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PASHMINA – Paradigm Shifts Modelling and Innovative Approaches

Indicators for Sustainable Energy Development – The PASHMINA Approach

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Abstract

In recent years the scientific discussion on how to best measure societal progress has gained increasing attention in the political arena. The underlying question is whether the indicators currently used are able to provide adequate information and are appropriate for guiding political decision making with respect to societal progress and welfare.

Closely related to the concept of sustainable development a wide range of measurement approaches evolved that focus on different aspects relevant for societal wellbeing and progress. For the PASHMINA project we develop a set of sustainability indicators focusing on stocks and flows using the EU Sustainability Development Indicators and the IEA-IAEA Sustainable Energy Development Indicators as starting point. The focus of the PASHMINA indicator set is put on energy supply and use. The motivation for this focus is twofold: first, energy plays a central role for all dimensions of sustainable development; second, energy is crucial when focusing on the role of stocks, flows and services relevant for wellbeing.

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Contents

1 Introduction

In recent years the scientific discussion on how to best measure societal progress has gained increasing attention in the political arena (see e.g. www.beyond-gdp.org; www.stiglitz-sen-fitoussi.fr; www.oecdbetterlifeindex.org). The underlying question is whether the indicators currently used are able to provide adequate information and are appropriate for guiding political decision making with respect to societal progress and welfare.

Gross domestic product (GDP) is the prevailing measure of economic activity. Securing and enhancing economic growth – measured by GDP growth rates – is widely regarded as a central target in economic policy as well as a precondition for coping with social problems and for meeting other challenges such as environmental problems[1]. Economic growth is hence perceived as a key factor for a society's welfare[2].

The conventional quantitative growth paradigm is questioned from the perspective of sustainable development which goes beyond merely economic aspects and accounts for the contribution of social and ecological factors to welfare. These dimensions have also been taken up in the policy agenda (Lisbon and Europe 2020 Strategy, UN Millennium Goals, Kyoto, etc.), but lose in priority in short term policy making, particularly if other pressing economic problems prevail e.g. the Euro crises. This also results from a lack of "prominent" and generally understandable measures for the non-economic dimensions that can be easily communicated. National and international research and policy initiatives (CMEPSP, Beyond GDP, OECD Better Life Initiative, etc.) hence emphasise the need for additional information and measurement approaches in order to capture relevant aspects that go beyond national accounting systems for supporting policy makers and to monitor policy impacts.

For the PASHMINA project we develop and propose a set of sustainability indicators focusing on stocks and flows. As a starting point and input for the PASHMINA approach two indicator sets are chosen: the EU Sustainability Development Indicators and the IEA/IAEA Sustainable Energy Development Indicators. The focus of the PASHMINA indicator set is put on indicators related to energy supply and use. The motivation for this focus is twofold:

- First, energy plays a central role for all dimensions of sustainable development – on the one hand it is crucial for economic and social development, but on the other hand the use of energy also entails diverse negative ecological effects.
- Second, energy is crucial when focusing on the role of stocks, flows and services relevant for wellbeing.

[1] For example, the environmental Kuznets curve literature often hypothesises decreasing environmental degradation with increasing income (see e.g. Dinda, 2004): While environmental degradation is assumed to increase in early stages of economic growth, it is assumed that the environmental quality is gradually improved after a certain level of (per capita) income is reached. This hypothesis however, shows ambiguous empirical evidence and therefore is exposed to criticism (see e.g. Stern, 2004; Dinda, 2004).

[2] In the paper the terms welfare, wellbeing and prosperity are used as synonyms.

The structure of the paper is as follows: We briefly discuss the motivation for new indicators for societal welfare and progress against the background of the sustainable development paradigm. We then present an overview of sustainable development indicator frameworks reviewed for the PASHMINA project followed by the PASHMINA indicator set. The last section concludes.

2 The need for going beyond GDP

GDP is the most prominent measure of economic activity and economic growth. The appealing features of GDP are that it provides an aggregate snapshot of market activity based on well developed statistical data that is easily communicable and globally available. If GDP is used as an indicator of welfare, a number of shortcomings prevail, one of which is that it provides only limited information by focusing on flows of goods and services produced in one year and neglecting changes in stocks as well as ecological or social factors. GDP growth is often regarded as a prerequisite for coping with societal and environmental challenges. Using GDP as superordinate policy objective when targeting societal welfare is, however, of limited use as the emphasis on increasing production without taking into account potential detrimental side effects on the environment or social cohesion may lead to inaccurate conclusions regarding societal progress.

GDP is a pure production indicator. Together with other indicators from the system of national accounts it reflects a country's economic activity organised through markets. Although for the industrialised countries a positive correlation between GDP and factors related to wellbeing such as life expectancy and literacy rate is observed at least for certain periods, the equation "more GDP = more prosperity" was never intended when national accounts and GDP were developed. The current practice to use GDP as a proxy for welfare is even less tenable, since it is well known that GDP has a number of shortcomings when it is used as a welfare indicator (see e.g. Kettner et al., 2007; Gossens et al., 2007; van den Bergh, 2009): Many activities that obviously increase individual welfare but are not based on any monetary transactions such as housework or volunteering, for example, remain unconsidered in GDP while other transactions that do not increase individual wellbeing such as income or costs resulting from the depletion of environmental resources or the removal of environmental damages increase GDP. The main criticisms of GDP and national accounts are summarised in Appendix I.

3 Sustainable development as a new guiding principle

The concept of sustainable development ties up to the main points of criticism of the system of national accounts. Most notably the publication of the so-called Brundtland Report 'Our Common Future' (WCED, 1987) has contributed to establishing the concept of sustainable development and challenging the dominant economic paradigm.

In essence, the Brundtland Report synthesised a wide range of experience, concepts and visions about the global design and the local consequences for our economies into the paradigm of sustainable development. In a nutshell, the pioneering contribution of the sustainable development paradigm consists of two components, namely

- extending the evaluation of development by complementing the economic dimension by environmental and social dimensions; and
- proposing to judge economic progress by considering the impact of current economic activity on future generations.

Since the publication of the Brundtland report, the concept of sustainability has gained in importance in political as well as economic discussions. The European Union and a number of other international organisations (e.g. World Bank, United Nations, OECD) have included sustainability as a central element in political strategies and are also involved in the theoretical development and operationalisation of the concept.

In essence there are three ways to extend the theoretical framework of national accounts and gross domestic product (see also Gossens et al., 2007): The first option is to correct GDP and the related indicators by taking into account environmental or social factors measured in monetary terms. The second option includes approaches to replace GDP by other indicators that measure wealth beyond traditional national accounts. Approaches that are designed to supplement GDP are the third possibility. They are neither intended to replace nor to correct national accounts and GDP but rather aim to provide additional information on social and ecological factors.

Approaches that try to correct GDP (e.g. the Index of Sustainable Economic Welfare (ISEW; Daly - Cobb, 1989), Genuine Savings (World Bank, 2005)) are confronted with a number of difficulties as they are only partially suited to represent social and ecological factors, since according to these concepts all aspects need to be expressed in monetary terms[3]. Most notably the monetary measurement of ecological aspects such as biodiversity or social factors proves difficult. Approaches that concentrate on a replacement of GDP by an alternative single indicator rely only on a limited number of factors, which represent wealth only in a very limited way (e.g. Ecological Footprint (Wackernagel and Rees, 1996), Human Development Index (HDI; UNDP, 2010)). Approaches that aim to complement GDP at least partly overcome these shortcomings more easily: By providing additional information economic development can be analysed from a comprehensive perspective, while useful information from the national accounts is preserved (e.g. NAMEA (see e.g. Haan – Keuning, 1996), sustainability indicator systems (see below)).

[3] Although performed for the ISEW and the Genuine Savings indicators the monetary valuation of sustainability indicators is highly questionable. In this context the evaluation of environmental aspects is of special concern as neither the cost of environmental pollution nor the depletion of environmental resources can be unambiguously evaluated. But on the other hand also the evaluation of housework and voluntary work proves difficult (e.g. should the output or the work be evaluated, what would be the adequate output prices or wage rates etc.).

4 Measuring sustainable development

Due to its multidimensionality the concept of sustainable development is of high complexity. Sets of indicators are considered an appropriate tool to reduce this complexity and to account for the interaction between society and ecosystems. They are developed and provided by a number of international institutions including the EU and the UN (EU, 2005a, 2005b; UNCSD, 2001) and cover all of the three pillars of sustainability (see e.g. Gossens et al., 2007).

One task within the PASHMINA project is to develop a set of sustainability indicators. The indicator set as presented in this paper has a focus both on stocks and flows. The indicators proposed here will be integrated into the structural energy model developed by WIFO for the PASHMINA project. We surveyed indicator systems with respect to their information on central research areas of the PASHMINA project: transport, energy and environment as well as land-use and ecosystem services. The purpose of this indicator survey is to illustrate the scope of available sustainable development indicator sets and to assess their suitability for the PASHMINA project. In the following we present a selection of general recognised sets of sustainability indicators – the EU Sustainable Development Indicators, the UN Indicators on Sustainable Development and the IEA/IAEA Indicators for Sustainable Energy Development – as well as sustainability indicators targeted on transport and the environment relevant for the PASHMINA project.

4.1 Energy in systems of sustainable development indicators

In the following three major initiatives for comprehensive sustainable development indicator systems are described. These indicator frameworks represent a selection from the vast amount of approaches that have been developed in past decades and contain information related to one of the core issues of the PASHMINA project – the energy-transport-environment nexus. Especially the IEA/IAEA Indicators for Sustainable Energy Development and the EU Sustainable Development Indicators prove to be valuable inputs for the development of the PASHMINA indicators. For a more general and exhaustive summary of indicator sets and measurement approaches see Kettner et al. (2007) and Gossens et al. (2007).

The EU Sustainable Development Indicators

In Article 2 of the *Treaty Establishing the European Communities* the promotion of sustainable development of economic activities and sustainable economic growth is defined as a main objective of the European Union. At the Gothenburg Summit in 2001 the EU Strategy for Sustainable Development was adopted, calling for the development of Sustainable Development indicators to monitor the implementation of the strategy. At the Barcelona Summit, the *Commission Communication on the External Dimension of Sustainable Development* was adopted.

The Sustainable Development Indicator (SDI) framework of the European Union is based on the following 10 themes (EC, 2005a,b):

- Economic development
- Poverty and social exclusion
- Ageing society
- Public health
- Climate change and energy
- Production and consumption patterns
- Management of natural resources
- Transport
- Good governance
- Global partnership

Within the framework the indicators are grouped in three hierarchically designed levels. On the highest level the framework consists of 12 headline indicators which are further divided into 45 core and 98 analytical indicators. The headline indicators are aimed at high-level policy-making and at the general public; the core indicators are conceived for the evaluation of the core policy areas and for the improvement of the communication between experts, politicians and a wider public; the analytical indicators are designed for further policy analysis and a better understanding of the trends and the complexity of issues within a specific theme or inter-linkages with other themes. Appendix A-1 summarises the different indicators.

The indicators can also be divided into 'best needed' and 'best available' indicators. The best available indicators can be compiled with existing data. Some of them are not optimal, but serve as proxies for the best needed indicators that cannot be compiled either because of a lack of concepts, definitions or data or because of poor quality of existing data.

The UN Indicators for Sustainable Development

The Preamble to the Charter of the United Nations defines the "promotion of the economic and social advancement of all peoples" as one of the UN's main objectives. For many years, the UN has committed itself to promoting sustainable growth in order to preserve the possibilities of future generations. Compared to the approaches of the European Commission (EC, 2005a,b) and the OECD (2005, 2007), this framework of sustainability indicators is focusing more on developing countries than on industrialised countries.

The concept of sustainable development adopted by the United Nations consists of four dimensions: An institutional dimension is added to the commonly used economic, social and environmental dimensions. Concerning this new dimension two major indicator groups, namely the countries' general infrastructure and the implementation of strategies fostering sustainable development, can be distinguished. The indicator framework of the UN is set up according to the four dimensions. Within them, the indicators can be arranged in the

following 15 groups, which can be rearranged in 38 sub-themes with 58 core indicators (see Appendix A-2):

- Economic Structure
- Consumption and Production Patterns
- Atmosphere
- Land
- Oceans, Seas and Coasts
- Fresh Water
- Biodiversity
- Equity
- Health
- Education
- Housing
- Security
- Population
- Institutional Framework
- Institutional Capacity

Most of the indicators have either a social or an environmental dimension. In effect, mere economic and institutional indicators are just supplements to the overall framework. The 58 core indicators were derived from 134 initial indicators that were proposed by the UNCSD to 22 testing countries from all regions of the world. The indicators can be divided into three categories:

- Driving Force Indicators are aimed at quantifying activities, processes and patterns that affect sustainable development positively or negatively.
- State indicators provide information about the conditions of sustainable development.
- Response indicators are aimed at measuring the success of human actions in promoting sustainable development.

The IEA/IAEA Indicators for Sustainable Energy Development

Some indicator sets such as the IEA/IAEA Sustainable Energy Development (SED) Indicators or the IAEA Energy Indicators for Sustainable Development focus mainly on energy as a key element in sustainable development. The SED indicators measure the development towards "*the provision of adequate energy services at affordable cost in a secure and environmentally benign manner, in conformity with social and economic development needs*" (IEA/IAEA, 2001). IEA and IAEA propose 41 indicators for sustainable energy development that cover the whole energy system and major driving forces such as economic and social development. This means the indicators cover primary energy supply, transformation technologies and final energy demand as well as energy intensities, fuel mix and demand for energy services. Economic factors (e.g. GDP, prices) and social factors (e.g.

population growth) influence the energy system and emissions resulting from energy consumption and energy supply. The complete list of ISED indicators is provided in Appendix A-3.

By now, the IEA SED indicators have been applied to a number of countries (e.g. Lithuania (Streimikiene, 2005), Cuba (Pérez et al., 2005), and Mexico (Medina-Ross et al. 2005)). Depending on the challenges of sustainable energy policy and data availability in most cases only a subset of indicators was used. Davidsdottir et al. (2007) applied a set of ISEDs to Iceland, UK, USA, Sweden, Brazil and Mexico. In addition, Davidsdottir et al. (2007) and Ibarrarán Viniegra et al. (2009) show that the SED indicators become highly operational when they are aggregated to a composite index, the so-called "Sustainable Energy Index", which consists of one sub-index for each dimension of sustainable development. These aggregate indices can be compared to other traditional economic measures such as GDP in order to identify synergies and conflicts between conventional and sustainability policies.

4.2 Theme-specific indicator systems

In addition to the general indicator systems a large number of theme-specific indicator frameworks exist. With regard to topics relevant for the PASHMINA project, transport and ecosystems, the following indicator systems can be mentioned: the Sustainable Mobility Indicators (Nicolas et al., 2003) and the Sustainable Transport Indicators (Litman et al., 2008), the Environmental Performance Index 2010 (EPI, 2010a,b) and the Millennium Assessment Ecosystem Service Indicators (Millennium Ecosystem Assessment, http://www.maweb.org).

5 The PASHMINA indicator framework

Taking the EU Sustainability Development Indicators and the IEA/IAEA Sustainable Energy Development Indicators as a starting point WIFO developed an indicator set focusing on indicators related to energy supply and use. This focus has a twofold motivation:

- First, energy plays a central role for all dimensions of sustainable development which is widely recognised in the different indicator sets (e.g. EU SDIs; UN ISDs).
- Second, energy is crucial when focusing on the role of stocks, flows and services relevant for wellbeing.

The ultimate aim is to integrate these indicators into the structural energy model WIFO is working on. The indicators could also be used for extensions of other energy models. This could be of special interest for models that are involved in PASHMINA project[4].

[4] For this purpose WIFO developed a questionnaire that covered a selection of sustainability indicator systems as described above and was sent out to the PASHMINA modelling groups. The models covered the FEEM model WITCH (see http://www.witchmodel.org/; Bosetti et al., 2007; Bosetti et al., 2008), the SMASH model IMACLIM-S (see http://www.imaclim.centre-cired.fr/spip.php?rubrique41&lang=en) as well as the IIASA models GLOBIOM (see http://www.iiasa.ac.at/Research/FOR/globiom.html; Havlík et al., 2011) and BEWHERE (see http://www.iiasa.ac.at/Research/FOR/biofuels.html?sb=13, Leduc et al., 2009).

5.1 Motivation

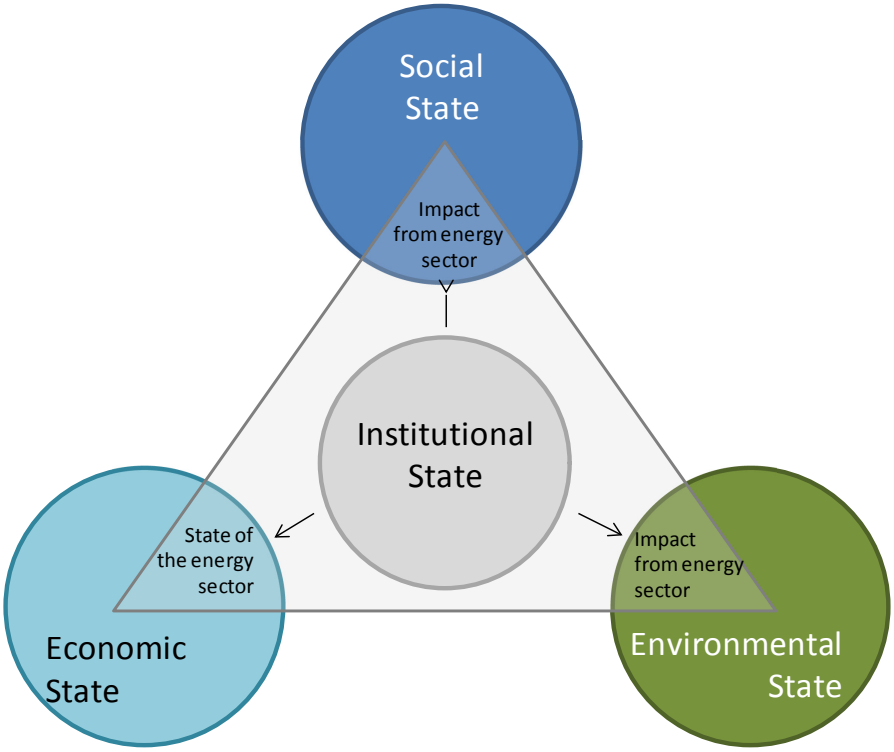
The concept of sustainable development emphasises the role of a wide range of environmental, social and economic aspects of welfare (see above). Energy plays a central role for all dimensions of sustainable development which is widely recognised in the different indicator sets (e.g. EU, 2005a,b; UNCSD, 2001):

- First, the use of energy is crucial for economic and social development. It provides basic (energy) services such as heat, light, information or mobility and is a crucial input to all kinds of production processes.
- Second, the use of (fossil) energy generates major ecological impacts as it accounts e.g. for a large part of total anthropogenic greenhouse gas emissions that are a key driver for global warming and climate change[5].
- Third, the present energy system relies to a large extent on the use of exhaustible fossil energy sources.

Institutional factors play a central role for the effects on all three dimensions of sustainable development (see Figure 1). Energy infrastructure or the capital stock in production for example shape the energy demand of an economy. Institutions and the regulatory framework for energy efficiency of buildings for example can influence whether low income households can afford well-tempered housing. An institutional framework that favours fossil fuels has detrimental effects on the environment. Besides the influence of institutional factors on the three dimensions of sustainable development, also interrelations between the social, environmental and economic aspects can be observed. Driving forces from the economic dimension such as income disparities can lead to unequal access to energy and thus affect the social dimension. Lower income may on the one hand constrain investment possibilities for energy saving housing or efficient heating systems with respective negative impacts on the environmental dimension. On the other hand it may result in lower demand for motorised individual mobility resulting in a lower negative environmental impact than from high income households. Economic production structures and growth are driving forces for energy demand with a corresponding impact of energy demand on the environmental dimension.

[5] Also, the emissions of other air pollutants are closely related to fossil energy use. From the social perspective energy is of relevance as it is not only required for the satisfaction of basic needs but also represents a significant share in household expenditures, especially in lower income percentiles.

Figure 1. Energy in the context of sustainable development



Source: Adapted from IEA (2001).

5.2 The PASHMINA energy indicator set

The IEA/IAEA system of Sustainable Energy Development (SED) indicators provides a broad range of indicators for all levels of the energy system (IEA/IAEA, 2001). We extend this concept in several aspects:

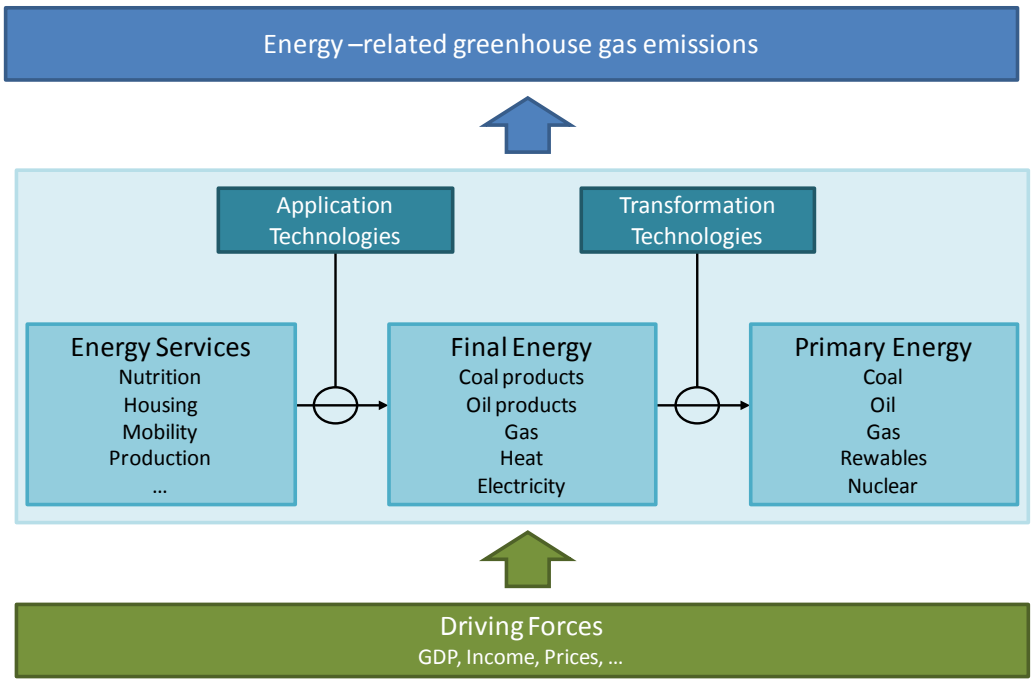
- We focus on the role of energy services, flows and related stocks.
- We choose a sectoral structure for the representation of indicators as this structure allows for a comprehensive and detailed analysis of specific status and impacts regarding respective stocks, energy flows and energy services as well as underlying driving forces (disaggregated by sectors in order to identify specific conditions).

Energy services play a crucial role for the development of sustainable energy structures (see also Köppl et al., 2011). It is not the quantity of energy demanded by households and companies that is relevant for welfare and development, but the amount and quality of the energy services consumed. These energy services, such as nutrition, housing, mobility and information, are provided by products (food, houses, fuel and media) combined with a wide range of capital stocks (as buildings, arable land, cars and the internet).

A given level of energy services can be provided by different combinations of technologies and energy flows. The range of available technologies and energy sources thus opens up a

spectrum of options, which result in different amounts of energy flows and greenhouse gas emissions (GHG) for any given level of services. From a sustainability point of view energy services should hence be provided with the lowest possible input of (fossil) fuels and minimal greenhouse gas emissions. This relationship between energy services, energy flows, technologies, driving forces of energy consumption and supply and related greenhouse gas emissions is depicted in Figure 2.

Figure 2. Structure of the energy cascade



Source: Authors' own illustration

As there is a strong connection between energy consumption and economic and social development we focus on indicators based on energy services that can be traced back through the energy system to energy consumption, taking into account the relevant technologies. We hence develop energy indicators starting from services that are related to the major components of final energy demand and which will be complemented by key indicators for electricity and heat production.

Table 1 shows the PASHMINA indicator system. In the first row, a set of meta-indicators is illustrated. These meta-indicators comprise information that is relevant for all sectors, like the countries' GDP and population; data on heating degree days, the energy/environment related R&D capital stock, the oil and gas burden as well as the distance to the national targets for renewable energy use and greenhouse gas emissions.

Below this level, the indicators are arranged in a matrix system. The columns illustrate the six sectors for which the indicators are provided: energy supply, manufacturing, services, households, passenger transport and freight transport, representing the major drivers for energy use.

The rows illustrate the different levels of the energy system: The first row summarises the contextual indicators which include information on the respective relevant stocks and supplementing data (like the share of energy imports, energy prices, etc.). In the second row indicators are summarised that describe or are used to approximate energy services, such as the gross value added (GVA) of the manufacturing and the service sector as well as the number of tonne-kilometres (tkm) and passenger-kilometres (pkm). For the household sector three different energy service indicators are used: the floor area for space heating and lighting; the number of persons living in the household as approximation for hot water demand and the number of appliances as proxy for other energy services (e.g. cooking or ICT). Energy intensities – i.e. the amount of final energy per energy service – and energy efficiencies of fossil energy generation are then depicted. The next indicator row gives the energy flows – transformation input and output as well as final energy consumption – that are the result of the energy services demanded and the energy efficiencies that are defined by the quality of the capital stocks. The last two rows provide information on environmental aspects (the ecological impacts of energy use and supply, such as emissions of GHG and air pollutants) and social aspects (the economic impacts of energy use for housing and passenger transport).

These indicators of course do not reflect an exhaustive list of factors relevant for wellbeing and sustainable development, but rather represent a selection on basis of data availability considerations. For compiling the indicator set data need to be available for the majority of the EU 27 countries and for a sufficiently long time period.

Table 1. The PASHMINA energy indicator set

Meta Indicators	**GDP**	**Population**	**HDD**	**Energy/environment related R&D capital stock**	**Distance to target - RES**	**Distance to target - GHG**	**Realisation of RES potentials**	**Oil and gas burden**
	Energy supply	**Manufacturing**	**Services**	**Households**	**Passenger transport**	**Freight transport**		
Context	Installed capacity of RES (in MW p.c.) Share of energy imports Share of electricity imports Final energy consumption	Share of GVA in GDP Energy prices	Share of GVA in GDP Energy prices	Households Household size Stock of appliances Stock of heating systems Floor area p.c. Household income Income inequality Energy prices	Stock of vehicles by category Energy prices Public pkm Private pkm Km of road / km of rail	Stock of trucks Energy prices Tkm road Tkm rail Tkm ship Km of road / km of rail		
Energy services		GVA	GVA	Space heating and lighting - proxy: floor area Hot water - proxy: number of persons Other (cooking, ICT, etc.) - proxy: number of appl.	Mobility - approx. by pkm	Mobility -approx. by tkm		
Energy intensities/ efficiencies	Energy efficiency of fossil generation	Energy per GVA	Energy per GVA	Energy per service by service type	Energy per pkm	Energy per tkm		
Energy use and provision	TO by energy source and installation type TI by energy source and installation type	FEC by energy source	FEC by energy source	FEC per household FEC by activity and energy source (percentage shares)	FEC by energy source and transport mode	FEC by energy source and transport mode		

Table 1. The PASHMINA energy indicator set (ctd.)

Environmental aspects	Air pollutants GHG emissions Share of agricultural land used for energy production Radioactive waste		Pollutants GHG emissions		Pollutants GHG emissions		Pollutants GHG emissions		Pollutants GHG emissions	
Social aspects							Share of energy costs in average household income Share of energy costs in household income of lowest 20% - proxy for energy poverty		Share of transport costs in average household income Share of transport costs in household income of lowest 20%	

Heating degree days (HDD):

Actual heating degree-days express the severity of the cold in a specific time period taking into consideration outdoor temperature and room temperature. The definition used by Eurostat for the calculation of heating degree days is (18 °C - Tm) x d if Tm is lower than or equal to 15 °C (heating threshold) and are nil if Tm is greater than 15 °C where Tm is the mean (Tmin + Tmax / 2) outdoor temperature over a period of d days. (see: http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-NQ-06-005/EN/KS-NQ-06-005-EN.PDF)

Environment related R&D capital stocks

Database used: Eurostat, Government appropriations or outlays for RD (GBAORD) by socio-economic objective, using the NABS (Nomenclature for the analysis and comparison of scientific programmes and budgets) classification including i.a. Environment, Transport, Energy.

Specific R&D Capital stocks can be calculated using the standard OECD perpetual inventory method with a scraping rate of eight years. This allows capturing the cumulative character of investment into research better and reducing the variation of the annual investments that may be more volatile than stocks.

Distance to target – RES

The EU Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources defines national targets for the share of energy from renewable sources in gross final consumption of energy in 2020. Based on the objectives and current shares the distance to target for the EU Member States can be calculated.

Distance to target – GHG

The greenhouse gas emission targets for 2020 from the EU Energy and Climate Package (EC, 2008) are disaggregated for Member States and compared to current emissions.

Oil and gas burden

Oil burden is defined as nominal oil expenditures (demand multiplied by the crude price) divided by nominal GDP. This is a proxy of how much any given economy spends on its oil needs in a given year. (http://www.iea.org/index_info.asp?id=1932) This calculation is also carried out for natural gas.

Income inequality – Gini coefficient

The Gini-coefficient is the most commonly used measure of inequality. The coefficient varies between 0, which reflects complete equality and 1, which indicates complete inequality (one person has all the income or consumption, all others have none).

(http://go.worldbank.org/3SLYUTVY00)

Transformation input and output

Primary energy used for electricity and heat generation is termed transformation input. Energy used as a transformation input is consumed only partly in the transformation process. The resulting transformed energy is termed transformation output. By subtracting transformation output from the inputs of the transformation sectors the transformation losses are calculated (i.e. transformation efficiency).

5.3 Indices for sustainable energy development

In addition to the indicator set, we develop a composite index for sustainable energy development. For the calculation of the indices a sub-sample of indicators for each sector will be selected in order to avoid over-laps and double counting of data.
The procedure for the calculation of this sustainable energy index follows Davidsdottir et al. (2007) and Ibarrarán Viniegra et al. (2009). While the sustainable energy index by Davidsdottir et al. and Ibarrarán Viniegra et al. is based on three sub-indices – one for each dimension of sustainability – the PASHMINA composite index is based on five sub-indices, one for each of the sectors electricity generation, manufacturing, services, households and transport. The sub-indices are calculated based on the following equation:

$$I_{i,t} = \sum_{j=1}^{n} w_j * \left(\frac{E_{i,j,t}}{E_{i,j,t=0}} - 1 \right)$$

where $I_{i,t}$ gives the sub index of the sustainability dimension i in year t, j is the energy indicator, n is the number of indicators, w_j is the weight for each indicator, and $E_{i,j,t}$ is the value of the energy indicator in year t. This means that each sub-index is the weighted sum of the change in the indicators compared to an assumed base year. The aggregate index in turn is calculated as the weighted sum of the sub-indices. Ibarrarán Viniegra et al. (2009) assume equal weights both for the calculation of the sub-indices and for the calculation of the aggregate index. The suitability of different weighting factors for the PASHMINA project will be discussed.

The main advantages of calculating the composite index and the sub-indices are that they facilitate the monitoring of different developments over time as interpreting and comparing many different indicators proves difficult when an overall conclusion about energy sustainability is aspired. The purpose of this composite index is to reduce the complexity, and to provide a useful instrument for policy monitoring and decision making. In addition, the index can serve as a communication instrument. Through summarising single indicators to composite indices information about specific details (e.g. sectoral developments), however, can be lost (e.g. OECD, 2002; OECD, 2008). We therefore also provide the single indicators that contain important information about energy sustainability in different areas.

6 Summary and outlook

In this working paper we present the structure of the PASHMINA indicator set for sustainable energy development. Systems of sustainability indicators are regarded as an advantageous way to extend the conventional measurement of wellbeing. The starting points for the

development of the PASHMINA indicators are the EU sustainability indicators and the indicators for sustainable energy development by IEA/IAEA. We extend these approaches in the following ways:

- We focus on the role of energy services, flows and related stocks.
- We choose a sectoral structure for the representation of indicators as this structure allows for a comprehensive and detailed analysis of specific status and impacts.

Furthermore, we propose an aggregate index for sustainable energy development as well as sectoral sub-indices that can be derived from a selection of the indicators.

The next steps of our work comprise the collection of data, the calculation of indicators and indices – including a summary of the methodological discussion regarding the construction of indices. Given the large number of countries considered in the study we will use explorative statistical methods (cluster analysis) in order to condense the large variety of observed conditions and developments across countries and over time to a few salient features. We will therefore aim at building country taxonomies based on key indicators from the different domains.

Furthermore, we will analyse developments of selected indicators for different PASHMINA scenarios in a structural energy model. A collaboration with SMASH is considered in order to extend the indicators' social dimension in a case study framework focusing on France.

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Appendix

Appendix I

DEFICITIS OF GDP

General deficits of GDP

One of the main criticisms of GDP is that the national accounts are focused on flows, while the prosperity of a country and individual wellbeing in the long term are more dependent on various types of stocks. For example, the annual expenditures on consumer goods (such as the purchase and leasing of cars within a year) are reported in the national accounts, while the stock of consumer durables (such as the existing stock of cars) is not reported[6]. Another example is that the annual sale of exhaustible resources is reported in the national accounts, while the remaining stock of resources as well as other forms of natural capital is not considered. This short-term perspective focused on flows does not consider future (production) potentials and thus ignores possible negative medium and long term effects for a country's prosperity.

The accounting of basic needs within national accounts is also problematic. The satisfaction of basic needs, such as food, shelter, social recognition or freedom, is of fundamental importance for a person's wellbeing; basic needs cannot – or only to a very small extent – be substituted by luxury goods or services. In the national accounts, these fundamental relationships are, however, not depicted: Immaterial basic needs are not covered at all and basic material needs such as drinking water are undervalued in the national accounts, as they are valued solely by their market value[7] just like luxury goods.

Criticism from an economic perspective

From an economic perspective, the main points of criticism of GDP lie in the valuation of unpaid or informal work, leisure, technological change and human capital.

Housework, educational work and voluntary work are not considered in the national accounts, mainly due to difficulties in the monetary evaluation of these factors. On the one hand, this leads to an underestimation of economic activity. Some pilot studies have calculated that housework and voluntary work contribute 30 percent or more to GDP, depending on the country and the assessment method (see e.g. Federal Statistical Office, 2002)[8]. On the other hand, the exclusion of housework from the national accounts can lead

[6] The SNA generally provides for the integration of stock accounts. Nevertheless, these are no core elements of national accounts and are reported only for some countries such as the US.

[7] The market price for natural resources like water for example may be too low if due to incomplete information it does not reflect the resources scarcity (in quantitative or qualitative terms).

[8] For Austria a share of housework in gross domestic product of at least 33 percent was estimated for 1992 (Austrian Central Statistical Office, 1996).

to an overestimation of economic growth when structural change within an economy is accompanied by a shift from housework to the market. Such a growth of market production ignores the fact that the effective economic performance remains unchanged as a whole.

Leisure contributes significantly to individual prosperity but is not considered adequately in the national accounts. Leisure time is accounted for in GDP only as a reduction of production possibilities. International comparisons are also hampered by the exclusion of leisure time as differences in holiday entitlement and the average number of holidays are not considered.

Another point of criticism of GDP lies in the lacking consideration of human capital, as the quality and the development of this factor are not adequately captured. Expenditures on education are recorded as consumption in the national accounts, although these expenditures rather have the characteristics of an investment. In addition, educational expenditures provide only limited information about the quality of training received.

Criticism from a social-ecological perspective

From an ecological and social perspective, the inadequate coverage of natural resources, the insufficient representation of health and the exclusion of distributional aspects have to be mentioned as the main points of criticisms of GDP.

The integration of natural resources in the national accounts is considered particularly problematic. The exploitation of natural resources – such as overfishing of the oceans or the loss of tropical rain forests – for instance increases GDP as the current production of a country is increased. The much larger, wealth-reducing effect of these actions is in contrast not measured in GDP. Services of natural capital that increase individual wellbeing, such as clean air or the recreational value of nature, are also not covered by national accounts.

Health is also not adequately reflected in GDP. Expenditures for health are classified as consumption expenditures just like educational expenditures. If these expenditures are related to health protection, they certainly increase wellbeing. If the expenditures are, however, related for example to the treatment of diseases of affluence or pollution-related diseases, the costs are rather instrumental and not increasing wellbeing, yet they lead to an increase in GDP. It also has to be stressed that the level of health expenditures does not necessarily reflect the quality of the treatment or the health status of society.

When using GDP per capita as an indicator for prosperity only an average value for the entire population of a country is reported that does not allow drawing conclusions about the distribution of income. For the assessment of a country's wellbeing, the distribution of income between individuals – or rather between the individual households – is, however, highly relevant: From a utilitarian point of view, income losses of the lowest income groups cannot be compensated by gains in the same amount in the highest income groups. A welfare indicator would therefore need to take into account the (in-)equality of income distribution in society.

A loss of social coherence, expressed for example in an increase in crime or in a higher risk of terrorist attacks, also increases GDP, as expenditures for security will rise. These expenditures are again rather instrumental than wealth-increasing.

Appendix II

Annex A - 1

EU SUSTAINABLE DEVELOPMENT INDICATORS

Headline Indicator	Level II Indicator	Level III Indicator
SDI-Theme: Socioeconomic Development		
Real GDP per capita, growth rate and totals		
Sub-theme: Economic development		
	Investment by institutional sectors (total, government, household, business)	
		Dispersion of regional GDP per inhabitant
		Net national income
		Household saving rate
Sub-theme: Innovation, competitiveness and eco-efficiency		
	Growth rate of labour productivity per hour worked	
		Total R&D expenditure
		Real effective exchange rate
		Turnover from innovation
		Energy intensity of the economy
Sub-theme: Employment		
	Total employment rate	
		Employment rate, by gender Employment rate, by highest level of education attained Dispersion of regional employment rates, by gender Unemployment rate, by gender Unemployment rate, by age group
Indicators to be developed Genuine savings Eco-innovations		

SDI-Theme: Sustainable Consumption and Production		
Resource productivity		
Sub-theme: Resource use and waste		
	Municipal waste generated	

Components of domestic material consumption

Domestic material consumption by material

Municipal waste treatment, by type of treatment method

Generation of hazardous waste, by economic activity

Emissions of acidifying substances by source sector

Emissions of ozone precursors by source sector

Emissions of particulate matter by source sector

Sub-theme: Consumption patterns

Electricity consumption of households

Final energy consumption, by sector

Consumption of certain foodstuffs per inhabitant

Motorisation rate

Sub-theme: Production patterns

Organisations and sites with EMAS registration

Eco-label awards

Area under agri-environmental commitment

Area under organic farming

Livestock density index

Contextual indicators

Number of households (for sub-theme Consumption patterns)

Household expenditure per inhabitant, by category (for sub-theme Consumption patterns)

Indicators to be developed
Total material consumption
Green public procurement
Share of consumption of products with an ecolabel / Awareness of ecolabels
Nitrogen balance
Ethical financing
Share of industrial production from enterprises with a formal environmental management system
Share of production of products with an ecolabel
Energy and material use per unit of output, by industrial sector

SDI-Theme: Social Inclusion

At-risk-of-poverty rate, by gender

Sub-theme: Monetary poverty and living conditions

At-persistent-risk-of-poverty rate

		At-risk-of-poverty rate, by age group
		At-risk-of-poverty rate, by household type
		Relative at-risk-of-poverty gap
		Inequality of income distribution
Sub-theme: Access to labour market		
	People living in jobless households, by age group	
		In-work poverty
		Total long-term unemployment rate
		Unadjusted gender pay gap
Sub-theme: Education		
	Early school-leavers	
		At-risk-of-poverty rate, by highest level of education attained
		Persons with low educational attainment, by age group
		Life-long learning
		Low reading literacy performance of pupils
		Individuals' level of computer skills
		Individuals' level of internet skills
Contextual indicator		
Public expenditure on education (for sub-theme Education)		
Indicators to be developed		
Child wellbeing		
Material deprivation		
Adequacy of housing conditions		

SDI-Theme: Demographic Changes
Employment rate of older workers
Sub-theme: Demography
Life expectancy at age 65, by gender
Total fertility rate
Crude rate of net migration
Sub-theme: Old-age income adequacy
Aggregate replacement ratio
At-risk-of-poverty rate of elderly people
Sub-theme: Public finance sustainability
General government debt
Average exit age from the labour market
Contextual indicators
Old-age-dependency ratio (for sub-theme Demographic changes)
Projected old-age dependency ratio (for sub-theme Demographic changes)
Projected evolution of EU-27 age-related public spending – baseline scenario (for sub-theme Public finance sustainability)
Projected evolution of theoretical income replacement ratios (for sub-theme Public finance sustainability)
Expenditure on care for the elderly (for sub-theme Public finance sustainability)
Indicators to be developed
Health expenditure on old age

SDI-Theme: Public Health

Healthy life years and life expectancy at birth, by gender

Sub-theme: Health and health inequalities

Death rate due to chronic diseases, by gender

Healthy life years and life expectancy at age 65, by gender

Suicide death rate, by age group

Suicide death rate, males by age group

Suicide death rate, females by age group

Self reported unmet need for medical examination or treatment, by income quintile

Dispersion of regional death rates

Sub-theme: Determinants of health

Index of production of toxic chemicals, by toxicity class

Population exposure to air pollution by particulate matter

Population exposure to air pollution by ozone

Population living in households considering that they suffer from noise

Serious accident at work

Indicators to be developed

Incidence of chronic diseases

Childhood health/diseases

Deaths due to infectious food-borne diseases

Index of apparent consumption of chemicals by toxicity class

Dioxins and PCBs in food and feed

Pesticide residues in food

Overweight people, by age group

Present smokers, by gender and by age group

Work with a high level of job strain/stress

Monetary damage of air pollution as % of GDP

SDI-Theme: Climate Change and Energy		
Greenhouse gas emissions (CO_2e)		
Share of renewables in gross inland energy consumption		
Sub-theme: Climate change		
	Greenhouse gas emissions by sector	
		Greenhouse gas emissions intensity of energy consumption
		Projections of greenhouse gas emissions
		Global surface average temperature
Sub-theme: Energy		
	Energy dependency	
		Gross inland energy consumption, by fuel
		Electricity generated from renewable sources
		Share of biofuels in fuel consumption of transport
		Combined heat and power generation
		Implicit tax rate on energy
Indicators to be developed		
Radioactive waste		
External costs of energy use		

SDI-Theme: Sustainable Transport

Energy consumption of transport

Sub-theme: Transport and mobility

Modal split of passenger transport

Modal split of freight transport

Volume of freight transport

Volume of passenger transport

Energy consumption by transport mode

Modal share of investment in transport infrastructure

Sub-theme: Transport impacts

Greenhouse gas emissions by transport mode

People killed in road accidents

Emissions of ozone precursors from transport

Emissions of particulate matter from transport

Average CO_2 emissions per km from new passenger cars

Contextual indicator

Price indices for transport (for sub-theme Transport and mobility)

Indicators to be developed

Vehicle-km by road

Use of public transport

External costs of transport activities

Fragmentation of natural and semi-natural areas (to appear either in this theme or in Natural resources, depending on the type of indicator that is developed)

SDI-Theme: Natural Resources		
Common bird index		
Fish catches taken from stocks outside safe biological limits		
Sub-theme: Biodiversity		
	Sufficiency of sites designated under the EU Habitats Directive	
		Deadwood on forest land
Sub-theme: Freshwater resources		
	Surface and groundwater abstraction as a share of available resources	
		Population connected to urban wastewater treatment with at least secondary treatment
		Biochemical oxygen demand in rivers
Sub-theme: Marine ecosystems		
	Concentration of mercury in fish and shellfish	
		Size of fishing fleet
Sub-theme: Land use		
	Built-up areas	
	Forest increment and fellings	
		Forest trees damaged by defoliation
		Percentage of total land area at risk of soil erosion
Indicators to be developed		
Biodiversity Index		
Abundance and distribution of selected species		
Change in status of species of European interest		
Red List Index for European species		
Index of toxic chemical risk to aquatic environment / Percentage of water bodies with high or good ecological status		
Concentration of organic matter as chemical oxygen demand of rivers		
Effective fishing capacity and quotas		
Structural support to fisheries and % allocated to promote environmentally friendly fishing practices		
Seagrasses		
Critical load exceedance for nitrogen		

SDI-Theme: Global Partnership

Official development assistance as share of gross national income

Sub-theme: Globalisation of trade

EU Imports from developing countries, by income group

EU Imports from developing countries, by group of products

EU Imports from least-developed countries, by group of products

Aggregated measurement of support for agriculture

Sub-theme: Financing for sustainable development

Total EU financing for developing countries, by type

Foreign direct investment in developing countries, by income group

Official development assistance, by income group

Untied official development assistance

Bilateral official development assistance dedicated to debt

Bilateral official development assistance dedicated to social services

Bilateral official development assistance dedicated to water supply and sanitation

Sub-theme: Global resources management

CO_2 emissions per inhabitant in the EU and in developing countries

Contextual indicators

Population living on less than 1USD a day (for sub-theme Financing for sustainable development)

Official development assistance per capita in donor and recipient countries (for sub-theme Financing for SD)

Population with sustainable access to an improved water source (for sub-theme global resource management)

Indicators to be developed

Sales of selected fair-trade-labelled products

Share of global greenhouse gas emissions from countries having agreed limits on their emissions

Contribution of the Clean Development Mechanism to greenhouse gas emission reductions in developing countries

Global footprint

SDI-Theme: Good Governance	
Sub-theme: Policy coherence and effectiveness	
New infringement cases, by policy area	
	Transposition of Community law by policy area
Sub-theme: Openness and participation	
Voter turnout in national and EU parliamentary elections	
	E-government on-line availability
	E-government usage by individuals
Sub-theme: Economic instruments	
Shares of environmental and labour taxes in total tax revenues	
Contextual indicator	
Level of citizens' confidence in EU institutions (for sub-theme Policy coherence and effectiveness)	
Indicators to be developed	
Administrative cost imposed by legislation	
Impact assessment	
Openness and participation	
Level of involvement of consumer groups and companies	
Public consultations	
Proportion of environmentally harmful subsidies	

Source: SEC(2005) 161 final; Šteinbuka and Wolff (2007), Eurostat (2009)

Annex A - 2

UN INDICATORS FOR SUSTAINABLE DEVELOPMENT

Dimension / Subtheme	Indicator
Social dimension	
Theme: Equity	
Poverty	Percent of Population Living below Poverty Line
	Gini Index of Income Inequality
	Unemployment Rate
Gender Equality	Ratio of Average Female Wage to Male Wage
Theme: Health	
Nutritional Status	Nutritional Status of Children
Mortality	Mortality Rate Under 5 Years Old
	Life Expectancy at Birth
Sanitation	Percent of Population with Adequate Sewage Disposal Facilities
Drinking Water	Population with Access to Safe Drinking Water
Healthcare Delivery	Percent of Population with Access to Primary Health Care
	Immunization Against Infectious Childhood Diseases
	Contraceptive Prevalence Rate
Theme: Education	
Education Level	Children Reaching Grade 5 of Primary Education
	Adult Secondary Education Achievement Level
Literacy	Adult Literacy Rate
Theme: Housing	
Living Conditions	Floor Area per Person
Theme: Security	
Crime	Number of Recorded Crimes per 100,000 Population
Theme: Population	
Population Change	Population Growth Rate
	Population of Urban Formal and Informal Settlements

Environmental Dimension	
Theme: Atmosphere	
Climate Change	Emissions of Greenhouse Gases
Ozone Layer Depletion	Consumption of Ozone Depleting Substances
Air Quality	Ambient Concentration of Air Pollutants in Urban Areas
Theme: Land	
Agriculture	Arable and Permanent Crop Land Area
	Use of Fertilizers
	Use of Agricultural Pesticides
Forests	Forest Area as a Percent of Land Area
	Wood Harvesting Intensity
Desertification	Land Affected by Desertification
Urbanization	Area of Urban Formal and Informal Settlements
Theme: Oceans, Seas and Coasts	
Coastal Zone	Algae Concentration in Coastal Waters
	Percent of Total Population Living in Coastal Areas
Fisheries	Annual Catch by Major Species
Theme: Fresh Water	
Water Quantity	Annual Withdrawal of Ground and Surface Water as a Percent of Total Available Water
Water Quality	BOD in Water Bodies
	Concentration of Faecal Coliform in Freshwater
Theme: Biodiversity	
Ecosystem	Area of Selected Key Ecosystems
	Protected Area as a % of Total Area
Species	Abundance of Selected Key Species

Social Dimension	
Theme: Economic Structure	
Economic Performance	GDP per Capita
	Investment Share in GDP
Trade	Balance of Trade in Goods and Services
Financial Status	Debt to GNP Ratio
	Total ODA Given or Received as a Percent of GNP
Theme: Consumption and Production Patterns	
Material Consumption	Intensity of Material Use
Energy Use	Annual Energy Consumption per Capita
	Share of Consumption of Renewable Energy Resources
	Intensity of Energy Use
Waste Generation and Management	Generation of Industrial and Municipal Solid Waste
	Generation of Hazardous Waste
	Generation of Radioactive Waste
	Waste Recycling and Reuse
Transportation	Distance Travelled per Capita by Mode of Transport

Institutional Dimension	
Theme: Institutional Framework	
Strategic Implementation of SD	National Sustainable Development Strategy
International Cooperation	Implementation of Ratified Global Agreements
Theme: Institutional Capacity	
Information Access	Number of Internet Subscribers per 1000 Inhabitants
Communication Infrastructure	Main Telephone Lines per 1000 Inhabitants
Science and Technology	Expenditure on Research and Development as a Percent of GDP
Disaster Preparedness and Response	Economic and Human Loss Due to Natural Disasters

Source: UN (2001)

Annex A - 3

IEA/IAEA INDICATORS FOR SUSTAINABLE ENERGY DEVELOPMENT

Dimension / Category	Indicator
Economic Dimension	
Indirect driving forces	
	Population: total; urban
	GDP per capita
	End-use energy prices with and without tax/subsidy
	Shares of sectors in GDP value added
	Distance travelled per capita : total, by urban public transport mode
	Freight transport activity : total, by mode
	Floor area per capita
	Manufacturing value added by selected energy intensive industries
Indirect driving forces (within energy sector)	
	Energy intensity : manufacturing, transportation, agriculture, commercial & public services, residential sector
	Final energy intensity of selected energy intensive products
	Energy mix: final energy, electricity generation, primary energy supply
	Energy supply efficiency : fossil fuel efficiency for electricity generation
	Status of deployment of pollution abatement technologies: extent of use, average performance
Direct driving forces	
	Energy use per unit of GDP
	Expenditure on energy sector: total investments, environmental control , hydrocarbon exploration & development, RD&D , net energy import expenses
State	
	Energy consumption per capita
	Indigenous energy production
	Net energy import dependence

Social Dimension (Energy accessibility and affordability)
Indirect driving forces
Income inequality
Indirect driving forces (within energy sector)
Ratio of daily disposable income/ private consumption per capita of 20% poorest population to the prices of electricity and major household fuels
Direct driving forces
Fraction of disposable income/ private consumption spent on fuel and electricity by: average population; group of 20% poorest population
State
Fraction of households: heavily dependent on non-commercial energy; without electricity

Environmental Dimension
Direct driving forces
Air pollution
Quantities of air pollutant emissions (SO_2, NO_x, particulates, CO, VOC)
Quantities of greenhouse gas emissions
Radionuclides in atmospheric radioactive discharges
Water pollution
Discharges into water basins : waste/storm water, radionuclides, oil into coastal waters
Waste
Generation of solid waste
Generation of radioactive waste
Land
Land area taken up by energy facilities and infrastructure
Energy resources depletion
Fraction of technically exploitable capability of hydropower currently not in use
Proven recoverable fossil fuel reserves
Proven uranium reserves
Deforestation
Intensity of use of forest resources as fuel wood
State
Air pollution
Ambient concentration of pollutants in urban areas : SO_2, NO_x, suspended particulates, CO, ozone
Land area where acidification exceeds critical load
Waste
Accumulated quantity of solid wastes to be managed
Accumulated quantity of radio-active wastes awaiting disposal
Accident risks
Fatalities due to accidents with breakdown by fuel chains
Energy resources depletion
Life time of proven fossil fuel reserves
Life time of proven uranium reserves
Deforestation
Rate of deforestation

Source: IEA/IAEA (2001); IAEA et al. (2005)

Annex A - 4

SUSTAINABLE MOBILITY INDICATORS

Dimension of sustainability	Indicator	Level of analysis
Mobility		
Service provided	Daily number of trips	Overall and by place of residence (Centre/1st ring/2nd ring)
	Structure of trip purposes	
	Daily average time budget	
Organization of urban mobility	Modal split	Overall and by mode of transport
	Daily average distance travelled	
	Average speed (global and per person)	
Economic		
Cost for the community	Annual costs chargeable to residents of the conurbation, due to their mobility in this zone (total, per resident and per passenger-km)	Overall and by mode (Car, Public Transport, Other)
Expenditures of the participants involved		
Households:	Annual average expenditures for their urban mobility (per person)	Overall and by mode
Companies:	Costs of employee parking	Overall and by mode
	Subsidies to employees (company cars…)	
	Possible local taxes (total, per resident and per employee)	
Public authorities:	Annual expenditures for investments and operates (total and per resident)	Overall and by mode (Road/Public Transport)
Social		
	Proportion of households owning 0, 1 or more cars	Overall, by income group (Low, medium, high) and place of residence (Centre/1st ring/2nd ring)
	Distance travelled	
	Expenditures for urban mobility: amounts for private/public transport; for fixed/variable cost of car	
	Expenditures for urban mobility: share of the average income of households	
Environmental		
Air pollution—Global issue	Annual energy consumption and CO_2 emissions (total and per resident)	Overall, by mode, by zone of emission, by place of residence
Air pollution—Local issue	Levels of CO, NO_x, hydrocarbons and particles (in g/m^2, total and per resident)	Overall, by mode, by zone of emission, by place of residence
Space consumption	Daily individual consumption of public space involved in travelling and parking (in m2 h)	Overall, by mode and by place of residence
	Space taken up by transport infrastructures	Overall and by place of residence
Other items	Noise intensity levels	
	Risk of accident	

Source: Nicolas et al. (2003)

Annex A - 5

SUSTAINABLE TRANSPORTATION INDICATORS

Sub-category	Indicator	Disaggregation	Rating
Category: Travel Activity			
Vehicles	Motor vehicle ownership	By type of vehicle, owner demographics, location	A
Mobility	Motor vehicle travel	Trip type, traveller type, travel conditions	A
Mode split	Portion of trips by auto, public transit, and non-motorized modes	Trip type, traveller type, travel conditions	A
Category: Air Pollution Emissions			
Emissions	Total vehicle emissions	Type of emission, mode, location	A
Air pollution exposure	Number of days of exposure per year	Demographic groups affected	A
Climate change	Climate change emissions (CO_2, CH_4)	Mode	A
Embodied emissions	Emissions from vehicle and facility construction	Type of emission and mode	A
Category: Noise Pollution			
Traffic noise	People exposed to traffic noise above 55 LAeq,T	Demographic group, location, transport mode	B
Aircraft noise	People exposed to aircraft noise above 57 LAeq,T	Demographic group, location, transport mode	B
Category: Traffic risk			
Crash Casualties	Crash deaths and injuries	Mode, road, type and cause of collision.	A
Crashes	Police-reported crashes	Mode, road, type and cause of collision.	A
Crash costs	Traffic crash economic costs	Mode, road, type and cause of collision.	B
Category: Economic Productivity			
Transport costs	Consumer expenditures on transport	Mode, user type, location	A
Commute costs (time and money)	Access to employment	Mode, user type, location	A
Transport reliability	Per capita congestion costs	Mode, location	B
Infrastructure costs	Expenditures on roads, public transit, parking, ports, etc.	Mode, location	A
Shipping costs	Freight transport efficiency	Mode, geographic area	B
Category: Overall Accessibility			
Mobility options	Quality of walking, cycling, public transit, driving, taxi, etc.	Trip purpose, location, user	A
Land use accessibility	Quality of land use accessibility	Trip purpose, location, user	B
Mobility substitutes	Internet access and delivery service quality	Trip purpose, location, user	B

Category: Land Use Impacts			
Sprawl	Per capita impervious surface area	By location and type of development	B
Transport land consumption	Land devoted to transport facilities	By mode	B
Ecological and cultural degradation	Habitat and cultural sites degraded by transportation facilities	Type of habitat and resource, location	B

Category: Equity			
Affordability – Transport	Portion of household budgets needed to provide adequate transport	Demographics, especially disadvantaged groups	A
Affordability – Housing	Affordable housing accessibility	By demographic group, especially low income and disabled groups	C
Basic accessibility	Quality of accessibility for people with disabilities	By geographic area, mode, type of disability	B

Category: Transport Policy and Planning			
Pricing efficiency	Cost-based pricing	By mode, type of cost (road, parking, etc.)	B
Strategic planning	Degree to which individual planning decisions support strategic goals	By mode, agency.	B
Planning efficiency	Comprehensive and neutral planning	By mode, agency.	C
User satisfaction	User survey results.	By group (disabled, children, low income...)	B

Rating

A Proposed for application in virtually every situations and jurisdictions

B Proposed for application if relevant/feasible

C Proposed for application when needed to address specific community needs

Source: Litman et al. (2008)

Annex A - 6

ENVIRONMENTAL PERFORMANCE INDEX (EPI) 2010

Policy Category	Indicators
Objective: Environmental Health	
Environmental burden of disease	Environmental burden of disease
Air pollution (effects on humans)	Indoor air pollution
	Outdoor air pollution
Water (effects on humans)	Access to water
	Access to sanitation
Objective: Ecosystem Vitality	
Air Pollution (effects on ecosystem)	Sulphur dioxide emissions per populated land area
	Nitrogen oxides emissions per populated land area
	Non-methane volatile organic compound emissions per populated land area
	Ecosystem ozone
Water (effects on ecosystem)	Water quality index
	Water stress index
	Water scarcity index
Biodiversity & Habitat	Biome protection
	Marine protection
	Critical habitat protection
Forestry	Growing stock change
	Forest cover change
Fisheries	Marine trophic index
	Trawling intensity
Agriculture	Agricultural water intensity
	Agricultural subsidies
	Pesticide regulation
Climate Change	Greenhouse gas emissions per capita (including land use emissions)
	CO_2 emissions per electricity generation
	Industrial greenhouse gas emissions intensity

Source: EPI (2010a, b)

MILLENIUM ASSESSMENT - ECOSYSTEM SERVICE INDICATORS

Service	Category	Indicator	
PROVISIONING SERVICES			
Food	Crops	Crop production	
		Dietary energy supply	
		Employment in crop production and processing	
		Value of crop production	
	Livestock	Livestock production	
		Livestock products production	
		Value of livestock products production	
	Capture fisheries	Employment in the marine products sector	
		Fish meal in animal feed	
		Fish products as a percent of total animal protein in peoples' diets	
		Total fish catch	
		Total marine production	
		Total value of marine products	
		Value of coastal products used for jewellery and curios	
	Aquaculture	Fish production from aquaculture	
		Total aquaculture production (including non-fish products)	
	Wild foods	Number of wild species used for human food	
Biological raw materials	**Timber and other wood products**	Employment in forest sector	Proxy
		Forest biomass production	
		Roundwood production	
		Value of forest products	
		Volume of forest products used for local crafts	
		Wood pulp production	
	Fibres and resins, animals skins, sand	Employment in fibres production	Proxy
		Fibres production	
		Production of wildlife-derived skins, wool, and feathers	
		Value of fibres production	
Biomass Fuel		Charcoal production	
		Fuelwood production	
		Industrial energy production from forest systems	
		Monetary value of fuel production	
Freshwater resources		Population served by renewable water resource	
		Renewable water supply	
		Renewable water supply accessible to humans	
		Water storage capacity	
Genetic resources		Investment into natural products prospecting	Proxy
		Number of species that have been the subject of major investment	Proxy
		Value of genetic resources	
Biochemicals, natural medicines, and pharmaceuticals		Number of organisms from which drugs have been derived	
		Value of pharmaceutical products developed in natural systems	

REGULATING SERVICES			
Regulating	**Air quality regulation**	Flux in atmospheric gases	Proxy
		Atmospheric cleansing (tropospheric oxidizing)	
Climate regulating	**Global climate regulation**	Atmospheric gases flux (CO_2, CH_4, etc)	
		Carbon accumulation	
		Carbon uptake	
		Cloud formation	
		Evapotranspiration	
		Carbon sequestration capacity	
		Surface albedo	
	Regional and local climate regulation	Canopy stomatal conductance	
		Cloud formation	
		Evapotranspiration	
	Water regulation	Soil water infiltration	
		Soil water storage	
	Erosion regulation	*No Indicators Identified*	
	Water purification and waste treatment	Amount of waste processed by ecosystems	
		Capacity of ecosystem to process waste	
		Value of ecosystem waste treatment and water purification	
	Disease regulation	Disease vector predator populations	Proxy
		Estimated change in disease burden as a result of changing ecosystems	Proxy
		Population increase in disease vectors mosquitoes following ecosystem conversion	Proxy
	Soil quality regulation	*No Indicators Identified*	
	Pest regulation	*No Indicators Identified*	
	Pollination	*No Indicators Identified*	
	Natural hazard regulation	Changes in seasonality of flood events	Proxy
		Economic losses associated with natural disasters	Proxy
		Flood attenuation potential: residence time of water in rivers, reservoirs, and soils	
		Floodplain water storage capacity	
		Soil capacity to transfer groundwater	
		Soil water storage capacity	
		Trends in number of damaging natural disasters	Proxy

CULTURAL SERVICES			
	Aesthetic/ ethical values	Comparative value of real estate near cleaner water bodies	Proxy
		Comparative value of real estate nearer to nature	Proxy
		Number of nature/rural visitors	Proxy
		Willingness to pay for improved water quality in local water bodies	Proxy
	Spiritual and religious values	*No Indicators Identified*	
	Recreation and ecotourism	Nature and/or rural tourism employment	Proxy
		Number of recreational anglers and hunters	Proxy
		Spending on nature tourism	Proxy
		Total recreational value	Proxy
		Visitors to natural areas	Proxy

Source: Millenium Assessment