sustainability

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Review

Energy Policies and Sustainable Management of Energy Sources

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Abstract: Sustainability of current energy policies and their mid-term outlooks are investigated. First, an overview is given about the trend of global energy demand and energy production. The share of energy sources and the geographic distribution of demand are analysed on the basis of the statistics and projections published by major agencies. Sustainability of selected renewable energy sources is then explored. Finally, potential use of Hydrogen for energy storage in systems with high share of renewable sources is investigated.

Keywords: sustainability; energy sources; renewable sources; energy efficiency; energy demand

1. Introduction

The concept of sustainability involves a web of environmental, economic and social factors and in the field of energy it clearly shows its complex interdisciplinary nature.

The core of energy sustainability concerns deals with the inescapable depletion of fossil fuels [1]. Formidable challenges and dramatic choices have to be faced to develop viable substitutes: development of renewable sources is mandatory, but it is not exempt from drawbacks for energy security; nuclear could be revitalized, but its well-known contraindications shall be taken into account and accepted. In general, development of low-carbon energy sources also rises an issue of affordability.

From the environmental perspective, the exploitation of fossil fuels for energy production is one of the main reasons of climate change and air pollution [2]. Actually, as it is clearly shown in Figure 1, the most common fossil fuels are associated to CO_2 emissions ranging from 0.5 to 1.1 kg CO_2/kWh eq. These values are more than halved when Carbon Capture and Storage (CCS) technologies are in use and are smaller by more than one order of magnitude for renewable energy sources. On the other hand, fossil fuels currently are the most common energy source, and only infrequently are associated to CCS installations. This is causing release of Carbon Dioxide (CO_2) at a rate higher than absorption by forests, oceans and other natural CO_2 sinks, resulting, as it is widely accepted, in the already perceived global temperature increase.

The scenarios and the outlooks for the emissions of Green House Gases (GHG) developed by several international organizations [3–7] clearly show that the goal of stopping the temperature rise before half of the century would require strict energy policies. Even the commitments of the 196 countries who signed the Paris agreement on climate change [8], enforced in November 2016, will be sufficient to slow down the growth of CO_2 emissions, but not enough to stop it. Stronger efforts would be needed, with heavy constraints about the amount and quality of energy consumptions. This could be—and has been to some extent—accepted in many mature economies [4]: it is possible to improve the energy efficiency of industrial processes, buildings and vehicles, or even to modify certain lifestyles in a perspective of eco-sustainability. Otherwise, in emerging countries a reduced use of coal and hydrocarbons would be an unacceptable burden, as low-cost energy is essential for their industrial growth, which in turn is a prerequisite to increase population welfare.

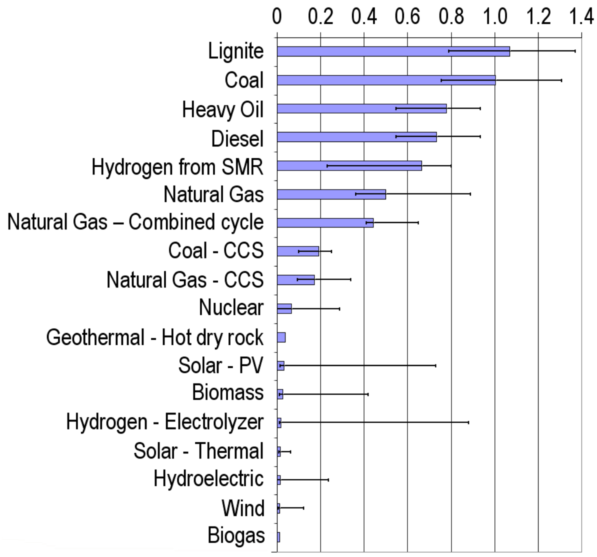

Figure 1. Emissions of Green House Gases (GHG) for selected energy sources (kg CO_2/kWh eq). The histograms refer to average values, while the error bars correspond to the reported values (Data sources: [9–11]).

On the other hand, sustainability is not limited to energy and environment: in the broadest sense of the term, an activity is said to be sustainable [12] if it can go on indefinitely without producing any adverse effects, either in environmental, economic, technical and social terms or in any other field. In other words, a sustainable activity does not result in limitations on the possibility that any other activities are carried out by different subjects, even at other times and elsewhere.

Thus, another issue of sustainability is the access to energy: today, large swathes of the global population have no access to electricity (16% of the world's population, including over 645 million people in Africa [13]). This situation cannot last too long: this number is expected to shrink, but not to vanish in the next decades (it has been estimated that in 2040 nearly 500 million people will be still without access to electricity).

The perspective of reducing the exploitation of fossil fuels could also pose different issues for the countries that currently are more strongly linked to their consumption and production. The envisaged regulatory policies would be able to manage in a planned way the reduction of global production of fossil fuels, avoiding shocks for sudden changes in availability of energy sources in the consuming countries as well as mitigating the social effects of economic transformations in the producing countries. This is also a matter of sustainability, when it is intended in its widest meaning [12].

In the next section an overview is given about the trends of global energy needs and production on the basis of the statistics and projections published by major international organizations [3–6]. The share among energy sources, the geographic distribution of consumptions and their medium-term evolution scenarios are reported and analysed. The sustainability of some promising technologies is also explored in Section 3.

2. Evolution of Energy Needs and Regulation Policies

According to the U.S. Energy Information Administration (EIA), the global Total Primary Energy Supply is currently larger than 14 Gtoe (10^9 Tonnes of Oil Equivalent), and is almost equally shared among Industry, Transportation and Buildings/Agriculture [4].

The amount and quality of energy needs in the near future are the subject of great attention, as most anthropogenic CO_2 is produced in the energy sector. Thus, several organizations like EIA and IEA (the International Energy Agency) yearly provide long-term outlooks, referred to updated statistics and different sets of assumptions related to international policies, economic growth and investments in the energy sector.

A crucial role will be played by the technological improvements achieved both in energy production and in user installations. In turn, they will both be affected by non-technological issues like the price of energy, which on the other side is dependent on factors like the amount of oil produced by OPEC (Organization of the Petroleum Exporting Countries) and the political stability in oil-producing countries.

Some effects of different assumptions on energy consumptions are addressed by taking into account both a Reference Scenario with 3%/year increase of the World Gross Domestic Product, and alternative scenarios for High/Low-Economic-Growth and High/Low-Oil-Price. The price of oil is indeed doubly linked to the rate of economic growth: in case of stagnation, the low energy demand could lead to an oversupply that would limit the oil price (the price of North Sea Brent crude could remain in the range $40–60/barrel (in 2016 dollars) until 2040) (1 barrel = 158.9873 L = 0.14 toe). In this scenario, interest in the development of renewable energies and in the technologies for sustainability of energy consumption would be rather feeble. In contrast, in case of robust economic growth, the strong energy demand would push the price of oil, which could exceed $220/barrel in 2040. Despite the economic prosperity, in this scenario the attention to energy policies could be much higher. Therefore, EIA developed separate outlooks for the different scenarios.

IEA also developed outlooks referred to as different sets of environmental policies. The reference scenario (IEA New Policies Scenario, NPS) is based on already-announced policy commitments and plans for reduction of green house gas emissions and improvements of energy efficiency. According to this scenario, the Total Primary Energy Supply (TPES), driven by increase of population and economic activities, will rise to nearly 18 Gtoe in 2040, with an average growth rate of about 1.4%/year. The corresponding Total Final Consumption (TFC) will be 12.54 Gtoe, with the industry sector still accounting for more than 31% (Figure 2). The graph also reports in grey the TPES for different years: it can be observed that according to the NPS, the ratio TFC/TPES will be still 70% in 2040. With respect to current trends, the NPS predicts some mitigation of environment modification rates.

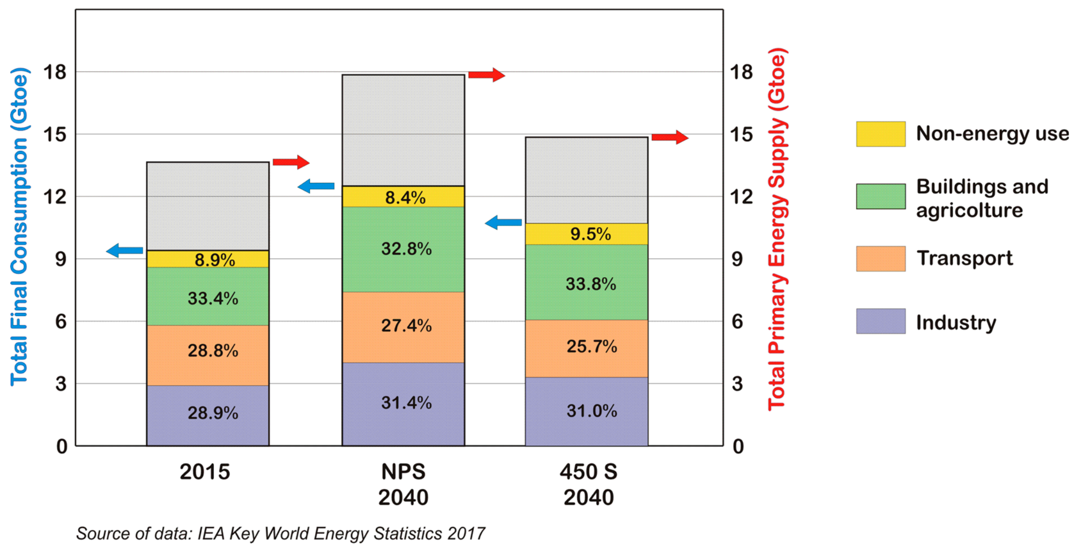

Figure 2. Total Primary Energy Supply (Grey) and Global Total Final Consumption by sector (colors). Outlooks for year 2040 are reported for different scenarios (Data from IEA, Key World Energy Statistics 2017 [3]).

Unfortunately, they are not sufficient to stop the increase of global temperature, which would be around +4 °C by 2035 instead of +6 °C, as a result of unstopped increase of carbon emissions (the energy-related CO_2 emissions would rise by 34% in 2040).

Otherwise the goal of stopping temperature increases, albeit in the second half of the century, is foreseen in the IEA 450 scenario This scenario envisages a set of challenging energetic policies, intended to limit the concentration of net CO_2 in the atmosphere to 450 ppm in 2035, in order to have a 50% chance to limit the temperature increase to +2 °C. In this case, in 2040 the TPES will be limited to less than 15 Gtoe, with a TFC around 10.7 Gtoe, and an improved TFC/TPES, increased to 72%. On the other hand, this goal would require hard efforts for decarbonisation and larger investments (nearly double than in the reference scenario) in low-carbon energy sources, as well as in efficiency and in Carbon Capture and Storage (CCS) systems [2]. As shown in Figure 3, in addition to an overall reduction of energy demand it entails a wider use of renewable and nuclear energy sources.

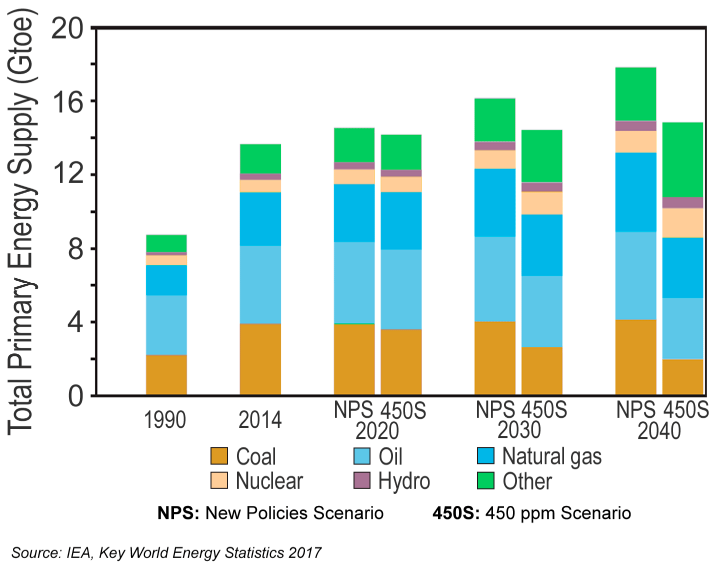

Figure 3. Breakdown of world Total Primary Energy Supply to 2040 by source and scenario (from IEA 2017 [3]).

The target temperature increase (+2 °C in 2035) set in the 450 Scenario is the same agreed by the 196 countries participating at the 2015 21st United Nations Climate Change Conference of Parties, UNCC COP 21, held in Paris [11,12]. They also pledged to make efforts to further lower the temperature increase to 1.5°C, in order to anticipate achievement of the zero-net-CO_2 emissions and to be able to stop temperature increase in the period 2040–2060.

Some countries are well underway to meet their climate commitments. In the European Union (EU), several countries enforced strong subsidies policies to promote Renewable Sources. Among them, Denmark reached record shares of wind energy, also developing interconnections with neighboring countries to sell random excess production and to trade it e.g., with occasional excess hydroelectric production from Norway. There and in other northern countries the District Heating, often combined with electricity generation (Combined Heat and Power, CHP), is regularly used to increase energy efficiency. In Denmark the share of biomass consumption for this application is reaching 50%. Thus, the CO_2/TPES ratio for several European countries is dropping well below the average value in the Organisation for Economic Co-operation and Development (OECD) countries (Table 1, [3]). On the other hand, they are small countries and their efforts can give just minor contributions to the global balance. Otherwise, an appreciable contribution could come from the United States of America (USA), where in 2015 the Clean Power Plan (CPP) was enforced. The related policies for reduction of coal consumption and development of renewable energies have been estimated to lead to a 2.5% reduction of global carbon reduction since the end of this decade. Unfortunately, the CPP has been questioned by the new USA administration and the future environmental contribution to reduce air pollution is somewhat uncertain.

Table 1. Selected indicators for some economies in 2015 (from IEA 2017 [3]).

	Population (Millions)	TPES (Mtoe)	TPES/Population (Toe/Capita)	CO_2/TPES (tCO_2/Toe)
World	7334	13,647	1.86	2.37
China	1379	2987	2.17	3.04
India	1311	851	0.65	2.43
Africa	1187	788	0.66	1.45
Non-OECD Asia	2438	1679	0.73	1.59
OECD	1277	5259	4.12	2.23
USA	321	2188	6.80	2.16
Denmark	5.7	16	2.83	1.99
Iceland	0.3	5.6	16.87	0.37
Italy	60.7	152.6	2.51	2.17

Generally, in mature economies, like those in the OECD countries, the production of greenhouse gases is going to stop rising and will start a slight decrease (Figure 4), as a result of subsidies and other environmental policies intended to favor increase of energy efficiency and development of renewable sources. In 2015, the OECD countries consisted of less than 20% of the world population and absorbed nearly 40% of TPES (Table 1). In the future, these percentages are going to change, even for demographic decline and slowed economy growth.

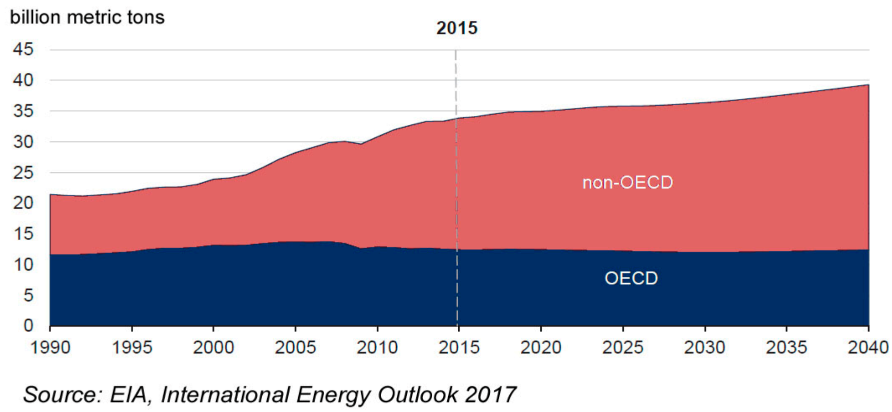

Figure 4. Energy-related CO_2 emissions (billion metric tons) (Source of data: EIA, *International Energy Outlook 2017* [4]).

However, the efforts for sustainability made in the high-income countries will be compensated by the increased production of Green House Gases in many emerging countries like India, China, south-east Asia, where inexpensive fossil sources, like coal, will continue to be widely used, at least in the first decades ahead (Figure 4). Actually, these countries are expected to undergo a strong demographic increase that, multiplied by their economic growth, is going to boost energy consumptions. This growth will be mostly sustained by fossil fuels and they are expected to be responsible for more than 80% of the increase in energy demand and fossil fuel consumptions (see Figure 5). I Only in China the consumption of coal is expected to saturate for the spreading of new installations based on nuclear energy. Thus, all energetic and environmental outlooks are going to be dominated by the choices, policies and political stability of these countries, still labeled as “emerging”.

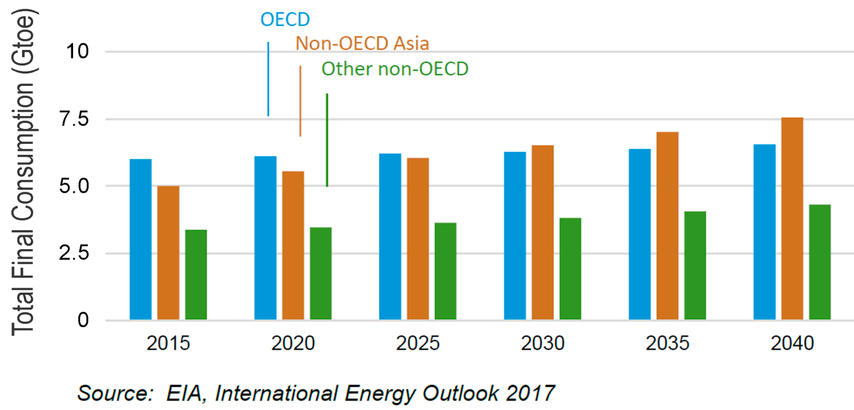

Figure 5. Projected growth in energy demand inside the OECD and outside it (Gtoe) [4].

However, even in the most challenging scenarios, the envisaged global reduction of fossil fuels would take place only in the long term. Thus, for the sake of energy security, in the short term a large share of investments will be still devoted to oil, gas and coal extraction, in order to maintain a fair set of operating sites for extraction of fossil sources.

According to the EIA [4], natural gas is going to grow more rapidly than the other fossil fuels: in 2040 its production will be increased by 50% (nearly 1.5%/year), supported by the production of non-conventional gas [5], and will provide 28–29% of global consumption, with a share nearly equivalent to coal and renewable energy sources. The growth of natural gas will be only limited by the economic competition with other sources: despite the low carbon emissions, low capital costs and high operational flexibility of gas-fired plants, the gap with costs of coal supplies will still be limiting their economical appeal.

An interesting market development will arise from the quick increase of Liquified Natural Gas (LNG). It allows gas trading among countries not connected to specific gas infrastructures, and will promote the expansion of exporters like the US and Australia, allowing new actors to step into this market.

Consumption of oil and other liquid fuels (see Figure 6) will be almost stable in the long term, as the increase in the developing countries will be offset by a corresponding decrease in the OECD countries, where oil will continue to be used mainly for petrolchemicals, aviation and freight. Oil production will take place mainly in the Middle East, with a minor contribution from the US arising by the tight oil, extracted by hydraulic fragmentation from geologic formations of low permeability.

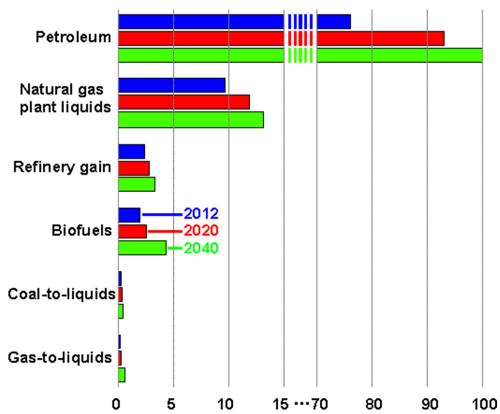

Figure 6. Production of liquid fuels by type (millions of barrels per day) (1 barrel = 0.14 toe) (Source of data EIA, *International Energy Outlook 2017* [4]).

In general, the oil demand will also depend on economic trends, especially in the emerging countries, which in turn will be linked to a series of geopolitical factors that hardly can be traced back to a mathematical model. Indeed, after OPEC decided to reduce oil prices from over $100 per barrel in mid-2014 to below $40 in early-2016 (see Figure 7), a certain uncertainty arose about the payback times of the upstream investments to search and develop new oil fields. Thus, after 2015 investments sharply dropped. This situation is harmful for energy security, as the existing fields have a limited operating time and in the early 2020s they could be insufficient to match demand, with a likely new boom of prices and backslashes on the global energy market. In that situation the tight oil produced in the US would be a valuable resource, even if with limited geographical spread.

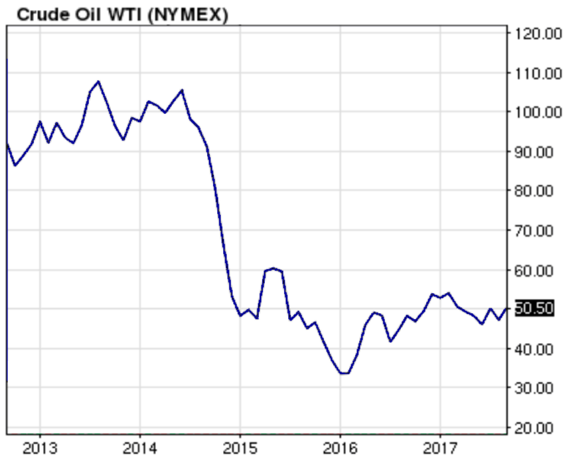

Figure 7. Price of crude oil in the last 5 years (US $) (Source of data: Nasdaq [14]).

Instead, coal production will remain nearly stationary on a global scale, at least in the Reference Scenario (Figure 8), where it is going to reach a plateau in China [4] and to decrease in higher-income economies (−60% in the EU, −40% in the USA). On the other hand, this reduction is going to be offset by the increase expected in India and, to a lesser extent, in other emerging economies, which cannot afford to neglect such a low-cost source. In fact, coal prices, despite the rebound observed in 2016, (Figure 9) currently are going to level off at values making coal still economically competitive with natural gas.

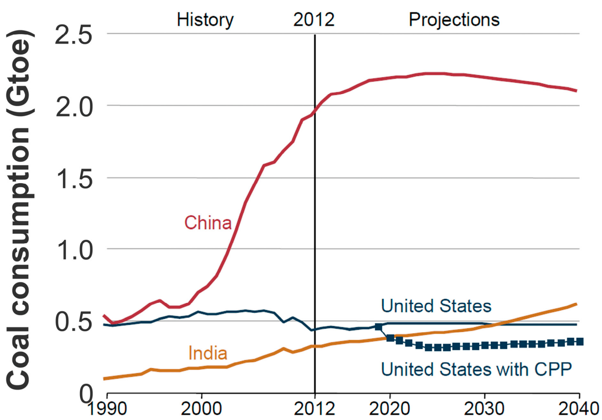

Figure 8. Projected coal consumption in the largest coal consumers. The expected effect of the Clean Power Plan is also highlighted (Source: EIA, *Analysis of the Impacts of the Clean Power Plan*, 2015 [15]).

Figure 9. Price of coal in the last 5 years (US$/t) (Source: [16]).

Nearly 25% of the global increase in energy production is currently destined to electricity production. In future, this share is going to rise to 40% in the main scenario and up to 85% in the 450 Scenario. Only 15% of this increase will occur in OECD countries. The increase will mostly take place in non-OECD Asia, notably in India and China. Thus, the environmental impact of energy production will be mostly determined by the energy policies taken in these countries.

Production of electrical energy is currently supported for about 75% from fossil fuels, for 10% from nuclear, for 10% from hydroelectricity and only for 5% from renewable sources. It is expected that the global production of electricity will rise from the current 25 billion kWh to 37 billion kWh in 2040 (see Figure 10). The use of fossil fuels for electricity generation will continue to rise, mostly for the increase of natural gas exploitation [5].

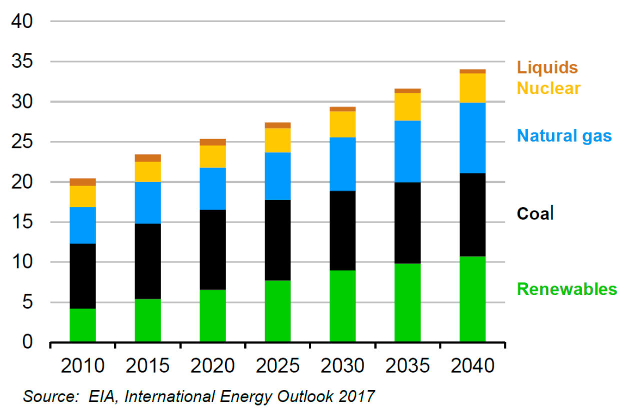

Figure 10. Projected growth of electricity production from different energy sources (PWh) (Source of data: EIA, *International Energy Outlook 2017* [4]).

Coal plants for electricity production are the largest source of energy-related CO_2 emissions and this trend will remain the same also in the next decades, even if their share of pollution will be reduced due to a larger exploitation of natural gas.

In the market of energy production, CO_2 emissions are continuing to rise in the non-OECD area, despite the fact that specific emissions are expected to decrease from today's 515 g CO_2/kWh to 335 g CO_2/kWh in the Main Scenario or down to 80 g CO_2/kWh in the 450 scenario (Figure 4). On the contrary, in OECD countries the trend of emissions will be sharply decreasing, as a result of increased deployment of alternative energy sources, like renewables and nuclear, and of enhanced efforts to increase energy efficiency.

Actually, the share of renewable sources is expected to undergo a strong increase (300%), mainly driven by wind farms (see Figure 11), and by hydroelectric production, which will grow at a smaller rate (40–50%).

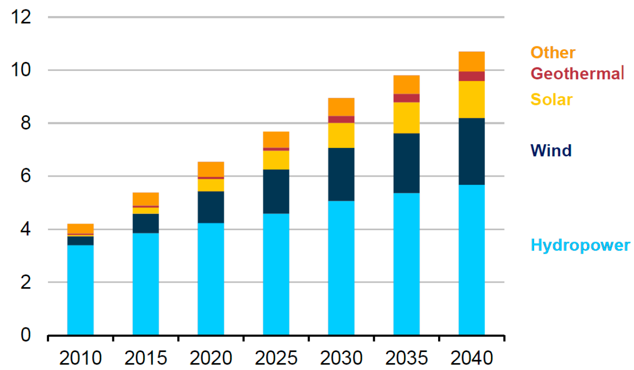

Figure 11. Projected growth of electricity production from renewable sources (PWh). Other sources include: biomass, waste, tide/wave/ocean (Source of data: EIA, *International Energy Outlook 2017* [4].

Similarly, an increased share of nuclear power is considered in most scenarios. In particular, the planned stop to the increase of coal consumption in China will be enabled by means of a planned massive deployment of nuclear installations. On the other hand, despite the fact that nuclear power is undoubtedly a low-carbon technology and cannot be neglected in a world where the main concerns arise from global warming and depletion of fossil fuels [2], its sustainability is largely questioned for the release of radioactive waste. Reprocessing techniques are available, but a small amount of radioactive end products still is produced and must be managed and stored for long time. Concrete structures have been built with an expected life of 10,000 years (twice the Egyptian pyramids), but after this enormous amount of time the radioactivity and the lethal potential of nuclear waste will be only partially mitigated. Even the idea of storing nuclear waste in deep geological cavities is not free from drawbacks [17,18].

In order to understand the relevance of nuclear technology, in 2011 the IEA also developed a low-nuclear 450 scenario [19] with a share of nuclear energy halved with respect to the Reference Scenario. The 450ppm target would be still achievable, but costs would appreciably increase due to a wider deployment of CCS and other means to absorb the residual CO_2 emissions. It would be also necessary to limit the growth of energy consumptions, with relevant effects especially in the economy of developing countries. Most of all, a larger contribution from variable renewable sources would be required, with implications on the energy security.

Energy efficiency has been also acknowledged as a basic energy source [20]. Its potential can be highlighted by comparing the data on the global energy production in (>13.6 Gtoe in 2015) with the final energy consumption (<9.4 Gtoe) [21]. For example: the average efficiency of the coal-fired and gas-fired thermal power plants in operation all around the world is around 33%, whereas the best plants currently in operation can provide efficiencies larger than 50%.

In different application fields the potential energy savings are bounded to specific technological issues: for example, in the industrial field relevant energy savings can be provided by improvements in the process efficiency; in the field of transportation, advantages would arise from shifting road freight traffic to rail or ship; in private transport, savings could arise from electric or hybrid vehicles; in the residential field, improvements could arise by introduction of sustainability criteria in building construction and by more efficient air conditioning techniques. Electricity consumption could be also halved in a range of end-use applications (e.g., fans, pumps, compressors, refrigerators) simply by upgrading electric motors power supplies with inverter drives.

Further relevant savings could arise from the reduction of losses along electricity distribution grids: they are nearly 2% in Europe, but are larger than 5% in many countries, and, despite recent improvements, are still close to 20% in India.

3. Renewable Sources and Sustainable Management of the Cycle of Energy

As discussed above, in the field of energy production a large growth is expected for renewable sources (2.6%/year in the NPS scenario, i.e., nearly 60% of new energy installations by 2040). The growth would be even larger in the most challenging scenarios. This trend will be also sustained by technological advances and economies of scale, which are expected to make renewable sources competitive even in the presence of reduced or null subsidies: e.g., prices of solar photovoltaic are expected to drop by 40–70%, prices of onshore wind by 10–15%.

The prospected growth makes it important to investigate implications and limits of the various energy sources, not only in terms of their environmental footprint during operation, but by life-cycle analyses taking into account all facets of their sustainability [22].

From a sustainability perspective, biomasses appear to be among the most interesting energy sources, as they provide a close approximation to a closed life-cycle: in fact, energy is produced while releasing as a waste product CO_2 that in turn can be fixed in new vegetal species by photosynthesis and solar radiation. This process could be supplied indefinitely, whereas other resources are consumed only for construction of the conversion plants and of the energy distribution infrastructures, to transport of the biomasses to the facilities themselves and to energy transport to the user. Among other advantages, biomass installations can easily operate at variable power, with short response times, following the trend of energy demand. On the other hand, environmental sustainability of biomasses is the subject of a quite lively debate. Cultivation of the biomasses intended for energy production takes territory, and for this reason it is in competition with the crops intended for food production. Consequently, the opportunity to have a relevant contribution of biomasses for global energy production is still debated. Other doubts on their use derive from the concern that profitability of the crops intended for energy production can boost deforestation and anthropization of wild lands, that otherwise should be protected as a shelter for biodiversity. Among biomasses, an interesting development occurred for wood pellets, which are establishing as an energy source for heat generation in buildings and small factories. They are also used for utility-scale electricity generation in Northern Countries like the United Kingdom, The Netherlands and Belgium.

Solar photovoltaic owes a part of its success to modular construction and to its natural tendency to match the daily energy demand curve. On the other hand, its relatively small power density entails wide land occupation exceeding the surfaces made available by integration in urban/industrial environment. However, their production is affected by relevant energy consumption. Precise lifecycle assessment depends on the specific solar cell technology, on the site of operation as well as on the energy mix in the place of manufacturing. Recent publications [23] estimate for typical installations based on the multi-crystalline technology a lifetime energy production of the order of ten times the energy needed for their manufacturing.

Otherwise for wind turbines the lifetime-energy-production can be two orders of magnitude larger than the manufacturing-energy-consumption. This fact, the low amount of resources involved in their manufacturing as well as the relatively low costs, are going to make wind farms the faster-growing renewable source in the next decades.

On the other hand, both solar photovoltaic and wind are characterized by variable energy production with prominent periodic variations, both hourly and seasonal, superimposed to large random fluctuations. As long as they will be providing a minor share in the energy systems, it will be possible to stabilize the balance between demand and production by strengthening the grid, or arranging different power plants ready to dispatch at short notice. Otherwise, in case of large share (a threshold is typically set at 25%), this approach will be hardly feasible. Thus, in order to guarantee energy security against their fluctuations, an extra capacity would be needed (e.g., it has been estimated that the EU grid would need at least 40% extra capacity). This, in turn, will make available surplus energy for long periods (estimated 1/3 of the time in the EU or 1/5 of the time in the US and India). This energy could be traded among neighboring countries, like it is already done in Northern Europe, or it could be stored in specific installations. Thus, the expected spreading of renewable energy sources is going to be accompanied by deployment of large energy storage facilities.

The available storage technologies use different forms of energy (Table 2): gravitational in hydroelectric basins, electrochemical in batteries, electrostatic in supercapacitors, kinetic in flywheels, magnetic in Supeconductor Magnetic Energy Storage, mechanic in compressed-air tanks.

Table 2. Storage technologies.

Storage Technology	Specific Energy (MJ/kg)	Energy Density (MJ/L)
Liquid hydrogen	141.86	8.491
Hydrogen (compressed at 700 bar)	141.86	1.3–1.6
Li-Ion batteries	0.4–0.9	0.9–2.7
Alkaline batteries	0.5	1.3
Lead batteries	0.17	0.56
Supercapacitors	0.01–0.04	0.06–0.05
Air (compressed at 200 bar)	0.5	0.14
Water (100 m height)	0.001	0.001

At present, no approach has been established as the most promising, both because any technology has different performance in terms of storage duration or response time and because of their environmental impact. Among the technologies suitable for seasonal storage, batteries have problems with raw materials, which could be toxic (e.g., Lead, of Cadmium) or not abundant on the Earth's crust (Lithium [24]). Otherwise, hydro-electrical basins have a relevant impact on landscapes, could modify local microclimate and could affect economy of the downstream populations. Thus, the available sites are nearly saturated. Compressed-air requires enormous geological cavities, like depleted oil fields, which are not easily found.

A very attractive approach is energy storage in the chemical bonds of hydrogen molecules [25,26]. Hydrogen is easy to transport, in tanks or via pipelines. It also allows long-term storage, similarly to hydroelectricity and compressed air. Moreover, its specific energy (142 MJ/kg) is by far the largest among the considered energy carriers. On the other hand, energy density of H_2 is considerably lower than that of fossil fuels (e.g., it is nearly 20% of that of natural gas, at the same pressure), albeit comparable with other storage technologies (V. Table 2) [26].

Mostly, the life-cycle of hydrogen can result in a very low environmental impact, when it is produced by electrolysis. This process consumes mainly water and electricity that could be entirely supplied from renewable sources. Unfortunately, the overall efficiency varies between 20% and 30%, depending on the specific process (see Figure 12) and this could be a limitation to the potential widespread diffusion of hydrogen storage.

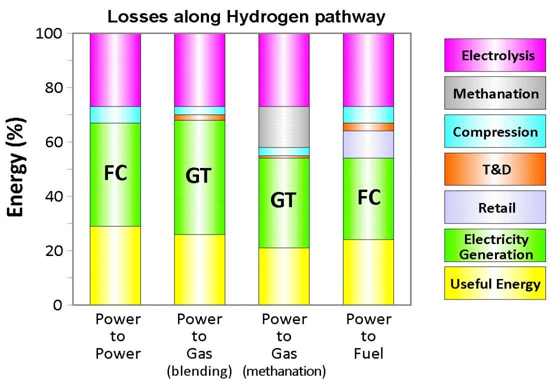

Figure 12. Energy balance in the different hydrogen integration schemes (FC: Fuel Cell, GT: Gas Turbine) (Source of data: IEA 2015 [25]).

4. Conclusions

Sustainability of energy system has been analysed in terms of some economic, social and environmental facets. The projections on energy consumption show that, in the next two decades, major changes will take place in energy consumption, in its geographical distribution and in the composition of the energy portfolio. The global energy demand, the share among different energy sources and the related environmental footprint will be determined by the energy policies of countries still labelled as "emerging". The even strong efforts made by the few countries with mature economies will be important, but not relevant enough to avoid the forthcoming climate changes. The good news is that almost all countries in the world, including the fast-growing giants, ratified the Paris Climate Agreement. When the Paris pledges will be translated in real policies the most favourable outlooks will come true and perhaps we will still be in time to stop temperature increase before irreversible damages are done.

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Conflicts of Interest: The authors declare no conflict of interest.

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