* The ISEW addresses this criterion inadequately as it basically measures current and past developments, rather economic and social impacts from resource use than environmental ones and does not directly relate to policies and consumption patterns. • *Can the indicator function as an early warning indicator?* Inadequately as it is basically used for ex-post evaluation.	1
Scope/levels of application	• *Does the indicator provide the required local information?* So far the ISEW has only been used on national levels although it should be possible to calculate it on regional scales. • *Is industry-level data provided by the methodology/indicator?* No. The ISEW focuses on the macro perspective.	1
Function- and needs related analysis	These issues are only partly addressed by the ISEW, as a general measure on the way, in which economies transform natural resources into societal wealth.	1
Accepted		**2**
Stakeholder acceptance	The concept is easily understandable and measuring (and reducing) defensive costs should fit well to concerns of most stakeholders. On the other hand the ISEW is currently not widely used and not used by policy or statistical offices as official indicator.	2
Credible		**1.5**
Unambiguous	• *Convey a clear, unambiguous message.* • *Allow for clear conclusions to guide political action.* • *Interpretation by the general public.* A clear message and interpretation by the public is possible due to the easily understandable concept. Guidance for policy action is difficult as policies cannot be directly related to ISEW components and links between policies and defensive costs are not explained by the concept. The value of ISEW to guide political action in terms of environmental impacts related to resource use is very limited.	1
Transparency of the method	As seen from existing studies the method is transparent, interpretable and reproducible. However, existing studies did not use a common and comparable method as calculations vary in terms of underlying data and concepts.	2
Easy		**1.3**
Data availability	Data for calculating the standard economic components of ISEW is available by statistical offices. Data on environmental costs related to resource use is limited and differs between countries. ISEW data	1

	is currently not available for all EU countries.	
Technical feasibility	The calculation does not need special software. The method is clearly defined but a standard – as has been developed for other indicators – is missing.	2
Complementarity and integration	• *Are there potential complements between the methodology/indicator and the others being assessed?* • *Is there the potential for further integration of the methodology/indicator with the others?* The method can complement resource use indicators by its measurement of defensive costs. Integration with other indicators seems rather limited. The method provides a complementary aspect to most other methods analysed here as it is based on monetary units.	1
Robust		**1.4**
Defensible theory	The concept underlying the ISEW calculations is widely acknowledged as being one major corrective of current GDP calculations. However, the concrete implementation varies considerably between studies.	2
Sensitivity	The ISEW might change only slowly with a time lag between resource use, impact and response.	1
Data quality	Data needed for the ISEW and its quality may vary from country to country. While basic economic data is available from statistical institutions, data on correction parameters are of much less quality.	2
Reliability	Reliability in the sense of repeatability and open exchangeable calculation is limited, as the concrete implementation of the concept differs from study to study.	1
Completeness	The ISEW only covers a very limited part of the problem, to which this study is addressed, in particular, as only some environmental impacts are included (in monetary terms).	1
Summary appraisal	+ Many impact categories (although in monetary units), shows costs of resource use. - No standard methodology; not compatible with SNA; only case studies available.	

Analysis of impact categories for ISEW[66]:

Criterion	Analysis	Score
Resource consumption	Included as "costs of resource depletion".	1

66 The evaluation has been based on the list of ISEW components presented by Lawn (2006, p. 141) and Lawn (2003).

Land use	Included as loss of farmland and loss of wetlands.	1
Climate change	Partly included in "long-term environmental damage".	1
Stratospheric ozone depletion	Included as cost of ozone depletion.	2
Human health impacts	Partly included in public expenditure on health and cost of noise, air and water pollution.	1
Eco-toxicity	Partly included in air and water pollution.	1
Photo-oxidant formation	Not included.	0
Acidification	Not included.	0
Eutrophication	Not included.	0
Ionizing radiation	Not included.	0
Impact on ecosystems and biological diversity	Included as costs of water and air pollution, loss of old-grown forests and costs of long-term environmental changes.	1
Summary appraisal		**8**

Sustainable Human Development Index (SHDI)

The SHDI is an index of four different components of which one measures resource consumption. It is a combination of the HDI developed and used by the UN for many years and an MFA indicator accepted in European and national statistics as indicator for resource use. The SDHI, however, is new and has so far only been proposed as an indicator and lacks broader applications. Calculated SHDIs are not available so far, although basic data for all of its components is available for all EU countries. The nature of being an index combining four different aspects of human development could provide links to policy guidance and directly visible effects of different policies. Impact categories are covered rather poorly as only the MFA component links to this issue. As a measure for human development this indicator covers also aspects that are not (or not directly) related to resource use but to sustainability in a broader sense.

<u>RACER analysis of SHDI:</u>

Criteria and Subcriteria	**Analysis**	**Score**
Relevant		**1**
Policy support, identification of targets and gaps	• *Is the indicator/methodology related to existing EU-specific policy objectives?* With its components (life expectancy, literacy, income and Total Material Requirement) it fits well to EU policy objectives although some of the components might be of greater concern for developing countries as EU countries are well positioned there (e.g. life expectancy and literacy). The SHDI has a direct link to the EU	1

	resource strategy as SHDI covers material consumption. However, in terms of links to the Resource Strategy, these links are only indirectly provided. • *Does it provide guidance in monitoring, strategic policy making and/or target setting?* In terms of policy making to reduce the environmental impacts related to resource use, the suitability of the SHDI is very limited, as it only includes information on mass flows. • *Does it quantify gaps between the current situation and specified targets?* The SHDI cannot directly quantify the gaps between the current level of impacts and related targets, as no information on impacts is provided. • *Does it provide adequate early warning to guide policy action?* The SHDI rather is a tool for ex-post evaluations which doesn't provide early warning guidance. Therefore it only addresses this point inadequately. • *Does it react to short-term changes that can (among other things) show whether policies are having an effect?* This aspect is also addressed only partly. It reacts to changes but all of its components might require policies in various policy fields and effects might only be seen in long or medium term. All components will further be influenced by behaviour outside of the policy domain (economy and households).	
Identification of trends	Calculating time series for SHDI is possible, but have not been done yet.	1
Forecasting and modelling	• *Can the methodology/indicator be used in a predictive sense to forecast future environmental impacts from natural resource use or for more sophisticated modelling where the impact of different potential policies or of technology progress and/or change of consumption patterns can be simulated?* Partly. It does not include measure for environmental impacts. The MFA component in the SHDI can reflect changes in technological progress and consumption patterns. • *Can the indicator function as an early warning indicator?* Inadequately as it is basically used for ex-post evaluation.	1
Scope/levels of application	• *Does the indicator provide the required local information?* SHDI is so far not available on local/regional scales but could be calculated although this might mean a considerable effort. • *Is industry-level data provided by the methodology/indicator?* No. The SHDI focuses on the macro perspective.	0
Function- and needs related	Through linking aspects of social and environmental development, the SHDI can provide information on some interlinkages between	2

analysis	issues of health, education, economic performance and resource flows.	
Accepted		**1**
Stakeholder acceptance	The SHDI has not been implemented yet. However, the HDI has been published for many years by the UN. The acceptance of the MFA component as the environmental addition will be very heterogenous between different actors.	1
Credible		**2.5**
Unambiguous	• *Convey a clear, unambiguous message.* It provides a clear message, but the method to weight the different components with different units is still under debate. • *Allow for clear conclusions to guide political action.* Due to it's complexity as an index and the limited number of its components the message is difficult to translate into policy actions. • *Interpretation by the general public.* SHDI is easy to understand.	2
Transparency of the method	The method is transparent, interpretable and reproducible.	3
Easy		**2.3**
Data availability	Data for HDI exists for all European countries. Data for Total Material Requirement as well but both information need to be integrated.	3
Technical feasibility	The calculation does not require special software. The method is clearly defined.	3
Complementarity and integration	• *Are there potential complements between the methodology/indicator and the others being assessed?* A complementary asset of the method is that it combines economic, social and environmental issues into one sustainability index. In terms of environmental impacts, it does not provide complementary information for a basket of indicators. • *Is there the potential for further integration of the methodology/indicator with the others?* Integration (but also doubling) with MFA exists by the definition of the indicator.	1
Robust		**1.8**
Defensible theory	While the concept is clearly defined, a weak point is that the SHDI is not an accepted and already used indicator but is only in the stage of being proposed, in particular with regard to the aggregation/weighting method. However, its components are well accepted and used over a couple of years.	2
Sensitivity	The SHDI will require time to change after policy actions. Further the combination of four different components might make the link	1

	between policies and indicator development less transparent.	
Data quality	Data needed for the SHDI fulfils the mentioned requirements, although underlying data of the HDI components can vary between countries.	3
Reliability	Reliability in the sense of repeatability and open exchangeable calculation details could be good although calculations of some components might not be transparent enough.	2
Completeness	The indicator addresses only specific issues and burden shifting between those (or issues not addressed) cannot be explained. SHDI only covers the mass flow aspect related to resource use, but not the resulting impacts.	1
Summary appraisal	+ Overall SD index, mostly reliable data. Easy communication. - So far only conceptually developed.	

Analysis of impact categories for SHDI:

Criterion	Analysis	Score
Resource consumption	Is well covered by the bulk MFA component.	2
Land use	Not covered.	0
Climate change	Only indirectly covered by consumption of fossil fuels.	1
Stratospheric ozone depletion	Not covered.	0
Human health impacts	Not covered.	0
Eco-toxicity	Not covered.	0
Photo-oxidant formation	Not covered.	0
Acidification	Not covered.	0
Eutrophication	Not covered.	0
Ionizing radiation	Not covered.	0
Impact on ecosystems and biological diversity	Not covered.	0
Summary appraisal		**3**

Material Flow Analysis (MFA)

MFA provides a sound method based on statistical conventions published by Eurostat to account for the total amount of resources extracted, processed and used. It allows the calculation of a range of indicators focusing on different aspects such as domestic material consumption, trade issues and international distribution of resource use and ecological rucksacks (so-called hidden flows). MFA data might also well integrate into economic-environmental modelling as it uses raw data on material production, imports and exports, which follow economic accounting conventions.

One of the often criticised points of MFA is its weak link to impact categories. Consumption of resources clearly entails negative environmental impacts. One of the main arguments for MFA is that a reduction in total resource consumption will reduce environmental impacts. This is however only true if neither the relative share of different resources does change nor the technologies used to extract and transport them and the countries where they come from do not alter. In any case, these impacts cannot be shown explicitly with MFA. As impacts vary by material categories, the missing information of MFA is which categories should be high on the policy agenda in order to reduce impacts.

RACER analysis of MFA:

Criteria and Subcriteria	**Analysis**	**Score**
Relevant		**1.6**
Policy support, identification of targets and gaps	• *Is the indicator/methodology related to existing EU-specific policy objectives?* MFA fits to EU specific policies, but quality aspects of resource consumption are only mentioned indirectly in policy documents. MFA measures total resource consumption but not any of the impacts, while reducing the overall environmental impacts of the use of natural resources is one of the main resource-related policy targets of the EU. • *Does it provide guidance in monitoring, strategic policy making and/or target setting?* MFA provides limited guidance in monitoring, target setting and guidance in strategic policy making, as it does not relate to impacts of resource use and cannot capture the implications for environmental impacts of changes from one resource to another, from one country to the other, or progress in technologies used to extract and process resources (e.g. metals). • *Does it quantify gaps between the current situation and specified targets?* It can if targets for mass-based resource consumption and resource productivity are set; it cannot quantify gaps in impacts, however. • *Does it provide adequate early warning to guide policy action?* Rather not as it basically reports resource use after it has taken place and does not account for impacts that occur later from the emissions of today's resource extraction. • *Does it react to short-term changes that can (among other things) show whether policies are having an effect?* It reacts to short term changes in resource use and resource specific policies. The indicator does hardly react on the aggregated	1

	level but can react on the disaggregated level of certain material categories. It does not react to any improvement in emission reduction and related impacts.	
Identification of trends	Calculating of time series for mass flows is possible and has been done for a large number of countries. The value of information in terms of impacts limited, as only mass basis is addressed.	2
Forecasting and modelling	• *Can the methodology/indicator be used in a predictive sense to forecast future environmental impacts from natural resource use or for more sophisticated modelling where the impact of different potential policies or of technology progress and/or change of consumption patterns can be simulated?* Predictions of future resource from the indicator alone are not possible as it measures past resource use. As it also does not relate to environmental impacts, this forecast cannot be done by the method alone. • *Can the indicator function as an early warning indicator?* Inadequately as it is basically used for ex-post evaluation.	1
Scope/levels of application	• *Does the indicator provide the required local information?* Some regional/local applications exist but most data is available only at the national level. • *Is industry-level data provided by the methodology/indicator?* Can be provided by sectoral MFA studies and through a combination with input-output techniques.	2
Function- and needs related analysis	These issues can be covered as the indicator accounts different material categories, fulfilling different human needs. The links to actual impacts is not given.	2
Accepted		**2**
Stakeholder acceptance	Stakeholder acceptance is differentiated. On the one hand, MFA is regarded as a sound methodology for measuring resource consumption and has been used in a large number of countries for many years, by academia, statistical offices and environmental agencies. On the other hand, MFA is criticised for not establishing links to environmental impacts and for possible derivation of aggregated weight-based indicators.	2
Credible		**2**
Unambiguous	• *Convey a clear, unambiguous message.* Advocates of the MFA method emphasise that a clear correlation between mass flows and impacts exists on the aggregated level. However, on the disaggregated level of certain materials, MFA does not provide information on impacts. Compared to the EF, no clear reduction target can be defined, as the limits for extraction and use are difficult to define for non-renewable resources. • *Allow for clear conclusions to guide political action.*	1

	Provides only an indicator basis for current development and policy effects and does not guide towards any improvements in terms of impacts. • *Interpretation by the general public.* The indicator is easy to understand, but could be misinterpreted with regard to environmental impacts.	
Transparency of the method	The method is transparent, interpretable and reproducible.	3
Easy		**3**
Data availability	Data needed for future calculations is available from national statistics and MFA studies and indicator exist for a broad range of countries in time series. However, data on sectoral or product as well as on regional or local level is limited.	3
Technical feasibility	Calculations have been done based on official on national levels. Calculation can be done with standard software.	3
Complementarity and integration	• *Are there potential complements between the methodology/indicator and the others being assessed?* MFA is one of the basic data accounts, on which other indicators are built. • *Is there the potential for further integration of the methodology/indicator with the others?* There is particular potential to integrate with EF, PIOT and EMC, where integration already exists.	3
Robust		**2**
Defensible theory	Material Flow analysis is based on a defensible sound theory arguing for input related indicators and accounting for total resource consumption. However, some issues still need to be resolved (e.g. inclusion of water and air).	3
Sensitivity	Resource use might change to policies only after a time lag but changes are reported immediately. As an aggregated indicator MFA is not very sensitive. There is limited sensitivity to policies or industry improvements resulting in less impacts (e.g. emissions), also not for changes among materials and energy carriers regarding related impacts.	1
Data quality	Data needed for the MFA accounts largely fulfils the mentioned requirements. However, some basic data (e.g. construction minerals, biomass uptake by grazing) are still badly covered in official statistics.	3
Reliability	Reliability in the sense of repeatability and open exchangeable calculation details seems good. However, reliability regarding the intended measure of the environmental impact of resource use is not given.	2

Completeness	The indicator addresses resource consumption of all resources and therefore burden shifting between use of different resources can be illustrated. However, impact categories are not covered.	1
Summary appraisal	+ Standardised methodology for overall resource use. Existing high-quality data. Underlying data base for several other indicators (EF, EMC, EVIL). - Very limited information on any impacts; bulk materials dominate aggregated indicators. No sectoral information.	

Analysis of impact categories for MFA:

Criterion	Analysis	Score
Resource consumption	MFA accounts resource consumption.	2
Land use	Could only be integrated indirectly (different material categories show different land use intensities). Generally this is not done by MFA.	0
Climate change	Can be included if output indicators are used.	1
Stratospheric ozone depletion	Not included.	0
Human health impacts	Not included.	0
Eco-toxicity	Not included.	0
Photo-oxidant formation	Not included.	0
Acidification	Not included.	0
Eutrophication	Not included.	0
Ionizing radiation	Not included.	0
Impact on ecosystems and biological diversity	Not included.	0
Summary appraisal		**3**

Environmentally Weighted Material Consumption (EMC)

The assessment of EMC has been based mainly on van der Voet et al (2005). The study combines the individual material and energy carrier components of the MFA indicator Domestic Material Consumption (DMC) with LCI data sets of the respective materials and energy carriers and multiplies these with LCIA impact factors and a set of weights across the different impact categories to calculate the EMC. MFA is also assessed separately for this report. MFA is a sound method based on statistical guidelines published by Eurostat. MFA indicators have been calculated in time series for all EU countries. MFA is an accepted method for calculating total amounts of resource extraction, processing and consumption for all material categories, while the need for further differentiated data by specific materials may need to go back to the underlying production and trade statistics. Data is available from statistical offices from production and trade data sources.

With EMC calculations for 28 European countries a major weakness and point of critique on MFA has been acknowledged: the neglection of environmental impacts. Thus it combines the aim of MFA to account the total amount of natural resources consumed with environmental impacts stemming from this resource use. The suggested indicator provides a workable first solution to combine MFA and LCA.

For calculating environmental impacts according to material consumption 13 impact categories were identified which where weighted equally to sum up impact values to one indicator (EMC value). Thereby, EMC can cover all impact categories which are also used in the assessment of this report.

Van der Voet el at (2005) mention in their study that the specific LCI database that they have used to demonstrate the approach is updated only every ten years, which is one of the biggest weak points. Other databases are however typically updated any 2 to 3 years, as required to capture relevant changes in production technologies and changing global supply-chains. There are a number of smaller methodological problems of both the MFA data and the LCI data, that still need to be solved as well as the general question which weighting set to apply across the impact categories. The latter issue is however the same for all methods aiming at addressing the overall environmental impact. On the other hand EMC can cover all resources consumed and all environmental impacts used in this assessment in a quantitative way. Also, time series can be built and eco-efficiency ratios with economic figures can be calculated. Therefore this or closely related approaches will be one of the best candidates for the set of indicators to be proposed.

<u>RACER analysis of EMC:</u>

Criteria and Subcriteria	**Analysis**	**Score**
Relevant		**2.4**
Policy support, identification of targets and gaps	• *Is the indicator/methodology related to existing EU-specific policy objectives?* EMC fits well to several EU specific policies. It measures total resource consumption and environmental impacts related. Sustainable use of natural resources is one of the policy targets of the EU, in particular in the EU SDS and resource strategy. However, no direct link to limits of the planet's carrying capacity is provided. • *Does it provide guidance in monitoring, strategic policy making and/or target setting?* EMC provides guidance in monitoring and guidance in strategic policy making. However, there are no targets being set by the indicator itself, these have to be set in a political process. • *Does it quantify gaps between the current situation and specified targets?* It can quantify the gaps between current environmental impacts and	3

	the defined target. • *Does it provide adequate early warning to guide policy action?* The EMC can to some extent illustrate impacts that will take place in the future due to current resource use (e.g. it reflects GHG potentials, which will affect the climate in the future). • *Does it react to short-term changes that can (among other things) show whether policies are having an effect?* It reacts to short term changes in resource use and resource specific policies.	
Identification of trends	Calculating of time series is possible and has already been done. Overall shape of time trend is influenced by the decision on how to aggregate the different components.	3
Forecasting and modelling	• *Can the methodology/indicator be used in a predictive sense to forecast future environmental impacts from natural resource use or for more sophisticated modelling where the impact of different potential policies or of technology progress and/or change of consumption patterns can be simulated?* Predictions of future resource from the indicator alone are not possible as it measures past resource use. But it could be used as input data for modelling as has already been done with other MFA data. Also does the underlying LCI method allows to be used for detailed forecasting models of technology development. • *Can the indicator function as an early warning indicator?* Limited, as it is basically used for ex-post evaluation, while it shows impacts that take place from present emissions in the future (time lag of effect included).	2
Scope/levels of application	• *Does the indicator provide the required local information?* It has been calculated on a national level. Regional/local application might be possible but require calculations of the indicator and data availability below the national level is insufficient. • *Is industry-level data provided by the methodology/indicator?* The EMC in the proposed form focuses on the macro perspective. If amounts of materials and energy carriers consumed by different industries are known, the impact results can also be related to different industries.	1
Function- and needs related analysis	This issue can be covered as the indicator account for different material categories, but limited as no link to goods and services and the underlying needs is given.	2
Accepted		**2**
Stakeholder acceptance	Is expected to be strongly differentiated, potentially well accepted by many policy makers and green groups, but likely rejected by basic materials and energy industry, as it could lead to a result that basic	2

	industries are responsible for most of the environmental pressures, while the causes/drivers behind resource use and impacts are also industrial production and demand. MFA is a sound methodology for measuring resource consumption and the combination with LCI and LCIA impact categories results in capturing quantitatively all relevant environmental impacts. However, EMC is not officially used so far and quality, appropriateness, and actuality of LCA data will be crucial for its acceptance. Furthermore, weighting is involved to form the aggregated EMC, as for all indicators that relate to the overall environmental impact.	
Credible		**2**
Unambiguous	• *Convey a clear, unambiguous message.* Provides a clear message although the method is quite complex. However, no reduction targets can be derived directly from the indicators. • *Allow for clear conclusions to guide political action.* Allows clear conclusion how to reduce environmental impacts and which resources are the priority targets of policy action. However, as for all methods of this type, it is difficult to compare different environmental impacts across different environmental media, as the common denominator is a weighted average. • *Interpretation by the general public.* In principle yes, although the method is complex.	2
Transparency of the method	The method is transparent, interpretable and reproducible, but the LCIA data used for the existing EMC studies is not freely available.	2
Easy		**2.6**
Data availability	EMC has already been calculated in a time series for EU-27 and Turkey. Data needed for future calculations is available from national statistics and LCA data base but has to be compiled to calculate EMC. LCI data for all required materials and energy carriers available in different databases.	3
Technical feasibility	In the mentioned study a specific LCA software has been used. The method is clearly defined. Some methodological issues need adjustment. Some expert knowledge required also if ready LCI data sets are used.	2
Complementarity and integration	• *Are there potential complements between the methodology/indicator and the others being assessed?* A main complement is the combination of resource use and impact categories. The EMC covers several aspects in a comprehensive manner, which are not covered by other tools being assessed. • *Is there the potential for further integration of the methodology/indicator with the others?* It might be possible to integrate EMC with PIOT to come up with sectoral information on impacts. Integration with EF is another	3

	option, which is suggested by researchers working with LCA.	
Robust		**2.6**
Defensible theory	MFA is based on a defensible sound theory arguing for input related indicators and accounting for total resource consumption. One of its weaknesses (not dealing with environmental impacts) is corrected with EMC. How to aggregate the different impact categories into one number remains an important point of discussion.	3
Sensitivity	The different sub-components of the EMC are sensitive to changes in the composition of resource use. Sensitivity of the aggregated indicator is much less pronounced, as changes in different directions might level out.	3
Data quality	MFA data needed for the EMC largely fulfils the mentioned requirements. This is not so clear for LCA data, but efforts are being made to improve this, on European level and in many ongoing national LCA projects worldwide.	2
Reliability	Reliability in the sense of repeatability and open exchangeable calculation details seems good. Studies may only be reproduced by experts having access to LCA data bases.	2
Completeness	The indicator addresses resource consumption of all resources and its environmental impacts and therefore burden shifting between use of different resources can be captured. (Although not in EMC but in the detailed data needed for the calculation.). Limits on impact data on land use.	3
Summary appraisal	+ Combines statistical and industry data; covers overall resource use, all impact categories, fine differentiation and high responsiveness to changes, captures future impacts from present emissions. - LCA data base used not freely available and updated only irregularly. Expert knowledge required. No limits/benchmarks. Acceptance by materials and energy carrier industry expected to be very limited.	

<u>Analysis of impact categories for EMC:</u>

Criterion	Analysis	Score
Resource consumption	Partly covered by abiotic depletion potential.	2
Land use	Covered as land competition.	1
Climate change	Covered as global warming potential.	2
Stratospheric ozone depletion	Covered by ozone depletion potential.	2

Human health impacts	Covered by human toxicity potential.	2
Eco-toxicity	Covered by freshwater aquatic, marine and terrestrial ecosystem toxicity potential	2
Photo-oxidant formation	Covered by photochemical oxidant creation potential.	2
Acidification	Covered by acidification potential.	2
Eutrophication	Covered by eutrophication potential.	2
Ionizing radiation	Covered by daily radiation.	2
Impact on ecosystems and biological diversity	Partly covered by final solid waste amounts.	1
Summary appraisal		**21**

Environmental Impact Load (EVIL)

A similar method for combining MFA data with environmental impacts has been developed in 2006 in a research project and in workshops on behalf of the German Environmental Agency (IFEU unpublished). This indicator is still under discussion, but shall be included here to introduce it as one potential indicator, although it has not been in the list of indicators in the proposal or first assessment of methods.

The EVIL indicator is oriented at the approach of “ecological scarcities” and “critical loads“ and calculates the measure of a single environmental impact for which long-term and sustainable safety is guaranteed for this issue. Therefore the measure “EVIL” has been introduced. For example: If global warming should not exceed 2° Celsius, world-wide emissions need to be limited. Based on a per-capita calculation, Germany would be allowed to emit 250 Mio. tons of CO2 equivalents. This amount of 250 Mio. tons then equal 1 EVIL.

EVIL units can in that way be calculated for several environmental impacts and amounts of consumed resources that are multiplied with the EVIL impact values. This method allows comparisons between different impact categories as all impacts are shown in one unit. This method includes subjective components which is mentioned and recognised by the group of experts that invented the method.

EVIL covers a range of environmental impacts and summarises them in a single comparable unit. This is seen as strength (as it makes impacts for different impact categories comparable), but also as a weakness that could raise great discussion and opposition, as subjective evaluations are part of the calculation process. A main weak point of the method also is that is has only been proposed recently and is still under development. This makes it unlikely to be used in the near future in the European context.

EVIL is so far focusing on impacts related to the use of abiotic raw materials, which could be a complementing aspect to the EF.

<u>RACER analysis of EVIL:</u>

Criteria and Subcriteria	Analysis	Score
Relevant		**2.0**
Policy support, identification of targets and gaps	• *Is the indicator/methodology related to existing EU-specific policy objectives?* EVIL is strongly related to EU policy objectives, in particular, the Resource Strategy, as it shows environmental impacts for a broad range of natural resources and impact categories. • *Does it provide guidance in monitoring, strategic policy making and/or target setting?* It does so as it allows determining main environmental impacts categories and related resources at which policies can be directed and for their consumption targets can be set. • *Does it quantify gaps between the current situation and specified targets?* EVIL is designed as a “distance-to-target” indicator and thus is very well suited to communicated gaps between the current situation and targets. • *Does it provide adequate early warning to guide policy action?* No, as it is an ex-post measure for impacts from current levels of resource use. • *Does it react to short-term changes that can (among other things) show whether policies are having an effect?* Yes, for those environmental impacts included in EVIL, short-term changes will be reflected in the indicator.	3
Identification of trends	Time series exist for used MFA data. Trends in impacts could be illustrated by the method, however, time series have not yet been calculated..	2
Forecasting and modelling	• *Can the methodology/indicator be used in a predictive sense to forecast future environmental impacts from natural resource use or for more sophisticated modelling where the impact of different potential policies or of technology progress and/or change of consumption patterns can be simulated?* Only if the indicator is linked to economic modelling or scenarios on resource use and changes in the composition of different resources consumed. • *Can the indicator function as an early warning indicator?* To some extent, EVIL can be used to predict likely future impacts, e.g. future impacts on global warming due to current emissions of GHG.	2
Scope/levels of application	• *Does the indicator provide the required local information?* Local resource consumption data from MFA studies rarely exist. A break-down of impact values to the local level has not been performed yet as the method is fairly new.	1

	• *Is industry-level data provided by the methodology/indicator?* No. So far, it focuses on the macro perspective.	
Function- and needs related analysis	This issue can be covered as the indicator accounts for different material categories. However, only abiotic resources are covered so far.	2
Accepted		**1**
Stakeholder acceptance	The stakeholder acceptance of this indicator can so far not be judged based on experiences, as the indicator is only now being developed. Subjective components in weighting different aspects to an aggregated measure might lead to criticism. On the other hand, the indicator has the potential to eliminate one of the main weaknesses of MFA indicators, i.e. the missing link to environmental impacts.	1
Credible		**2**
Unambiguous	• *Convey a clear, unambiguous message.* The message of the indicator is clear although subjective components of weighting influence the aggregated results. • *Allow for clear conclusions to guide political action.* EVIL allows clear conclusions as it identifies resources relevant for the highest environmental impacts. However, as mentioned above, the inclusion of weighting factors can have an impact on the policy conclusions. • *Interpretation by the general public.* Interpretation might be good even if the method might be too complex for the general public.	2
Transparency of the method	The method is transparent but it is not fostered yet as it is only suggested by a group of experts and still in development.	2
Easy		**1.6**
Data availability	Data is currently available only for a pilot study in Germany.	1
Technical feasibility	Technical feasibility strongly depends on defining the impact units which can only be performed for a limited number of impact categories. If the impact factors are available and transparent, calculation of EVIL is straightforward, given that information on the physical quantities is provided.	2
Complementarity and integration	• *Are there potential complements between the methodology/indicator and the others being assessed?* It mainly complements MFA as it combines MFA data with environmental impact values. • *Is there the potential for further integration of the methodology/indicator with the others?*	2

	With MFA and therefore also PIOT. Also with EMC, as EMC applies a very similar concept.	
Robust		**1.6**
Defensible theory	The aim and intention for the indicator is clear. MFA data used for its calculation is based on a defensible theory but the calculation of a common impact unit for different impact categories is debatable.	2
Sensitivity	The sub-components of EVIL are sensitive to changes in amounts and composition of resource use.	2
Data quality	MFA data needed fulfils the mentioned requirements. Data for EVIL do currently not (yet) exist.	1
Reliability	Reliability depends on the method how different environmental impacts are aggregated into one single unit. As the method is only in the testing phase at the moment, reliability has to be checked at a later stage of implementation.	1
Completeness	The indicator so far covers only abiotic mineral resources and many related environmental impacts. Biotic materials should be added in the next step, in order to make EVIL a truly comprehensive indicator of resource-related impacts.	2
Summary appraisal	+ Based on MFA data; includes several key impact categories; allows illustrating "distance-to-target" - Pilot phase (Germany); so far only abiotic minerals; normative decisions involved (definition of EVILs).	

<u>Analysis of impact categories for EVIL:</u>

Criterion	Analysis	Score
Resource consumption	Covered by MFA data.	2
Land use	Covered as sealed area.	1
Climate change	All "Kyoto gases" are included in the indicator.	2
Stratospheric ozone depletion	Not covered.	0
Human health impacts	Partly covered by air emissions.	1
Eco-toxicity	Partly covered by water and air emissions (adsorbable organic halogen compounds, SO2, NOx, NH3, NMVOC).	1
Photo-oxidant formation	Partly covered with NOx and NMVOC emissions.	1
Acidification	Not covered.	0
Eutrophication	Partly covered by N emissions to water systems.	1
Ionizing radiation	Not covered.	0
Impact on ecosystems and biological diversity	Not covered.	0

Summary appraisal		**9**

Physical Input Output Tables (PIOT)

PIOTs are based on a combination of material flow analysis and economic input output tables. PIOTs can provide complementary information to MFA (as well as carbon and Footprint) as they deliver information on material flows between economic sectors and the effects of sectoral changes to material extraction, processing and consumption. Furthermore, PIOTs separate material inputs used for production processes from those directly delivered to final demand. This makes PIOTs highly valuable for policy recommendations and effective (economic and sectoral) policies to reduce resource consumption.

One of the weakest points of PIOTs is the effort in calculating them and that therefore they have so far only been accounted for a small number of countries and for single years or materials. PIOTs for several material flows have already been published for the Netherlands, Germany, Denmark and Finland

Elaborating PIOTs is a very time consuming effort. Methods used so far vary between different studies or countries so that results are not directly comparable.

Furthermore, aggregated PIOTs, such as those presented for Germany, sum up all kinds of different materials with different environmental impacts and are thus criticised with the same arguments as for MFA. In order to better link PIOT to environmental impacts of specific materials, PIOTs have to be disaggregated by different types of materials, as was done in the case of Denmark.

PIOTs are basically an accounting framework and to not themselves illustrate whether policies do have a positive impact. However, PIOTs can be a valuable tool in developing indicators, increasing their quality and helping in understanding functional aspects of resource use, such material flows between sectors and the links between intermediate production and final consumption. Main weaknesses are efforts and costs to compile PIOTs. Regarding environmental impacts, PIOTs can deal with resource use and, if compiled in complete form, also with issues of climate change (via GHG emissions) and waste.

<u>RACER analysis of PIOT:</u>

Criteria and Subcriteria	**Analysis**	**Score**
Relevant		**1.6**
Policy support, identification of targets and gaps	• *Is the indicator/methodology related to existing EU-specific policy objectives?* PIOT fits well to EU specific policies as sustainable use of natural resources and sustainable production and consumption are one of	2

	the policy targets of the EU. However, mass-based PIOTs only link indirectly to the objectives of the Resource Strategy. • *Does it provide guidance in monitoring, strategic policy making and/or target setting?* PIOT provides good guidance in strategic policy making and target setting as it identifies economic sectors which are mainly responsible for resource consumption and allows policy to focus directly on those resource-intensive sectors. However, the ability to directly link to specific impacts depends on the level of aggregation of the input-output tables. • *Does it quantify gaps between the current situation and specified targets?* It can if targets are formulated for example for specific sectors or specific consumption categories. For identifying gaps between overall resource consumption and correlated targets easier methods (such as MFA) could be used. The main value of PIOT lies in the sectoral disaggregation and the separation of intermediate production from final consumption. • *Does it provide adequate early warning to guide policy action?* Only partly as it identifies resource intensive sectors (which can be seen as early warning if this information is combined with projections for sectoral development). But basically it is applied as an ex-post analysis tool. • *Does it react to short-term changes that can (among other things) show whether policies are having an effect?* Reaction to short term changes are limited as PIOTs have in most cases so far only been accounted for one single year.	
Identification of trends	PIOTs could in principle be calculated in time series. But due to the huge effort in compiling these tables, PIOTs so far exist only for single years for some countries.	1
Forecasting and modelling	• *Can the methodology/indicator be used in a predictive sense to forecast future environmental impacts from natural resource use or for more sophisticated modelling where the impact of different potential policies or of technology progress and/or change of consumption patterns can be simulated?* The link to environmental impacts is weak and due to the limited availability of time series, also the potential for modelling and forecasting of resource use is limited. • *Can the indicator function as an early warning indicator?* Only indirectly if combined with information on sectoral development (see above).	1
Scope/levels of application	• *Does the indicator provide the required local information?* Regional/local applications do not exist so far and are unlikely to be expected due to the high efforts for compiling a PIOT.	2

	• *Is industry-level data provided by the methodology/indicator?* Yes. A main advantage of PIOTs is that it directly shows material flows between industries/sectors.	
Function- and needs related analysis	This can be done if a PIOT comprises all material categories. The best option are PIOTs for different material categories (e.g. Metals, plastics, etc.), which can best be linked to specific needs.	3
Accepted		**2**
Stakeholder acceptance	Expected to be good for policy makers as PIOTs allow identifying resource-intensive sectors and production chains and helps identifying policy strategies to reduce resource consumption along the whole production-consumption chain. On the other hand the method seems to be complex to be used for communication with the broad public and for awareness raising. Furthermore PIOTs are not used widely so far due to the high effort of compilation.	2
Credible		**2**
Unambiguous	• *Convey a clear, unambiguous message.* The message provided is rather complex (including all material categories and economic sectors) – though this complexity is also a main advantage for using PIOT as a policy tool and explaining links between resource use and economic development in different sectors. • *Allow for clear conclusions to guide political action.* As it shows resource consumption for economic sectors it allows clear conclusions to direct policies at the main driving forces. However, direct links to impacts are limited. • *Interpretation by the general public.* Is rather limited as the method is complex.	2
Transparency of the method	A standard method has not been developed so far and methods from different studies vary. The method is also quite complex.	2
Easy		**1.3**
Data availability	Data collection to compile PIOTS is a very expensive and time consuming effort. Therefore, PIOTs so far only exist for a small number of countries and years.	1
Technical feasibility	Calculations of PIOTs have so far only been carried out by some statistical offices or scientific institutions and require expert knowledge	1
Complementarity and integration	• *Are there potential complements between the methodology/indicator and the others being assessed?* The strongest complementary component is the sectoral information on resource flows. • *Is there the potential for further integration of the methodology/indicator with the others?*	2

	It is already integrated with MFA (or EFA, if PIOTs are presented in energy units). Integration with EMC and land use might be possible.	
Robust		**2.0**
Defensible theory	PIOTs are based on a defensible theory as they are oriented towards established monetary input-output tables and the methods of MFA for which methodological standards exists. PIOTs are also one part of the international SEEA system.	4
Sensitivity	PIOTs could react fast to economic changes and changes in resource consumption. But due to the fact that PIOTs are only accounted for single years so far (and are not expected to be calculated more often than every couple of years) in practice PIOTs cannot show short term changes.	1
Data quality	Data collection is time consuming and expensive. Quality of the data depends of the robustness of the underlying work to compile PIOTs from a large number of statistical sources.	1
Reliability	A standard method has not been developed yet and repeatability is weak due to the effort.	1
Completeness	PIOTs can liver a comprehensive picture of resource use for all material categories across all economic sectors. However, direct links to environmental impacts are weak.	3
Summary appraisal	+ Complete accounting of nature-economy relationship, including sectoral disaggregation. - Huge efforts for compilation; data only available for few countries; no standards; weak links to impacts.	

Analysis of impact categories for PIOT:

Criterion	Analysis	Score
Resource consumption	PIOTs account for resource consumption.	2
Land use	Not included.	0
Climate change	Indirectly via GHG emissions	1
Stratospheric ozone depletion	Not included.	0
Human health impacts	Not included.	0
Eco-toxicity	Not included.	0
Photo-oxidant formation	Not included.	0
Acidification	Not included.	0
Eutrophication	Not included.	0
Ionizing radiation	Not included.	0

Impact on ecosystems and biological diversity	Not included.	0
Summary appraisal		**3**

Substance Flow Analysis (SFA)

SFA tracks single substances throughout the economy, between economy and nature and within the natural systems. SFA mostly focuses on substances of high environmental and health concerns and harmfulness (such as heavy metals) but can also be used for “bulk materials” that dominate overall resource use (such as minerals, concrete or steel). The detailed information provided by SFA on how materials are used and how they flow through which processes and sectors within the economy is one its major strengths that helps to define specific polices and address them to the right “hot spots”.

The depth in the analysis on the other hand comes along with a focus on single issues. This can be seen as one of the weak points of SFA. SFA studies normally do not provide information on overall resource use and can lead to designing single issue policies neglecting aspects of overall resource use, trade-offs between environmental and health problems and substitution processes between materials.

SFA normally focuses on substances of high concern. This makes it highly policy relevant and of importance to public interest. The focus on materials of high concern also results in a good possibility to cover many environmental impact categories although existing studies may cover only one (depending on the substance analysed).

Calculations of SFA might be very time consuming and might in many cases require generation of primary data from companies and stakeholders. Therefore it cannot be based on easily available or already published data.

<u>RACER analysis of SFA:</u>

Criteria and Subcriteria	**Analysis**	**Score**
Relevant		**2.2**
Policy support, identification of targets and gaps	• *Is the indicator/methodology related to existing EU-specific policy objectives?* SFA is relevant to specific environmental problem oriented policies. If it is used for bulk materials it is also relevant for less environmentally harmful materials that dominate overall amounts of resources consumed. It can provide helpful links between environmental and health issues. • *Does it provide guidance in monitoring, strategic policy making and/or target setting?* SFA can do so as it shows which materials are used in which	3

	processes by the economy and therefore can help to plan strategic policies in reducing resource flows with a particular potential for environmental harm. • *Does it quantify gaps between the current situation and specified targets?* Yes, if specific targets are set for specific materials. Measuring current situations of overall resource use might be easier with simpler methods that do not track material flows throughout the economy but tracking them helps to define and evaluate specific policies. • *Does it provide adequate early warning to guide policy action?* SFA is basically an ex-post evaluation tool with a strong focus on analytical aspects by understanding substance flows through the economy and between economy and nature. • *Does it react to short-term changes that can (among other things) show whether policies are having an effect?* Yes, especially concerning policies for single substances with particular environmental or health impact.	
Identification of trends	SFA could be used for analysing trends although the effort for performing SFA analyses might entail that they will only be set up every couple of years or in single studies.	2
Forecasting and modelling	• *Can the methodology/indicator be used in a predictive sense to forecast future environmental impacts from natural resource use or for more sophisticated modelling where the impact of different potential policies or of technology progress and/or change of consumption patterns can be simulated?* SFA is appropriate for these tasks as it links economic processes with resource use and focuses on economic sectors. Therefore it can be used for modelling effects of sectoral changes on substance flows. • *Can the indicator function as an early warning indicator?* SFA mainly focuses on analysis of current situations. However, it could serve as an early warning indicator, if also the stocks within society are accounted (e.g. stocks of heavy metals in equipment, which will become waste in the future).	2
Scope/levels of application	• *Does the indicator provide the required local information?* SFA is often used in regional, local and sectoral applications. • *Is industry-level data provided by the methodology/indicator?* SFA often focuses on specific industries or the use of substances across industries and sectors.	3
Function- and needs related analysis	As most studies focus on one or a limited number of substances currently these aspects are often ignored.	1

Accepted		**2**
Stakeholder acceptance	Stakeholder acceptance should be high as SFA often focuses on substances harmful to the environment or human or ecosystem health. Communication to the public could be difficult due to the complexity of the analysis although results could be presented in easily understandable flow diagrams.	2
Credible		**2**
Unambiguous	• *Convey a clear, unambiguous message.* The message is clear. However, methods for analysing substance flows may vary between different case studies. • *Allow for clear conclusions to guide political action.* Conclusions are clear for single substances as the analysis shows in which economic processes the substances are used and policies can be focussed on these processes and related industries. SFA helps to reduce harmful substances by specific policies. A weak point however is that SFA often have a very specific focus, which ignores trade-offs and overall environmental burden and could support a trend towards "single issue" policies. • *Interpretation by the general public.* Is rather limited as the method is complex. But if information from the studies is presented in a way easily understandable interpretation can be good. The focus on single issues of harmful materials might strengthen the interest of the public in SFA.	2
Transparency of the method	A harmonised method has not been developed so far and methods from different studies vary.	2
Easy		**2.3**
Data availability	Data has to be collected with an expensive and time consuming effort. SFA studies focus on single substances and industries which are analysed in detail often based on data that has to be generated primarily.	2
Technical feasibility	Calculations of SFAs require detailed understanding of economic processes as well as technologies. Practical feasibility strongly depends on the availability of data or the willingness of companies or stakeholders to provide required data.	2
Complementarity and integration	• *Are there potential complements between the methodology/indicator and the others being assessed?* SFA offers complementary elements as it can focus on both very harmful materials and materials dominating overall resource use. It also offers complementary information through its link to processes, techniques and sectors as well as to local and regional information. Therefore it contributes to a better understanding of material flow within the economy and points at "hot spots" for policy makers. • *Is there the potential for further integration of the methodology/indicator with the others?*	3

	Integration is best possible with bulk MFA and physical input output tables.	
Robust		**2**
Defensible theory	The method underlying SFA is clear and builds on the laws of thermodynamics. It provides a detailed analysis of materials of high environmental concern.	3
Sensitivity	SFA can provide information to all the mentioned issues.	3
Data quality	Data collection is time consuming and expensive. Data may often have to be generated from companies based on their acceptance to provide data.	1
Reliability	A standard method has not been developed yet and repeatability is weak due to high efforts.	2
Completeness	This is one of the main weak points of SFA. It focuses on single substances and could therefore neglect trade-offs and substitution effects between materials and environmental impacts. For dealing with these problems, several SFAs for various substances would have to be combined or an economy-wide method (such as MFA) needs to be applied.	1
Summary appraisal	+ Detail of analysis; links to specific impacts (depending on substances analysed). - Large efforts for compilation; no standards; missing completeness of scope (substitution!).	

Analysis of impact categories for SFA:

Remark: SFA normally focuses on single substances. Depending on which substances are analysed several impact categories could be covered. Single studies however might normally only cover one of these impact categories. Therefore the summary score has been put into brackets as it might not occur to most SFAs.

Criterion	Analysis	Score
Resource consumption	SFA does not account overall resource consumption but focuses on single substances for which overall consumption or parts of it are analysed.	1
Land use	SFA does not provide land use information although this issue could be integrated into SFAs.	0
Climate change	Included if flows of carbon or greenhouse gases are analysed.	2
Stratospheric ozone depletion	Included if focussing on relevant substances.	2
Human health impacts	Included if focussing on relevant substances.	2
Eco-toxicity	Included if focussing on relevant substances.	2

Photo-oxidant formation	Included if focussing on relevant substances.	2
Acidification	Included if focussing on relevant substances.	2
Eutrophication	Included if focussing on relevant substances.	2
Ionizing radiation	Included if focussing on relevant substances.	2
Impact on ecosystems and biological diversity	Included if impacts are part of the analysis (SFA might also focus “only” on the flows within the economy).	0
Summary appraisal		**17**

Energy Flow Accounting (EFA)

This assessment of EFA is mainly based on the method proposed by Schandl et. al. (2002). According to the authors, EFA goes beyond energy statistics and conventional energy balances, but energy statistics are one important basis for conducting EFA, providing necessary data and focus on specific aspects of energy use. EFA on the other hand is an analytical tool describing the energy systems of a society as a whole guaranteeing that energy inputs and outputs are equal following the law of conservation of energy. EFA includes all “energy rich materials”. That means biomass is included even if it is not used for energetic purposes (so EFA e.g. includes harvested biomass and foodstuff). Conventional energy balances are limited to energy carriers. In a complete sense EFA could include all energy incorporated in all materials extracted domestically (or imported). For practical reasons, EFA concentrates – beside of energy carriers – on energy-rich materials of “special interest” (like e.g. feedstuffs, food, timber, paper). EFA also includes energy inputs in products which become part of the energy stock of a society and might be used energetically later (e.g. by combustion of waste). Conventional energy statistics treat such inputs as “non-energetic use”.

Energy Flow Analysis adds a complementary element by analysing energy flows in energy units instead of mass units and partly including energetic use of materials (not only energy carriers). It deals with an issue of high political relevance (global warming) and can build upon established energy statistics and institutions (energy agencies). If EFA includes not only fossil energy but also renewables and energy in “energy rich materials”, it can give a comprehensive picture of energy consumption and can provide information on global warming, land use, changes in the energy system of a society and potentials of renewable energies.

Using energy units can put a focus on the energy requirements of the economy and societies, illustrating purpose and location (e.g. which sectors) of energy use and energy efficiency. Issues of EFA might also be covered by other methods (such as MFA or Ecological Footprint) which already include the consumption of fossil fuels and renewable energy carriers. According to Schandl et al. (2002), EFA is compatible with MFA using the same system boundaries, links to energy and land use accounting methods (such as LUA and HANPP) and is viable tool in analysing economic transitions influencing energy consumption, land use and greenhouse gas emissions.

EFA cover impacts on global warming and partly those on resource use including fossil fuels and biotic energy materials.

RACER analysis of EFA:

Criteria and Subcriteria	Analysis	Score
Relevant		**2.2**
Policy support, identification of targets and gaps	• *Is the indicator/methodology related to existing EU-specific policy objectives?* EFA is related to policies concerning global warming and reduction of greenhouse gas emissions. EFA also covers energy and resource efficiency issues. • *Does it provide guidance in monitoring, strategic policy making and/or target setting?* EFA can do so by analysing flows of energy through the economy and the efficiency of energy use. However, EFA cannot help to set targets for environmental impacts. • *Does it quantify gaps between the current situation and specified targets?* EFA can quantify gaps between amounts of energy consumed and (in-)efficiencies and targets set for both. This can be done on the macro or the sectoral level. Again, limitations occur due to the focus on energy (instead of the impacts related to energy use). • *Does it provide adequate early warning to guide policy action?* Partly. EFA focuses on ex-post analysis of energy consumption but can be regarded as early warning indicator for global warming. • *Does it react to short-term changes that can (among other things) show whether policies are having an effect?* If concerning policies to reduce energy consumption and greenhouse gas emissions, yes.	2
Identification of trends	EFA can and has been produced in time series. Energy statistics are published annually for all EU countries. Detailed analyses of energy flows in specific sectors or specific production processes might however be restricted to single case studies.	3
Forecasting and modelling	• *Can the methodology/indicator be used in a predictive sense to forecast future environmental impacts from natural resource use or for more sophisticated modelling where the impact of different potential policies or of technology progress and/or change of consumption patterns can be simulated?* EFA can only be used in this matter if it is linked with economic data and models. Energy projections and modelling of energy consumption have a long tradition and are regularly published.	2

	• *Can the indicator function as an early warning indicator?* Partly, as it measures today's energy consumption which will have long term effects for global warming. But generally EFA is an ex-post analysis tool.	
Scope/levels of application	• *Does the indicator provide the required local information?* EFAs are so far mostly executed on national levels but regional and local applications (often with an historic background by analysing energy systems over long time periods) exist. • *Is industry-level data provided by the methodology/indicator?* Not generally. On the economy-wide level, EFA analyses the energy flows through the whole economy as a black box (as does MFA).	2
Function- and needs related analysis	Energy flow accounting can include various energy carriers (not only fossil energy) and therefore also biomass and renewable energy. EFA can illustrate trade-offs between different forms of energy use and different energy carriers. The linkage to other materials or environmental aspects is, however, limited. Links between material use and energy use and consumption exist (e.g. if energy incorporated in products is analysed) but this aspects have so far only been studied partly.	2
Accepted		**2**
Stakeholder acceptance	EFA of energy carriers is done by official institutions and published in annual energy reports on national and international levels. Therefore, acceptance for this part of EFA is high and energy issues are among the most important in current policy making. However, comprehensive EFA (including the energetic aspects of products other than energy carriers) have only been performed in academic studies so far.	2
Credible		**2.0**
Unambiguous	• *Convey a clear, unambiguous message.* The message is clear although probably the choice of energy units might not reflect highest environmental relevance (which could probably be seen in amounts of energy carriers used or related GHG emissions). • *Allow for clear conclusions to guide political action.* EFA allows deriving conclusions for energy policies and policies, which concern the use of energy-containing materials and products (e.g. from agriculture). If the economy is treated as a black box, conclusion for specific (e.g. sectoral) policies cannot be drawn. Links to other environmental problems or other natural resources are not directly explained. • *Interpretation by the general public.* Interpretation by the general public should be easy as the issue is clear and results are often presented in understandable energy flow	2

	charts.	
Transparency of the method	As energy flow data is published by official institutions, a common method exists, to some extent also with regard to sectoral disaggregation (e.g. as done by the International Energy Agency). A common methodology for regional and local studies is missing, as is a harmonised methodology to account other energy-containing materials.	2
Easy		**2.3**
Data availability	Basic data needed for EFA on a national level is published regularly by statistical offices and international organisations (International Energy Agency, OECD). Data for regional and local level would have to be collected primarily.	2
Technical feasibility	Technical feasibility seems good at the national level but more difficult at regional or local levels. The EFA method so far is not internationally harmonised.	2
Complementarity and integration	• *Are there potential complements between the methodology/indicator and the others being assessed?* The main complementarity of EFA is that it uses energy units, which could be combined with other methods to link to issues of material flows, land use and emission. • *Is there the potential for further integration of the methodology/indicator with the others?* Integration is possible with material-based methods (MFA, EMC, PIOT, SFA) and also with land use based methods (LUA, Ecological Footprint). The latter is possible with regard to emissions stemming from fossil energy use, sequestration land and land area needed to provide energy from renewable sources.	3
Robust		**2.4**
Defensible theory	EFA and energy statistics have a long history and can build on official statistics by national and international institutions. A weakness can be seen in a missing common methodology to account for the energy content in other energy-rich materials and products.	3
Sensitivity	EFA results are sensitive to changes in the energy structure of economic systems as well as to changes in other metabolic components, which effect the consumption of energy-rich materials (e.g. agriculture, meat production, etc.).	3
Data quality	Basic data is available in published form from statistical offices and international institutions and is in general of good quality. Comprehensive EFAs, which in addition require information on energy contents of materials and products, require additional data from academic literature.	2
Reliability	EFA is rated as reliable as it is already used by energy agencies	2

	and official institutions. Comprehensive EFAs (including energy contents of materials) rely on additional data, which's reliability varies between studies.	
Completeness	EFA focuses on energy carriers (fossils and renewables) and energy-rich materials. Other aspects of resource use must be covered by other methods.	2
Summary appraisal	+ Focus on issues of energy use and climate change. - Difficult to compile, as comprehensive EFA requires more data than available from energy statistics.	

Analysis of impact categories for EFA:

Criterion	Analysis	Score
Resource consumption	Only partly covered for fossil and renewable energy carriers – and also only indirectly as energy consumption is measured in energy units.	1
Land use	Could be covered indirectly if EFA is not restricted to fossil fuels but also includes energy flows from renewables. But land use data is not reported by EFA.	0
Climate change	A direct link exists from consumption of fossil fuels although CO2 emissions (and other greenhouse gas emission) are not reported.	2
Stratospheric ozone depletion	Not included.	0
Human health impacts	Might only be indirectly included as consumption of fossil fuels and renewables will have an effect (e.g. oils spills, land use change).	0
Eco-toxicity	Might only be indirectly included as consumption of fossil fuels and renewables will have an effect (e.g. oils spills, land use change).	0
Photo-oxidant formation	Not included.	0
Acidification	Not included.	0
Eutrophication	Not included.	0
Ionizing radiation	Not included.	0
Impact on ecosystems and biological diversity	Might only be indirectly included as consumption of fossil fuels and renewables will have an effect (e.g. oils spills, land use change).	0
Summary appraisal		**3**

Human Appropriation of Net Primary Production (HANPP)

HANPP is a measure of human domination of ecosystems and can be defined as the amount of terrestrial NPP required to derive food and fibre products consumed by humans, including the organic matter that is lost during the harvesting and processing of whole plants into end products (Haberl et al., 2007; Imhoff *et al*., 2004). HANPP is complementary to the Ecological Footprint as it measures how much bioproductivity is appropriated within a country whereas the Footprint measures how much biocapacity is utilized by a country wherever it is located on the planet. The policy relevance of HANPP is currently hampered by poor understanding of HANPP's ecological effects, so 'sustainability thresholds' cannot currently be meaningfully defined. If clear, causal and empirical relationships between HANPP and biodiversity were established, than HANPP could play a significant role as an indicator for human pressures on biodiversity (Haberl *et al*., 2004). HANPP can also link to the SEA and forms part of the Material and Energy Flow Accounting framework of tools and techniques.

RACER analysis of HANPP:

Criteria and Subcriteria	**Analysis**	**Score**
Relevant		**2.4**
Policy support, identification of targets and gaps	• *Is the indicator/methodology related to existing EU-specific policy objectives?* HANPP identifies the intensity with which humans use land areas in a defined territory and is related to landscape structure and diversity. HANPP relates resource supply to land use intensity, which is relevant to EU policy objectives on sustainable use of natural resources, biodiversity and land use. • *Does it provide guidance in monitoring, strategic policy making and/or target setting?* HANPP provides guidance in monitoring the intensity of ecosystem use over time. However, the lack of a clear and identifiable sustainable threshold for HANPP means that it is not yet used in policy making and target setting. • *Does it quantify gaps between the current situation and specified targets?* HANPP could do that only if targets were set for intensity of land use and appropriation of NPP, therefore it addresses this requirement inadequately. • *Does it provide adequate early warning to guide policy action?* HANPP can be regarded as an early warning indicator with regard to human pressures on ecosystems and biodiversity. Through illustrating the gap between current resource extraction and a natural state, HANPP provides indications on e.g. potential losses of	3

	biodiversity due to human pressures. • *Does it react to short-term changes that can (among other things) show whether policies are having an effect?* It reacts to factors such as changes in land use and harvest and these can be influenced and induced by policies.	

Identification of trends	Time series of HANPP have been calculated, in order to illustrate trends in the intensity of human appropriation of biomass. However, trends in a number of other impact categories cannot be directly monitored.	3
Forecasting and modelling	• *Can the methodology/indicator be used in a predictive sense to forecast future environmental impacts from natural resource use or for more sophisticated modelling where the impact of different potential policies or of technology progress and/or change of consumption patterns can be simulated?* HANPP addresses this requirement only partly as it has primarily been calculated for past resource use, but it could be used as input data for modelling as has already been done for other Material and Energy Flow Accounting indicators. HANPP has been calculated as an indicator of environmental impact of land use scenarios for Austria in 2020 (Haberl *et al.*, 2002). • *Can the indicator function as an early warning indicator?* HANPP can be regarded as an early warning indicator for pressures on ecosystem functions and biodiversity. Changes in components of HANPP can provide early warning of environmental degradation and of trends in land use over time.	2
Scope/levels of application	• *Does the indicator provide the required local information?* HANPP can be calculated at a range of spatial scales and has been calculated nationally and mapped in a spatially explicit manner. • *Is industry-level data provided by the methodology/indicator?* No, HANPP does not address this.	2
Function- and needs related analysis	HANPP translates the "colonialisation of ecosystems" for the provision of human needs (e.g. intensive agriculture for providing food and feed) into an illustrative indicator on the domination of ecosystems.	2
Accepted		**2**
Stakeholder acceptance	The concept is easily understood and complementary to other concepts, such as the Ecological Footprint. HANPP does not form part of official indicator sets so far, but could be adopted by DG Env or EEA in the future.	2
Credible		**2.5**
Unambiguous	• *Convey a clear, unambiguous message.* Although HANPP as a concept is clear and unambiguous, the calculation of HANPP for a country or region demonstrates how much NPP is being appropriated but is unable to put that into context by providing a clear indication of the ecological effects of HANPP. • *Allow for clear conclusions to guide political action.* HANPP does not allow for clear conclusions that could be used to guide policy until a 'sustainability threshold' has been agreed or an	2

	empirical link between HANPP and impacts on biodiversity established. • *Interpretation by the general public.* HANPP can be interpreted by the public as a measure of human dominance of ecosystems but further work is needed to determine thresholds to provide a clear indicator.	

Transparency of the method	The methodology outlined in the existing HANPP publications is to a large extent transparent and reproducible.	3
Easy		**2.6**
Data availability	Data availability is good for EU countries. Also first assessments on the global level have been presented.	3
Technical feasibility	The methodology is clearly defined. Application and visualisation of HANPP indicator requires special mapping software (e.g GIS software).	2
Complementarity and integration	• *Are there potential complements between the methodology/indicator and the others being assessed?* HANPP is complementary to the EF as both share land use as their common denominator. HANPP could be one indicator in the basket, illustrating the consequences of resource use for land cover changes and intensity of land use. • *Is there the potential for further integration of the methodology/indicator with the others?* PIOT's would make it possible to link HANPP and other MEFA indicators to economic models. It might be possible to link LCA-based methods such as EMC with information on net primary production affected by the consumption of specific materials and products.	3
Robust		**2.4**
Defensible theory	HANPP is built on a clear theory of human colonialisation of natural systems.	3
Sensitivity	HANPP is sensitive to input parameters but the lack of identified threshold means it is unclear whether this would be policy significant	2
Data quality	Data quality with regard to extraction of biomass from ecosystems can be generally regarded as good. Data on potential net primary production is less reliable.	2
Reliability	If underlying data are of high quality, reliability of the results of the HANPP calculations can be regarded as good.	3
Completeness	HANPP specifically addresses questions of how intensively a defined area of land is being used in terms of ecosystem energetics; how much potentially available energy is being diverted by humans; and how strongly does human use of a defined area affect its primary productivity. HANPP must be complemented by other indicators, in order to reflect other impacts related to resource use.	2
Summary appraisal	+ Can be linked to MFA and EFA. Good data quality. Possible complements to EF. - Difficult to understand meaning of the indicator and to define sustainable threshold.	

Analysis of impact categories for HANPP:

Criterion	Analysis	Score
Resource consumption	Partly included as calculates consumption of primary productivity	1
Land use	The land use dimension is the core impact category of HANPP.	2
Climate change	Not included	0
Stratospheric ozone depletion	Not included	0
Human health impacts	Not included	0
Eco-toxicity	Not included	0
Photo-oxidant formation	Not included	0
Acidification	Not included	0
Eutrophication	Not included	0
Ionizing radiation	Not included	0
Impact on ecosystems and biological diversity	Partly included as high levels of HANPP are a potential risk to biodiversity	1
Summary appraisal		**4**

Land and Ecosystems Accounts (LEAC)

LEAC is a method for observing actual land cover and land use. Thereby, it adds a complementary element to other methods as it shows land use and related land cover changes induced by resource extraction and consumption. To the Ecological Footprint it adds a complementary element by looking at actual land use (in hectares) instead of the biocapacity the land represents. LEAC can show where, within a given territory, land is actually used for which purpose (e.g. agriculture, industry, transport, etc.) and which types of land are transformed (like e.g. if land for transport is coming from natural ecosystems, agricultural land or already built up land so far used in another way).

Land cover data is published officially by national and European institutions and several data bases for land cover and land use exist. The most important data set on the European level is the Corine data set, which is a standardised land cover inventory from satellite imagery (EEA, 2006).

For using land use data for policy making and modelling it needs to be combined with economic data showing driving forces for land cover change and land use by different sectors. Otherwise it will stay a pure – but valuable – ex-post reporting tool illustrating land cover and land use changes and also being able to report short term changes and developments on the local and regional level. There also exist first studies to estimate land embodied in internationally traded products.

LEAC has a strong ability to report environmental impacts on land use as this is the core of the method. It has a strong link to report impacts on ecosystems. It can show the loss of ecosystems for different ecosystem types. A link between land use and biodiversity definitely exist but LEAC does not directly show effects on biodiversity (e.g. by reporting numbers of lost species or increase of threats).

RACER analysis of LEAC:

Criteria and Subcriteria	Analysis	Score
Relevant		**2.4**
Policy support, identification of targets and gaps	• *Is the indicator/methodology related to existing EU-specific policy objectives?* LEAC is relevant to all EU policies concerning land use and ecosystem conservation. Furthermore it fits to the Resource Strategy as it show the impacts on land use stemming from resource extraction and consumption. Land use is also covered by specific EU policies (such as urban environment or coastal zone management). • *Does it provide guidance in monitoring, strategic policy making and/or target setting?* LEAC measures actual land cover and land use changes and therefore is a valuable tool for monitoring, policy planning and target setting. For example, some countries (such as Germany) have set national targets for additional built-up land on an annual basis, which can be evaluated by LEAC approaches. • *Does it quantify gaps between the current situation and specified targets?* Yes, if targets for specific types of land use exist. • *Does it provide adequate early warning to guide policy action?* No, LEAC so far only measures actual land use. An early warning indicator would have to look at driving forces influencing future land cover and land use. It could to some extend be an early warning indicator for soil erosion and loss of biodiversity induced by current land use. To some extent LEAC can be regarded as an early warning indicator for loss of ecosystems. As an ex-post tool is only can show ecosystem land already lost but by analysing trends it can show which ecosystems are under pressure. • *Does it react to short-term changes that can (among other things) show whether policies are having an effect?* Yes, but depending on the level of aggregation of data	3
Identification of trends	LEAC data do exist as time series and thus can reflect trends in land use change. Problems with analysing trends arise by changes in land use classifications which result in “artificial” breaks in time	3

	series.	
Forecasting and modelling	• *Can the methodology/indicator be used in a predictive sense to forecast future environmental impacts from natural resource use or for more sophisticated modelling where the impact of different potential policies or of technology progress and/or change of consumption patterns can be simulated?* LEAC could be used for these purposes if it is combined with modelling techniques and sectoral economic data. A number of integrated land use models exist to predict future developments. • *Can the indicator function as an early warning indicator?* LEAC is not suited for this purpose as it primarily measures actual land use. Information from LEAC could be used as an early warning indicator for pressures on biodiversity.	2
Scope/levels of application	• *Does the indicator provide the required local information?* LEAC does provide very detailed local information. • *Is industry-level data provided by the methodology/indicator?* Only very limited, as the current LEAC accounts only separate a very small number of sectors (e.g. industry, transportation).	2
Function- and needs related analysis	LEAC can show changes for different types of land use. If land use data is combined with economic data it could also show impacts on land use from economic developments. Links to other environmental aspects (such as trade-offs between land use and resource use) could only be measured indirectly. LEAC can illustrate flows and changes between different land use types in a matrix form.	2
Accepted		**2**
Stakeholder acceptance	Stakeholder acceptance is generally high. Land use is reported within the EU since many years. The concept is easy to understand and can easily be communicated e.g. through maps. Some stakeholders, however, state that policies to reduce environmental pressures related to resource use must be related to product policies and thus the aggregated information on land cover and land use would not significantly contribute to these policies.	2
Credible		**2.5**
Unambiguous	• *Convey a clear, unambiguous message.* It provides a clear message although some limitations exist as pure land cover data do not directly illustrate environmental effects of different forms of land use (e.g. loss of biodiversity or soil erosion); monitoring these aspects requires additional data. • *Allow for clear conclusions to guide political action.* LEAC can do so as it reports different forms of land use. Conclusions for policy action would be improved if land use data is linked to impacts (e.g. loss of biodiversity by loss of different natural land types) or economic analysis (economic driving forces behind	3

	different forms of land use). • *Interpretation by the general public.* Interpretation by the general public should be easy as the issue is clear and results are often presented in easily understandable maps.	
Transparency of the method	Land use accounting has been used for many years and is reported by statistical offices and environmental agencies. Methodological problems can be identified with regard to different classifications for land categories and changes in classifications. Classifications and land use categories might also differ between countries and regions which poses a problem for comparability.	2
Easy		**2.6**
Data availability	Data are available from national and EU data bases. However problems with classifications could arise and grid sizes for local land use might vary. Furthermore, allocation of land use data to economic sectors poses significant problems.	3
Technical feasibility	Technical feasibility is expected to be good as data is officially published and experiences in land use accounting exist for many years. However, transformation and use of the data requires special software and skills.	2
Complementarity and integration	• *Are there potential complements between the methodology/indicator and the others being assessed?* The main complementary element of LEAC to other methods is its focus on land use as a result from resource extraction and consumption. A main complement to the Ecological Footprint is that LEAC looks at "real" land use instead of calculated land appropriation based on consumption data. • *Is there the potential for further integration of the methodology/indicator with the others?* LEAC could be further integrated with the Ecological Footprint (comparing hypothetical and real land use), with MFA (looking at land use induced by resource use) and input-output techniques and modelling.	3
Robust		**2,6**
Defensible theory	LEAC is basically a geographic measuring and reporting method not based on a complex theory.	2
Sensitivity	LEAC can provide information to all the mentioned issues.	3
Data quality	LEAC data are officially published by the EEA and data quality for the old EU member countries can be rated as good, whereas less reliable for the new EU members. Problems could arise with different land use categories and levels of detail between countries or regions.	2
Reliability	As LEAC is a harmonised system for data collection and	3

	processing, results can be regarded as reliable.	
Completeness	LEAC focuses on land cover and land use. The LEAC systems must be complemented by other indicators, which illustrate the non-land related impacts.	2
Summary appraisal	+ Harmonised data available for many European countries; availability of regional and local data; links land cover and socio-economic variables. - Data deficit for category of built-up land and links to detailed sectoral data.	

Analysis of impact categories for LUA:

Criterion	Analysis	Score
Resource consumption	Only indirectly covered as land use changes with resource consumption. Import/export issues (lands use induces in other countries through trade) are neglected.	0
Land use	Covered.	2
Climate change	Some land-related aspects of climate change could be indirectly covered (e.g. Deforestation, melting of permafrost soils, etc.)	1
Stratospheric ozone depletion	Not covered.	0
Human health impacts	Not covered.	0
Eco-toxicity	Not covered.	0
Photo-oxidant formation	Not covered.	0
Acidification	Not covered.	0
Eutrophication	Not covered.	0
Ionizing radiation	Not covered.	0
Impact on ecosystems and biological diversity	Land use can be reported for different eco-systems types (and loss of ecosystem types) which provides a strong link ecosystem aspects. Impacts on biodiversity are not shown directly.	1
Summary appraisal		**4**