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RESEARCH ARTICLE

Biomass and Energy Sources with the Lowest Ecological Footprint

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ABSTRACT

The aim of the current study is to carry out an analysis of energy sources and find a source with the lowest ecological footprint; it is based on a desk study using data from databases that centralize energy sources globally. Currently, energy is sourced from seven types of resources: fossil fuels, hydro, solar, wind, nuclear, bio-fuel (biodiesel, biomass, ethanol, wood, etc.), and geothermal. The combustion of hydrogen obtained by electrolysis is still at the prototype stage. In recent decades, studies have focused on renewable sources, with the main focus on wind and solar energy. In 2019, the global energy produced from renewable sources represented only 7%, registering an increase of only 4% compared to 2000. This small increase indicates the premise of a long transition process, accompanied by increases in energy prices and inefficiency in the current use other alternative energy sources compared with fossil fuels. The most cost-effective energy source of the future is biomass because it is an inexhaustible source of energy, which regenerates at a rapid rate; it is produced naturally without the need for infrastructure and equipment; it fixes the CO_2 produced by its combustion during the process of photosynthesis, with zero risk compared to nuclear energy. The extraction of biomass from different crops, including woody species (trees and shrubs), represents a way of reducing the pressure on wild plant diversity. The energy source with the most advantages regarding energy production is plant biomass; future studies should be oriented towards this source.

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1. Introduction

In our modern society where the standard of living is getting higher and higher, the need for energy is constantly increasing. To satisfy the increased need for energy, the academic communities at the request of energy producers have been searching for different sources of energy. Looking at energy consumption at the country level, it is often a strong reflection of population size and living standards rather than actual fossil fuel consumption per person. The pandemic crisis followed by the armed conflict in Ukraine has led to an increase in energy prices and the desire of European states to become energy independent of Russia. Currently, seven types of energy are used in parallel (fossil fuels, hydro, solar, wind, nuclear, bio-fuel and geothermal); in the prototype stage being the combustion of hydrogen obtained by electrolysis.

Fossil fuels are mixed hydrocarbon-containing materials, representing complex substances formed underground from the remains of dead plants and animals, that humans extract and burn to release energy which is further used in different areas of activity (Erisman et al., 2008; Sorrell, 2015; EESI, 2020; GSI, 2021). Fossil fuels, including coal, oil, and natural gas, which humans extract through mining and drilling, have been powering economies for over 150 years, and currently supply over 80 per cent of the world's energy (EESI, 2020).

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They can be burned directly to provide heat for homes or for cooking, to power engines (such as internal combustion engines in cars), or to generate electricity (GSI, 2021).

Fossil fuels are the result of the anaerobic process through which the organic matter of dead plants and animals is decomposed (Sato, 1990; Williams, 2016). The transition from these source materials to high-carbon fossil fuels typically involves a lengthy geological process which can sometimes last more than 650 million years (Mann et al., 2009; Williams, 2016).

Fossil fuels can be transformed into other chemicals or derivatives by the refining and chemical industries. Commonly-used refined fossil fuels include kerosene, gasoline and propane, while most plastics and agricultural chemicals such as fertilizers and pesticides belong to the class of common chemicals (Erisman et al., 2008). The use of fossil fuels causes serious environmental damage and has direct negative consequences on local communities at every stage of their usage: extraction, transportation, and consumption; even the neutralization and storage of the waste resulting from their processing and burning affects negatively the local flora and fauna (Erisman et al., 2008; Williams, 2016; Stephenson, 2018; Ambrose, 2020; MET Group, 2021; Energy Education, n.d.; Forest Research, n.d.).

Nuclear energy represents the process through which electricity is obtained from nuclear reactions. This process consists of splitting atoms in a reactor to heat water into steam, which further turns a turbine and generates electricity. There are several ways in which it can be obtained, such as nuclear fission, nuclear decay and nuclear fusion reactions. At the present moment, the vast majority of electricity obtained from nuclear power is produced by the nuclear fission of uranium and plutonium in nuclear power plants. This type of energy is considered clean with respect to greenhouse gas emissions. However, it has two major disadvantages (Galindo, 2021). On one hand, the fission and fusion reactions cannot be completely controlled, hence a risk of nuclear incidents/accidents is always present. On the other hand, the nuclear waste resulting from the use of nuclear fuel cannot be neutralized, and its storage requires special conditions. Such conditions are mandatory, as the physical and radioactive cooling generates radiation with harmful effects on human health, flora and fauna. Therefore, waste storage requires special enclosures and caves in areas with low seismic risk (Galindo, 2021). Ninety-three nuclear reactors in 28 states generate nearly 20 per cent of the nation's electricity, all without carbon emissions because reactors use uranium and not fossil fuels. These power plants function constantly/are constantly in use: well-operated to avoid interruptions and built to withstand extreme weather (Ritchie et al., 2021; NEI, n.d.; *Nuclear Power*, n.d.).

Renewable energy: At the current moment, renewable energy sources consist of solar, wind, hydro (continental hydropower and tidal energy), geothermal, and bio-fuels (biomass, biodiesel, wood, herbs). Tidal and waves energy is another form of hydro energy that uses twice-daily tidal currents and waves to drive the turbines of generators. Although tidal flow is not constant (unlike some other hydro energy sources), it is highly predictable and therefore, it is able to compensate for the periods when the tide is current low (Griffin, 1992). Hydropower also known as water power, is the use of falling or fast-running water to produce electricity or to power machines. This is achieved through the gravitational potential or kinetic energy of a water source to produce power (Egré & Milewski, 2002; *Hydropower*, n.d.). Hydropower is a method of sustainable energy production. Since ancient times, hydropower from watermills has been used as a renewable energy source for irrigation and the operation of mechanical devices, such as gristmills, sawmills textile mills, trip hammers, dock cranes, domestic lifts, and ore mills (Egré & Milewski, 2002; Donald, 2013; *Hydropower*, n.d.). Water energy is mainly used for hydroelectric power generation. Half of this is produced by the free gravitational fall of water and half by the pumped water in dams. Hydropower is an attractive alternative to fossil fuels as it does not directly produce carbon dioxide or other atmospheric pollutants and also provides a relatively consistent source of power. Nonetheless, it has economic, sociological, and environmental downsides and requires a sufficient power source of water, such as a river or an elevated lake (Egré & Milewski, 2002; Donald, 2013; *Hydropower*, n.d.). International institutions such as the World Bank view hydropower as a low-carbon means for economic development (Bartle, 2002; Schneider, 2013; *Hydropower*, n.d.). Globally, it is seen that hydropower is the largest modern renewable source (since traditional biomass is not included here), however, this is not a priority in the development of renewable sources of energy. This is explained by the fact that the hydrographic network and water resources are unevenly distributed on the surface of the globe; for example, some states, such as those on the African continent, are extremely limited in surface water sources (BP, 2020; Ritchie et al., 2022).

Wind power is the result of using wind turbines to generate electricity. Wind power is a popular, sustainable, and renewable energy source that has a much smaller impact on the environment than burning fossil fuels. Wind farms consist of many individual wind turbines, which are connected to the electric power transmission network (*Wind Power*, n.d.).

Offshore wind is more constant and stronger than the one on land and, it has a lower visual impact. Although there are fewer offshore wind farms at the present moment, and construction and maintenance costs are higher, it is expected to expand in the future (Millborrow, 2010; Hulazan, 2011; Fouad, 2016; *Wind Farm*, n.d.; *Wind Power*, n.d.). Onshore wind farms have a greater visual impact on the landscape than other power plants, as they need to be spread over more land (*Wind Farm*, n.d.; *Wind Power*, n.d.) and need to be built in rural areas

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(Fouad, 2016). Small onshore wind farms can supply some energy to the grid or provide power in remote off-grid locations. Therefore, energy management techniques are used to match supply with demand, such as: hybrid wind power systems, hydropower or other renewable energy sources, the geographical distribution of turbines, the excess production capacity, and the export and import of energy in neighboring areas, network storage and demand reduction when wind production is low. As the proportion of wind energy in a region increases, the grid may need to be upgraded (Jones et al., 2015; Our World in Data, 2021; IEA, 2022). Weather forecast allows the electricity grid to be prepared for the foreseeable variations in production that occur (Holttinen et al., 2006; Szarka, 2007; Abbess, 2009; IEA, 2019).

Solar energy is represented by radiant light and heat from the Sun. This energy can by harnessed using a range of technologies in order to generate electricity and thermal energy which can be used for heating the water or the air in one's house (IEA, 2012; Walther, 2021; *Solar Energy*, n.d.). It is an essential source of renewable energy, and its technologies are broadly characterized as either passive solar or active solar, depending on how they capture and distribute solar energy or convert it into other energy sources. Active solar techniques include the use of photovoltaic systems, concentrated solar power, and solar water heating to harness the energy. Passive solar techniques, on the other hand, include orienting a building to the Sun, selecting materials with favorable thermal mass or light-dispersing properties, and designing spaces in which the air circulates naturally. In 2021, Carbon Tracker Initiative estimated the land area needed to generate all energy from solar alone was 450,000 km^2 or about the same as the area of Sweden, Morocco, or California (0.3% of the Earth's total land area) (Walther, 2021; RSC, n.d.).

Biofuel is a fuel that is produced by contemporary biomass processes, rather than by the very slow geological processes involved in the formation of fossil fuels, such as oil. Because biomass can be used as a direct fuel (for example, logs), some people use the terms biomass and biofuel interchangeably (Karatzos et al., 2014; EIA, n.d.; *Biofuel*, n.d.). In most cases, however, the word biomass simply refers to the biological raw material from which the fuel is made or a thermally/chemically modified product in its final solid form, such as pellets or roasted briquettes (van Dyk et al., 2019; Bond et al., 2020; EIA, n.d.; *Biofuel*, n.d.).

Biofuel can be produced from plants (i.e., energy crops), or from agricultural, commercial, domestic, and/or industrial waste (if the waste has a biological origin). Biofuel generally involves contemporary carbon fixation, such as those that occur in plants or microalgae through the process of photosynthesis. The greenhouse gas mitigation potential of biofuel varies considerably, from emission levels comparable to fossil fuels in some scenarios to negative emissions in others. The IPCC (Intergovernmental Panel on Climate Change) defines bioenergy as a renewable form of energy (van Dyk et al., 2019; EIA, n.d.; *Biofuel*, n.d.). Bioethanol and biodiesel are the two most common types of biofuels. The first one, bioethanol, is an alcohol obtained by fermentation, mostly from carbohydrates produced in sugar or starch crops such as corn, sugarcane, or sweet sorghum. Cellulosic biomass, derived from non-food sources, such as trees and grasses, is also being developed as a feedstock for ethanol production. Ethanol can be used as a fuel for vehicles in its pure form (E100), but it is usually used as a gasoline additive to increase octane and improve vehicle emissions. Bioethanol is widely used in the United States and in Brazil. Biodiesel, on the other hand, is produced from oils or fats using transesterification and is the most common biofuel in Europe (Edenhofer et al., 2012; AFDC, n.d.; EIA, n.d.). It can be used as a fuel for vehicles in its pure form (B100), but it is usually used as a diesel additive to reduce levels of particulates, carbon monoxide, and hydrocarbons from diesel-powered vehicles (EIA, n.d.; *Biofuel*, n.d.).

As mentioned previously, biomass, biodiesel, bio-ethanol and wood are renewable fuels. Moreover, they represent a way of storing CO_2 through the process of photosynthesis.

Although the calorific value of wood is only 14 MJ kg^{-1}, half that of coal (29 MJ kg^{-1}) and one third of crude oil (42 MJ kg^{-1}). It does not require any equipment for its production, as forests grow without energy and material resources. Enriching carbon wood by incomplete combustion and obtaining charcoal with a calorific value of 28 MJ kg^{-1} is a way to improve the quality of biofuels. In the process of the carbonization or destructive distillation of wood, a liquid -wood tar–is obtained that can be burnt in internal combustion engines. Bio-ethanol and biodiesel are liquid bio-fuels with the caloric power 27 MJ kg^{-1}, respectively 37 Mm kg^{-1} that can be burned in internal combustion engines (Mamvura & Danha, 2020; EIA, n.d.).

Geothermal energy is made up of two components, namely the thermal energy in the Earth's crust which results from the cooling of the magma and the energy which ensues from the disintegration of radioactive materials. The ratio between the two components is currently uncertain (Dye, 2012; National Geographic, 2022), but there is a possibility of roughly equal (*Geothermal Energy*, n.d.) proportions in some cases. The high temperature and pressure in the Earth's core cause some rock to melt and solid mantle to behave plastically. This results in parts of the mantle converting upward since it is lighter than the surrounding rock. Temperatures at the core-mantle boundary can reach over 4000 °C (7200 °F, the KamLAND Collaboration, 2011).

Geothermal heating using water from hot springs, for example, has been used for bathing since Paleolithic times and for space heating since ancient Roman times. More recently, geothermal power, the term used for generation of electricity from geothermal energy, has gained importance. It is estimated

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that the earth's geothermal resources are theoretically more than adequate to supply humanity's energy needs, although only a very small fraction is currently being profitably exploited, often in areas near tectonic plate boundaries.

As a result of government assisted research and industry experience, the cost of generating geothermal power decreased by 25% over the 1980s and 1990s (Lay et al., 2008). More recent technological advances have dramatically reduced costs and thereby expanded the range and size of viable resources (Helen, 2002).

The present study carried out an analysis of the world production of energy from different type sources, in the context where part of the resources are exhaustible and energy consumption is increasing. The goal of the study is to propose the renewable, inexhaustible energy source with the lowest possible ecological footprint to solve a possible energy crisis.

2. Materials and Methods

This study was performed based on eight data sets: "Our World in Data" (Our World in Data, 2021), Statistical Review of World Energy (BP, 2022), IEA Report, 2021, Wind Power - Analysis" (IEA, 2022) and "National Statistical Yearbooks", “Romania in numbers” (National Institute of Statistics, 2019). Based on these data, all types of energy sources and the amount of energy produced by them were identified. The database “Our World in Data” also provided information related to the carbon dioxide emitted by different sources to produce energy as well as the number of deaths that would be based on pollution of the energy industry.

These data sets provided information on the amount of energy produced at global level, by each country, every year, starting from 1965, for each energy source (fossil fuels -coal, oil, gas, nuclear energy, and renewable energy- hydro, solar, wind, biomass, biodiesel, and ethanol).The ecological footprint for the production of a TWh (Terawatt hour) of energy from different sources has been assessed according to the amount of CO_2 emitted for the production of this TWh and the number of deaths for which this pollution would be criminalized. The following constants were used to estimate CO_2 emissions: 820 t CO_2 for producing 1 GWh (Gigawatt hour) coming from coal; 720 t CO_2 for producing 1 GWh coming from oil; 490 t CO_2 for producing 1 GWh coming from natural gas, 3 t CO_2 t for producing 1 GWh for producing nuclear, 3 t CO_2 for producing 1 GWh coming from hydropower, 4 t CO_2 for producing 1 GWh coming from wind, 5 t CO_2 for producing 1 GWh coming from solar, 78-230 t CO_2 for producing 1 GWh coming from biofuels, 3 t CO2 for producing 1 GWh coming from geothermal. The following values were used to calculate the number of deaths: 24.9 deaths for 1 TWh coming from coal; 18.4 deaths for 1 TWh coming from oil; 2.8 deaths for 1 TWh coming from gas, 0.07 deaths for 1 TWh coming from nuclear, 0.02 deaths for 1 TWh coming from hydropower, 0.04 deaths for 1 TWh coming from wind, 0.02 deaths for 1 TWh coming from solar, 4.6 deaths for 1 TWh coming from biofuels, 0.002 deaths for 1 TWh coming from geothermal (Stephenson, 2018; Ambrose, 2020; MET Group, 2021; Our World in Data, 2021; Ritchie et al., 2021; Energy Education, n.d.; Forest Research, n.d.).

3. Results and Discussion

Between 1965 and 2020, global energy production was 21,193,083.31 TWh; 96.541% coming from fossil fuels, 1.565% hydropower, 1.380% nuclear energy y, 0.267% bio-fuel, 0.186% wind, 0.059% solar and $0.033x10^{-3}$ geothermal (Figures 1a and 1b).

The largest amount of energy was produced by burning oil (9,052,371.307 TWh) followed by burning coal (6,529,712.834 TWh) and gas (4,878,018.781 TWh), the quantities used to be the following: 775,916,919.9 t oil, 810,584,393.1 t coal and 462,127,725.3 t gas. In the process of burning these fossil fuels, a quantity of $1,426x10^{13}$ t of CO_2 was produced, $6.517x10^{12}$ t coming from oil, $5.354x10^{12}$ t from coal and $2.390x10^{12}$ t from gas. Although no direct causation has been proven, gaseous emissions, ash and suspended dust resulting from fossil fuels combustion are allegedly the cause of the 342,811,934 deaths recorded globally, from 1965 until now. The highest incidence was in the case of emissions from the coal combustion 162,589,850; followed by 166,563,632 from oil combustion and 13,658,453 from combustion of gas. Most significantly, the burning of fossil fuels produces around 35 billion tons of carbon dioxide per year, or about 89% of all carbon dioxide emissions. Natural processes on Earth (mostly through absorption by the ocean) can only absorb a small part of this amount; therefore, there is a net increase of several billion tons of atmospheric carbon dioxide per year. Carbon dioxide is a greenhouse gas that increases radiative forcing, thus fossil fuels are the main source of greenhouse gas emissions causing global warming and ocean acidification.

Total amount of nuclear energy (292,541.89 TWh) was largely produced between 1985 and 2019, and the quantity of CO_2 emitted to produce this energy is 877,625,681.01 t, and this caused almost 20,477.93 deaths. Civilian nuclear power supplied 2,586 TWh of electricity in 2019, equivalent to about 10% of the global electricity production, and was the second-largest low-carbon power source after hydroelectricity. Since 2000 until the present day, energy producers have focused on the development of renewable energy sources, the amount of energy produced from renewable sources being 440,438.494 TWh, the largest share being hydro energy 331,805.804 TWh (75.33%). The ecological footprint of this energy production is 995,417,412.06 in terms of t CO_2 and 6,636.12 deaths.

Despite the fact that global environmental policies militate for the reduction of energy production from fossil fuels, in 2019 there was a decrease of less than 3%, from 96.54% to 93.76%.

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In the last 45 years there have been significant changes in the share of each type of fossil fuels, as follows: the energy coming from oil has decreased by 6%, the one from coal has decreased by 1% and the energy coming from gas has increased by 4% (Figures 1a, 1b, 2a, and 2b).

In the last 45 years, the ecological footprint of fossil fuel energy production in terms of CO_2 has decreased by $0.34896x10^{12}$ t (an increase in $0.0956x10^{12}$ t from the use of more gas and a decrease in $0.05354x10^{12}$ t from the reduction of burning of the coal and $0.39102x10^{12}$ t from the reduction of oil burning).

The ecological footprint, in terms of the number of deaths produced by pollution coming from burning fossils fuels, decreased in 2019 compared to 1965 with 10,874,689 deaths (an increase in 546,338 from the use of more gas and a decrease 9,755,391 from the reduction of burning the coal and 1,665,636 from the reduction of oil burning).

Less than 7% of energy comes from nuclear and renewable sources (Figures 2a and 2b).

In 2019, 44 states were producing nuclear power globally, some of which ceased production, such as Italy, Lithuania, and Kazakhstan, 18 maintained or had a steady increase in production and 22 reduced their production. In the last 20 years, the decrease in production was 2921.3 TWh, *i.e.*, 10% of the total production of global nuclear energy (292541.8 TWh); a significant amount in which Japan, Germany and France participated the most. The 10% reduction in nuclear energy production is accompanied by a reduction in emissions of CO_2 87762.57 t and a number of 2,048 deaths. The amount of energy produced globally from renewable sources has not increased significantly in the last 45 years (only 6%). In the last 20 years there have been significant changes in the share of each type, as follows: hydro energy has decreased by 4%, the biofuel has decreased by 1%, that of wind has increased by 10% and the solar one with 5%. Between 1965 and 2019 global hydropower has fallen by 4% due to climate change-induced disturbances that cause imbalances in precipitation over time and space, producing fluctuations in production associated with periods of drought and floods that severely affect the storage lakes (Figures 1a, 1b, 2a, and 2b). In 2020, with the health crisis caused by Covid-19, the decrease in production from other sources made the hydropower generation increase 124 TWh (+3%) in 2020, reaching 4418 TWh and remaining the largest renewable source of electricity, generating more than all other renewable technologies combined. After five consecutive years of decline, hydropower capacity additions rebounded in 2020 and reached 21 GW (Gigawatt) thanks to commissioning of several large power plants in China and Turkey. Also, in 2020, wind supplied almost 1600 TWh of electricity, which was over 5% of the worldwide electrical production and about 2% of energy consumption. With over 100 GW added during 2020, mostly in China, global installed wind power capacity reached more than 730 GW. The creation of capacities to increase these productions from renewable sources was accompanied by a decrease in the ecological footprint with 111,356.64 t CO_2 and 2,435 deaths. The changes that have appeared in the last 45 years in the type and the share of energy sources at a global level, produced a decrease in the ecological footprint; the amount of CO_2 generated for energy production has decreased by 348,960,199,119 t CO_2 (2.45%) and 10,879,172 deaths (3.17%).

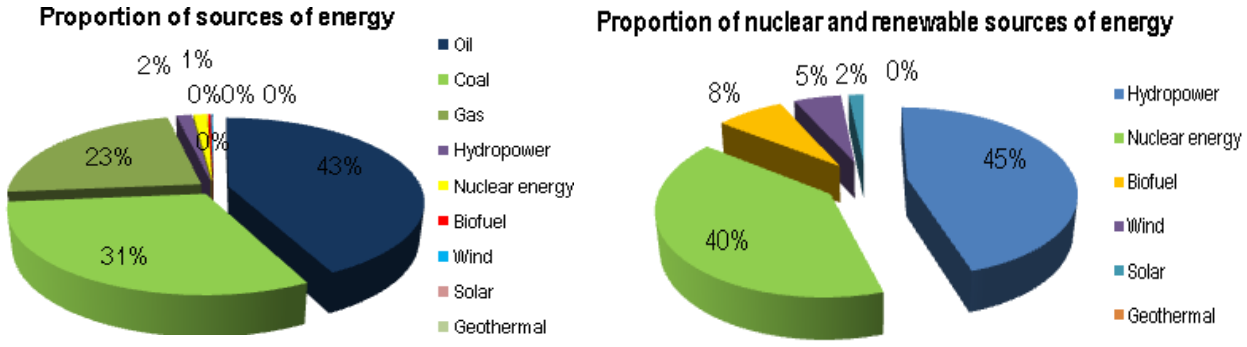


Figure 1. (a) Global energy production by different sources, in period 1965-2020. **(b)** Global energy production by different renewable sources, in period 1965-2020.

Since the amount of energy obtained from non-renewable sources is several orders of magnitude (Figures 1a and 2a), we have taken up the renewable sources in detail (Figures 1b and 2b).

Although the policy of developed countries was to promote renewable energy sources in 2019 compared to the period 1965-2020, energy obtained from nuclear sources decreased by 10%, from hydropower by 4% and biofuel by 1%. These reductions were offset by increases in solar energy (5%), wind energy (10%) and other energy sources (4%), an increase of only 4% from renewable sources, the use of biomass being abandoned from the point of view of promotion (Figures 1a, 1b, 2a, and 2b).

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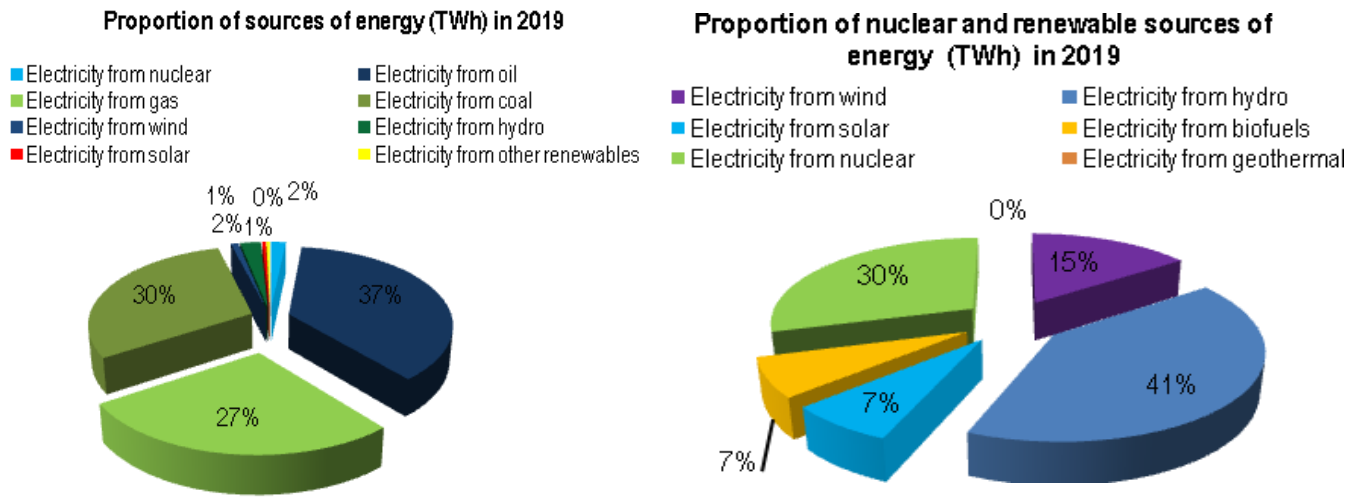


Figure 2. (a) Global energy production by different sources in 2019. **(b)** Global energy production by different renewable sources in 2019.

4. Conclusion

Today the global energy system is still dominated by fossil fuels. Although CO_2 emissions and pollution-related deaths are low in the case of renewable energy sources, at the current time these sources account only for 7% of the total global energy. The energy obtained from fossil fuels, although polluting, will still be needed, and its replacement with non-polluting energy sources will be a long process. The transition period will be marked by considerable increases in the price of energy; and humanity will have to choose between reducing greenhouse gas production, pollution or energy production. Educating the population to use energy wisely, saving energy when the situation allows it, alongside the diversification of generation sources can be temporary solutions to the energy crisis. Currently, there is no ideal solution for global energy needs. Even though scientists are working to improve technology in the case of unconventional energy sources and looking for new energy sources, these still involve a lot of problems. Nuclear power is dropping with 10% because it is a source limited by the resources of radioactive metals (plutonium, thorium, and uranium) and it presents a certain risk. Furthermore, nuclear reactions are not fully controllable, and radioactive waste cannot be neutralized. An ideal radioactive waste management would be to find a technology through which unstable isotopes resulting from the burning of radioactive fuel by fission become fuels in radioactive fusion reactors. This technology should also focus on increasing the control of fission and fusion reactions, reducing the risk of nuclear accident/incident. Under these conditions, nuclear energy could become a source of the future, and the recycling of radioactive waste in fusion reactors would reduce the need for fuel and would eliminate the exhaustible factor. The construction of nuclear power plants with one or more reactors requires energy and material resources, but the long period of operation justifies the ecological footprint. Renewable energy -hydro, wind, sun and geothermal- are produced in small quantities and are limited by the distribution of the hydrographic network, air mass circulation, intensity of light in night-day alternation and thermal water reserve. All three types of energy sources require equipment for production of energy and storage. The production of this equipment requires material resources and energy consumption, and their decommissioning represents a substantial source of waste. The production process of photovoltaic panels (used in the case of solar energy) requires large amounts of aluminum. This metal is extracted from bauxite ore, with the aid of a pollutant and energy-consuming technology, by electric arc discharge between two graphite electrodes. Hence, this causes the ecological footprint in terms of CO_2 emissions increase from 4 t TWh^{-1} in the case of wind energy to 5 t TWh^{-1} in the case of solar energy. Storage batteries also require large amounts of lithium, a relatively rare metal that is in limited quantities.

Biomass, biodiesel, wood, and ethanol are renewable fuels, the regeneration rate being extremely high. Moreover, they represent a way of storing CO_2 through the process of photosynthesis; the carbon content in the biomass is approximately 50%. The conversion of agricultural lands destined for food and fodder plants into lands for crops destined for biomass production, especially biodiesel crops, has led to an increase in the price of vegetable and animal products. This was one of the reasons why the idea of biomass, biodiesel, and wood as energy sources is not supported by energy producers, as well as the relatively high amount of CO_2 emissions from combustion and expensive adaptations of internal combustion engines in the case of biodiesel combustion. Despite these small disadvantages, biofuels are an inexhaustible source of energy with a very low ecological footprint. Concluding, biomass is an inexhaustible source of energy which regenerates at a rapid rate compared to the regeneration rate of other inexhaustible resources, it is produced naturally without the need for

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infrastructure and equipment and it also fixes and recycle the CO_2 resulted from combustion through the process of photosynthesis. Hence, biomass is the most cost-effective source of energy for the future, having zero risk compared to nuclear energy.

Conflict of Interest

The authors declare that they have no conflict of interest.

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