Affordable and Clean Energy: A Study on the Advantages and Disadvantages of the Main Modalities

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Abstract The purpose of this study is to identify several renewable and clean energy sources and investigate their accessibility. The structuring of the energetic sources was outlined to display the advantages and disadvantages of their use. To do so, the literature review method and the snowball method were used as the research methodology. Previous results had determined the elements of a sample of the main existing forms of energy. Therefore, this research analysed the following sources: solar energy, wind energy, hydroelectric power, thermoelectric energy with renewable fuels, tidal energy, biogas energy, geothermal energy and hydrogen energy. The results discuss the benefits of using sustainable energies, such as being helpful to the environment, as well as the implementation obstacles that, in this case, are stripped down to the high financial cost of initial investment. Because no previous research provided a structure to compare different energy forms, this study is expected to act as an initial guide for researchers and professionals in the field. As a limitation and recommendation for future research efforts, it is suggested to discover and verify mechanisms capable of reducing the high initial investment costs associated with sustainable energies.

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1 Introduction

Presently, the quest for self-sufficiency in energy generation, together with a diversification of the energy matrix, keeps increasing the demand for different sources of alternative energy. Organizations and countries are increasingly seeking clean energies and renewable resources to supply their own demand. This inclination has been amplified due to the trend of fossil fuel shortages. The environmental, social and economic changes resulting from this reality are gradually reaching the spotlight of the academic community's agenda, which continually explores these factors to ensure society's progress. In addition to governments and the academic world, the demand for clean and renewable energy is also part of the reality of NGOs, consumers, private companies and other institutions.

The use of clean and renewable energies is regarded as a priority in our contemporary climate, and the development of their use is increasingly receiving financial and research resources. Pacheco (2006) defines clean energy as a source of energy not produced by fossil fuels. These energy sources are also commonly known as green energies, because they do not pollute the atmosphere and contribute to the greenhouse gas effect. Renewable energy is any type of energy sourced in natural cycles of solar radiation conversion; in other words, it is the product of natural processes, such as sunlight and wind (Bhattacharya et al. 2016) and includes almost every source of energy naturally available on Earth. The term "renewable" means that the main source is inexhaustible; therefore, it does not harmor influence the planet's thermal balance. Another trait is that renewable energy sources have no usage limit, as long as they are properly cared for (Marques 2007; Pacheco 2006).

In September 2015, following the favourable trend of these energy forms, the United Nations approved a global agenda with 17 goals and 169 targets for the implementation of initiatives capable of making the planet more sustainable, resilient and socially fair The objectives and targets are intended to stimulate action during the next 15 years in fields deeply important for humanity and the planet (United Nations 2018a). Specifically, among these objectives, goal no. 7, which is the object of this research, seeks to establish universal, reliable, sustainable, modern and affordable access to energy services for everyone by 2030, thus significantly increasing the share of renewable energy in the global energy matrix, doubling the overall rate of energy efficiency improvement, and bolstering international support for the promotion of access, research and investments in energy infrastructure and clean energy technologies (United Nations 2018a). These goals are an extension of the actions of the Brundtland Report, since 1987, has consubstantiated the importance of sustainable development (United Nations 2018b).

Nevertheless, in order for these goals to be accomplished, specificpremises have to be accepted; for instance, for global progress, each nation has to comply with

the requirement to use renewable energy (Yüksel 2010). The push is to have the energy scene progress toward 100% sustainable use; in other words, the world will be responsible for using fully renewable energies by the year 2050 (Greenpeace 2018; Fiesp 2018). As an example of forward progress in this direction, Brazil intends to increase energy usage from renewable sources from 28 to 33% by the year 2030 (Brasil 2016).

To accomplish these goals and reap the many benefits of relying on clean, renewable energy, the study of energies is a pivotal element for human evolution, since its results are needed by present and future generations. Therefore, understanding and distinguishing between different types of energy is a decisive step toward magnifying the strengths and neutralizing the weaknesses of each energy matrix. In this regard, the objective of this paper's research is the following: to review the advantages and disadvantages of the main sources of renewable energy and establish a comparative table to engage and support the debate on the accessibility of each energy type. Therefore, this work is justified from both a practical and a theoretical standpoint. Regarding the practical side, this document will serve as a tool to help in the achievement and development of the United Nation's Goal 7 while also being a guide for corporations and governments that intend to collaborate in the work of sustainable development. As a theoretical contribution, the article will be the starting point for future research that requires a list of the main types of existing clean energy and a comparison of their accessibility (using advantages and disadvantages).

2 Methodology

The literature review method was used to identify the main sources of existing clean energies and the main modalities.

The following databases were consulted: Web of Science, Google Scholar and Scopus. The initial research strings were based on the following word combinations: "clean energy", "renewable energy", "energy matrix", "advantages" and "disadvantages". To assess the existence of potential and new modalities, the *snowball* technique was used. This technique uses the references of the initial articles as a kind of network, allow in researchers to discover new information through articles not encountered by the initial searches (Baldin and Munhoz 2011). Thus, the references of the first articles were analyzed in order to find other similar documents.

3 Results

Based on the findings of the literature review—in the main results found—this research investigates the following energy sources: solar energy, wind energy, hydroelectric power, thermoelectric energy with renewable fuels, tidal energy, biogas energy, geothermal energy and hydrogen energy. Following the investigation, the

primary results are presented, and the research protocol is explained. Table 1 presents a summary of the results.

4 Solar Energy

Solar energy is one of the renewable sources with greater potential to be used in the future. Solar energy is one of the best options to address future energy demands, because it is an inexhaustible, clean, affordable and inexpensive source compared to other renewable energy sources (Kabir et al. 2018).

According to Hernandez et al. (2014), of all renewable energies, solar energy has one of the lowest impacts on climate change due to its low emissions of pollutant substances. Furthermore, one of the main advantages of solar systems is the generation of energy near the place of usage, which reduces costs and losses in its diffusion. This happens mostly in urban areas with the use of walls and roofs in homes to capture energy.

Nonetheless, the collection and concentration of solar energy for consumption requires vast amounts of space, which can cause negative impacts on natural ecosystems and biodiversity (Hernandez et al. 2014; Northrup and Wittemyer 2013). Kabir et al. (2018) declare that the system requires high initial expenditures for the installation of this energy's capturing method. Also, the efficiencies of most domestic solar panels account for 10–20%, and more efficient solar panels have higher costs; these higher costs are the deficiency of solar technology. Other shortcomings identified are associated with the maintenance of systems, such as the shortage of manpower to address the growing demands related to the installation, maintenance, repair and evaluation of solar energy systems (Kabir et al. 2018).

5 Wind Energy

Although most people think of "wind energy" as synonymous with "wind", wind energy comes from the heat released by the sun (Ilkiliç et al. 2011). The sun is responsible for the Earth's heat release, causing different temperature ratios in the most diverse geographical areas of the planet. The surface response is to absorb, retain, reflect and release the captured heat, phenomena that result in the origin of wind (Ilkiliç and Türkbay 2010). Aerogenerators capture the kinetic movement of the wind and transform it into electrical energy (Dincer 2011).

Wind energy is a source of free, clean and inexhaustible energy (Alsaad et al. 2013). The use of this type of energy was expanded due to society's growing environmental concerns in the last decades, resulting in an increased awareness of green energy (Ilkiliç and Türkbay 2010; Tabassum et al. 2014).

Benefits include cleanliness, low cost and the abundance of wind in any part of the globe. The technology that converts wind energy into other types of energy is

Table 1 Types of renewable energy, advantages and disadvantages

Affordability		
Type of renewable energy	Advantages	Disadvantages
Solar	It does not pollute, and it requires minimal maintenance. Installation is easy, and it does not require a high investment for its diffusion	It requires extensive urban areas for energy capturing and depends on daily solar irradiation
Wind	It is a free, clean, unlimited source of energy and also one of the cheapest sources of energy; it does not require a fuel supply	Production depends on weather conditions; it changes the usual behaviour of wild animals while also contributing to noise pollution
Hydropower	It does not emit polluting substances and is inexhaustible; the production cost is low	There are significant costs related to installation and deactivation; it requires large water reservoirs and contributes to soil erosion that has a negative effect on local vegetation
Thermoelectric with renewable fuels	The thermoelectric energy conversion system does not present obstacles; it is compact, soundless, highly reliable and does not harm the environment	The conversion process may be inefficient, reaching a level deemed low when there is interference with other energy sources
Tidal wave	A source of clean energy that does not present major environmental hazards, it is an inexhaustible resource, and the energy-generating equipment has low maintenance costs	Production depends on sea conditions; the installation of equipment for tidal power generation requires a significant investment
Biogas	It is regarded as an efficient, sustainable and low-cost alternative; the transformation of organic waste into biogas has environmental advantages	Generates a high concentration of methane gas, which contributes significantly to environmental pollution
Geothermal	Low levels of pollution and environmental impact but economically viable	If not properly extracted, it damages the planet. The implementation has significant costs, and geothermal plants produce noise pollution
Hydrogen	Provides renewable and sustainable energy while also producing electricity and hot water steam; has a high potential for technological development	A high cost when compared to conventional energy sources; highly hazardous and significant costs related to the transportation and distribution of hydrogen gas

Source the authors (2018)

cheaper than other conversion systems. The wind is commonly available in nature, and through wind turbines and mechanical conversion, wind energy can be transformed into electrical energy (Ilkiliç and Türkbay 2010). To operate, wind turbines do not need fuel. Wind power generation does not produce emissions like carbon dioxide, sulphur dioxide, mercury, particulates or any kind of air pollution (Alsaad 2013; Fang 2014).

When compared to traditional means, wind energy has high costs (Alsaad 2013). The negative impacts derived from wind power projects manifest locally; in other words, they mostly have to do with the dislodgment of wild animals in the surroundings, as well as visual and sound effects (Slattery et al. 2012).

6 Hydroelectric Power

The cornerstone of hydroelectric power is the conversion of water's potential force into energy. Hydro turbines transform hydraulic pressure into energy resources for processing machines, which is the same as what happens with electricity generators (Frey and Linke 2002; Yuksek et al. 2006). Even though it is feasible to merge the usage, the turbines used in the process have two classifications: impulse and reaction. The energy associated with water pressure is converted into kinetic energy, in which the movements of the items, required for the process, change the flow of the water stream, thereby generating energy initiation (Balje 1981; Bartle 2002; Date et al. 2013). Water is pressurized as it moves through the production process (Date et al. 2013).

Currently, hydroelectric power is the most used renewable resource for electricity generation (Frey and Linke 2002; Yuksek et al. 2006; Kendir and Ozdamar 2013). Since the most important component for viability is proper water management, it is deemed sustainable in the long term (Yuksek et al. 2006).

Hydroelectric is still the most efficient way to generate electricity, because modern turbines can convert approximately 90% of the energy available into electricity (Yuksek et al. 2006). In comparison, fossil fuel plants are only 50% efficient (Frey and Linke 2002). Its usage contributes to energy independence for countries without fossil fuel resources (Yuksek et al. 2006). Its benefits are associated with human well-being, including a safe water supply, irrigation for food production, flood control and social improvements, such as increased navigation, the development of fishing activities, home-based industries and more (WCD 2000; Yuksek et al. 2006). These advantages can be associated with electric power or related to the environment's development (OUD 2002). The indirect benefits are also better than fossil-based energy generation. In 1997, the estimates indicated that hydroelectric power prevented the production of emissions equivalent to the pollution of every car on the planet (IHA et al. 2000).

This type of energy is highly renewable (over 90%) and has low energy costs, high longevity (200 years), a short amortization period (5 and 10 years) and extremely

low operational costs (0.20 cents/kWh). Moreover, it does not depend on external energy sources and incurs no fuel costs (Kendir and Ozdamar 2013).

Proper geographic conditions are required to support the creation of hydroelectric plants. Developing countries have great potential to develop hydroelectric (Iea 2002; Koch 2002; Yuksek et al. 2006). In comparison to thermal power generation, hydroelectric plants require more time for business forecasting. For example, their approval needs to overcome more hurdles, construction can take significantly longer and they require a higher initial investment, which means that recovering the capital invested entails more time (Yuksek et al. 2006).

7 Thermoelectric Energy with Renewable Fuels

Thermal generation directly transforms thermal energy into electricity using thermoelectric conversion materials, like oil and its derivatives, natural gas and mineral coal, among others (Chen et al. 2012). The steam generated is used to handle the plant's turbines. Generally speaking, the thermoelectric power conversion system does not pose major obstacles, it is compact, quiet, highly reliable and environmentally friendly (Kim et al. 2006; Bell 2008; Gou et al. 2010). Nevertheless, renewable fuels such as ethanol, biodiesel and biomass may also be used.

Thermoelectric devices (thermoelectric modules) maintain the ideal temperature. Therefore, the energy is transformed by the thermoelectric generator, which is represented by a single heat engine, safeguarding the loading, transportation and fluid work services (Riffat and Ma 2003). As long as the temperature remains controlled, the devices connected to the module will generate energy (Riffat and Ma 2003).

Thermoelectric plants are essentially silent when compared to other energy options. Their operation is reliable, as it includes several fuels, such as petroleum, for the execution and generation of electrical energy.

Nonetheless, the conversion process is inefficient, attaining a level deemed low when there is interference from other energy sources (Gou et al. 2010). In thermoelectric power, energy generators are limited by their low efficiency (Rowe and Min 1998. Riffat and Ma 2003).

8 Tidal Energy

Tides are being increasingly applied in different forms. Presently, ocean exploration is giving birth to new concepts and shapes. Particularly, the kinetic energy of tidal flows can generate relevant levels of electricity (O'Rourke et al. 2010; Neill et al. 2016). Waves are generated through several factors, such as the interaction between the Earth, the moon and the sun. Waves, whenever they are influenced by the moon, cause an imbalance between the forces acting on a particle due to the gravitational

attraction, which triggers a centrifugal force due to Earth's rotation on the centre of gravity (Neill et al. 2016). With the movements deriving from the unevenness of the weather, and also from the sea, it is possible to generate power through dams and turbines (Devine-wright 2011).

The energy of the tides is acknowledged by society as an important potential source of clean energy, because it is a structure in which kinetic energy can be extracted from tidal currents. The forecasts indicate that this type of energy will acquire more notoriety and space in power extraction within the next decades, reaching a great percentage of generation of total electricity production (Atwater and Lawrence 2011).

The method's potential expansion is one of the key future benefits, as is the high index of seas to be explored (O'Rourke et al. 2010; Neill et al. 2016). The turbines of tidal streams have a high-performance percentage between cycles, and there are none of the interruptions that occur with other devices that capture renewable energy (Fagan et al. 2016).

Many energy conversion systems for tidal streams do not have the capacity to actively respond to direction changes. They rely on nearby bidirectional flows or energy conversion systems that are relatively insensitive to small directional changes (Harding and Bryden 2012). There are also regulatory and economic issues, which, in all likelihood, will limit the generation of tidal energy to levels significantly lower than the maximum values that are physically possible (Atwater and Lawrence 2011). Generally speaking, to date, few empirical studies are available on the subject's specificities and complexity (Devine-wright 2011).

9 Biogas Energy

Biogas is a renewable energy source derived from the anaerobic digestion of biomass, which can be a product of organic waste, animal manure, sewage and industrial effluents. It often consists of 40–75% methane, 20–45% carbon dioxide and other compounds (Budzianowski 2012).

According to Deublein and Steinhauser (2008), anaerobic digestion has great potential for energy production, yet the process also relies on energy to maintain itself. Therefore, energy has to be used to heat new substrates and to make up for the loss of heat in digesters and pipes. This energy can be made from the biogas combustion itself. The amount of energy required depends on different factors, such as the temperature of the digester, the temperature of new substrates, the room temperature and the insulation of digesters and pipes to reduce their heat loss. Furthermore, pumps, agitation equipment and monitoring are required. The replacement of fossil fuels by biogas also reduces the greenhouse gas emissions (Morken and Sapci 2013).

On the other hand, there are some obstacles to using biogas for electrical power generation, particularly the lack of suitable technology for its conversion into energy (Coelho et al. 2004). The lack of information on biogas production, as well as market studies on the energy to be produced, discourage potential investors. Likewise, project

technology assessments, safety, legislation, capital costs, operation and maintenance are extremely important, but they still lack a reliable body of research and coverage in the scholarly literature (Coelho et al. 2004).

10 Geothermal Energy

Geothermal energy is produced by the Earth's internal heat, and it can be regarded as a solution to the current issues of energy shortage and combustion of fossil fuels (Arboit et al. 2013). According to Rabelo et al. (2002), the ideal temperature for the use of this heat ranges between 35 °C and 148° for residential, industrial and agricultural purposes, but it must be higher than 300 °C for the generation of energy.

Geothermal energy can be economically viable. Furthermore, it is also a source of clean energy available in different regions of the planet. If robust and viable technologies are developed for its capture and use, an energy revolution may take place, and humanity's dependence on fossil fuels may be reduced (Vichi and Mansor 2009).

According to Campos et al. (2017), there are some cons relating to geothermal energy's operating conditions. For instance, plants can only be established in propitious geological zones, which are located in only 10% of the planet. Additionally, it has a high initial cost fora plant's well drilling, study and establishment, and there is significant noise pollution during plant construction.

11 Hydrogen Energy

Hydrogen energy is obtained through the combination of hydrogen and oxygen, causing vapours capable of releasing energy (Zhang et al. 2016). Hydrogen can be produced from different means, such as fossil fuels, nuclear energy, renewable biomass and renewable electricity using thermal energy and biochemicals (Mazloomi and Gomes 2012; Zhang et al. 2016). Presently, the majority of hydrogen production is derived from fossil fuels (Zhang et al. 2016). The hydrogen produced can be stored in compressed or liquid gases, which are widely used in the industry. Hydrogen technology has the potential to change energy infrastructure and current lifestyles (Zhang et al. 2016). Hydrogen is an important *driver* of energy storage that benefits renewable and sustainable energy (Zhang et al. 2016). Hydrogen energy provides an energy vector needed for storage and for energy exchange between smart centres (Maroufmashat et al. 2016). Hydrogen is an efficient energy carrier, because it registers a low number of losses during transportation when compared to the traditional grid (Mazloomi and Gomes 2012; Walker et al. 2016).

There are limitations in energy generation, and the gaseous storage requires quite large tanks. In addition, liquefaction requires great initial workforce and storage tanks and major insulation efforts, while a metal hydride may absorb only small amounts

of hydrogen (Mazloomi and Gomes 2012; Kanoglu et al. 2016). The hydrogen energy method is criticized for its high energy consumption and carbon emissions (Kanoglu et al. 2016).

12 Discussion and Conclusion

This research intended to identify the advantages and disadvantages of several sustainable energy sources. In the future, this article is expected to be the initial instrument for theoretical and practical analyses that will precede any other form of application.

Due to the conceivable scarcity of non-renewable resources, like coal and oil, as well as the damage that their extraction and usage do to human health and the environment, the search for renewable energy forms is increasing. Therefore, it is important to have a general background of the possible forms of energy generation in order to enable a systematic view of the decision-making process.

The main benefit of renewable and clean energy sources is the reduction of the environmental impact due to the lowering of greenhouse gas emissions and the use of non-finite resources. The use of different clean energy generation technologies can reduce the consumption of resources and the emission of polluting gases into the environment, while also aiding in human efforts to tackle climate change, acid pollution and photochemical pollution (Hongtao and Wenjia 2018). Nevertheless, the main disadvantage identified in this research is that, given the few viable technologies and the lack of government incentives, renewable sources demand a high investment (Lima 2012).

The proposed methodology produced a list of eight different types of energy (solar energy, wind energy, hydroelectric power, renewable energy, tidal energy, biogas energy, geothermal energy and hydrogen energy). It was possible to identify energy forms that are not usually discussed in comparison with other types of renewable energy—for example, geothermal energy, which does not have thorough coverage in academic literature. On the other hand, other energy forms, like solar, wind and hydroelectric, have a wide theoretical body of literature, favouring research and implementation.

Generally speaking, because different types of energy have different generation costs, the production of clean and renewable energy demands considerable financial resources (Hongtao and Wenjia 2018). Likewise, a significant investment in infrastructure may take several years (besides having to rely on geographic assistance, asis the case with hydroelectric, wind and geothermal energies). Regardless of the cost and difficulty of execution, these types of energy forms will write off the investment in the long run, not only due to their benefits to the planet, but also due to their ability to save resources. The most commonly used renewable energy sources are hydroelectric and thermoelectric plants with renewable fuels, whereas solar, wind and biogas energies have attained considerable growth. Nonetheless, each form has

its own pros and cons, and it is important to verify the existing investment conditions, scenarios and available local resources.

Counterweighting the aforementioned movement, only the long-term perspective creates the need to analyse the investment in this type of energy in the future. The conscious search for energy also ends up supporting economic development, since the implementation costs offset the amount invested in the long run. The ideology behind sustainable energy has moved from a reflective idea to a worldwide need of governments, companies and society. It is possible to benefit the environment while also acquiring great economic advantages (Lima 2012).

Finally, this research supports the development of goal no. 7 of the UN's Sustainable Development Goals, highlighting the advantages and disadvantages of the eight types of energy deemed sustainable. Although goal no. 7 significantly stimulates the use of renewable energies in the global energy matrix, this research identifies the initial price of investing in clean energy as a primary hindrance to its adoption. As previously seen, it is a major obstacle to society's broad adoption of sustainable energy. Therefore, the suggestion for future research efforts is to find methods to popularize clean and renewable energies.

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