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Sustainable energy policy indicators: Review and recommendations

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Abstract

Nowadays, the development of a sustainable indicators' framework towards the sustainable energy policy making should be characterized by clarity and transparency. Even though the energy policy making has been the subject of many researchers, studies proposing an appropriate framework of sustainable indicators that have to be used are not present in the international literature. The purpose of the current paper is to present an integrated review of the methodologies and the related activities of the energy indicators and to recommend an operational framework of appropriate indicators supporting thus the policy makers/analysts/citizens towards a sustainable energy policy making.

Keywords: Energy policy; Energy indicators; Sustainability

1. Introduction

A number of indicators quantify and simplify phenomena in order to understand better a complex reality in the science, technology or society. According to the OECD (1993), indicators are defined as a value that comes from several parameters and gives information about a phenomenon [1]. Moreover, indicators do not represent reality, but they just approach the truth and they mostly present quantified information, processing different and multiple data [2].

Use of indicators is popular in many fields, above all the economic indicators, poverty, health, environmental and energy indicators. As far as energy indicators are concerned, they describe the relation between the use of energy and human activity and they can present economical and social activities' impacts of the energy market [3]. Energy indicators are mostly used for the correlation of energy (or the carbon emissions), in every activity or final use as a measurement unit of this activity. The basic form of indicators is the "normalization" of the use of energy to a specific activity, named as "intensity", which offers the advantage of comparison among similar activities or countries and gives the potential of monitoring the evolution of corresponding information in time. According to Patlitzianas and Psarras, energy indicators can usually reveal important information and characteristics of the energy market, even when analytical data are not available [4].

The energy policy is directed by the security of supply, the competitiveness of energy industry and the environmental protection, based on the European Union (EU) energy objectives. In this context, based on Kagiannas et al. [5], the energy indicators could be a very useful energy policy tools for supporting the procedures of decision making. Furthermore, the indicators are important as a guide to the decision making and for monitoring of evolution of policies that have been implemented [6].

Indeed, energy indicators could allow communication between policy makers and analysts between policy makers and citizens and between analysts and citizens. As required by the OECD [7], the indicators must be as clear as possible, so as to be understood and mutually acceptable to the above stated actors. In particular, they can help policy makers in [8]:

- monitoring of targets, which are set by national and international level,

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- estimating policies impacts that had already been implemented,
- planning of future policy actions, establishing priorities, recognizing basic key parameters that can influence the energy market.

The indicators can be used to measure the influence of changes in the energy demand or of changes in all activities using energy, i.e. in total energy use [9]. In addition to this, the indicators help to show how the use of energy is related with economical and technological parameters, as the energy prices, the economy's evolution and the new technologies. Moreover, the indicators and the comparisons that they provide, both in country level and internationally, provide analysts with the ability of comprehension of changes that involve relative policies and strategies [10].

The paper's approach that was adopted (based in a large part on the context of an on going FP-6 projects by the European Commission) incorporated desk analysis for the review, investigation of the role of international developers (EC, IEA, UN, etc.), as well as the development of a proposed methodological framework. In this context, the objective of the current paper is to present an integrated review of the methodologies/activities of the energy indicators and to recommend an operational framework of appropriate indicators, supporting thus the policy makers/analysts/citizens towards a sustainable energy policy making.

Apart from the introduction, the current paper is structured along the following parts. The second part is devoted to the review of widely spread indicators' methodologies and the related activities. The third part is devoted to the recommendation of an operational framework of energy policy indicators towards sustainability. Finally, in the last section the main points drawn up from this paper are summarized.

2. A review of related methodologies and activities

2.1. Methodologies

On the basis of literature review [2], several kinds of indicators have been developed. In particular, energy indicators can be categorized as follows:

- *Descriptive indicators*, for example, the percentages of energy per fuel.
- *Basic normalized indicators*, which indicate the use of energy of every field, divided by population or Gross Domestic Product (GDP).
- *Comparative indicators*, which try to indicate the similarity in characteristics between different countries, using necessary normalizations.
- *Structural indicators*, which distribute the economic or human activities in several scales or forms of performance.
- *Intensity indicators*, which relate the use of energy with a specific activity and they are mostly connected with the energy performance.
- *Decomposition indicators*, which indicate how different sections of total use of energy influence the total releases.
- *Causal indicators*, which indicate which kind of fundamental economic, demographic or geographical parameters influence most the use of energy.
- *Consequential indicators*, e.g., the exhaust gas, which measure the connection between the human activities and the use of energy, in terms of the environmental pollution or other disturbance of environment.
- *Physical indicators*, which indicate the change of the energy performance and productivity.

Moreover, according to the international literature, the main indicators' methodologies are summarized as follows.

Pressure–State–Response: This methodology was developed by the OECD, for the categorization of environmental indicators, and is based on the ''stress–response'' model [1]. The PSR methodology does not try to determine the nature or to shape interactions between human activities and the situation of the environment but tried to express how the human activities exert pressures in the environment that can involve changes. The society then reacts through the changes with environmental and economical policies and programs, which intend to prevent or to decrease pressures. The methodology's components are described as follows:

- *Pressure*: It describes direct and indirect pressures of human activities that are applied in the environment. Usually, the pressures are reported in factors or forces, such as the increase of population and consumption.
- *State*: It concerns the environmental conditions from the above-mentioned pressures, such as the atmospheric pollution, since environments state influences the human health and the socio-economic situation of the society. These indicators are directly connected with those of pressures and facilitate at the same time the planning of corrective actions.
- *Response*: It describes the actions taken to prevent or to decrease the environmental repercussions and to maintain the natural resources.

Driving force–State–Response: It was developed by the United Nations for monitoring the sustainable growth. The term ''Pressure'' was replaced by the term ''Force'', so as to incorporate in addition social, economical and institutional indicators. In addition to this, the use of this term allows positive or negative repercussions of the sustainable growth. In particular, the DSR is a table that includes horizontally the three types of indicators and vertically the dimensions of sustainable growth, namely the social, economical, environmental and institutional. The components of this framework are as follows:

- *Driving forces*: Human activities and procedures that affect the sustainable growth;

- *State*: The prevailing situation of sustainable growth;
- *Response*: Political and other reactions towards the sustainable growth.

Driving force–Pressure–State–Impact–Response: The widespread and most common acceptable methodological framework of indicators is DPSIR, which was adopted by the EU and provides a total mechanism for the analysis of environmental problems. The components' methodology is described as follows:

- *Driving forces*: These indicators describe social, demographical and economical developments in societies and their related changes that have impact on the way of life, the levels of consumption and the models of production. Driving forces can be considered as the increase of population and needs and activities of individuals. These initial driving forces cause changes in all levels of production and consumption and exert pressure in the environment.
- *Pressure*: These indicators describe the evolution of emissions, the use of natural resources and the ground. Examples of pressures are emissions of CO_2 per sector and the extent of ground that is used for the manufacture of streets.
- *State*: These indicators describe the quantity and the quality of natural phenomena (i.e., the temperature), biological phenomena (i.e., the volume of fishes remaining for fishery) and chemical phenomena (i.e., CO_2 concentrations in atmosphere) in a specific region. These indicators can, as an example, describe the existing resources in forests and wildlife or the level of noise in nearby regions.
- *Impacts*: These indicators are used to describe the effects that involve the changes that are caused by the above-mentioned pressures. Such effects are observed in the social and economic operations related to the environment, such as the availability of natural resources and the existence of satisfactory good conditions in the sector of health.
- *Response*: These indicators are reported in the reactions that appear in the society, as well as in the efforts of governments in order to deter, compensate, improve or adapt the changes of environment's situation. Examples of such indicators are the percentage of cars with catalyst and the percentage of recycling of domestic litter.

Pyramid: The growth of this methodology was based on the work carried out by the University of Utrecht and represents how analytical data and indicators can be combined so as to give total indicators, higher in pyramid [10].

A difficult step is the quantification of the contribution of various uses of energy and services that these indicators provide. If these contributions are known, then the efficiencies can be transformed into energy intensities (e.g., use of energy per kilometer of vehicle) or concrete energy requirements (e.g., use of energy per ton). In particular:

- *First element*: Intensities of each sector, which contain the total use of energy (per sector).
- *Second element*: Energy requirements of each main sector that have been selected in order to reflect a total aggregation of activities in each sector.
- *Third element*: Intensities of subsectors, representing the subsectors or the final uses that each sector recommends.
- *Characteristics*: This line contains an important collection of required elements, which is difficult to measure, either totally or (even each one) separately.
- *Lower line*: It represents even in bigger detail the natural or mechanical level that the real requirements may reflect.

2.2. Activities

2.2.1. Developers of energy indicators

European Commission: The European Commission (EC) has developed a range of appropriate energy indicators, mostly through Eurostat [11] and European Environment Agency—EEA [12]:

- The Energy Yearly Statistics publications with the energy balance sheets of the EU member states, which include related energy indicators [13].
- The studies for the expenses in research and development use the Frascati methodology guide [14].
- In 2000, results of a study, concerning the relation of environment and employment in the Netherlands were published [15].
- In collaborations of the IEA, for more than 25 years, a number of indicators have been developed, aiming at reassurance of energy supply of countries and the energy efficiency [16].
- The EU's Statistical Programme Committee founded a team for the creation of indicators so that a common approach for the European statistical system can be promoted. Furthermore, from the efforts of EEA more than 25 indicators are available as important tools to promote sustainable development. The indicators emphasize the environmental subjects.
- The EC collects elements for the database Newcronos that contains statistical data for the member states, and as far as the large number of printed publications concerns, characteristic are the LFS User Guide publications [17].

Organization for Economic Co-operation and Development: In the past few years, the Organization for Economic Co-operation and Development (OECD) has carried out

pioneering work in the sector of indicators, with the development of the following energy indicators [7]:

- Core Environmental Indicators (CEI), to monitor the environmental progress and factors that are related with the analysis of environmental policies. The 50 indicators cover subjects that reflect the main environmental concerns. The basic environmental indicators (Key Environmental Indicators—KEI) verified from the ministers of environment of OECD countries, constitute a smaller team of indicators that inform the citizens and provide important information to the policy makers.
- Sectored Environmental Indicators (SEI), to help in the unification of various environmental reflections in applied sectors' policies. Each group of indicators focus on different sectors (transports, energy, domestic consumption, tourism, agriculture). The indicators are classified based on an adoptive PSR model, reflecting sectored tendencies of environmental importance and their interactions (positive and negative result) with the environment.
- Environmental Accounting Indicators, to help with the unification of environmental subjects in economic policies and policies of management of resources.
- Decoupling Environmental Indicators (DEI), to measure the degree of the effect of environmental pressures in the economic development.

International Energy Agency (IEA): The IEA focused on the development of indicators for the energy use and efficiency in various sectors of the economy. The program of energy indicators of IEA has worked in collaboration with the governments and the research institutions is 12 member countries of IEA and also collaborated with the corresponding activities of the Committee [19]. More specifically:

- The effort of IEA on indicators began with a work on the Lawrence Berkeley National Laboratory in 1994 [20].
- The IEA undertook officially the analysis of international indicators, beginning in 1995 with the effort to connect the energy indicators with CO_2 emissions for the member states [21].
- The IEA developed in 2000, a model of energy and emission indicators [22], which presents the relations between the economy and the requirements of individuals and companies.

United Nations: Beginning in 1995, the United Nations, via the program United Nations Programme on Indicators of Sustainable Development, developed a basic department of indicators for the sustainable growth, which covers environmental, social, economical and institutional subjects of the energy and other sectors [23]. More specifically:

- In collaboration with a large number of governmental, intergovernmental and non-governmental organizations, United Nations Commission on Sustainable Development (CSD) developed in 1996, a preliminary list with 134 indicators [24].
- In 1998, the Department of Sustainable Development (DSD) shaped a collection of 43 main indicators and a provisional basic collection of 17 indicators for the measurement of changes in consumption and production [25].

International Atomic Energy Agency: The growth of indicators for the measurement and the imposition of one or more dimensions of sustainable development and their harmonization in local, national and world level constituted a fundamental effort of the International Atomic Energy Agency (IAEA) [16]. The mentioned effort was continued in the summit for sustainable development (World Summit on Sustainable Development—WSSD) that was realized in Johannesburg in 2002 with the shaping of core of energy indicators (Energy Indicators for Sustainable Development—EISD). The 30 indicators that constitute the core of the program EISD are classified according to three main dimensions: (a) social, (b) economical and (c) environmental. These dimensions are separated further in sections, such as objectivity and health for the social dimension, use of energy and energy safety for economic dimensions; atmospheric, aquatic and land situation for environmental dimension. The most recent application of the EISD program was realized in 2004 in the Baltic countries and the results were published in June 2005 [26].

Asia Pacific Energy Research Center: The Asia Pacific Energy Research Center (APERC) has undertaken the creation of energy efficiency indicators and the development of methodologies for their use. The indicators of energy efficiency can be considered as derivatives of indicators related to energy consumption and industrial production [27].

2.2.2. Research efforts

Based on the current analysis, the following research efforts were also recorded:

- The Lawrence Berkeley National Laboratory (LBNL) has created a particularly detailed, comprehensive and reliable sum of elements for the final energy uses and it constitutes roughly 90% of energy consumed in the tertiary sector. The data collected concerned the period 1994–1996 [28–30].
- The study of the Environmental Technology and Management Department of Mechanical Engineering of the University of Linkoping of Sweden examined the importance and use of energy indicators in the environmental research and management [31].
- The report of the Danish Environmental Protection Agency (DEPA) presented a series of important indicators for the social/cultural and economic dimension of energy services, specifically for the domestic sector [32].

- An effort on energy indicators related to the population and the uses of energy in the commercial buildings and was carried out by the Energy Information Administration (EIA), for the first time in 1979, and the eighth and more recent rounds of this research were carried out in 2004 [33–35].
- A study of the World Energy Council (WEC) was divided in units that cover the technologies in the industry, the buildings and the transport sector. Each sector of technology of final use is examined as for the specific technologies, the related objectives and challenges in the R&D [36,37].
- The European barometer of RES in the framework of the EurObserv'ER program is a tool that presents suitable indicators for the promotion of RES [38].
- The ADL study of Roth et al. (2002) undertook an estimation of the office's equipment energy consumption in the commercial sector [39].
- The Battelle program concerned data collected from eight countries (France, Germany, the United States of America, Japan, Italy, Canada, Great Britain, the Netherlands). The data included both governmental owned and private expenses for projects that can be undertaken by energy companies [40,41].
- In the final report of the Priority Setting Initiative (PSI) project, a series of indicators were developed. The data are mostly collected by member states, not including Belgium, Luxembourg and Sweden, but including Norway [42].
- The InterSEE program provided an in-depth analysis of parameters obtained on the social/cultural and economical dimension of energy services in small to medium-sized enterprises, via the development of a number of quantitative and qualitative indicators [43].
- The study Strategic Technology Scanning on research for strategic technologies [44] dealt with the relation of technologies and companies' strategy.
- The University of Technology of Vienna developed a methodology of indicators that found particular application in the domestic sector [45].
- The Senser program dealt with the European and national strategies for R&D expenditure data. The data that were collected concerned the years 1994–1996 [46].
- The ODYSSEE program provided energy indicators for the evaluation of energy efficiency in final consumption. The program included macro indicators as final energy intensities, normalized with GDP and climatic corrective factors, industry indicators as energy intensities of the industrial sector, transport indicators as specific energy consumption per passenger kilometer and household sector indicators as specific energy consumption of households per m^2 [47].
- The Research and Development Spending (REDS) program for the development of indicators and data regarding R&D for the RES in the EU concerned the period 1992–2001 [48] and this effort was continued in 2004 [48].
- European Committee [49] presented a set of indicators for monitoring the evolution of the aims of sustainable development.
- The Pilot 2006 Environmental Performance Index (EPI) of Yale Centre for Environmental Law & Policy (Columbia University) provides benchmarks for current national pollution control and natural resource management results. The issue-by-issue and aggregate rankings facilitate cross-country comparisons both globally and within relevant peer groups. The EPI thus provides a powerful tool for improving policy making and shifting environmental decision making onto firmer analytic foundations [50,51].
- Living in One World by the World Energy Council was a study of the linkages between human activity and the environment in which we live. Its aim was to clarify the linkages between the environment and the actions we take and in doing so to lay out the background to the challenge of sustainable development. In practical language, it looked at all linkages, including the important role of energy in development, and it examined indicators, which are often used to measure sustainability [52].

3. A recommended sustainable framework

3.1. Energy policy objectives

Nowadays, the sustainable energy policy making is directed by the objectives and priorities taking into consideration the impact of the specified characteristics in each country. Even if each state or geopolitical region has various energy policy objectives, depending on the level of economical growth as well as its status (importer, producer, exporter of energy), the three European objectives are described [4]:

O.1 *Security of supply*: The expected important economic growth of developing countries, mainly Asia and Africa, will have as a result the redeployment of available primary energy resources. While the importing countries try to cover their energy needs and minimize dangers that arise from their energy dependence, the producing countries face the danger of resources depletion. This act leads them to efforts of discovering new, difficult deposits, and also to the development of modern technologies [5].

O.2 *Competitiveness of energy market*: The energy market was deregulated and a large number of private companies began to participate in the energy production and distribution, increasing thus the competitiveness of the energy sector. Subsequently, the need for the establishment of regulating rules for the growth of competition in the energy sector was created. The impact of the deregulation and the introduction of

competitiveness in the energy market constituted the most crucial characteristic of energy policy.

O.3 *Environmental protection*: The operation of the energy market changes under the influence of the increased importance given to the environmental dimension, mainly through the increased weight given to the climate change [18].

3.2. Selection criteria for indicators

A number of related energy indicators, apart from the technological and techno-physical, such as socioeconomic (e.g., employment, turnover) and R&D expenditures indicators are of critical relevance [4]. However, the appropriate selection of energy indicators depends to the high degree on the policies that are decided to be monitored [52,53]. These policies determine the type of indicators, the level of analysis and, consequently, the data that should be available [54].

Moreover, a unique common framework of indicators does not exist, but depends on the specific characteristics of the decision-making problem to be monitored [55]. In addition to this, a reliable analytical framework and a pull of analytically and politically related indicators are needed [56]. Of course, it has to be also stated that the sufficient analysis of data does not necessarily drives to right decisions [57]. Even a completed database of indicators does not guarantee that the decisions will be to the right direction.

Based on the above mentioned, a number of criteria have to be taken into consideration for the selection of indicators, as illustrated in Table 1.

3.3. Recommended indicators

The energy policy making could be based on the following indicators for each one of the energy policy objectives.

Table 1
Criteria for the sustainable indicators' selection

C.1	*Appropriateness*
C.1.1	Realistic description
C.1.2	Transparency
C.1.3	Simplicity
C.1.4	Ability of comparison
C.2	*Completeness*
C.2.1	Technical and scientific adequacy
C.2.2	International acknowledgement
C.3	*Flexibility*
C.3.1	Easy calculation
C.3.2	Existence of right quality data
C.3.3	Ability of mapping changes
C.3.4	Easy connection with other models

Table 2
Indicators of the security of energy supply

No.	Indicator
I.1.1	Dependence on imports
I.1.2	Dependence on imports of solid fuel
I.1.3	Dependence on oil imports
I.1.4	Dependence on natural gas imports
I.1.5	Differentiation of primary fuel
I.1.6	Differentiation of fuel of electrical energy production
I.1.7	Differentiation of energy fuel
I.1.8	Strategic oil supplies

Table 3
Indicators of the competitive energy market

Nos.	Indicator
I.2.1	Energy intensity
I.2.2	Efficiency of energy conversion
I.2.3	Efficiency of electrical energy production
I.2.4	Transformation of energy sector
I.2.4.1	*Independent energy regulator*
I.2.4.2	*Private participation*
I.2.4.3	*Dividing of public enterprise*
I.2.4.4	*Energy law for the reforming and privatization of energy enterprises*
I.2.4.5	*Adjustment of energy pricelist*
I.2.5	Level of competition
I.2.6	Per capita energy consumption
I.2.7	Per capita electrical energy consumption

Table 4
Indicators of the environmental protection

No.	Indicator
I.3.1	Percentage of renewable energy sources in the primary energy production
I.3.2	Percentage of renewable energy sources in the electrical energy production
I.3.3	Indicators of intensity of emitted CO_2
I.3.3.1	*Emitted CO_2 per GDP*
I.3.3.2	*Emitted CO_2 per Gross Domestic Energy Consumption*
I.3.3.3	*Emitted CO_2 per capita*
I.3.3.4	*Emitted CO_2 per electricity and steam production*
I.3.4	Application of Kyoto Protocol

O.1 *Security of supply*: The securing of energy supply does not aim to maximize the independence on energy or to minimize the dependence of a country, but to minimize the dangers involved in dependening on external supply. Table 2 presents the proposed indicators of this objective.

O.2 *Competitive energy market*: This objective reflects the capacity for the provision of energy products and services that can compete with the international standards. Table 3 shows the proposed indicators that were related to the analysis of this objective.

O.3 *Environmental protection*: The third objective of energy policy refers to the protection from all external

parameters that are influenced by production of energy. Table 4 shows the proposed indicators for this objective.

4. Conclusions

The energy policy making constitutes an important process for the development of the energy sector, taking into consideration the energy developments and incorporating multiple and often three conflicting objectives (security of energy supply, competitiveness of energy market and the environmental protection).

In the above context, indicators constitute a communication channel to promote the exchange of information. Indeed, the need for analysis and description of energy issues, led to the creation of energy indicators and to the growth of methodologies, different indicators to address different corresponding issues under examination. The initial effort at description of concrete problems was followed by an effort at using energy indicators as guides for supporting decision making and formulating appropriate policies. Their usefulness is the main reason for their wide usage not in the field of energy, but also in many more fields.

Taking into consideration the above analysis, the main points are the following:

- *Development of indicators mainly from international organizations*: The efforts at developing indicators are by international organizations, and limited efforts have been made as national level. The research efforts for the development of methodologies and frameworks are until now limited in the international scientific literature.
- *Methodological frameworks that do not propose action of improvement*: The methodological frameworks of indicators that have been developed (PSR, DSR, DPSIR) concern mainly the environment and the sustainable growth. These frameworks, even if they support the decision making, do not propose appropriate actions of improvement.
- *Limited analysis of energy indicators for decision making*: Limited are the number of efforts at developing energy indicators concerning the evolution of energy policy goals. In addition to this, the indicators that have been developed reach great standards of analysis and they require analytical data, which many times are not available and sometimes even unreliable. Last, further work is necessary, aiming to improve the quality of already existing indicators and to better connect the indicators with policies, aims and their interactions.

For the above reasons, the need for the development of a limited number of indicators based on the three energy policy objectives (like the ones presented in paragraph 3.3) is evident, and processing to better cover the need for communication between involved parts.

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