Indicators Used in the Energy Sector

F. Martins and C. Felgueiras

Abstract—**World energy mix still depends heavily on fossil fuels but the foreseen increase demand, the scarcity of those resources, their unevenly distribution as well as other factors such as economic burdens due to fossil fuel prices and climate change concerns contributed to the establishment and implementation of new policies in the energy sector. Renewable energy sources are being promoted worldwide as a pathway to reduce external energy dependency, moving towards lower carbon energy systems. It is important to policy makers, investors and other stakeholders to have tools for deciding which policies, investments and measures should be implemented in the future. Thus indicators play very important role for fulfilling that task.**

This work present a structured presentation of several indicators commonly used to compare solutions in the energy domain.

Index Terms—**Energy, RES, Indicators, Sustainability.**

I. INTRODUCTION

In 2012 the world energy mix still relied heavily on fossil fuels, namely oil, coal and natural gas (Fig. 1). Since 1973 there was a slight reduction on fossil fuels but it is necessary to point out that the energy more than duplicate since then. The percentage of fossil fuels for total primary energy supply was around 82% in 2012 [1]. One main problem related to these energy sources is the fact that they are not renewable and they will be depleted if today's consumption rate increases or even if continues.

Coal is more abundant then oil or gas and is widely distributed, constituting 65% of the total of fossil fuel reserves. Main reserves of oil are in the Middle East and the two major reserves of gas are located in the Middle East and in Russia [2].

Another problem is the security of supply since some of these resources, such oil, are located in the Middle East. Concerning gas supply the recent conflict between Russia and Ukraine have increased concerns about gas supply security [3].

Since it is the most abundant fossil fuel and well distributed in the world, coal could be an option however its use stills presents very high environmental impacts.

Nuclear resources although not renewable were seen as an option to some countries. However Chernobyl and more recently the Fukushima accident had led to a shift in many countries that don't want to continue investing in nuclear energy due to the high impacts in case of an accident. Energy demand is foreseen to increase in the future and electricity is the final form of energy that presents the high

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rate of growing but power sector is contributing to the reduction in the share of fossil fuels in this sector [3].

In 2012 the electricity generation was 3.7 higher than in 1973 and in this sector the mix presents significant changes with a heavy decrease in oil as energy source (Fig. 2).
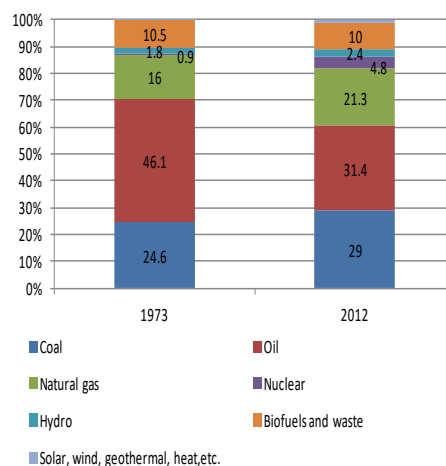

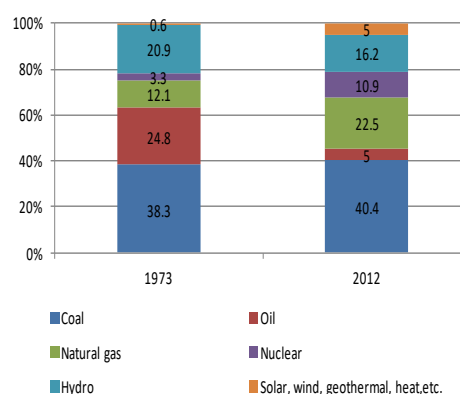Fig. 1. Energy mix for energy supply (data from [1])

Fig. 2. Energy mix for electricity generation (data from [1])

In this context Renewable Energy Sources (RES), such as solar, wind, hydropower, geothermal and biomass are being explored worldwide since they are renewable and they are able to contribute to solve the above mentioned problems. Moreover environmental aspects such as global warming are also solved or very attenuated and RES are critical to achieve low carbon energy systems. Energy efficiency is also important to decrease the demand and many efforts are being done in many countries in many fields, transports included [3].

However, renewable energy production and integration poses some economic and technical problems and its deployment has been promoted by governments for example by means of support mechanisms.

In most countries the use of more capital expensive technologies such as the ones associated with RES and the high prices of fossil fuels have increased the costs of

electricity to end-user [3].

For policy-makers, investors and other stakeholders it is important to have tools to identify which investments should to be done and the advantages and disadvantages of each technology. To carry on adequate decisions indicators play an important role once they define pathways to draw future energy systems. Many indicators are now used in the energy sector, each of them point out different aspects of energy system performance and for that reason it is important to synthesize and organize these indicators in order to better understand and used them.

This work presents the most common energy indicators used in the energy sector and their characteristics.

II. INDICATORS CRITERIA

Many authors have been publishing work about indicators for the energy sector. Some of these indicators are base on economical or financial information such as capital costs, operation and maintenance costs, net present value (NPV). Others use environmental information being one the most commonly used the CO_2 emissions. Other features also used to define indicators are technical aspects such as efficiency of the technology.

Social indicators can be based on, for example, job creation by production technology or country external energy dependency.

Some of economical, environmental, social or technical indicators follow a life cycle approach considering the life cycle of the project or production technology.

Finally there is the multi-criteria approach combining different indicators to help in the decision-making process. This multi-criteria approach can be developed under sustainability concerns.

III. ECONOMIC INDICATORS

In this section some of the economic indicators used will be listed (Table I).

TABLE I: ECONOMIC INDICATORS

Reference	Indicator
[4]	Net present value
[5]	Internal rate of return
[6]	Return on investment
[6]	Payback period
[7]	Benefit cost ratio
[4]	Capital cost
[4]	Operation & Maintenance costs
[8]	Levelised cost of electricity

Most of the indicators are generally known being widely used in many areas including energy sector. *Net present value*, *Internal rate of return*, *Return on* investment, *Payback period*, *Benefit cost ratio*, *Capital cost* and *Operation & Maintenance costs* fall in this category.

Concerning the *levelised cost of electricity* (LCOE) it is an indicator that is frequently used for renewable energy projects. The *levelised cost of electricity* is the average cost over the lifetime of the plant per MWh of electricity generated [9]. Key inputs to calculating LCOE include capital costs, fuel costs, fixed and variable operations and maintenance costs, etc.

In order to established the level of support for RES European Union considers the cost-based approach, namely the *levelised cost of electricity* as best practice. One important advantage of this method is to make systems more comparable [8].

IV. ENVIRONMENTAL INDICATORS

In Table II are listed some of the environmental indicators used to assess energy projects.

Due to climate change concerns the first two are often use. Renewable energy is able to reduce *greenhouse gas emissions* since the use of fossil fuels largely contributes to greenhouse gas emissions.

Other indicators used other pollutant emissions such SO_2 and nitrogen oxides.

In what concerns *human toxicity* some individualized indicators can be considered such as *carcinogenics* and *respiratory effects*.

Some of these environmental indicators are often used in a life cycle assessment (LCA) approach. Turconi at al. for example presented a critical review of many cases doing the life cycle assessment of electricity generation on hard coal, lignite, natural gas, oil, nuclear, biomass, hydropower, solar photovoltaic and wind. They considered three life cycle phases namely fuel provision, plant operation and infrastructure and they concluded among other things that *greenhouse gas emissions* could not be used as a single indicator to represent the environmental performance of a system or technology [10].

TABLE II: ENVIRONMENTAL INDICATORS

Reference	Indicator
[11]	CO_2 emissions
[12]	Greenhouse gas emissions
[13]	SO_2 emissions
[13]	Nitrogen oxides emissions
[14]	Abiotic depletion
[14]	Ozone layer depletion
[14]	Human toxicity
[14]	Photochemical oxidation
[14]	Acidification & Eutrophication
[14]	Land occupation
[15]	Water footprint
[14]	Ecotoxicity

V. TECHNICAL INDICATORS

In this section some of the technical indicators often used will be mentioned (Table III). Some of them are also determined using a life cycle assessment approach such as *cumulative energy demand* and *energy payback ratio*. The *cumulative energy demand* is the ratio between all energy required to build, maintain and supply (includes embedded energy) and the final energy product generated during the life span. The *net energy ratio* is the inverse of *cumulative energy demand* [16]. The *energy payback time* is the length of time a system must operate before it recovers the energy invested throughout its life time. The *energy return on energy*

investment is the ratio between the energy obtained from a system and primary energy invested in upstream activities [17]. *Efficiency of technology* is a unit less indicator and, when considering nonrenewable plants, is calculated using heat rates [18]. *Efficiency* can also be defined as the electricity generated by power installed and this case it calculates the amount of electricity generated per kW installed [19], [20]. Usually the power installed depends on the energy to be obtained based on also on site characteristics. This indicator allows verifying the performance of the system. The *capacity factor* is a unit less ratio between the energy produced for a given period of time and the energy that would be produced if the system was operating at its full capacity for the same period of time.

TABLE III: TECHNICAL INDICATORS

Reference	Indicator
[21]	Cumulative energy demand
[22]	Net energy ratio
[17]	Energy payback time
[17]	Energy return on energy investment
[22]	Efficiency of technology
[22]	Capacity factor
[20]	Efficiency

VI. SOCIAL INDICATORS

In Table IV are presented some social indicators that can be used. *Job creation* measures the number of jobs created for a given technology during its lifetime.

External energy dependency is the ratio between imported energy and total energy required. *Fuel dependency* is the ratio between imported fuel and fuel required. Finally, the *fuel reserve years* are the number of years until full depletion of a given non-renewable resource [22].

TABLE III: SOCIAL INDICATORS

Reference	Indicator
[22]	Job creation by technology
[23]	External energy dependency
[22]	Fuel dependency
[22]	Fuel reserve years

VII. MULTI-CRITERIA ANALYSIS

There are many works that use a multi-criteria approach some of them embedded with sustainability concerns [16], [22], [24]. Some of them use an Analytic Hierarchy Process to build their models and others use multi-criteria decision-making (MCDM) methods such as Dominance, Maximin, Lexicographic, TOPSIS (Technique for Order Performance by Similarity to Ideal Solution) and SAW (Simple Additive Weighting). In these works generally are considered indicators from different categories, economic, environmental, technical and social.

VIII. CONCLUSIONS

The energy sector is now facing many challenges due to the scarcity of non-renewable resources, their uneven distribution, the environmental and sustainability concerns. New policies and measures are being implementing worldwide to face a foreseen increase in energy demand and to reduce greenhouse gas emissions. RES deployment and integration is necessary because it allow the exploitation of renewable resources available in the regions contributing to reduce the use of fossil fuels and, in many cases, to the reduction of external energy dependency which in turns increases the security of supply and reduces the economic burden. This can make countries' economies more competitive are less vulnerable to the increasing fossil fuel prices. Besides, it can also create new jobs increasing the welfare of populations. However RES integration in the energy systems poses technical problems that should be address in order to be able to move to low carbon economies. For that reason, indicators are important tools for policy-makers and other practitioners because they help to assess different pathways for the future. The use of the indicators presented allows the establishment of targets and to perform benchmarking analysis.

As demonstrated the indicators considered in this work allow the assessment of energy systems, by considering different criteria namely economic, environmental, technical and social. Some authors already use a set of indicators from different areas (e.g. economic, environmental, etc.) to assess different alternatives. Other authors use a life cycle assessment approach to assess indicators related to energy systems. Overall the use of indicators is able to promote sustainability of energy systems.

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