INtegrating MainSTREAM Economic Indicators with Sustainable Development Objectives

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1. Introduction and overview

Sustainable development started as the predicament about intergenerational distribution of resources (natural resources and environmental quality) over very long time horizons (eternity) and was gradually extended to include a whole range of economic and social aspects of human development. Dozens of definitions and hundreds of indicators have been proposed by international agencies, national governments, non-governmental organizations and research institutes. The diversity of definitions indicates a general tendency to incorporate all current social, economic and environmental concerns in the concept of sustainability. The definitions also reflect the highly normative nature of what the proponents consider important for charting sustainable development. Accordingly, the wide range of proposed and adopted sustainability indicators reflects the values and aspirations of communities, countries or regions that developed or accepted them.

Originally, mainstream indicators of development focused on the total volume of goods and services produced in a year (GDP), its growth rate and the average amount per capita. Yet even representatives of the neoclassical synthesis maintain that GDP and the associated measures of welfare are imperfect indicators of the actual level of and improvements over time in fulfilling human needs and desires. (Samuelson and Nordhaus, 2006)

Over the past two decades since the publication of the report by the World Commission on Environment and Development (WCED), also known as the Brundtland Commission (WCED, 1987), attempts to develop sustainability indicators and link them to mainstream indicators of economic development have proliferated. These attempts adopted diverse approaches and different degrees of integration.

This report presents results of a literature survey conducted for the IN-STREAM project. It presents a simple typology and classifies the surveyed literature in the main categories presented below.

Category 1. Indicator lists and subsets

Indicator lists and subsets collect a number of indicators that are thought to represent the current status, past and possible future evolution of features and processes of social, economic and environmental systems that relate to selected sustainability concerns. Often these indicator lists involve a set of stand-alone indicators, each representing one aspect but not related to others in the set. Other lists (e.g., the original indicator set of UN DESA, 1996) are organized into thematic (economic, social, environmental, institutional) and/or some cause-effect framework.

A partly related approach is to define short-lists of the most important elements from broader indicator lists or set them up independently for specific purposes. Such short-lists or headline indicators are mostly used for specific policy-related functions (e.g., monitor implementation and effectiveness of policies related to sustainability) or for communication to the broader public.

Category 2. Capital and accounting frameworks

These approaches represent different types of extensions of the mainstream national accounting frameworks. Their objective is to include selected facets of sustainability into analytical foundations for policymaking.

Category 2a. Capital frameworks attempt to capture and aggregate in monetary terms all types of capital stocks that contribute to the satisfaction of human needs. From the mainstream economic accounting, they include produced capital goods and financial capital and they are complemented by the imputed values of natural, human, social and institutional capital stocks. The non-declining volume of national wealth, defined as the sum of all capital stocks, is the key sustainability criteria in this framework.

Category 2b. Accounting frameworks represent another approach to integrating sustainability concerns into traditional economic systems by extending existing accounting frameworks to include environmental features. The technique is to define satellite accounts measuring selected environmental attributes. This approach improves the consistency and complementarity of sustainability indicators with mainstream economic data and indicator systems. Accounting frameworks can incorporate both monetized and non-monetized aspects (e.g. material flows).

Category 3. Composite indicators

Composite sustainable development indexes allow the integration of environmental, economic and social concerns for sustainability evaluation. Such indexes might help in the development and monitoring of national strategies for sustainable development. Several sustainable development indices and underlying indicators have been developed and applied at different levels of aggregation.

Category 4. Other techniques to link indicators

In recent years, various approaches have been developed and applied to link mainstream economic and SD indicators. The literature survey focused on two groups of techniques: models and participatory approaches.

Category 4a. Models to link indicators. The modeling techniques applied to link indicators range from relatively simple statistical techniques (like factor analysis) to more complex models (systems analysis, optimization models, etc.).

Category 4b. Participatory approaches to sustainability indicator definition and selection. A variety of participatory methods have been used to engage a targeted group of stakeholders or the public at large to identify sustainability indicators that adequately reflect public perception and concerns about various components of sustainability, especially economic performance (income, employment) and environmental quality (pollution).

Category 5. Sectoral indicators

The use of natural resources and the emissions of pollutants by some of the economic sectors are fundamental determinants of sustainability. These sectors (land use and agriculture, the energy sector, the steel industry, etc.) are given special attention in sustainability assessments with a view to linking their economic characteristics (costs, sales, profits, jobs) and their resources and environmental attributes.

Category 6. Indicator reviews and assessments

With the increasing body of literature about developing and applying sustainability indicators, there is a need for stocktaking and critical appraisal of the applicability and usefulness of various indicator sets and composite indexes. These reviews tally the benefits and drawbacks of sustainability indicators and provide guidance both for using them for various purposes in different contexts and for developing better indicators in the future.

Sections 2 to 7 of this report summarize selected items of the literature survey sorted into the six categories above. In several cases it was difficult to decide into which category one should classify a given indicator set, index or other tool because the publication included several aspects (for example, developing a composite index by a participatory process of stakeholders). In such cases the classification was made on the basis of the key features or most important aspects of the given indicator product.

The literature was assessed and the results are presented according to four main features for which the following coding is used in the review sections:

a) practical aim of sustainable development indicator (who should use it and for what)

b) theoretical basis (if any)

c) main characteristics (total number of indicators, is there a core list, etc)

d) other interesting features

In some cases, however, an unstructured summary is more appropriate and the review is provided in that form.

Section 8 presents the sustainability indicators discussed in recent EU efforts that are highly relevant for the IN-STREAM project. The closing section makes some observations about the advantages and drawbacks of linking and/or integrating mainstream economic indicators with sustainability indicators.

2. Indicator lists and subsets

One of the early efforts to compile a list of sustainability indicators was the set of Sustainable Development Indicators (SDI) of the United Nations Department of Economic and Social Affairs (UNDESA, 2007). The UNDESA activity is also related to the work of the Consultative Group on Sustainable Development Indicators, that, in collaboration with the UN Commission on Sustainable Development (CSD), has produced a “straw” set of sustainability indicators organized around the CSD’s indicator framework. These straw indicators include aggregated measures on the environment, social issues, the economy, institutions, as well as an average of these four.

This section reviews publications that propose, present and discuss mainstream economic and sustainability indicators in general or for specific purposes as an unstructured set (list of stand-alone indicators), a set of indicators sorted into thematic groups (horizontal structuring) or indicators organized hierarchically into basic and higher level groups (e.g., detailed or general versus higher level or headline indicators).

Management framework for sustainable development indicators

a) Practical aim
Hezri and Hasan (2004) present a management framework for using sustainable development indicators in a Malaysian region. The authors observe that the sustainable development indicator literature has only recently begun to acknowledge the connection of indicator programmes with broader political systems. In this project, the question of user’s needs is clarified first, namely sustainable development indicator development in the state of Selangor. The foundation for institutionalising the reporting and use of sustainable development indicators is provided by balancing the instrumental rationality with the ‘incrementalism’ of the policy process and then followed by the prescription of indicators sets. Although a relatively new concern for sustainable development indicator, the need to link indicators to policy processes has long been recognised by some researchers. The authors suggest a careful match between the SD indicator system and the existing system of users.

b) Theoretical basis
The initial framing in this paper is provided by models of the decision-making stage in public policy-making of government, for example comprehensive rationality, bounded rationality and incrementalism. A typology of indicator uses is developed on the basis of the degree of rationality exercised in the policy process. The main categories include instrumental use, conceptual use (or use for enlightenment), tactical use, symbolic use, political use. Hezri and Hasan propose using ‘fitness-for-purpose’ indicators rather than a definitive set of indicators. In order to be useful in the policy process, sustainable development indicators must be developed together with policy-makers. Fitness-for-purpose sustainable development indicators are based on the objectivity of the rational model, but adjusted to the context provided by the political model of decision-making.

c) Main characteristics
This paper proposes a three-tier sustainable development indicator system comprising indicators for state sustainability, sectoral sustainability and for the assessment of sustainability at the local government level. The initial set includes 30 indicators in the following four areas: economy (5 indicators), environment (6), natural resource (6) and social (13).

d) Other interesting features
Case study: State of Selangor, Malaysia

Sustainability indicators for the information society

What will be the criteria and the related indicators for measuring the sustainability of the information society? Spangenberg (2005) explores the prospects for transition towards a sustainable knowledge society. He maintains that the information society is not sustainable because information alone is meaningless for the reason that only the context provides the meaning. Therefore a proper context is required for converting information into knowledge. Whether a knowledge society will be sustainable depends on the context. The author argues that in a normative neoliberal framework the knowledge society represents individualization and dismantling social structures. This is in contrast with the context of a (just as normative) sustainability strategy in which the meaning of the 'knowledge society' is different, because it is focused on supporting active citizenship. Therefore criteria for a sustainable knowledge society cannot be restricted to access to information, but must also cover the kind of information, the provision of content as much as the infrastructure. In the last decade or so, a huge number of sustainability indicators has been developed but the work on integrated systems of indicators is relatively new. This is especially true for indicators to characterize the sustainability of the knowledge society. The paper proposes an initial set of indicators towards this end. Results of an evaluation exercise demonstrate that the current trend towards a knowledge economy is not yet sustainable.

3. Capital and accounting frameworks

3.1 Capital frameworks

Indicators for sustainable economic welfare (ISEW): Theoretical foundations

a) Practical aim
The Index of Sustainable Economic Welfare (ISEW) has become an important composite measure among the sustainability indicators. It attempts to measure the so-called “net income”. Brennan (2008) reviews the conceptual foundations of ISEW by attempting to expand on the critical themes and fill any thematic gaps. The main purpose of the paper is to interpret and apply the underlying theories as well as to make critical remarks on certain points.

b) Theoretical basis
Economics for Community, Entropic Net Psychic Income, Social Welfare Function

c) Main characteristics
Brennan (2008) identifies three theoretical foundations of ISEW:
1) The ISEW is conceptually rooted in the “Economics for Community”. According to the author, ISEW is (i) a realistic paradigm based on the principle of internalization; in which (ii) income is based on strong sustainability in principle; and (iii) service to the community is based on the oikonomia model.
2) The paper maintains that the ISEW is conceptually based on “Entropic Net Psychic Income” whereby (i) Psychic income and outgo flow from the capital stocks; (ii) the notion of Fisherian Income is based on minimizing consumption and maximizing the service; (iii) depletion of the finite stock of ecological capital is an entropic process; and (iv) sustainable economic welfare rests on the optimal scale.

3) According to the author, the ISEW is theoretically based on a “Social Welfare Function” in which (i) decision utility is a function of consumption expenditures (GDP); (ii) a workable social welfare function is constructed by combining social choice, partial comparability and cost–benefit analysis;

(iii) negative social and environmental externalities can be calculated by compensatory or defensive expenditures; and (iv) systems analysis is imbedded in the adjusted-GDP indicator to assess the net benefits of economic growth.

The focus of the above three theories is on evaluating the positive and negative implications of economic growth in order to achieve a practical measure of sustainable economic welfare. A critical appraisal shows that the three theories include some major aspects, but have only partial, underdeveloped explanations of the benefits/costs generated in the socioeconomic system. A critical examination of the dialectic of service and disservice is needed in order to separate in the ISEW services that improve community well-being from those that are 'commoditized'.

d) Other interesting features
theoretical considerations

3.2 Accounting frameworks

Resource efficiency indicators

Andersen (2003) investigates the specific material flows and use of energy and land, which cause severe environmental and health problems in Denmark in a risk assessment framework. The author defines resource efficiency in terms of material flows and estimates the efficiency indicator to be 0.07 without unused flows and 0.04 with unused flows for Denmark in 1990. According to Andersen, this indicator shows that the path to both a global sustainable environment and welfare goes through increasing resource efficiency, increasing lifetime of products, detoxification, dematerialization of welfare and increasing quality and quantity of ecosystems. The proposed indicator system applied for Denmark consists of formal indicators structured as a pyramid. Indicators for aggregated material and energy flows, almost unaffected nature and the flows of dangerous substances are at the top of the indicator pyramid. The formal indicators represent flows of resources and emissions, resources and emissions related to ecological space, economic turnover and number of inhabitants as well as resource efficiency, lifetime of materials and material welfare.

Constructing sustainability indicators properly

a) Practical aim
Hueting and Reijnders (2004) observes that many sustainability indicators covering economic, social and environmental aspects of human activities have emerged. One of these efforts is undertaken by a state research institute in the Netherlands (RIVM, renamed in the meantime as the Netherlands Environmental Assessment Agency or PBL) that promotes the construction of sustainability indicators on the basis of different world views. The author is concerned that this world views based approach and the essentially additive character of indicators hide conflicts and therefore cover up difficult choices. Hueting suggests that economic and social elements should be presented as separate indicators. In such a system, physical indicators for sustainability of renewable resources should focus on the processes that form part of life support systems. One attempt at creating sustainability indicators, the so-called "genuine savings" (GS), is only a proper indicator of sustainability when a number of conditions are met; this is currently not yet the case. (See also Section 8.)

b) Theoretical basis
sustainable national income (SNI), Genuine savings (GS)

c) Main characteristics

Hueting and Reijnders (2004) reviews the RIVM proposal for constructing a sustainability indicator covering environmental, social and economic aspects on a country basis that considers these aspects to be interdependent. In this framework, sustainability in terms of a sustainable production level as estimated in the sustainable national income (SNI) is called 'narrow sustainability', whereas the 'three-pillars approach' is described as 'broad sustainability'. According to the RIVM proposal, different indicators should be constructed in line with different world views. Within the framework of specific world views, computing the indicator will apparently be a matter of adding up the composing elements. The authors discuss three problematic aspects of these indicators:

- Relations between production and environmental sustainability: a negative relation seems more likely;
- World view: different social perceptions of what sustainability is;
- Conflicting goals: production level in the short run vs. long term wishes.

According to Hueting and Reijnders, safeguarding the maximum attainable production level without putting at risk future production possibilities is precisely the definition of environmental sustainability and the SNI. Alongside an environmental sustainability indicator, separate economic and social indicators should be presented. Combining these items in one indicator is undesirable because they are often in conflict with one another.

4. Composite indicators

The pioneers of the composite indicators include the following:

- The Environmental Sustainability Index (ESI) (YCELP and CIESIN, 2005)
- The Wellbeing Index (Prescott-Allen, 2001).
- The Dashboard of Sustainability of the International Institute for Sustainable Development (IISD, 2001),
- The Ecological Footprint (Ewing et al., 2008).

ESI was developed by the Yale Center for Environmental Law and Policy, and the Center for International Earth Science Information in collaboration with the World Economic Forum (Geneva, Switzerland) and the Joint Research Centre of the European Commission (Ispra, Italy). ESI measures overall progress toward environmental sustainability for 142 countries through 20 indicators, each of which combines two to eight variables, for a total of 68 underlying data sets. The ESI tracks relative success for each country in five core components:

- Environmental Systems
- Reducing Stresses
- Reducing Human Vulnerability
- Social and Institutional Capacity
- Global Stewardship

There is not a single country from this project that is covered by each of the 68 variables. Altogether 22 percent of the 9,656 data points in the ESI database were missing and the authors estimated missing values for 24 variables, based on a judgment that variables were correlated in the data set. To calculate the Environmental Sustainability Index, the authors averaged the values of the 20 indicators and calculated a standard normal percentile for each country.

Because the 20 indicators span many distinct dimensions of environmental sustainability, it is possible for countries to have similar ESI scores but very different environmental profiles. The

Netherlands and Laos, for example, have very similar ESI scores of 55.2 and 56.3. But they are far from each other for many indicators. Laos has relatively poor scores for human vulnerability, capacity and water quality, areas in which the Netherlands is relatively strong. Similarly, while the Netherlands has quite poor scores for air and water pollution emissions as well as climate change and transboundary pollution, Laos has relatively good results on these metrics.

The **Wellbeing Index** by Prescott-Allen combines a number of measures of human welfare and ecosystem health, producing three aggregated measures: a Human Wellbeing Index, an Ecosystem Wellbeing Index and a Wellbeing Index which is the average of the two (Prescott-Allen, 2001). The Wellbeing of Nations surveys 180 countries using the so-called Wellbeing Assessment, a method of measuring human and ecosystem wellbeing developed with the support of Canada's International Development Research Centre (IDRC) and IUCN-The World Conservation Union. The Wellbeing Assessment method began as a synthesis of assessment approaches formulated by Prescott-Allen's Barometer of Sustainability method. The Barometer of Sustainability is the performance scale designed to measure human and ecosystem wellbeing together. Socio-economic and environmental indicators are combined independently and this enables analysis of the people-ecosystem interactions. It provides the information how close a country is to the goal of sustainability and how it compares with other countries, the rate and direction of change, and major strengths and weaknesses.

Dashboard of Sustainability was made functional by using 46 indicators to compose the three main clusters for over one hundred countries. It is an instrument panel designed to inform decision-makers, the media and the general public on the status of a nation's progress toward sustainability. Since 1996 this concept grew out of the work of the Consultative Group on Sustainable Development Indicators (CGSDI) that has been engaged in critical assessments and design discussions. The Dashboard project is part of the sustainability indicator initiative of the Bellagio Forum for Sustainable Development. Currently, all indicators within one Dashboard are given the same weight during the aggregation. The present dashboard uses inter-country comparisons, and provides only a judgement for one year.

The **Ecological Footprint**, produced by the Global Footprint Network, includes aspects of human waste production and resources consumption that could potentially be sustainable. It shows those resources that within given limits can be regenerated and those wastes that at sufficiently low levels can be absorbed by the biosphere. Ecological Footprint can be used at the level of individuals, cities and nations, though the national accounts are the most robust.

These frameworks and the related methodologies are adopted, modified or taken as a starting point for creating other composite indicators presented in this section.

Genuine Progress Indicator at multiple scales

a) Practical aim

Costanza et al. (2004) present the first attempt to estimate the Genuine Progress Indicator (GPI) at multiple scales (city, county and state levels). They demonstrate the feasibility of applying the GPI approach at these scales and of comparing results across scales and with the national average. The authors admit that data limitations and problems still exist, but they argue that potential solutions to these problems also exist.

b) Theoretical basis

According to Costanza et al. (2004), the Genuine Progress Indicator (GPI), a version of the Index of Sustainable Economic Welfare (ISEW), is a much more comprehensive approach to assessing economic progress than conventional measures like gross domestic product (GDP). GPI adjusts for income distribution effects, the value of household and volunteer work, costs of mobility and pollution, and the depletion of social and natural capital.

c) Main characteristics
The authors summarize descriptions of the 26 elements of the GPI, how they are calculated in general and the basis of the regional estimates. The process starts with the adjusted personal consumption expenditures and entails:
additions: that cover estimates of non-marketed positive benefits (e.g., value of unpaid household work, services of highways and streets); and
subtractions: that account for losses of social capital (cost of crime, cost of family breakdown and divorce, loss of leisure time, cost of underemployment) and losses in natural capital (depletion of non-renewable resources, long-term environmental damage and cost of ozone depletion).
Finally, net investment and net “foreign” lending and borrowing are calculated and incorporated, that can be either positive or negative.

d) Other interesting features
Case study, US

Ecological footprint for world regions

a) Practical aim
Van Vuuren and Bouwman (2005) present long-term scenarios of ecological footprints (EFs) for 17 world regions based on earlier scenarios that were developed using the IMAGE 2.2 Integrated Assessment Model. The IMAGE model involves spatially explicit land-use and land-cover simulation, including climate change and CO2 feedback mechanisms that make this model an appropriate tool for EF calculations. The main objectives of this study are threefold: (i) to use information on energy and land-use systems to analyse the different components of the EF for different world regions, both for the recent past and for possible developments during the 21st century; (ii) to analyse the major factors determining EF trends; and (iii) to provide some insight into possibilities for reducing the world’s EF.

b) Theoretical basis
Van Vuuren and Bouwman (2005) adopt the concept of “Ecological Footprint” in which it is defined as the amount of environmental resources required to support the consumption of a given population.

c) Main characteristics
The starting point for the analysis is the set of global scenarios developed by the Intergovernmental Panel on Climate Change (IPCC) and published in the Special Report on Emissions Scenarios (SRES). The results from the elaboration of the SRES scenarios by the IMAGE model Version 2.2 are used to assess the possible trends of EF-type indicators in different world region, both during the historic 1970–1995 period and, for different scenarios.

d) Other interesting features
Van Vuuren and Bouwman (2005) conduct a global assessment by dividing the world into 17 regions and analyse future trends at this regional level. They focus on the individual EF indicators for different resources. In addition, they present results in terms of a more aggregated EF.

Ecological Footprint assessment for Austria

a) Practical aim
Erb (2004) assesses the land area required for consumption by Austrians in the period between1926 and 2000. In contrast to the conventional Ecological Footprint approach that expresses its results in global average hectares, this study uses country-specific yields for estimating the area of arable land, pastures and forests needed to sustain Austria's socio-economic metabolism.

b) Theoretical basis
The study by Erb is an interesting variation of the Ecological Footprint approach. The main difference between the conventional Footprint method and the method used by Erb is that he does not use global average yields, and hence does not calculate 'global average hectares' (usually referred to as gah).

c) Main characteristics
Erb (2004) aggregates the results according to the customary Ecological Footprint classification into the following land-use classes: pasture area (meat and products from ruminants), arable land area including permanent crops (agricultural cultivars), forest area (roundwood, paper, furniture, etc.) and built-up area (infrastructure area). In addition to these land-use related items, energy land was also calculated.

d) Other interesting features
The Austrian case-study shows that the area demand depends on two factors: consumption level and yields per hectare. In the case of Austria, considerable increases in consumption were counterbalanced by increases in yields. For this reason, Erb suggests that indicators of area demand should be complemented by indicators that evaluate the environmental effects of land use.

The ecological footprint of sustainable tourism

Hunter and Shaw (2007) argue for ecological footprint (EF) analysis to become widely adopted as a key environmental indicator of sustainable tourism (ST). It is suggested that EF analysis provides a unique global perspective on sustainability that is absent with the use of locally derived and contextualised ST indicators. A simple methodology to estimate indicative, minimum EF values for international tourism activities involving air travel is presented. Critically, the methodology accounts for the EF that would have been used by a tourist at home during the tourist trip, providing an estimate of the net, as well as the gross, tourism-related EF. Illustrations of the application of the methodology are provided, including the evaluation and comparison of specific tourism products. It is suggested that some (eco)tourism products may, potentially, make a positive contribution to resource conservation at the global scale.

Non-renewable resource consumption in the ecological footprint

a) Practical aim
The main objective of Nguyen and Yamamoto (2007) is to modify the ecological footprint (EF) methodology by incorporating non-renewable or abiotic resources as an additional category in the ecological footprint evaluation method. The approach is based on the assumption that the use of abiotic resources can be quantified as global hectare by using thermodynamic approaches.

b) Theoretical basis
Ecological footprint

c) Main characteristics
Nguyen and Yamamoto (2007) propose a modification of the original ecological footprint calculation to include the non-renewable, non-fuel resource consumption. According to their method, the resource scarcity of non-renewable resources can be evaluated on the basis of the thermodynamic approach using exergy loss to measure resource depletion, i.e. the decrease in resource potential functions available for future generations. The authors then convert the exergy loss due to the utilization of non-renewable resources into surface area, which is able to absorb solar energy to compensate the losses of exergy. This issue has been considered as one of the limiting factors for sustainable development. As result of the proposed modification, the original EF includes only the occupied biotic area and the required biotic area while the modified EF includes an additional required abiotic area due to non-renewable, non-fuel resource consumption.

A two-dimensional measure of sustainable development

a) Practical aim
Moran et al. (2008) aim to assess progress in two dimensions of sustainable development: advancement of human well-being and development within the ecological limits of the biosphere. The authors assess human well-being with the UN Human Development Index (HDI) whereas development within the ecological capacity of planet Earth is measured with the Ecological Footprint. The analysis compares changes in the two indicators in the time period between 1975 and 2003.

b) Theoretical basis
The assessment by Moran et al. (2008) uses the UN Human Development Index (HDI) and the Ecological Footprint.

c) Main characteristics
Moran et al. (2008) propose as a necessary condition for sustainable development the following thresholds: HDI ≥0.8 and Footprint to biocapacity ratio ≤1. They find that Cuba is the only one country among the 93 surveyed that was in these thresholds. According to the authors, the analysis shows that (a) minimum conditions for sustainable development can be measured; (b) overall, the sustainable development challenge, as defined by minimum conditions that are necessary but not sufficient, is not currently being met; and (c) almost all national and regional trends are moving away from sustainable development.

d) Other interesting features
By analyzing the two selected indicators, Moran et al. (2008) find that countries with the highest HDI currently have the highest Footprint to biocapacity ratios, and high income countries tend to show smaller increases in HDI with greater increases in Footprint to biocapacity ratio relative to lower income countries. They conclude that a combination of ecologically sound development in low income countries and strong efforts to reduce demands on the biosphere in high income countries will be needed for humanity to secure people's wellbeing now and in the future.

Critical comments on the ecological footprint

a) Practical aim
Fiala (2008) offers some critical comments on the ecological footprint concept as a measure of sustainability using examples and historical data. Special attention is given to the paper by Moran et al. (2008), whose work well illustrates the problems of using the footprint to make sustainability arguments.

b) Theoretical basis
Ecological footprint

c) Main characteristics
Fiala’s criticisms of the ecological footprint include the following items: it assumes the need for zero greenhouse gas emissions; it uses national (administrative) boundaries arbitrarily; the footprint in fact measures inequality of resources; it cannot capture technological change, so it fails to address intensive production growth, while it can be useful in understanding extensive growth; as a static concept it cannot capture land degradation.
Fiala (2008) concludes that, while the ecological footprint offers a simple and intuitive estimate of the production inputs for a given consumption level, it fails to address the sustainability of consumption that it was originally conceived to do.

An integrated assessment model for calculating a composite sustainable development index

a) Practical aim
Krajnc and Glavic (2005) developed a model for deriving a composite sustainable development index (ICSD) in order to track integrated information about economic, environmental and social performance of a ***company*** over time.

c) Main characteristics
The authors combine normalized indicators into three sustainability sub-indices and finally integrate them into an overall indicator of a company performance. The process involves determining the impact of individual indicators on the overall sustainability of a company using the concept of analytic hierarchy process.

d) Other interesting features
The ICSD by Krajnc and Glavic (2005) estimates company level sustainability and uses Henkel as the case study company.

Life cycle assessment of environmental impacts

a) Practical aim
Rebitzer et al. (2004) start from the proposition that achieving ‘‘sustainable development’’ requires methods and tools to help quantify and compare the environmental impacts of providing goods and services (‘‘products’’) to societies. The authors observe that practitioners and researchers from many domains come together in life cycle assessment (LCA) to calculate indicators of potential environmental impacts that are linked to products. LCAs assist in the identification of opportunities for pollution prevention and reductions in resource consumption while taking the entire product life cycle into consideration.

b) Theoretical basis
LCA

c) Main characteristics
Rebitzer et al. (2004) reckon that, by helping to support new business opportunities in conjunction with the drive towards sustainable development, LCA is becoming an essential part of most organisations’ toolbox. They conclude that LCA is a powerful set of tools for quantifying, evaluating, comparing and improving goods and services in terms of their potential environmental impacts.

Carrying capacity of agricultural crops

a) Practical aim
Cuadra and Björklund (2007) evaluate the relationship between, and usefulness of, three different analytical methods to assess economic profitability and ecological carrying capacity as two important aspects for sustainable development in tropical crop production.

b) Theoretical basis
The authors use the following three methods in this study: cost and return estimation, ecological footprint and emergy analysis.

c) Main characteristics
In the context of the study by Cuadra and Björklund (2007), sustainable development involves the improvement of production to increase the long-term economic viability and at the same time the need to stay within the ecological carrying capacity of the area. The authors analysed six agricultural crop production systems in Nicaragua. The three methods were used as follows:
(1) cost and return estimation (CAR) is one of the most common economic analyses used by farmers and extensionists to project and evaluate the economic outcome of a production system;
(2) ecological footprint (EF) that does not includes economic valuation, but it has a human centred approach. It is a measure of consumption of a geographically defined population, expressed in terms of bioproductive land area.
(3) emergy analysis (EA) that has an eco-centric approach, since the valuation is based on the environmental work, direct and indirect, needed to generate a resource or a process, irrespective of human preferences.

d) Other interesting features
The results by Cuadra and Björklund (2007) contribute to the body of knowledge on the poor coherence between economic profitability and ecological sustainability. The authors argue that these evaluations may be used as methods for quantitatively assessing different production systems, leading to indices weighting together economic and environmental aspects that may be useful in decision making.

Combining indicators in a fuzzy logic framework

a) Practical aim
Gagliardi et al. (2007) use fuzzy logic to assign weights to different indicators that can be taken into consideration in an environmental impact assessment in order to ensure a significant level of homogeneity and objectivity.

b) Theoretical basis
The methodological foundation of combining the indicators in the Gagliardi et al. (2007) study is fuzzy logic.

c) Main characteristics
Gagliardi et al. (2007) conclude that the final result is a combination of values assigned by expert opinion for the various criteria, processed using fuzzy logic to obtain a weight with significant objectivity. They maintain that it is possible to estimate the sustainability of a city by using these weights.

Embodied energy as an indicator of sustainability

a) Practical aim
Hong et al. (2007) estimate embodied energy (EE) in international trade flow in China during the 1996–2004 period. The authors quantify the effects of EE on sustainability by using one of the most popular indicators—Ecological footprint (EF). The results show that, except for the years between 1997 and 1999, China was a net importer of EE during the period covered by this study.

b) Theoretical basis
The methodological frameworks adopted by Hong et al. (2007) include embodied energy (EE) and the Ecological footprint (EF).

c) Main characteristics
Hong et al. (2007) start with the observation that traditional EF analyses include only consumption and emissions that require land areas. For most imported and exported manufactured goods, which require land area and energy indirectly, EE is adopted to take them into consideration. The authors calculate "energy land" by assessing the amount of a hypothetical planted forest set aside in order to store the CO2 released into the atmosphere by human activities.

d) Other interesting features
Based on their calculation of the above indicators, Hong et al. (2007) conclude that the increasing ecological deficit indicates that China is moving away from sustainability. According to the calculated indicators, Chinese consumption is met by overshooting local resources and occupying foreign resources.

Sustainability index for Taipei
a) Practical aim
Lee and Huang (2007) select 51 sustainability indicators as a basis for assessing sustainable development in Taipei City between 1994 and 2004. The authors classify the 51 indicators into economic, social, environmental and institutional dimensions. They also calculate sustainability indexes for these four dimensions and for Taipei as a whole. From analysing the indexes, the authors conclude that the social and environmental indicators are moving towards SD, while the economic and institutional dimensions are performing relatively poorly. Yet the results also show that since 2002 the economic sustainability index has gradually been moving towards sustainability. The overall Taipei sustainability index indicates a gradual trend towards sustainable development during the past 11 years.

c) Main characteristics
The sustainability indicators selected by Lee and Huang (2007) for Taipei are sorted into four categories of the original UN DESA framework and include the following:

In the social dimension:	*In the environmental dimension*:
1 Average personal income 2 Female/male employment rate 3 Unemployment rate 4 Percentage of households with internet connections 5 Percentage of public places with wireless internet connections 6 Average daily per capita water use (liter) (excluding industrial use) 7 Electricity consumption per person	31 Number of bird species living naturally in the environment 32 Number of fish species living naturally in the environment 33 Green resource index 34 Permeable rate in urban lands 35 Number of days with PSIN100 36 Per capita CO2 emissions 37 Proportion of slightly-polluted rivers 38 Reservoir water quality 39 Tap-water quality

In the economic dimension:
8 Urban population density
9 Female/male life expectancy
10 Number of households below the poverty line
11 Wealth gap
12 Crime rate
13 Annual casualties from public disasters
14 Annual number of transportation accidents
15 Per capita attendance of art and cultural activities
16 Average number of students per classroom
17 Ratio of the population with a college level education
18 Rate of expansion of urban development lands (including residential, commercial, industrial, and public facilities)
19 Per capital floor area of private dwellings
20 Public facility area ratio to urban land areas
21 Per capita park and green areas
22 Riverside park and green area per person
23 Sewerage and waste removal efficiency
24 Rate of sanitary sewerage to total sewerage system
25 Car ownership rate
26 Motorcycle ownership rate
27 Areas covered with public transportation system
28 Per capita pedestrian walkway index
29 Per capita bikeway index
30 Number of bicycle kickstands
40 Per capita daily waste production
41 Recycling ratio for solid waste
42 Ratio of solid waste composted to total waste production
43 Utilization rate for renewable resources (bottom ashes)

In the institutional dimension:
44 Enforcement of local environmental plans
45 Citizen participation in major planning and decision making
46 Joint international cooperation regarding SD
47 Environmental and ecological budget ratio to total budget
48 Social welfare expenditure ratio to total expenditure
49 Government expenditure on pollution prevention and resource recycling
50 Ratio of completed assessments to initiated assessments
51 Appellate statistics of court cases related to environmental pollution

Source: Lee and Huang (2007)

Taking the environmental–social–economic–institutional framework as the starting point, the authors combine the indicators with an equal weighting method to calculate the sustainability index of the environmental, social, economic and institutional dimensions, respectively. In the next step, they use the equal weighting method again to derive a sustainability index from those four dimensions in order to examine the overall trend of sustainable development in Taipei,

d) Other interesting features
Based on their analysis of the overall sustainability trends and those in the four main dimensions, Lee and Huang (2007) recommend that sustainability indicators should be reviewed in three- to five-year intervals to reassess their appropriateness.

Dashboard of Sustainability in an urban context

a) Practical aim
Scipioni et al. (2009) describe the application of the Dashboard of Sustainability to a local urban context, namely the Italian municipality of Padua. The authors verify the validity of this tool in guiding the Local Agenda 21 process and its suitability to address the sustainability measurement problems.

b) Theoretical basis

The Dashboard of Sustainability (DS) is a mathematical and graphical tool developed to measure the different dimensions of sustainability and support the decision-making process by creating concise evaluations.

c) Main characteristics
The original DS was adapted to an urban context whereby two important modifications were made. Instead of the commonly used indicators (mainly at the national level), locally relevant indicators were chosen that were developed by Padua's civic forum. For the comparative evaluation, the sustainability of Padua at several points of time was considered. For the DS software, the 61 indicators were grouped into four categories: economic (12 indicators), environmental (12), social (22), and indicators related to the health board and justice department (15). The time period was 1997-2001. The same unitary weight was assigned to each indicator.

Environmental indicators		*Economic indicators*	
Code	Name of indicator	Code	Name of indicator
A 1	Potable water consumption	E 1	Unemployment rate
A 2	Air temperature	E 2	Inflation
A 3	Annual rainfall	E 3	Poverty thresholds
A 4	Average humidity (%)	E 4	Entrepreneurial attitude
A 5	Sulphur dioxide (SO2)	E 5	New companies
A 6	Particulate Matter	E 6	Insolvent companies
A 7	Nitrogen dioxide (NO2)	E 7	GDP
A 8	Ozone (O3)	E 8	Visitors to museums
A 9	Carbon monoxide (CO)	E 9	Tourist arrivals
A 10	Waste	E 10	Tourist presence
A 11	Recyclable waste	E 11	Hotel use rate
A 12	Electrical energy consumption	E 12	Average stay

Social indicators		*Health board—justice indicators*	
Code	Name of indicator	Code	Name of indicator
S 1	Population density	G 1	Hospital admissions
S 2	Nature balance	G 2	Average stay in hospital
S 3	Migratory balance	G 3	Causes of death
S 4	Immigration rate	G 4	No. of inhabitants per doctor
S 5	Foreign immigration rate	G 5	No. of inhabitants per hospital attendant
S 6	Chief town attraction rate	G 6	No. of health issues
S 7	Birth rate	G 7	Old age rate
S 8	Nationalized foreign residents	G 8	Dependence rate
S 9	Motorization rate	G 9	Number of persons with substandard lodging
S10	Bicycle lanes	G 10	Number of persons without fixed abode
S 11	Pedestrian areas	G 11	Murders
S 12	Road accident rate	G 12	Thefts
S 13	Death rate	G 13	Bag-snatchings and pickpocketings
S 14	Injury rate	G 14	Suicide rate
S 15	Riskiness rate	G 15	Juvenile criminality
S 16	Public transport coverage		
S 17	Seats available on public transport		
S 18	Variation in the number of subscriptions		
S 19	Public transport services		
S 20	Habitable space		
S 21	Sport and recreation facilities		
S 22	Public parks and gardens		

Source: Scipioni et al. (2009)

A participatory approach to creating regional eco-efficiency indicators

a) Practical aim
Mickwitz et al. (2006) report about a Life-Environment project (ECOREG) carried out in the Finnish region of Kymenlaakso. The project explored the use of eco-efficiency indicators as tools for regional sustainability policy. The project adopted a participatory approach to produce indicators that are relevant for regional decision-makers and that will actually be used. The approach established a system through which decision-makers are able to monitor changes using several economic-environmental ratio indicators, and at the same time obtain information on the social progress taking place in the region. The authors emphasize that in the future, an ongoing dialogue among the different actors in the region will be needed in order to ensure that the indicators are indeed used to promote sustainable development.

b) Theoretical basis
Mickwitz et al. (2006) define eco-efficiency as ‘‘the efficiency with which ecological resources are used to meet human needs’’. They maintain that in a broader sense the social dimension of SD are also covered.

c) Main characteristics
Mickwitz et al. (2006) devote more attention to describing the procedure of developing the indicators rather than the indicators themselves. The working procedures involve three groups: a project team, a steering group and workshops participants. The starting point for designing indicators for the eco-efficiency of Kymenlaakso was to first produce indicators for all the three dimensions of sustainability and then to refine them into indicators for regional eco-efficiency. The project applied the newest methodologies (e.g., LCA, MFA), statistical analysis and input-output tables. The combined eco-efficiency ratios were calculated for the whole region, as well as for the most important sectors, and they were constructed so that they may either be calculated for only the activities taking place in the region itself, or be presented including the upstream processes to the extent possible.

d) Other interesting features
The study by Mickwitz et al. (2006) summarizes a regional sustainable development case study in Finland.

Optimal consumption patters as indicator of sustainable consumption

The main focus of the study by Nansai et al. (2007) is on sustainable consumption. The authors calculate optimal consumption patterns of Japanese households using a linear programming model, taking into account the different environmental burdens to be minimized. They define 94 industrial sectors and 94 commodities in the model. In the field of minimizing environmental burdens, the study considered energy consumption, $CO2$ emissions, waste, and NOx emissions. According to the direction (increase or decrease) of adjusted final demand for a commodity in the household, the authors classify commodities into three types: (1) a commodity for which optimal demand should be decreased in all cases of reducing various environmental burdens; (2) a commodity whose optimal demand should be increased in all cases; and (3) a commodity whose optimal demand depends on the type of environmental burden. The study identified 63 commodities whose final demand was assumed to be adjustable. Among these 63 commodities, 47 were categorized as commodity type 1, nine were categorized as commodity type 2, and seven belonged to commodity type 3. The assessment also characterized each type of commodity from the viewpoint of economic and environmental properties.

Constructing composite indicators by mathematical programming

a) Practical aim
Zhou et al. (2007) recognize that composite indicators (CIs) have become widely accepted as a tool for performance monitoring, benchmarking, policy analysis and public communication in many fields, including economy, environment and society. They propose a mathematical programming approach to constructing CIs.

b) Theoretical basis
Zhou et al. (2007) adopt the approach called "Data envelopment analysis (DEA)".

c) Main characteristics
The starting point for the approach developed by Zhou et al. (2007) is the recognition that to a large extent, the usefulness of a composite indicator (CI) depends heavily on the underlying weighting and aggregation schemes. Compared with previous studies, the approach proposed here does not require prior knowledge of the weights for sub-indicators. The weights to be used can be generated by solving a series of DEA-like models. The approach proposed by the authors uses two sets of weights that are most and least favourable for each entity, therefore it might provide a more reasonable and encompassing CI. In addition, the proposed approach can easily incorporate additional information about the relative importance of sub-indicators when they are available.

The approach developed by Zhou et al. (2007) has been applied to elaborate a CI for modelling the sustainable energy development of 18 countries in the APEC region in 2002. The authors found that the two sets of SEI values are highly correlated with each other that may indicate the robustness of the proposed approach in constructing CIs.

d) Other interesting features
The calculation of the CI involves an aggregation method based on mathematical programming.

A multidimensional index of sustainability to measure well-being

a) Practical aim
Distaso (2007) intends to demonstrate that Sen's theory of well-being can be applied to operationalize the concept of sustainable human development by building a multidimensional index of sustainability that takes into account economic, social and environmental variables simultaneously. The author applies this index to EU countries by using the standardised deviation methodology that, in his view, is the closest and most suitable methodology to be adopted for building multidimensional indices.

b) Theoretical basis
The underlying concept is Sen's theory of well-being (also called the "capability approach"). The main difference between the mainstream utilitarian theory and Sen's theory is that in the latter goods or income are an instrument for reaching well-being, but they are not themselves an index of well-being. According to Distaso, three new analytical categories enter the field of welfare economics: functionings, capabilities and freedom.

c) Main characteristics
Distaso (2007) proposes to examine the possibility of creating more adequate indicators of sustainable development, as an alternative to the conventional measures based on the utilitarian/welfarist theories. The author has built a multidimensional index based on the capabilities

approach in order to measure sustainability and/or wellbeing. In his function sustainable development depends on the following variables: consumption, income distribution, life expectancy, health, education, employment, pollution, aesthetic and cultural values. The proposed ways to measure these variables (i.e. turn into indicators) are listed in the table below. They determine the numerical value of Sen's sustainable development indicator.

Variable	Indicator
Consumption (C),	Final consumption expenditure of households and non-profit institutions, expressed in current series in million ECU/EUR adjusted for purchasing power parity (PPS)
Basic functionings:	
Lexb (life expectancy)	Lexb (life expectancy for boys),
Lexg	Lexg (life expectancy for girls),
H (health),	Number of physicians per 100,000 inhabitants
Em (employment),	Rate of employed people aged 15–64 as a share of the total population of the same age group;
E (education),	Number of students enrolled in tertiary education
I (income distribution)	Ratio of total income received by the 20% of population with the highest income on the total income received by the 20% of the population with the lowest income
Relevant functionings:	
Pollution (P)	Emissions of NO2 and SO2
Aesthetic and cultural values, (Acv)]	Percentage of protected areas

According to Distaso, the aggregated wellbeing will be reached through the building of a decreasing ranking which will allow the comparison of the status of well-being of European countries. The aggregation is carried out by giving equal weight to each variable.

d) Other interesting features
According to Distaso's (2007) results from adopting the proposed procedure to derive aggregated wellbeing indicators, Sweden, Austria, France and Germany are ranked as top four in the European Union.

5. Other techniques to link indicators

5.1 Models to link indicators

Sustainability Assessment by Fuzzy Evaluation

a) Practical aim
Phillis and Andriantiatsaholiniaina (2001) develop a model called Sustainability Assessment by Fuzzy Evaluation (SAFE), which provides a mechanism for measuring development sustainability. The model treats ecological (land, water, air, and biodiversity) and human (economical, social, educational, and political) inputs individually and then combines them by using a fuzzy logic technique to provide an overall measure. The output of the model is a degree (%) of sustainability of the system under examination (locality, state, country, etc.).

b) Theoretical basis
The aggregation of the composite indicator is based on a model using fuzzy logic.

c) Main characteristics

Phillis and Andriantiatsaholiniaina (2001) establish an overall system consisting of two subsystems: ecological (air, water, land, biodiversity) and human (health, wealth, knowledge, policy priorities). The authors evaluate each component by using three types of indicators: pressure, status and response indicators. They combine each group of indicators by means of fuzzy logic to provide a measurement of sustainability for each subsystem.

Decision making based on the Sustainability Assessment by Fuzzy Evaluation

a) Practical aim

Andriantiatsaholiniaina et al. (2004) provide an approach to sustainable decision-making at the national level by using sensitivity analysis of the SAFE model. The authors maintain that sensitivity analysis reveals the most important factors contributing to a sustainable society. They apply the proposed method to a number of countries. They find that there is no unique sustainable path and, therefore, policymakers should choose different criteria and strategies to make efficient sustainable decisions for each country.

b) Theoretical basis

The aggregation of the composite indicator in the model presented by Andriantiatsaholiniaina et al. (2004) is based on a model using fuzzy logic. The authors developed a model called Sustainability Assessment by Fuzzy Evaluation (SAFE), which uses basic indicators of environmental integrity, economic efficiency, and social welfare as inputs, and employs fuzzy logic reasoning to provide sustainability measures on the local, regional, or national levels.

c) Main characteristics

Andriantiatsaholiniaina et al. (2004) define overall sustainability (OSUS) as the sum of ecological sustainability (ECOS) and human sustainability (HUMS). The authors use the following ECOS indicators: land (pressure: 4, status: 2, response: 4), water (2+3+2), biodiversity (7+1+2), air (1+4+3). The HUMS indicators include the following groups: political (2+5+1), economic welfare (3+6+4), health (4+4+5), education (4+5+4). All in all, the system comprises of 79 indicators whereby some indicators used in more than one categories.

d) Other interesting features

The SAFE model applies linguistic variables and linguistic rules and provides quantitative measures of human and ecological sustainability which are then combined into overall sustainability. A sensitivity analysis of the SAFE model explores the responses of sustainability variables subject to perturbations in the values of basic indicators. The authors propose that the key problems of sustainable decision-making are establishing priorities among basic indicators and designing appropriate policies that will guarantee the sustainability of development.

The authors conclude that successful policies differ from country to country. More developed countries need to focus mostly on environmental degradation, whereas less developed countries should strive to improve both the environment and the human system. According to the authors, the

SAFE approach provides new insights of sustainable development, and it may serve as a practical tool for decision-making and policy design at the local or regional levels.

Indicators in participatory decision-making

a) Practical aim
Thomson (2005) distinguishes and reviews three major components of participatory decision-making: knowledge, communication and reporting. He develops a prototype knowledge management system based on these components in the context of community forestry.

c) Main characteristics
Thompson's knowledge management system addresses key issues such as differences in literacy levels, interests and technical capability of the participants and organizations and it is organized on the basis of a hierarchical structure of Principles, Criteria and Indicators (PC&I).

d) Other interesting features
According to Thomson (2005), indicators add measurable elements to the criteria. He defines indicators as "a quantitative or qualitative parameter which can be assessed in relation to a criterion. It describes in an objectively verifiable and unambiguous way features of the ecosystem or the related social system or it describes elements of the prevailing policy and management conditions and human driven processes indicative of the state of the eco- and social system." With this framing, the author adopts the proposition that the purpose of an indicator is to show how well a system is working.

An integrated systems approach to intergenerational equity

Narayanan et al. (2007) present engineering for sustainable development (ESD) as an integrated systems approach in the spirit of the Brundtland report, which aims at developing a balance between the requirements of the current stakeholders without compromising the ability of the future generations to meet their needs. According to the authors, this is a multi-criteria decision-making process that involves the identification of the most optimal sustainable process, which satisfies economic, ecological and social criteria as well as safety and health requirements. The authors also observe that certain difficulties are encountered when ESD is applied, such as ill-defined criteria, scarcity of information, lack of process-specific data, metrics and the need to satisfy multiple decision makers. To overcome these difficulties, ESD can be broken down into three major steps, starting with the life cycle assessment (LCA) of the process, followed by generation of non-dominating alternatives, and finally selecting the most sustainable process by employing an analytic hierarchical selection process. The ESD methodology starts with the prioritization of the sustainability metrics (health and safety, economic, ecological and social components). Then the alternatives are subjected to a pair-wise comparison with respect to each Sustainable Development (SD) indicator and prioritized depending on their performance. The SD indicator priority score and each individual alternative's performance score together are used to determine the most sustainable alternative. Narayanan et al. (2007) apply the analytical approach and metrics for ESD to bio-diesel production.

Measuring inequalities in resources use

a) Practical aim
Druckman and Jackson (2008) propose the Area-based Resource Gini (AR-Gini) indicator for exploring the distribution of resources in order to improve the understanding of area-based resource inequalities and their drivers.

b) Theoretical basis
The conceptual foundation of AR-Gini is the widely used inequality indicator, the Gini-coefficient.

c) Main characteristics
Druckman and Jackson (2008) present the concept and methodology for an area-based indicator of inequalities in resource use. They call the indicator AR-Gini (Area-based Resource Gini) and propose that it enables exploration of inequalities in resource use between neighbourhoods. According to the authors, AR-Gini can also be applied to emissions arising from resource use, such as carbon dioxide emissions due to fossil energy consumption and solid waste arising as a result of clothing or food consumption. The AR-Gini is calculated by using results from the Local Area Resource Analysis (LARA) model developed by the University of Surrey.

d) Other interesting features
The review by Druckman and Jackson (2008) shows that the Gini coefficient is increasingly being applied to non-monetary inequalities (especially in energy consumption); but they are not aware of an indicator of inequalities in non-energy resources. According to the authors, the area basis of the AR-Gini is a novel development. The indicator measures inequalities between small local geographical areas and this is of particular relevance to policymakers because sustainable development strategies are often best pursued at local area or community levels.

A Factor Weighting technique to derive composite indexes

a) Practical aim
The objective of the study by Salvati and Zitti (2009) is to develop a regional Factor Weighting Model (FWM) that can be used to estimate the importance of different environmental variables entering a composite index. They apply the FWM in three case studies in Italy for the assessment of sensitivity to land degradation.

c) Main characteristics
The goal for Salvati and Zitti (2009) is to develop an assessments through the use of single variables and thematic indicators which are able to describe the ecological, social and economic dimensions. The authors intend to reach this goal by a procedure that includes the following steps: (i) selecting proxy variables and integrating the information associated to the various dimensions; (ii) translating variables into adequate environmental indicators; (iii) estimating a weight for each indicator through a multivariate time-series approach; and (iv) determining and interpreting possible changes in indicator weights over time. The number of indicators selected and assessed in the three case studies is 14, 14 and 9, respectively. The indicators are sorted into four groups, each representing one

theme: climate quality, soil quality, land use and human pressure. Salvati and Zitti (2009) employ a multiway factor analysis to explore over time the relationships among the selected indicators. Results of the factor analysis show the importance of the environmental indicators by attributing a percent weight to each of them. In all three case studies completed by the authors, the climate and soil dimensions account for the highest weights in the composite index.

Production efficiency as a measure of sustainable development

a) Practical aim

Raab and Feroz (2007) develop a generalized linear-programming approach to international production-efficiency rankings, which can be applied to a wide range of countries in various stages of sustainable development.

b) Theoretical basis

The ranking procedure by Raab and Feroz (2007) involves linear programming, Data Envelopment Analysis and productivity growth accounting.

c) Main characteristics

Raab and Feroz (2007) prepare a ranking of 57 countries (both developing and developed) in terms of overall production efficiency, by employing four components of gross national product (output - maximize) and five resource-availability indicators (input - minimize). The authors adopt the Data Envelopment Analysis (DEA) linear-programming approach and thereby maximize the components of Gross National Product (GNP), subject to minimizing specific resource-input measures. The model includes the following indicators:

Inputs (minimize resources):
- Labor force (total)
- Arable land (hectares)
- Commercial energy use (kilotons of oil equivalent)
- Net merchandise imports (merchandise imports less fuel imports in current US$)
- Net service imports (service imports less travel imports in Balance of Payments in current U.S. $)

Outputs (maximize outputs):
- Private consumption (constant 1995 U.S. $)
- Government consumption (constant 1995 U.S. $)
- Gross domestic investment (constant 1995 U.S. $)
- Exports of goods and services (constant 1995 U.S. $)

Raab and Feroz (2007) observe a significant correlation between material well-being (average GDP per capita) and efficiency when comparing the relative efficiency of developed and developing nations using a common metric. They maintain that, with appropriate precautions, the DEA-based comparative production-efficiency measures can be used by individual national governments and international organizations like the World Bank and the International Monetary Fund to make equitable and sustainable lending-allocation decisions in the public and private sectors of the increasingly interdependent global economy.

d) Other interesting features

Raab and Feroz (2007) believe that production efficiency should be as important a consideration as the aggregate wealth measured by GDP and GNP in sustainable resource-allocation decisions at the national and international public and private sector levels. Comparative statistics that are simply based on aggregate measures such as GNP and GDP without accounting for productivity growth can be inadequate if not misleading.

5.2 Participatory approaches to sustainability indicator definition and selection

Identifying sustainability indicators by participatory processes

a) Practical aim
Fraser et al. (2006) evaluate the impact of participatory processes on sustainability indicator identification and environmental management in three case studies.

b) Theoretical basis
The authors focus on the procedures of the participatory approach.

c) Main characteristics
The three case studies reported by Fraser et al. (2006) are the following:
1) Forest management in Coastal British Columbia, Canada: 'ecosystem management' common basis, 'wellbeing assessment' methodology (combines 5 categories of social and 5 of environmental indicators
2) Kalahari Rangelands, Botswana: work with pastoralist communities to better understand desertification ('sustainable livelihoods analysis', identifying early-warning indicators)
3) The states of Guernsey, UK: the government decided to establish key indicators to monitor the overall effect of economic transition and globalisation in a small and relatively homogenous community

From an in-depth analysis of the three cases, Fraser et al. (2006) conclude that community input can be used to select and choose relevant indicators to monitor and guide planning pathways towards sustainable development. The authors warn, however, that the community input must directly and quickly feed back into the formal planning process. Indicators need to be collected at the lowest possible local level and then aggregated using a relatively simple and transparent aggregation process. In the authors view, this will allow information to be both summarized quickly for policymakers, and unpacked for more careful monitoring and follow-up.

A participatory approach to developing sustainable development indicators in Finland

a) Practical aim
Rosenström and Kyllönen (2007) explore the role of a participatory approach in the outcome of the Finnish sustainable development indicator (SDI) exercise in 1998–2002. The authors analyze the process through three main objectives of the exercise: to achieve stronger democracy, better quality of the end product and a more effective process.

b) Theoretical basis
The authors evaluate a participatory approach for developing national-scale indicators

c) Main characteristics
Rosenström and Kyllönen (2007) report about a long and complex process for selecting sustainable development indicators (SDIs) at the national scale. The final set of SDIs included 83 indicators divided into 20 issues in 3 dimensions. The authors conclude that the Finnish SDI process was successful in producing a widely accepted and feasible set of indicators. They evaluate the participatory approach of the Finnish SDI process and show that the intense and broad participation

of experts and civil servants increased the competence level of the outcome and led to greater efficiency in working methods. According to the authors, however, this led to technocratic participation, absence of democratic participation and absence of social learning.

Combining expert-driven and public participation processes in selecting sustainable development indicators

a) Practical aim
Doody et al. (2009) describe and evaluate the use of the so-called “Q-method” to combine a ‘top-down’ expert-driven process with a ‘bottom-up’ public participation process to develop a list of sustainable development indicators.

b) Theoretical basis
The authors chose the Q-method of discourse analysis because in their view, it has the potential to overcome the difficulties outlined by both ‘top-down’ and ‘bottom-up’ proponents of indicator development by combining both approaches. This fosters the development sustainable development indicators that are both technically sound and incorporate the views of the public.

c) Main characteristics
The Q-method adopted by Doody et al. (2009) involves statement collection in focus groups, followed by statement analysis, Q-sorts and Q-sort analysis. For the list of statements (40 selected) a preliminary list of indicators was developed by a team of experts. Then members of the public evaluated the preliminary list of indicators (37). The final list of indicators was selected so that they were technically sound and incorporated the views of the public.

d) Other interesting features
According to Doody et al. (2009), the Q-method facilitated the participants in making a significant and worthwhile contribution to the development of the indicators by allowing them to discuss sustainable development in their own words and in the context of their lives

6. Sectoral indicators

Sustainability indicators for the transport sector

a) Practical aim
Zachariadis (2005) presents a transport simulation and forecast model which is designed for the assessment of policy options aiming to achieve sustainability in transportation.

c) Main characteristics
Zachariadis (2005) starts from a simulation of the economic behaviour of consumers and producers within a microeconomic optimisation framework and the resulting calculation of the modal split, the allocation of the vehicle stock into vintages and technological groups is modelled. In the next step, a technology-oriented algorithm, incorporating the relevant state-of-the-art knowledge in Europe, calculates emissions of air pollutants and greenhouse gases as well as appropriate indicators for traffic congestion, noise and road accidents.

Sustainability indicators for the information society

The study by Heinonen et al. (2005) considers the development of an information society to be one route on the road to reaching sustainable development. Yet the author observes that the concept of a Sustainable Information Society (SIS) remains vague for many actors. To address this problem, Heinonen et al. (2005) highlights the central concepts of SIS, presents results that consider the current use of sustainable development indicators in Finland, the policy makers' needs and views on SIS, and discusses the criteria for SIS. In addition, the author also suggests two indicator sets as tools for operationalizing and monitoring the development of an SIS. The author proposes that there are clear needs that require the development of cross-sectoral indicators in order to conceptualize SIS better and to provide decision-making processes with new and better indicators. The paper also discusses the adequacy and nature of the suggested indicator sets and puts forward further recommendations.

Multi-indicator assessment of water programmes

He et al. (2007) present an assessment of water (river and lake) environment quality. Their main focus is on a multi-indicator assessment methodology for governmental environmental auditing of water protection programs. The authors suggest that this method can be used to evaluate the performance of national environmental protection programs and provide technical support for environmental auditors.

Indicators of sustainable energy consumption

a) Practical aim
Lenzen et al. (2006) evaluate sustainable household consumption from a global perspective. The authors take per capita energy requirements as an indicator of environmental pressure and investigate the importance of income growth in a cross-country analysis.

c) Main characteristics
Lenzen et al. (2006) start from the observation that one particular stream of sustainable consumption research is directed towards characterising household consumption patterns with respect to their environmental implications while another stream of research aims at explaining the temporal relationship between environmental pressure and economic development, or income. The Environmental Kuznets Curve (EKC) hypothesis proposes an inverse U-formed relationship between per-capita income and environmental degradation.

Lenzen et al. (2006) undertake a cross-country analysis for the following countries: Australia, Brazil, Denmark, India and Japan. They conclude that the data does not support the hypothesis of a Kuznets curve for household energy requirements. The latter increase monotonically with household expenditure and a turning point is not observed. The authors also find that the data does not support the existence of a single, uniform cross-country relationship between energy requirements and household expenditure: elasticities vary across countries. The characteristics of energy consumption are unique to each country and they are determined by distinctive features such as resource endowment, historical events (such as energy supply shortages or introduction of taxes), socio-cultural norms, behaviour and present market conditions, as well as energy and environmental policy measures. Consequently, there is no general recipe to plan for energy demand reductions. Moreover, the results show significant differences in average energy requirements, even at equal income levels. The authors attribute these differences to geographical conditions and population density, but they indicate that energy conservation and technology and consumer lifestyles are also important factors whereas they find that climatic conditions appear to play a minor role in the overall picture. Finally, Lenzen et al. (2006) conclude that demographic and other socioeconomic factors generally have similar influences on energy requirements (age and house type: positive; household size and urbanity: negative).

d) Other interesting features
The study by Lenzen et al. (2006) provides an in-depth comparative analysis of a relatively small segment of the indicators for sustainable energy development.

The role of energy indictors among overall sustainability indicators

a) Practical aim
The study by Kemmler and Spreng (2007) starts from the observation that, due to the fact that human activities and most sustainability issues are closely related to energy use, the energy system is a sound framework for providing lead indicators for sustainable development. General energy-economic models enable the estimation of future states of the energy system. The authors maintain that an energy system-based lead indicator set can be used to develop consistent and coherent future indicator estimates and to track sustainability that would bring a clear advantage over existing indicator sets. Another reflection made by the authors is that in developed countries, the sustainability discussion is focused on environmental topics, while in developing countries the issues of poverty and equity are equally important. Consequently, for measuring sustainable development in a developing country, the inclusion of a poverty indicator in a set of lead indicators is essential. Using correlation and descriptive analysis, Kemmler and Spreng (2007) show that reliable energy-based indicators of poverty can be created. They argue that, although no one-dimensional indicator is a comprehensive measure of poverty, the explanatory power of energy poverty indicators is comparable to that of other poverty indicators. Therefore, in their view, the use of energy indicators is not restricted to environmental and economic issues but is also relevant for social issues.

c) Main characteristics
Energy indicators proposed by Kemmler and Spreng (2007) that are strongly linked to one or the other important sustainability topic for a small set of lead indicators include the following:

Sustainability issue	*Proposed indicator*
energy resource conservation	the ratio of primary renewable energy to total primary energy
economic activity and efficiency	+total primary energy to show activity and performance of the economy +energy intensity, defined as the ratio of total energy consumption to economic output (GDP) +sector-specific energy use and energy intensities
climate change	CO2 equivalent emissions of greenhouse gases – here CO2, CH4 and N2O
air pollution	SOx and NOx emissions caused by fuel combustion as indicators of local air pollution Number of people living in households that rely on solid fuels, as indicator of indoor air pollution
poverty and equity	The energy access-consumption matrix is applied as an indicator of poverty. It is based on the household energy-use pattern and takes the consumed useful energy quantity as well as fuel types into account. Distribution of energy use as indicator of equity: the Gini index of an access-adjusted useful energy measure is estimated

d) Other interesting features
Kemmler and Spreng (2007) state that such cases when one is interested in a basic orientation or wants to compare different regions, a single indicator is often more suitable. They argue that this is exactly the case in the context of the proposed energy system framework for lead indicators of sustainable development at the national level and that these indicators are meant to provide a quick general overview of system behaviour and development. Therefore, according to the authors, for the purpose of lead indicators of sustainable development, the use of the energy access-consumption matrix as a proxy indicator of poverty is adequate, particularly if it is complemented with the equity measure. They conclude that the energy system provides reliable indicator estimates for all the main sustainability areas and that their proposed framework is useful for tracking sustainability on fairly aggregate levels.

Sectoral sustainable development indicators for the aluminium industry

a) Practical aim
Nordheim and Barrasso (2007) report about a programme initiated by the European aluminium industry through its member organisation, the European Aluminium Association (EAA), to explore issues of sustainable development for the aluminium industry. In the first step of this programme, a set of sustainable development (SD) indicators was developed for the industry with the contribution by both internal and external stakeholder groups.

c) Main characteristics
Nordheim and Barrasso (2007) recount a list of 34 indicators that was used in the first survey that attempted to cover approximately 800 plants in Europe producing alumina, primary aluminium, rolling ingots, extrusion ingots, foil and recycled aluminium. The survey used two points in time, 1997 and 2002, in order to start developing a trend for the individual indicators and to measure progress over time. The authors state that the industry response to the survey was very positive, with a total industry coverage of over 80% for 2002 data and 70% for 1997 data based on tonnage reported. They conclude that the EAA is committed to conducting this as a regular exercise and is engaged in a number of stakeholder workshops in order to present the survey results, to review the indicators used and to also consider adjustments in them on the basis of feedback from stakeholders and experiences from the first data collection.

d) Other interesting features
Nordheim and Barrasso (2007) report about sustainable development indicators at the sectoral level for the aluminium industry.

Sectoral sustainable development indicators and index for the steel industry

a) Practical aim
Singh et al. (2007) introduce the notion of sustainability and present a conceptual decision model. The model is using the analytical hierarchy process (AHP) to assist in evaluating the impact of an organization's sustainability performance. The AHP has also been used to determine the weights at various levels. In the process, sub-indices have been evaluated and aggregated to form a composite sustainability performance index (CSPI). The authors evaluate the effectiveness of the proposed model in a case study for a major steel company in India.

d) Other interesting features

Singh et al. (2007) report about sustainable development indicators and composite index at the sectoral level for the steel industry to assess sustainability at the scale of companies and an industrial branch.

Energy indicators for sustainable development

a) Practical aim
Vera and Langlois (2007) summarize the outcome of an international partnership initiative on indicators for sustainable energy development that aims to provide an analytical tool for assessing current energy production and use patterns at the national level. The authors maintain that the EISD are useful for policymakers, energy analysts and statisticians for their assessment of current conditions of energy systems, effectiveness of energy policies in place and in the definition of energy strategies for sustainable development.

c) Main characteristics
The report underlying the summary by Vera and Langlois (2007) identifies and describes 30 Energy Indicators for Sustainable Development (EISD) and provides guidelines and specific methodologies on how to construct them. The indicators are classified into three major dimensions of sustainable development—social (4), economic(16) and environmental (10). They are further classified into seven themes and 19 sub-themes.

d) Other interesting features
Vera and Langlois (2007) illustrate the EISD by presenting short case studies.

Energy indicators for sustainable development in the Baltic region

a) Practical aim
Streimikiene et al. (2007) set the goal to show how the 'energy indicators for sustainable development' (EISD) approach can be used in analysing trends in the development of the energy sector in the Baltic States in terms of sustainability. Additional objectives include setting goals for sustainable energy development according to national and EU priorities, assessing progress made towards sustainable development and identifying new policy actions necessary to achieve these goals.

c) Main characteristics
The basis for the assessment by Streimikiene et al. is the EISD, developed as an analytical tool to help energy decision- and policymakers at all levels incorporate the concept of sustainable development into energy policy. The 30 indicators are classified into three dimensions: social, economic and environmental. Within these dimensions, the indicators are further classified into seven themes and 19 sub-themes.

d) Other interesting features
Streimikiene et al. (2007) report about a case study on sustainable energy development in the Baltic states.

7. Indicator reviews and assessments

A critical review of measures of economic performance, quality of life and sustainable-development

In 2008, French President Nicholas Sarkozy created the Commission on the Measurement of Economic Performance and Social Progress. The Commission, chaired by Joseph Stiglitz and featuring prominent academics and statisticians among its members, released its findings in September 2009 (CMEPSP, 2009). The Commission assessed key issues and made recommendations in three areas: 1) GDP and traditional economic indicators; 2) quality of life issues; and 3) sustainable development issues. The findings are highly relevant to the assessments undertaken within the IN-STREAM project.

A critique of the sustainable development concept and indicators

Lawn (2004) starts with the observation that, while there has been a lot of discussion about how to achieve sustainable development (SD), there has been much less discussion about whether nations have been successful in moving towards the SD goal. According to the author, this is partly due to the haste with which many SD indicators have been devised and the lack of a commitment on the part of the proponents to determine their worthiness, in particular, their policy-guiding value. The author puts forward a concrete representation of the socio-economic process as a means to establishing both broad and narrow definitions of SD. The latter is required to facilitate the emergence of operational rules of thumb that can serve as the basis for a congruent set of SD indicators. Lawn analyses many of the currently existing SD indicators in the paper within this context. He concludes that, despite each indicator possessing inherent deficiencies, they can, especially when examined collectively rather than individually, provide important information to policymakers about past and present activities. Yet the author warns that the policy-guiding value of SD indicators depends very much upon their continuous improvement and, where necessary, the rejection of unworthy indicators.

A review of the core indicators for sustainable development

Hens and de Wit (2003) undertake a review of sustainable development indicators. They observe that experience with the establishment of indicators for sustainable development shows that it is scientifically feasible, most useful for communication with the public, and a necessary navigation instrument to establish measures pertaining to the sustainability process objective. The authors also notice that in most cases long lists of indicators were established to describe the complexity of sustainable development but more recently, these rather technical lists have been reduced to sets of core indicators. Hens and de Wit (2003) compare the shortlists for the USA, the UK and Sweden, and show that six indicators (GDP, greenhouse gas emissions, crime rate, employment, education level and life expectancy) are used by each of them. Based on the comparative analysis, the authors suggest that, despite the limitations related to the way the indicators are measured and the specific national priorities, these commonly used measures might provide the backbone for other countries to develop their core indicator lists. The authors also propose that this strategy be probably the most feasible as long as there are no widely accepted aggregated indicators.

Constructing composite indicators: The experience in natural resources and environmental accounting

a) Practical aim

Alfsen and Greaker (2007) summarise the experiences with natural resource accounting and the parallel debate on how far one should go in synthesising and summarising the information contained in natural resources and environmental accounts into a single aggregate measure like “green GDP”. They briefly describe the latest development in Norway towards the establishment of a set of indicators of sustainable development, and address the relationship between accounting according to the System of Integrated Environmental and Economic Accounts (SEEA) style and the indicators.

b) Theoretical basis
Alfsen and Greaker (2007) address natural resources and environmental accounting and build on the concept of national wealth as a theoretical framework.

c) Main characteristics
The background to the Alfsen and Greaker (2007) study is that the Norwegian commission set up to develop a set of indicators for sustainable development and decided to base the indicator set on *national wealth* as the key-unifying concept. The strategy in the selection of indicators of sustainability was to chose indicators that best reflect the value, defined as the welfare effects, of the various components of national wealth.

Alfsen and Greaker (2007) present an overview of indicators of sustainable development as follows:

Issues that the indicators shall cover	Indicators
1. Climate change	Norwegian emission of greenhouse gases compared with the Kyoto target
2. Acidification	Percentage of Norway’s land area where the critical load for acidification has been exceeded
3. Terrestrial ecosystems	Bird index-population trends of nesting wild birds
4. Fresh water ecosystems	Percentage of rivers and lakes with clearly good ecological status
5. Coastal ecosystems	Percentage of localities along coastal waters with clearly good ecological status
6. Efficiency of resource use	Energy use per capita
7. Management ofrenewable resources	Recommended quota, TAC actually set, and catches of Northeast Arctic cod.
8. Hazardous substances	Household consumption of hazardous substances
9. Sources of income	Net national income per capita, by sources of income: • resource rent from renewable natural resources, • resource rent from non-renewable natural resources, • return on produced assets, • return on human and environmental capital, and • return net income from abroad
10. Sustainable consumption	Petroleum adjusted savings
11. Level of education	Population by highest level of education completed
12. Sustainable public finances	Generational accounts: need for tightening of public finances as share of GDP
13. Health and welfare	Life expectancy at birth
14. Exclusion for the labour market	Long-term unemployed persons and disability pensioners
15. Global poverty reduction	Trade with Africa, by LDC counties and other African countries
16. Global poverty reduction	Norwegian development assistance as percentage of gross national income

d) Other interesting features
Based on their assessment, Alfsen and Greaker (2007) warn that, without a theoretical framework and a solid statistical underpinning, the aggregated SD indicators are likely to lead to little policy relevant information.

Sustainable development indexes at the regional scale

a) Practical aim

Blinc et al. (2006) discuss the concept of sustainable development and relate it to some of the scenarios presented at the Club of Rome Ankara Meeting in 2002, by taking into account the situation after the then prevailing Iraq crisis. The geographical focus of their analysis is on South-East European countries, and they take a closer look at Slovenia and Croatia.

c) Main characteristics

Blinc et al. (2006) analyze the development of South-East European countries and some of their neighbours by comparing several composite socio-economic indexes like ESI, HDI, Real GNP per capita, Globalization Index and Happiness and Life Satisfaction (HLS). They show that Slovenia and Croatia are currently not sustainable. The comparative analysis of Slovenia and Croatia with neighbouring countries, countries in the South-East European region and developed countries demonstrates that both HDI and GI are comparable to countries of a similar level of economic development, and that HLS Index is rather low. In contrast, the authors find that the ESI is actually better than they expected for the level of economic development as measured by GNP.

A survey of sustainability indices

a) Practical aim

Böhringer and Jochem (2007) review the explanatory power of various sustainability indices applied in policy practice. They show that these indices fail to fulfil fundamental scientific requirements making them rather useless if not misleading with respect to policy advice. The authors examine 11 SD indices with a view to their consistency and meaningfulness: the Living Planet Index (LPI), Ecological Footprint (EF), City Development Index (CDI), Human Development Index (HDI), Environmental Sustainability Index (ESI), Environmental Performance Index (EPI), Environmental Vulnerability Index (EVI), Index of Sustainable Economic Welfare/Genuine Progress Index (ISEW/GPI), Well-Being Index (WI), Genuine Savings Index (GS), and Environmental Adjusted Domestic Product (EDP).

b) Theoretical basis

Böhringer and Jochem (2007) focus on scientific rules and the methodologies of aggregating variables.

c) Main characteristics

Böhringer and Jochem (2007) review the following characteristics of SD indices:

Index	Countries	Variables
Living Planet Index (LPI)	n.a.	1100
Ecological Footprint (EF)	148	Arbitrary
City Development Index (CDI)	125	11
Human Development Index (HDI)	177	4
Environmental Sustainability Index (ESI)	146	76
Environmental Performance Index (EPI)	133	16
Environmental Vulnerability Index (EVI)	235	50
Index of Sustainable Economic Welfare (ISEW)	6	25
Well Being Index (WI)	180	87
Genuine Savings Index (GS)	104	5
Environmental Adjusted Domestic Product (EDP)	n.a.	(Many)

Böhringer and Jochem (2007) also document and evaluate the methods of SD indices regarding scale, normalization, weighting and aggregation.

Index	Scale	Normalization	Weighting	Aggregation
Living Planet Index	RNC	$\left(\frac{x_{i,t}}{x_{i,t-1}}\right)$	Equal	$\sqrt[N]{\prod_{i=1}^{N}\frac{x_{i,t}}{x_{i,t-1}}}$
Ecological Footprint	RNC	Transformation in square km	Equal	$\sum_{i=1}^{N} x_i$
City Development Index	RNC	$\frac{x_i - \underline{x}}{\overline{x} - \underline{x}}$	2 steps PCA/experts	$\frac{1}{N}\sum_{i=1}^{N} w_i x_i$
Human Development Index	RNC	$\frac{x_i - \underline{x}}{\overline{x} - \underline{x}}$	Equal	$\frac{1}{N}\sum_{i=1}^{N} x_i$
Environmental Sustainability Index 2005	RNC	Standard deviation	Equal/experts	$\frac{1}{N}\sum_{i=1}^{N} x_i$
Environmental Performance Index	RNC	Best=100 worst=0	PCA and experts	$\sum_{i=1}^{N} w_i x_i$
Environmental Vulnerability Index	RNC/INC	Aim=1 worst=7	Equal	$\frac{1}{N}\sum_{i=1}^{N} x_i$
Index of Sustainable Economic Welfare	RNC	Monetarized	Equal	$\sum_{i=1}^{N} x_i$
Well Being Index	RNC	Best=100 worst=0	Subjective (not derived)	$\frac{1}{N}\sum_{i=1}^{N} (w_i) x_i$
Genuine Savings Index	RNC	Monetarized	Equal	$\sum_{i=1}^{N} x_i$
Environmentally Adjusted Domestic Product (EDP)	RNC	Monetarized	Equal	$\sum_{i=1}^{N} x_i$

With variables represented by xi, weights by wi, and countries by i and years by t.
*Classes of scales:*INC - interval-scale non-comparability; IFC - interval-scale full comparability; RNC - ratio-scale non comparability; RFC - ratioscale full comparability . (Source: Böhringer and Jochem (2007).

d) Other interesting features

Böhringer and Jochem (2007) survey eleven indices that are widely used in policy practice to measure national sustainable development. They have critically assessed the question to what extent the three central steps of index formation – normalization, weighting, aggregation – satisfy fundamental scientific requirements. The authors find that normalization and weighting of indicators – which in general are associated with subjective judgments – reveal a high degree of arbitrariness without mentioning or systematically assessing critical assumptions. They maintain that for undertaking indicator aggregation, there are scientific rules which guarantee consistency and meaningfulness of composite indices but they observe that these rules are often not taken into account. Böhringer and Jochem (2007) conclude that as a consequence of these flaws, SD indices currently employed in policy practice are doomed to be useless if not misleading with respect to concrete policy advice.

Categorising tools for sustainability assessment

a) Practical aim
Based on an inventory of sustainability assessment tools, Ness et al. (2007) present an overview of the tools and attempt to evaluate to what degree existing approaches are able to incorporate the different dimensions of sustainability. The categorisation of sustainability assessment tools is based on the following factors: temporal characteristics, focus areas, integration of nature-society system.

b) Theoretical basis
Sustainability science

c) Main characteristics
The three major categories of the tools for sustainability assessment defined by the authors are:
1) indicators and indices -- non-integrated and integrated,
2) product-related assessment tools -- life cycle perspective,
3) integrated assessment, focused on policy change or project implementation.
An overarching category is monetary valuation that is used when non-market values appear in the above three categories. In the temporal dimension, the tools can be retrospective or prospective.

d) Other interesting features
Suggested definition of sustainability assessment: the purpose of sustainability assessment is to provide decision-makers with an evaluation of global to local integrated nature–society systems in short- and long-term perspectives in order to assist them to determine which actions should or should not be taken in an attempt to make society sustainable.

Prescriptive vs. descriptive elements of sustainability

a) Practical aim
The objective of Korhonen (2007) is to address the prescriptive vs. descriptive divide in sustainable development research. The particular focus of the study is on systems approaches and systems analysis in the environmental dimension of sustainable development.

b) Theoretical basis
Korhonen (2007) uses systems analysis for analyzing prescriptive and descriptive aspects of sustainability.

c) Main characteristics
Korhonen (2007) shows the difficulties and limitations of the four prescriptive and normative planning, design and management principles for systems approaches to sustainable development. The author revises the four principles (roundput, diversity, cooperation, locality) and develops them into four descriptive indicators or metrics. Korhonen maintains that these indicators can be used in sustainability analysis of all complex systems. The contribution of the argument is to raise the issue of prescriptive and normative principles vs. descriptive indicators and metrics in sustainability systems level planning and analysis.

Ecological economics and sustainability indicators

a) Practical aim

Patterson (2006) reviews the development of ecological economics in Australia and New Zealand since its beginnings in the late 1970s. He finds that the main areas of expertise developed by ecological economists in Australian and New Zealand include: theoretical foundations and visions for ecological economics; biodiversity and resilience; input–output analysis; heterodox valuation approaches; analysis of economy–environment interactions; sustainability indicators; sustainable agriculture, fisheries and oceans; and energy/thermodynamics.

c) Main characteristics
According to the citation analysis undertaken by Patterson (2006), research into sustainability indicators has been relatively active compared with the international situation. He finds that a number of indicator approaches have been pursued by the Australia New Zealand Society for Ecological Economics (ANZSEE) members: ecological footprinting, genuine progress indicators, ethical basis to indicators, Kuznets curves, pressure-state-response, aggregating indicators using principal component analysis, accounting approaches and GIS approaches.

Best practice for developing and applying local sustainability indicators

a) Practical aim
Reed et al. (2006) analyse the literature on developing and applying sustainability indicators at local scales to develop a methodological framework that summarises best practice.

c) Main characteristics
Reed et al. (2006) take the following examples of methodological frameworks for developing and applying sustainability indicators at a local scale:

Selected examples	Brief description
Bottom–up	
Soft Systems Analysis	Builds on systems thinking and experiential learning to develop indicators as part of a participatory learning process to enhance sustainability with stakeholders
Sustainable Livelihoods Analysis	Develops indicators of livelihood sustainability that can monitor changes in natural, physical, human, social and financial capital based on entitlements theory
Classification Hierarchy Framework	Identifies indicators by incrementally increasing the resolution of the system component being assessed, e.g., element = soil; property = productivity; descriptor = soil fertility; indicator = % organic matter
The Natural Step	Develops indicators to represent four conditions for a sustainable society to identify sustainability problems, visions and strategies
Top–Down	
Panarchy Theory and Adaptive Management	Based on a model that assesses how ecosystems respond to disturbance, the Panarchy framework suggests that key indicators fall into one of three categories: wealth, connectivity, diversity. Wealthy, connected and simple systems are most vulnerable to disturbances
Orientation Theory	Develops indicators to represent system “orientators” (existence, effectiveness, freedom of action, security, adaptability, coexistence and psychological needs) to assess system viability and performance
Pressure-State-Response	Identifies environmental indicators based on human pressures on the environment, the environmental states this leads to and societal responses to change for a series of environmental themes. Later versions replaced pressure with driving forces (which can be both positive and negative, unlike pressures which are negative) (DSR) and included environmental impacts (DPSIR)
Framework for Evaluating Sustainable Land	A systematic procedure for developing indicators and thresholds of sustainability to maintain environmental, economic and social

Management	opportunities with present and future generations while maintaining and enhancing the quality of the land
Well-being Assessment	Uses four indices to measure human and ecosystem wellbeing: a human well-being index, an ecosystem well-being index, a combined ecosystem and human well-being index, and a fourth index quantifying the impact of improvements in human well-being on ecosystem health
Thematic Indicator Development	Identifies indicators in each of the following sectors or themes: environmental, economic, social and institutional, often subdividing these into policy issues

Reed et al. (2006) observe two methodological paradigms for developing and applying sustainability indicators at local scales: top-down and bottom-up. They also explore how each method implement four basic steps and provide the following scheme:

Methodological paradigm	Step 1: establish context	Step 2: establish sustainability goals and strategies	Step 3: identify, evaluate and select indicators	Step 4: collect data to monitor progress
Top–down	Typically land use or environmental system boundaries define the context in which indicators are developed, such as a watershed or agricultural system	Natural scientists identify key ecological conditions that they feel must be maintained to ensure system integrity	Based on expert knowledge, researchers identify indicators that are widely accepted in the scientific community and select the most appropriate indicators using a list of pre-set evaluation criteria	Indicators are used by experts to collect quantitative data which they analyse to monitor environmental change
Bottom–up	Context is established through local community consultation that identifies strengths, weaknesses, opportunities and threats for specific systems	Multi-stakeholder processes identify sometimes competing visions, end-state goals and scenarios for sustainability	Communities identify potential indicators, evaluate them against their own (potentially weighted) criteria and select indicators they can use	Indicators are used by communities to collect quantitative or qualitative data that they can analyse to monitor progress towards their sustainability goals

Based on their observations, Reed et al. (2006) propose the following criteria for evaluating sustainability indicators:

Objectivity criteria	Ease of use criteria
Indicators should	
Be accurate and bias free	Be easily measured
Be reliable and consistent over space and time	Make use of available data
Assess trends over time	Have social appeal and resonance
Provide early warning of detrimental change	Be cost effective to measure
Be representative of system variability	Be rapid to measure
Provide timely information	Be clear and unambiguous, easy to understand and interpret
Be scientifically robust and credible	Simplify complex phenomena and facilitate communication of information
Be verifiable and replicable	Be limited in number
Be relevant to the local system/environment	Use existing data
Sensitive to system stresses or the changes it is meant to indicate	Measure what is important to stakeholders
Have a target level, baseline or threshold against	Be easily accessible to decisionmakers

which to measure them	Be diverse to meet the requirements of different users Be linked to practical action Be developed by the end-users

Based on their extensive evaluation, Reed et al. (2006) conclude that it is possible to build on the strengths of both top–down reductionist and scientific methods to measure sustainability and bottom–up, community-driven participatory methods in the adaptive learning process. They argue that the inclusion of both bottom–up and top–down stages in the proposed process is vital in achieving the hybrid knowledge required to provide a more nuanced understanding of environmental, social and economic system interactions that are required to provide more informed inputs to local sustainable development initiatives.

A critical comparison of sustainable development indicator metrics

a) Practical aim
Wilson et al. (2007) start with the argument that it is relevant to ask if SDIs have been effective at facilitating sustainable development. The authors address a critical aspect of this question by exploring whether predominant global SDI metrics convey a consistent message towards sustainable development. Towards this end, they compare six global SDI metrics.

c) Main characteristics
Wilson et al. (2007) compare the six global SDI metrics by relative ranking in colour coded tabular format and spatially in map format. Their combined presentation of results clearly illustrates that the different metrics arrive at varying interpretations about the sustainability of nations. The authors analyze the degree of variability between the metrics using correlation analysis.

The six global SDI metrics included in the analysis by Wilson et al. (2007) are the following:
- ecological footprint (EF),
- surplus biocapacity measure (SB),
- environmental sustainability index (ESI),
- wellbeing index (WI).
- human development index (HDI)
- gross domestic product (GDP)

Wilson et al. (2007) present the different SDI metrics collectively in table format and individually in map format in terms of relative sustainability ranking by quintile and conclude that the SDI metrics provide differing, and in many cases conflicting, assessments of country sustainability. The authors observe that there is a fair degree of correlation among some of the metrics: e.g., high positive correlation among the ESI and the WI, and among the WI, HDI and GDP. They also find high negative correlation between the EF and the WI, HDI, and GDP, respectively. Wilson et al. (2007) conclude that the EF and the WI, HDI and GDP provide conflicting sustainable development guidance while there is little correlation between the SB and the other metrics.

According to Wilson et al. (2007), the standard dimension of sustainability most heavily influencing metric can be summarized as follows:

	Environmental	Social	Economic
Ecological footprint	x		
Surplus biocapacity	x		
Environmental sustainability index		x	
Wellbeing index	x	x	
Human development index		x	
Gross domestic product			x

Nevertheless, Wilson et al. (2007) argue that each measure offers potentially valuable information if it is properly interpreted and used in the right context.

d) Other interesting features
The final conclusion of Wilson et al. (2007) is that there is likely no one ‘‘best measure’’ for assessing sustainability and that sustainable development varies according to needs, priorities and values. The study presents Canada as a case study to highlight and explain the discrepancies between SDI measures.

Relationships between sustainability and happiness

a) Practical aim
Zidansek (2007) presents a new strategy that aims to explore the relation between sustainability and happiness in order to promote sustainable development. The author raises the question whether sustainable development in the interest of future generations requires a happiness sacrifice by the current generation. Zidansek concludes from his analysis that apparently no sacrifices in happiness are required because, according to his opinion, it is possible to design strategies that improve happiness and sustainability simultaneously.

c) Main characteristics
Zidansek (2007) assumes that increase in happiness would also benefit sustainable development. To prove this, he compares different measures of happiness with the environmental sustainability indices ESI and EPI. The author maintains that the correlations of IAH and HLY with ESI on the one hand and with measures of political and economic freedom on the other hand demonstrate that people are more motivated to increase freedom than to accept the apparent limitations of sustainable development. From this, he draws the conclusion that societies need such kind of sustainable strategies that increase freedom. According to Zidansek’s opinion, his analysis demonstrates that there is a relatively strong correlation between happiness and sustainability and therefore there seems to be no need to sacrifice happiness of current generation for sustainable development of future generations.

A comprehensive review of sustainability methodologies

a) Practical aim
Singh et al. (2009) present an overview of various sustainability indices that are practically implemented to measure sustainable development and applied in policy practice. They also compile the information related to sustainability indices formulation strategy, scaling, normalisation, weighting and aggregation methodology.

c) Main characteristics

Singh et al. (2009) compile the information about how the various indexes were formulated by implementing the three main steps, i.e., normalisation, weighting and aggregation. These steps are also presented in the overview table.
Summary table of the sustainability indices from Singh et al.(2009):

	Name	Number of sub-indicators	Scaling/normalisation	Weighting	Aggregation
1	Summary innovation, index	17	[+10 -10] mean subtraction	Equal weights	Number of indicators that are more than 20% above the European average minus the number of indicators which are more than 20% below and division by the total number of available indicators for each country
2	Internal Market Index	19	Percentage annual differences	PCA	Synthesis of variables using PCA
3	Business climate indicator	5	--100 to 100	PCA and FA	PCA applied to define weights. One principal component adopted as the composite indicator
4	Investment in the knowledge-based economy	7	Mean subtraction and division by the standard deviation Choice of weights is up to the user Weighted average		
5	Performance in the knowledge-based economy	7	Mean subtraction and division by the standard deviation	Choice of weights is up to the user	Weighted average
6	Relative intensity of regional problems in the community	3	Mean subtraction and division by the standard deviation	Empirical weights are determined considering the degree of correlation between two sub-indicators	Neutralising the effect of correlation
7	Economic sentiment indicator	4	Dividing the month-to-month changes with the average month-to-month change	Equal weights	Summation
8	Composite leading indicators	Number varies across Member States	Mean subtraction and division by the mean of the absolute differences from the mean	Smoothing via ‘‘Months for cyclical dominance moving average’’	Arithmetic average of the normalised indicators

9	Information and communication technologies	5	Country rankings for each indicator		Sum of rankings
10	Environmental sustainability index	68	Mean subtraction and division by the standard deviation	Equal weights	Arithmetic average of the normalised indicators
11	Human development index	3	[0, 1], using minimum and maximum value for each indicator as goal post	Equal	Arithmetic average of the scaled indicators
12	Technology achievement index	8 (grouped in 4 sub-indices)	[0, 1] using minimum and maximum value for each indicator as goal post	Equal	Arithmetic average of the 4 sub-indices
13	Overall health system attainment	5	[0, 100]	Weights based on survey of preferences of informed individuals	Summation
14	Two ''Synthetic environmental indices''	22	Indicators are combined into 2 synthetic indices a structural and a functional one	Equal Arithmetic average of the indicators	
15	National innovation capacity	8	The logarithmic values of the sub-indicators are considered	Multiple regression model	Regression analysis employed
16	General Indicator of Science and Technology	13	FA/PCA was applied to define weights	PCA	PCA (primary principal component of each set)
17	Success of software process improvement	14	Subjective scale	PCA	–
18	European labour market performance	3	[0, 100] efficiency frontier (objective method)	Weight based on value judgement	–
19	Eco-indicator 99	3	Division by a reference value for each indicator	Weighting scheme is selected by a panel of experts	–
20	Concern about environmental problems	11	Dividing the value in each year by the value for the year for which each indicator is first available	Weights derived from public opinion polls	Sum of normalised weights multiplied by the corresponding normalised indicators
21	National Health Care systems performance	6	No standardisation	'Budget allocation' survey of 1000 people across the UK defined the weights for the indicators	Weighted average

22	Index of sustainable and economic welfare	20	Sub-indicators are expressed in monetary terms.	Equal. Allow the user to change the weightings and assumptions used in the index	Arithmetic average of the indicators
23	Index of environmental friendliness	11	Normalisation of problem indices by dividing the sectoral problem index by the value of the national problem index.	Subjective weights for the normalised problem indices are determined from experts by means of the Analytic Hierarchy Process.	Weighted sum
24	Environmental policy performance indicator	6 theme indicators (composed of several simple indicators)	Division by the corresponding (a) sustainability levels, and (b) policy targets	Equal	Sum of the six theme indicators
25	Living planet index	2000 populations of more than 11,000 species	Ratio to current and previous year	Equal weights	Geometric mean
26	Ecological footprint	6	Area	Equal	Summation
27	City development index	5	Distance from mean	PCA/experts	Weighted average
28	Environment performance index	Six policy categories	[0, 100]	PCA/experts	Weighted average
29	Environment vulnerability index	50	Aim = 1, worst = 7	Equal	Average
30	Well being index	87	[0, 100]	Subjective	Weighted average
31	Composite sustainability performance index	Five categories; 59 indicators	Distance from mean divided by standard deviation	AHP	Weighted average
32	Composite sustainable development index	Three categories; 38 indicators	Distance from maximum and minimum	AHP	Weighted average
33	Ford of Europe's product sustainability index	8	Life Cycle Impact assessment	–	–
34	Genuine savings index	3 capitals	Monetized	Equal	Summation
35	Sustainability performance index	5	Area	Equal	Total area per unit product divided by area per capita
36	Compass index of sustainability	Four categories of indicators	[0, 100] normative judgement	Equal	Average

37	ITT Flygt sustainability index	40	[+10, -100]	Company opinion	Summation
38	Environment quality index	Based on multi-attribute utility theory	[0, 10], linear utility function	AHP	Weighted sum
39	Life cycle index	4 categories; 21 indicators	Linear and non linear functions	AHP	Geometric mean
40	G score	5 categories	Subjective	Equal	Summation
41	Index of sustainable society	5 categories; 22 indicators	Mathematical formula for each indicator	Equal	Summation

Singh et al. (2009) confirm the prevalent opinion that indices and rating systems are heavily influenced by subjectivity despite the relative objectivity of the methods employed in the assessments of sustainability. They note that only few efforts to measuring sustainability have an integral approach taking into account environmental, economic and social aspects. The authors also warn that composite indicators may send misleading, non-robust policy messages if they are poorly constructed or misinterpreted. They suggest that sensitivity analysis can help in testing an index for robustness.

8. Selected indicators considered in recent EU projects

This section provides an overview of two recent efforts closely related to the work of the IN-STREAM project. They review and exchange experience regarding the development and application of sustainability indicators that encompass diverse social and environmental factors considered to be important for increasing and maintaining wellbeing in a broader sense but not represented properly in mainstream indicators. Our main focus is on a selection of indicators contributed to the Beyond GDP conference (Section 8.1). Some key findings are summarized from the EU project on "Indicator-Based Evaluation of Interlinkages between Different Sustainable Development Objectives, the INDI-LINK project (Section 8.2).

8.1 Selected indicators considered in the Beyond GDP project

Although GDP remains the most widely used measure of economic performance in the world, there is increasing recognition that measuring economic growth in itself does not take into account all aspect of sustainability, sustainable growth or development. Alternative indicators are needed to complement GDP in order to effectively measure social progress, wealth and well-being in a broader sense. These indicators also need to incorporate social and environmental costs and benefits of alternative development pathways. The "Beyond-GDP" conference brought together high-level experts and policymakers to discuss and clarify what indicators and composite indices are most appropriate to measure progress; and how these can best be integrated into the decision making processes and taken up in public debates. An explicit objective of the conference was to send a clear message to policymakers, the media and the public at large that it is time to look beyond GDP if one wants to get a true picture about socioeconomic development. The conference assessed the feasibility and implications of wide range of indicators.

This section presents an overview of a selected set of contributions to the so-called "Virtual Indicator Expo" arranged as part of the Beyond GDP project. We have reviewed and evaluated the large number of indicators and indices included in this valuable effort. We selected and report about those that are most relevant for pursuing further analysis of possible linkages between the mainstream and sustainability indicators in the In-Stream project. The selected indicators fall into two main categories defined in Section 1: Indicator lists and subsets (see section 8.1) and Composite indicators (see section 8.2).

8.1.1 Beyond GDP indicator selection: Indicator lists and subsets

The Beyond GDP project included a number of interesting ideas that belong to this category of indicators in our classification scheme introduced in Section 1. The selection presented here reveals a large variety, ranging from various net income indicators to large and comprehensive indicators sets, sorted into several subsets according to the main domains of interest.

Adjusted Net Saving as percentage of GNI

Sears and Ruta (2007) present one of the products of The Word Bank activities in developing sustainability indicators. Adjusted net saving (ANS) is intended to measure the actual savings rate in an economy after accounting for both positive and negative factors: environmental changes (like the depletion of natural resources and damages caused by pollution) on the negative side and social aspects (like investments in human capital) as positive items. Adjusted net saving, also known as genuine saving, attempts to assess the sustainability of an economy on the basis of the concepts of extended national accounts. In the spirit of the Brundtland Commission's definition of sustainable development, positive savings are those that foster growing wealth over time and thus ensure that future generations enjoy at least as many opportunities as current generations. In this sense, adjusted net saving provides policymakers with an indicator that helps them track the progress of their country towards a "sustainable" development pathway.

Four adjustments have to be made when deriving adjusted net saving from the standard national accounting measure of gross saving:
(i) consumption of fixed capital is deducted to obtain net national saving;
(ii) current public expenditure on education is added to account for investment in human capital;
(iii) estimates of the depletion of natural resources are deducted to reflect the decline in asset values associated with extraction and depletion;
(iv) deductions are made for damages from carbon dioxide and particulate emissions.

Conceptually, this involves two main steps:
Net National Saving (NNS) = Gross national saving – Consumption of fixed capital
Adjusted Net Saving (ANS) = Net National Saving + Education Expenditure – Energy depletion – Mineral depletion – Net forest depletion – Damage form carbon dioxide emissions – Damage from particulate emissions.
The final step is to divide ANS by GNI to get the ANS indicator measured in percentage terms.

Genuine Progress Indicator

The Genuine Progress Indicator (GPI) (Talberth, 2007) is one of the various attempts to expand the mainstream GDP measures by accounting for social and environmental characteristics considered to be important. Calculation of GPI includes the three steps common to these kinds of “green GDP” indicators. The first step takes personal consumption expenditures, weighted by an index of inequality in the distribution of income to reflect the social costs of inequality and diminishing returns to income received by the wealthy. The second steps involves a series of additions to account for the non-market benefits associated with volunteer time, housework, parenting, and other socially productive time uses as well as services from both household capital and public infrastructure. Finally, deductions are made in the third step to take into account solely defensive expenditures such as pollution related costs or the costs of automobile accidents as well as costs that reflect the undesirable side effects of economic progress. This step also includes deductions for costs associated with degradation and depletion of natural capital incurred by existing and future generations.

A typical GPI calculation includes the following items. On the contributions side, personal consumption expenditures, inequality adjusted weighted personal consumption expenditures, the values attributed to housework and parenting, higher education and volunteer work, services of consumer durables and of streets and highways, and net capital investment are added to obtain the total positive contributions to the GPI. The long list of deductions includes the cost of crime, loss of leisure time, the costs of unemployment and underemployment, consumer durable purchases, commuting, household pollution abatement and auto accidents, plus the costs of water, air and noise pollution, losses of renewable resources like wetlands, farmland and primary forest cover, the depletion of non-renewable resources, damages from carbon emissions due to climate change, the cost of ozone depletion and net foreign borrowing. The difference between the positive contributions and the total negative deductions gives the GPI value for a given year.

(Regional) Index of Sustainable Economic Welfare

Yet another attempt to correct the deficiencies of the traditional GDP as an indicator of wellbeing is the (Regional) Index of Sustainable Economic Welfare (ISEW) presented by Jackson et al. (2007). It is an adjusted economic indicator that includes the costs and benefits not traditionally measured in monetary terms. The ISEW combines a wide range of economic, social and environmental issues into one analytical framework. The quantification of the indicator draws to a large extent on government statistics while non-monetary values are assessed in monetary terms on the basis of unit costs taken from government or academic sources.

The starting point for calculating the ISEW is consumer expenditure. Positive and negative adjustments are made in order to account for various social, economic and environmental factors believed to be important in shaping actual wellbeing. The calculation procedure and its main components are similar to other true-wellbeing attempts. The formula is:

ISEW = Personal consumer expenditure
- adjustment for income inequality
+ public expenditures (deemed non-defensive)
+ value of domestic labour & volunteering
+ economic adjustments
- defensive private expenditures
- costs of environmental degradation
- depreciation of natural capital.

Some further adjustments are made to account for net capital growth and net international position. These may be positive or negative depending on the particular economic situation in a given year. The main challenge of this approach is to monetize assets, good and services for which no markets exist and no market prices can be observed.

Happy Life Years

Among the many attempts to measure and compare quality of life across several countries and over time, several efforts are made to assess happiness. The Happy Life Years (HLY) is one such attempt. It combines data on average happiness assessed in surveys of the overall population on the one hand and data on longevity taken from civic registration, on the other (see Veenhoven, 2007).

The first component of the HLY indicator derives data from survey questions regarding how satisfied or dissatisfied people are with their lives as a whole, measured on a scale between 1 and 10. The second component estimates longevity on the basis of life expectancy. The HLY indicator is then computed by multiplying life expectancy with the happiness component normalized into the 0-1 interval.

EU set of Sustainable Development Indicators

The renewed sustainable development strategy of the EU identifies seven key challenges regarding the achievement of the overall long-term objective of improving the quality of life and well-being on earth for present and future generations. The EU set of Sustainable Development Indicators (SDIs) was developed to measure the progress in tackling each of these challenges (Ledoux, 2007). The SDIs cover ten themes, reflecting the seven key challenges of the EU sustainable development strategy, the key objective of economic prosperity and guiding principles related to good governance. The themes include economic, social, environmental and institutional dimensions. Each theme is divided into subthemes and incorporates one or more headline indicator(s).

- The socio-economic development theme includes three sub-themes: economic development; innovation, competitiveness and eco-efficiency; and employment; with growth rate of GDP per inhabitant as the headline indicator.
- The theme sustainable consumption and production is divided into resource use and waste, consumption patterns and production patterns sub-themes; and resource productivity is the selected headline indicator.
- The theme depicting social inclusion has also three sub-themes: monetary poverty and living conditions, access to labour market and education; while the related headline indicator is the at-risk-of-poverty rate after social transfers.
- The sub-themes in the demographic changes theme include demography, old-age income adequacy and public finance sustainability with employment rate of older workers as the headline indicator.
- The public health theme involves two important sub-themes: health and health inequalities and determinants of health, with healthy life years and life expectancy at birth, by gender as headline indicators.
- Climate change and energy has become a theme of increasing public and political attention in recent years. The two sub-themes are climate change and energy and the two headline indicators are greenhouse gas emissions and the consumption of renewables.
- The theme sustainable transport encompasses three sub-themes: transport growth, transport prices and the social and environmental impacts of transport, with energy consumption by transport as the headline indicator.
- The natural resources theme consists of the biodiversity, freshwater resources, marine ecosystems and land use subthemes, and it is characterized by two headline indicators: the so-called Common Bird Index and the fish catches outside safe biological limits.
- Global partnership as theme points beyond the EU and confirms its sustainability concerns about the whole planet. The three sub-themes are globalisation of trade, financing for sustainable development and global resource management. The selected headline indicator is Official Development Assistance.

- Finally, the good governance theme includes policy coherence and effectiveness; openness and participation; and economic instruments as sub-themes, but no headline indicator.

8.1.2 Beyond GDP indicator selection: Composite indicators

Sustainable Society Index

The Sustainable Society Index (SSI) (van de Kerk and Manuel, 2007) is a composite index based on the Bundtland Commission's definition of sustainable development. The aspiration is to create an index that shows the level of a country's sustainability at a glance. The revised version of the UN CSD's definition emphasizes three main characteristics of a sustainable society: it meets the needs of the present generation, it does not compromise the ability of future generations to meet their own needs, and each human being has the opportunity to develop itself in freedom within a well-balanced society and in harmony with its surroundings.

The index is composed of 22 indicators clustered into 5 categories. They are:
- personal development (healthy life, sufficient food, sufficient to drink, safe sanitation, education opportunities and gender)
- clean environment (air quality, surface water quality and land quality)
- well-balanced society (good governance, unemployment, population growth, income distribution and public debt)
- sustainable use of resources (waste recycling, use of renewable water resources, consumption of renewable energy)
- sustainable world (forest area, preservation of biodiversity, emission of greenhouse gases, ecological footprint and international cooperation).

Each of the 22 indicators is measure on a normalized scale from zero (no sustainability at all) to 10 (full sustainability) and the meaning of sustainability is defined for each indicator. In some cases an absolute definition is claimed to be possible, in other cases the maximum value of the indicator in a given sample is taken as "full sustainability" whereas the lowest value is assigned the zero sustainability value.

(Environmentally) Sustainable National Income (eSNI)

Hueting (2007) proposes that in addition to the standard national income (NI), an extended indicator is needed to account for environmental losses. He claims that the "eSNI is the only indicator which (1) is directly comparable with standard NI because it is estimated in accordance with the conventions of the System of National Accounts (SNA); (2) relates the measurable physical environment ('ecology') with subjective preferences (economy); (3) provides the distance between the actual (NI) and sustainable (eSNI) production level in factor costs; and (4) shows the development of this distance in the course of time and thus shows whether or not society is drifting further away from environmental sustainability defined as keeping vital environmental functions available for future generations" (Hueting 2007).

The eSNI is defined in a given year as the maximal attainable production level by which vital environmental functions remain available for future generations, based on the technology available at that year. It follows that the eSNI provides information about the distance between the current and a sustainable situation.

Human Development Index

The Human Development Index (HDI) was first introduced in the 1990 edition of the UN Human Development Report to incorporate social aspects, beyond GDP, in the overall frame of reference for both social and economic development. The HDI is a composite index measuring the progress of a country's average level of long-term human development (Gaye, 2007). It covers three basic dimensions: a long and healthy life, access to knowledge and a decent standard of living. In each dimension so-called goalposts (a minimum and a maximum value) are set that show where a given country stands in relation to these goalposts, expressed as a value between 0 and 1.

The life expectancy component is established in the range between a minimum value for life expectancy of 25 years and maximum value of 85 years. The knowledge component is itself a composite measure that reflects the adult literacy rates and the combined gross enrolment ratio in primary, secondary and tertiary education, weighted to give adult literacy more importance (two-thirds). The lower end of this goalpost is set at 0 and the upper end at 100%. Finally, the standard of living is derived from GDP per capita converted to US dollar at purchasing power parity (PPP) and by setting the goalpost for minimum income is US$100 and the maximum is $40,000. Similarly to the Bernullian utility function widely used in economics, a logarithm of income is used to reflect the diminishing importance of income with increasing GDP in the calculation of the HDI. The scores for the three HDI components are then averaged in an overall index.

Ecological Footprint

Wackernagel (2007) starts from the premise that renewable natural resources represent a vital asset for sustainability. A fundamental requirement for their sustainable use is that appropriation should be slower than the natural replenishment rate. Violation of this minimum condition means running an ecological deficit. To manage ecological assets properly, a measure of the use of nature is needed in the form of resource accounts that keep track of the amount of "nature" available and the amount used. The principles of ecological accounting are similar to those of financial accounting: available capital, revenues and expenditures are measured and accounted.

The Ecological Footprint measures both the resources consumed and the wastes produced by societies. They cover resources from forests, cropland, fisheries, grazing land and other ecosystems goods and services. The built environment affects the land's ability to provide biological resources. At the other end of the material life cycle, ecosystems absorb and assimilate the wastes produced by the processes of human societies' resource metabolism. The Ecological Footprint calculates and sums up the required ecosystem areas to measure total human demand on nature. This is compared to the limited capacity of ecosystems to supply natural resources due to the limited availability of water, climatic resources, solar energy, etc. under a given set of technologies and management practices called biocapacity. When a society's Ecological Footprint exceeds its biocapacity, biological resource 'overshoot' occurs and ecological deficit is made.

Best et al. (2008) assessed the potential of the Ecological Footprint (and related resource-use indicators) for use by the European Union as a means of monitoring environmental impacts from natural resource use. The study identified a basket of four resource indicators considered promising as a means of assessing the EU's progress in fulfilling its Thematic Strategy on the Sustainable Use of Natural Resources.

World Happiness Index

The World Happiness Index (WHI) (le Roy, 2007) is a comprehensive index that attempts to account for all important factors that make countries and the world happy. Forty indicators are chosen altogether, ten each in four main domains. The overwhelming majority of the selected indicators represent social and political attributes.

In the domain *peace and security* indicators include: the number of nuclear warheads, number of victims of major armed conflicts, military expenditures, number of violent deaths, number of refugees, number of victims of natural or technological disasters, corruption, economic and financial security, and the probability of dying before age 60.
The cluster *freedom, democracy and, human rights* incorporates the number of people living freely, level of democracy in the world, press freedom, children rights represented by the under-5 mortality rate, death penalty, women rights measured by a gender development index, the percentage of female parliamentarians, women's school enrolment, boys' and girls' school enrolment and child labour.
Components of the *quality of life* domain consists of GDP per capita, GDP per capita disparities, life expectancy at birth, human poverty index, GINI coefficient, suicides, CO2 rate, forest area per capita, water and hygiene and clean air.
Finally the domain *research, education, information, communication and culture* incorporates research and development, boys and girls education rate, adults literacy rate, education disparities, number of copies of daily newspapers per capita, number of television receivers per capita, information and communication technologies (ICT) covering phones, PC and Internet, number of movies and international tourist trips.

Corruption Perceptions Index

Concerns about corruption have been increasing in most countries in recent years because it heavily affects social wellbeing and it often has severe implications for natural resources and the environment. Transparency International (2007) developed the Corruption Perceptions Index (CPI) as a composite index (practically a survey of surveys) that assesses and compares perceived levels of corruption among public officials and politicians in many countries around the world. Transparency International estimates and publishes the CPI annually. The index reflects the views of business people and country analysts from around the world. The overall objective of the CPI is to provide a global assessment of corruption and enhance comparative understanding of levels of corruption worldwide. The CPI effort demonstrates that corruption can be measured with a sound methodological instrument.

The CPI method combines data from a range of corruption surveys into an index. It takes results of surveys of experts and business people carried out by various independent institutions. These interviews involve experts and business people who are residents or non-residents of the country at hand as well as experts of international organizations. The data gathering also includes quality control: data must be well documented in order to qualify for inclusion in the CPI. The methodology also includes a sort of data smoothing: the index calculation combines expert assessments from the last two years to avoid the possible distorting effects of recent events such as one major corruption scandal.

Index of Individual Living Conditions

The Index of Individual Living Conditions (IILC) (Noll, 2007) is part of the European System of Social Indicators (EUSI). It is a composite index developed to provide a synoptic view of the quality of living conditions in a single measure. In contrast to most other indicators, the IILC is derived from microdata at personal and household levels. The IILC is calculated as the mean score of seven subindices, each ranging from 1 to 5. The subindices cover the following areas: income and standard of living, housing, housing area, education, health, social relations and work. Accordingly, the Living Conditions Index is also measured on a scale between 1 (worst) and 5 (best).

The micro-level framing is both a virtue and a drawback. When the data are collected in a comprehensive microsurvey, the IILC can be calculated to compare the situation of subgroups (based on age, gender, educational level etc.) within a population. However, designing and implementing such surveys requires a major effort and it is difficult to ensure international comparability.

Canadian Index of Wellbeing (CIW)

Slotek (2007) summarizes a recent Canadian initiative to measure and report on the quality of life of Canadians. The initiative involves eight domains in which various aspects of quality of life are estimated and then combined in a composite index.

Wellbeing in the eight domains are measured according to the following definitions (see Slotek, 2007):
Living Standards as a concept is the closest to traditional wellbeing measures. It is defined as the quality and quantity of goods and services, both public and private, available to the population, also considering the distribution of these goods and services within the population.
Healthy Populations measures the status and trends of health of a population in the broadest sense – being alive and well, experiencing disease, disability and delaying death, lifestyles and care received.
Educated Populace includes basic features like the literacy skills required to function effectively in society. It also accounts for contextual situations and systems, social and economic interconnections, current world events, the processes of the natural world, and the influence of current lifestyles on population health and on the choices and quality of life of future generations.
Vital Communities are characterized by strong, active and inclusive relationships between residents, private sector, public sector and voluntary organizations that work to foster individual and collective wellbeing. Vital communities are those that are able to cultivate these relationships in order to create, adapt and thrive in the changing world and thus improve wellbeing of citizens.
Ecosystem Health measures the state of wellbeing and integrity of the natural environment. This includes the sustainability of Canada's natural resources and the capacity of the ecosystems and watersheds to provide a sustained level of ecological goods and services for the wellbeing of Canadians and other species in nature. This domain examines both the current state of Canada's ecosystems and changes over time.
Civic Engagement measures the health of democracy. It addresses three aspects of public lives and the governance of society: the extent to which citizens are engaged in public life and governance; to what extent governments function in an open, transparent, effective, fair, equitable and accessible manner; and how far are Canadians, the governments and corporations good global citizens. Civic engagement includes the electoral processes as well as the policy and decision-making processes at all levels of government.
Time Use measures the use of time, the way people experience time, the factors controlling use of time and the ways these affect wellbeing.
Arts and Culture (this is still a working concept, not a definition yet) are difficult to define in abstract terms. Culture is conceived as a rather general term covering all forms of human expression, like people's language and how the contours of Canada's multicultural society can be sketched with measures of linguistic usage. Art is a particular type of culture and includes performing, visual and media arts as well as facilities like galleries and all kinds of museums, historical and heritage sites.

Sustainability Vision and Indicators

Kobayashi (2007) presents the Sustainability Vision and Indicators (SVIs) developed by the Japan for Sustainability institute. It includes 20 headline indicators for sustainability based on an analysis of over 200 data sets in several sustainability-related categories.

The 20 SVIs are selected to represent key sustainability concerns in 4 main domains: nature, economy, society and well-being. Each of these domains is characterized by five headline indicators.

8.2 An indicator-based evaluation of interlinkages between different sustainable development objectives: The INDI-LINK project

The main objective of the INDI-LINK project was to improve the EU Sustainable Development Indicators. The project assessed the interlinkages between the different priorities of the renewed EU Sustainable Development Strategy and derived policy conclusions for its implementation.

The INDI-LINK project selected nine indicators from the Eurostat list of indicators denoted as "indicators to-be-developed". These indicators were picked because they their conceptual or methodological foundations were found to be underdeveloped and in need of improvement (Hak, 2009). By using two criteria in combination (relevance and credibility) the following indicators were selected for further development:

- Unmet needs for healthcare
- Child wellbeing
- Green public procurement
- Administrative cost imposed by legislation
- External costs of energy consumption
- Vehicle-km
- Biodiversity index
- Total material consumption and GDP at constant prices
- Environmentally weighted indicator of material consumption

The work on these indicators revealed severe problems in both the conceptual foundations and the methodologies of implementation. For several indicators the poor availability of data raised questions about their practicality. Therefore the INDI-LINK project performed in-depth reviews and assessments of the current status of the relevant concepts, approaches, tools and methodologies. These reviews revealed that the indicators "Biodiversity index" and "Child wellbeing" are not yet operationalised properly. The project also proposed methodological improvements for the following indicators: "Vehicle kilometres", "Environmentally weighted indicator of material consumption", and "Unmet needs for healthcare". Another set of activities involved pilot calculations and methodological comparisons for "Total material consumption", "External costs of energy use", "Green public procurement" and "Administrative cost imposed by legislation".

The component of the INDI-LINK project that is of special interest to IN-STREAM carried out model-based experiments for interlinking indicators for sustainability (van Drunen, 2009). This activity started out with a review of possible methods and tools for assessing such interlinkages. Five methods and tools were selected for detailed evaluation to explore to what extent they can reveal interlinkages between different sustainable development indicators. The selected methods are summarized in the table below.

Overview of methods and tools for future interlinkages assessment

Multicriteria analysis (MCA)	Global Vector-Autoregression model (GVAR)	Global INterindustry FOrecasting System (GINFORS)	Dynamic applied general Equilibrium model with pollution and Abatement for The Netherlands (DEAN)	Advanced sustainablitiy analysis (ASA)
Multi-criteria analysis supports comparison of different policy options on the basis of a set of criteria. It can integrate a diversity of criteria in a multidimensional guise and it can be adapted to a large variety of contexts.	The global VAR model is deduced from a set of country vector autoregression models. They deliver linkages or relations between different variables within a country. Using specific weights, the coefficients of the global VAR model are calculated.	GINFORS is an economy- energy-environment model with global coverage. All EU-25 countries, all OECD countries and their major trade partners are explicitly modelled. The model is based on international statistics data from 1980 to 2004.	DEAN is a multi-sectoral dynamic applied general equilibrium model for a small open economy with special attention to the specification of pollution and abatement for several major environmental themes simultaneously.	ASA applies the decomposition technique into environmental stress or social welfare indicators and interprets the decomposed factors as indicators either advancing or threatening sustainability.

Source: van Drunen (2009)

These methods and tools were tested in case studies on different aspects of EU climate policies. The first observation was that most models do not reveal interlinkages *per se*, therefore additional analysis is required in many cases. Only a few tools involve a theory about the nature of the interlinkages that allows specifying cause-effect relationships between the observed trends of different indicators. The lack of underlying theories about future interlinkages between indicators of the social, environmental and economic pillars of sustainability limits the usefulness of many methods.

The INDI-LINK project found that only few methods and tools are able to identify quantitative and causal interlinkages between sustainability indicators. These are typically the coupled environment-economy models. A few case studies implemented in the INDI-LINK project (including those applying Multicriteria Analysis or Vector Autoregression) involved social indicators such as literacy rate and life expectancy. These case studies also found that integrated economy-environment and general equilibrium models appear to be most suitable for exploring trade-offs and synergies between sustainability indicators and national or international policies. The INDI-LINK project concluded that "There is no single, best method or tool to analyze interlinkages between the whole range of sustainable development indicators (SDIs). The choice depends on the policy scale (EU, national, local), the interlinkages to be investigated (pillars, causality), (historical) data availability, and the intended use of the study" (van Drunen 2009).

9. Summary and conclusions

A large amount of effort has been devoted to establish conceptual, quantitative and policy-oriented linkages between traditional mainstream and sustainability indicators. The large variety of the theoretical frameworks and methodological approaches reflects the still existing diversions in the interpretations of what sustainability is and what might be the appropriate indicators to measure progress towards it on the one hand, and in the possible applications of the sustainability measures in analysis, diagnosis and decision making.

The proliferation of the scientific literature about sustainability indicators can be best illustrated by a few numbers that were gathered during the literature search and assessment reported here. When searching for the combined term “sustainable development and indicators” in the fields Abstract plus Title plus Keywords, around 350 hits were found in Science Direct and over 2200 in Scopus. The upward trend in the number of publications found with the above search term is demonstrated by the Scopus results:

1990 – 5
1995 – 23
2000 – 81
2005 – 228
2009 – 265

These numbers clearly show a sustained high interest in the last five years. When searching for the combined term “sustainable development and indicators” in full text or all fields, the number of hits is much higher: around 8,000 -11,000. The Web search by Scirus system provided more than 200,000 hits.

A similar quantitative assessment was made by searching for selected sustainability and sustainable development indicators. The results show overwhelming interest in Ecological Footprint and the Human Development Index, as shown below:

Ecological Footprint	~1000
Human Development Index	~1000
Index of Sustainable Economic Welfare	~200
Genuine Progress Indicator	~100
Genuine Savings	~60
Well-being Indicator	~30
Dashboard of Sustainability	~15

A number of lessons can be draw from the literature survey presented in the preceding sections concerning the various options to link indicators or to combine them into a composite index in order to provide a summary characterization by one number.

Problems with the composite indicators

Despite many attempts to build a sustainable development index, the “perfect” index doesn’t exist yet and most of the sustainable indices have the following similar problems:

- **Missing data** - usually there is not a single country that is covered by each of the variables used for indicators. The estimation of missing values can be based on a judgment that these variables are correlated with other variables or with external predictive variables. Thus the estimation of missing data is an important and necessary procedure, but could potentially put the process of evaluation into another level of complication and/or controversy.
- **Data quality -** Any data being used for an index should be of the highest possible standard, but many indicators are not standardized and their definitions are different for different countries.
- **No common denominator –** Developing a single sustainable development index is difficult because a common denominator for adding up assets is lacking. Indicators are valued in monetary terms, energy units and other measures, but dollar or energy values are often difficult and/or controversial to assign to social or environmental assets. Thus, the aggregation of very different types of data place fundamentally irreconcilable issues into a common unit of measure so that

they can be combined, and this brings about another level of potential complication and controversy.

- **Implied tradeoffs –** The aggregation, for example, of a range of environmental indicators into a common unit of measure, implies a set of trade-offs that may not in fact exist. How much improvement in radioactive discharges, for instance, could compensate for a serious increase in the GHG's levels.
- **Weighting –** Another problem is to aggregate upwards into a single overall figure. Currently the aggregation of indicators into an index is usually based on the assumption of equal weights for all indicators though this approach could bring some inaccuracy.
- **Differing targets –** In addition, as far as the countries have different climate, economical structure, level of economic development, availability of natural resources and so on, the definition of sustainability in terms of real values could be different. A comprehensive analysis of where countries are at in terms of their own sustainability objectives may be useful.

Due to these deficiencies and the difficulties to alleviate them, the diversity of ideas concerning frameworks end methodologies to devise sustainability indicators and link them to well-established mainstream indicators is healthy. The above list also entails various reasons why it is not possible to decide which indicator or index is better than the other. The old "horses-for-courses" principle applies: analysts should assess the main characteristics of the socio-economic, environmental and policy context in which indicators are needed for a sustainability assessment for charting future development pathways and select existing or develop new indicators as required.

The review also shows that most indicators, even those that appear to be rather peculiar at the first look, might provide guidance for analysis, goal setting, strategy formulation and policymaking. Suitability for purpose depends on prevailing ethical principles, social values and individual aspirations as well. Moreover, the choice of the "appropriate" indicators also depends on the purpose and intended use as well as on the targeted audience.

Our survey confirms an important observation that is not new by any means: there is no single best indicator or index of sustainable development. No one-size-fits-all solution can be made available regarding which targets and measurements take societies closer to sustainability. Therefore no miraculous recipe can be provided how best to link mainstream and sustainability indicators. There is a need for further experimentation, continuous testing and improvements in both developing and linking indicators. The review presented in this report is hoped to support activities in the IN-STREAM project in their endeavour to contribute to this process.

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