Renewable Technologies: Solar Power and Wind Power Energy Utilization – Advantages and Disadvantages

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1 Introduction

Energy and technology work hand in hand to improve the economy. Nowadays, many industries use technologies that are dependent on electricity such as housing, schools, hospitals, manufacturing companies, and so on. With the increasing worldwide population, the demand for technology and energy has been above average. This began after the industrial revolution in Europe when the use of fossil fuels increased at the same rate as the increased expectations of living standards. Using conventional energy resources, such as oil, natural gas, and carbon, has limits, and with the intensity of economic expansion, they might not be sufficient to keep up with the growth. Experts have warned that these resources will be consumed before 2040. However, the consumption of resources is not the only issue. Although using conventional energy in industry is effective, it leads to many environmental problems such as global warming (Dincer, 2000), which occurs via the process of using energy and emitting greenhouse gases. Not only do emissions affect climate change, but they also affect sea levels and wildlife lifecycles, creating an unbalanced system around the world (Marks-Bielska et al., 2020).

Utilizing a limitless resource like renewable energy is a controversial topic, and knowing what source to use and why is a cause for concern. Many factors should be

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considered such as environmental effects, cost, efficiency, cleanliness, and stability. Unfortunately, many industries are still using and depending on fossil fuels to generate electricity, and there is no doubt that fossil fuels are very efficient in power production quality. Nevertheless, it should be noted that the continued use of fossil fuels will be harmful in the long run, and the fact that it is a limited resource should encourage the use of other sources of energy such as renewable energy (NASA, 2018). Renewable energy can be defined as a continuous generation of energy directly from the sun (photoelectric, photochemical, and thermal), indirectly from the sun (energy stored in biomass, hydropower, and wind), or from the natural movement of the environment (geothermal and tidal energy), which makes it a sustainable solution for generating power. Even though many countries are leaning toward renewable energy, it is not yet the main energy source across industries. Like any system, the renewable system has shortcomings, and if many industries use renewable energy, the advantages and disadvantages are easier to spot. This paper aims to discuss the advantages of renewable energy regarding the three sources mentioned above, that is, directly from the sun, indirectly from the sun, and from natural movement. The advantages will be compared with the disadvantages of each source, followed by a discussion about the new and improved technologies that have been developed to create better systems and reduce the disadvantages as much as possible (Ellabban et al., 2014).

The literature review will first discuss the background and history of renewable energy sources, focusing on solar energy and wind energy. It will also outline how to use each resource correctly, what to expect, and what to be aware of before choosing a preferred source. The review will also highlight the mechanisms of each system for a deeper understanding of the technology, compare the advantages and disadvantages, and describe the latest technologies used in each system. Data are collected from different sources to draw conclusions about how to improve the existing technology to make it sustainable in the long run without harming the environment. This research will help scientists understand the challenges in renewable energy and how they might affect the environment.

2 Literature Review

2.1 Solar Energy

The sun is the earth's most abundant energy source. Solar energy is the source of all wind, fossil fuel, hydro, and biomass energy, and it falls at a rate of 120 petawatts (1 petawatt = 1015 watts) onto the earth's surface. This indicates that all of the solar energy captured from the sun in a single day could meet the world's needs for almost 20 years. Figure 1 presents the forecasts and calculations for the future potential of each source of renewable energy based on today's technology. The more advanced the technology, the more potential it has as an energy source. The

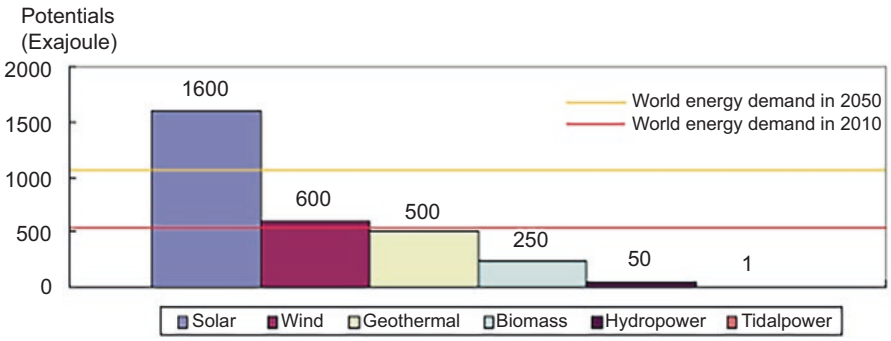

Fig. 1 Potential for renewable energy sources (based on today's technology level)

world's energy requirements are expected to increase by 5% every year; therefore, solar energy might be the best option to fulfill the ever-increasing demand.

2.1.1 Background and History

Edmond Becquerel, a 19-year-old French experimental physicist, discovered photovoltaic effects during an experiment with electrolytic cells. During the nineteenth century, inventors and businessmen in Europe and the United States created solar energy technology that would later provide the foundation for current designs. Augustin Mouchot, a French mathematician, received funding from the French government to study an alternative source of energy and constructed a solar-powered steam engine in 1878. Using parabolic dish collectors, he built the first solar steam-powered plant, which was a major draw at the 1878 World Exposition in Paris. Although the French government did not grant more financing because it was too expensive, this method of generating solar energy is still employed today. Over the next few decades, there was a lot of buzz about the solar energy's possibilities (Jones & Bouamane, 2012).

2.1.2 Technology Mechanisms

Electromagnetic radiation and solar radiation are synonyms for light that is discharged from the sun. Sunlight might vary from one country to another and from one season to another, and it might also be scattered, absorbed, or reflected by clouds, ducts, pollution, air molecules, etc. Solar technology captures light, or so-called solar radiation, and converts it from one form of energy into a useful form of energy such as electricity. Solar energy technologies can be divided into two main types: photovoltaics (PV) and concentrating solar-thermal power (CSP). PV is the most familiar technology as it comprises installed solar panels that turn light into electricity. A single PV device is a cell that can produce 1 or 2 watts of power.

Semiconductors are used to build these cells, which are of the same thickness as that of human hair. The cell is between two isolated layers of plastic or glass, and it lasts for decades. “When the sunlight passes on a solar panel, the PV cells in the panel collect the energy from the sun. This energy causes electricity to flow through, forcing electrical charges to move in response to an internal electrical field in the cell.”

CSP is on a larger scale and can be built in a very large power plant that contains mirrors to reflect the sun onto a receiver that gathers the solar energy to transform it into heat to produce electricity that can be used or stored. Many types of systems use the same mechanism to convert the concentrated sunlight into heat to produce electricity, for example, the Power Tower System CSP or CSP that uses concave mirrors and many other methods (Figs. 2 and 3).

Solar power by PV or CSP is not only limited by the amount generated, but its integration into these systems should be applied to existing electrical grids, businesses, and homes in different combinations of traditional and other renewable energy sources (Office of Energy Efficiency & Renewable Energy 2017).

2.1.3 Advantages and Disadvantages

Solar energy has advantages and setbacks, both of which will be discussed in this section. In terms of advantages, installing solar panels on homes and commercial and educational buildings allows users to become less dependent on electric utilities, as the solar panels will generate electricity and reduce the monthly electricity

Fig. 2 Solar panel tower (www.energy.gov/eere/solar/how-does-solar-work)

Fig. 3 Concave solar system (https://www.alamy.com/concave-mirror-technology-of-the-solar-power-plant-la-risca)

bill. It also gives the user a feeling of independence as they are generating their own electricity. Another advantage is that solar panels will typically last between 20 and 25 years; therefore, monthly bills will be reduced for decades. Furthermore, it is assumed that solar panels work better in hot climates, but they can function in more than one climate and actually function more efficiently in colder weather because extreme heat may lead to a voltage output reduction.

It is also a common assumption that the more a solar panel is exposed to sunlight, the more electricity it might generate; however, today's technologies are very effective, even when dealing with a minimal amount of light. One of the main advantages of solar energy is that it is considered to be renewable energy that will not harm the environment and, in particular, the climate. Additionally, solar power systems have no moving parts, thus reducing the likelihood of noise pollution. The fact that it is not noisy makes it favorable to other types of renewable energy that do create noise, for instance, wind turbines. Solar panels just need to be positioned at the correct angle.

One of the core disadvantages of solar panels is that they are initially costly, and they should be considered an investment for the future. Furthermore, solar panels may cause problems during installation on some roofs, as they do not work on every type of roof material. For example, old houses with slate or cedar roof tiles are tough for solar technicians to work on and pose a challenge because certain solar cells need to use elements that are both costly and scarce. This is particularly true for thin-film solar cells made of cadmium telluride (CdTe) or copper indium gallium selenide (CIGS). Some industrial procedures used in the production of solar panels are linked to greenhouse gas emissions. Unfortunately, sulfur hexafluoride and nitrogen trifluoride have been tracked back to the manufacture of solar panels. A

subjective setback is that solar panels are sometimes considered ugly or unappealing once they are installed on buildings.

However, solar energy is gaining popularity in several European nations, including Poland. It is frequently chosen by occupants in single-family dwellings who build PV systems and allow them to generate power. When putting such systems in place, the benefits and drawbacks of solar energy should be considered.

2.1.4 Latest Technologies

The continuous development of solar power has tried to achieve maximum effectiveness at the lowest cost. As previously mentioned, solar panels use semiconductors to produce electricity, and the three main semiconducting materials that have been developed are crystalline Si, thin films, and next-generation perovskite solar cells (PSCs). Crystalline silicon is one of the most common and popular materials that is low-cost and slightly less efficient than theoretical efficiency (which is around 20%). The National Renewable Energy Laboratory (NREL) is developing a hybrid that is low-cost but more efficient at 11%. Thin film is a standout technology for the future with a very narrow design (the light-absorbing layers are 350 times smaller than standard Si-panels), and it is flexible, lightweight, and easy to install. Usually, the following four materials are used for production: CdTe, amorphous silicon, CIGS, and gallium arsenide (GaAs). The toxicity of CdTe is a problem because of the cadmium, but CIGS solar cells are emerging as a more promising highly efficient and cost-effective alternative for both residential and commercial installations, with an efficiency of up to 21%. PSCs are an emerging technology yet to be tested for their efficiency. However, it might have a bright future as it is less costly, has a thinner design, is lightweight and flexible, and can work in lower temperatures.

The materials for capturing light are also improving along with the technology. For example, the Swiss have developed Insolight, which uses embedded lenses as optical boosters in the panels' protective glass to focus light beams 200 times while maintaining a 30% efficiency. Furthermore, a recent prototype development is a reverse solar panel that generates electricity at night using the heat irradiating from the panels (Fig. 4).

Another technology in the near future might be solar paints, including solar paint hydrogen (which generates energy from PV water splitting), quantum dots (PV paint), and perovskite-based paints. The innovative transparent solar window has already achieved 10% efficiency. The solar energy industry is predicted to expand in the next 5 years, thanks to the rapid development of low-cost, high-performance semiconducting materials, space-saving thin films, and simple installable technologies. Despite the pandemic's setback, the projected cost drop from 15% to 35% for solar systems by 2024 is optimistic and might make this renewable energy more accessible.

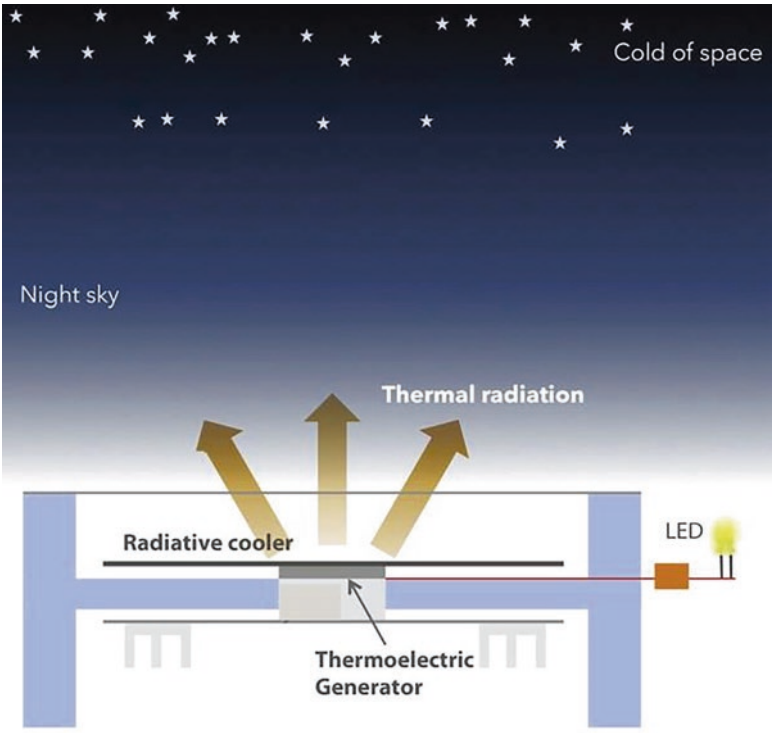

Fig. 4 Graphical abstract showing how the concept of reverse solar panels works (www.energy.gov/eere/solar)

2.2 Wind Energy

Wind energy is a form of solar energy. Wind is created when the earth has different temperatures in different places. Even though the wind consists of air particles that are light and transparent, wind force can be powerful, but it can be used as an advantage. One of the earliest applications of wind force is sailing, as wind is used to guide and move a ship in the sea. Wind energy is the utilization of wind force to generate electricity. Wind is generated when the atmosphere at the equator is warmer than the rest of the world, and the warm air travels from the equator to the poles, creating a low-pressure system. In contrast, cooler and denser air from the poles can move to the equator to create a high-pressure system. The movement of the wind is usually caused by moving from high to low pressure (National Geographic Society, 2012).

2.2.1 Background and History

The use of wind energy and wind power is rapidly expanding because it is cheaper. According to the International Renewable Energy Agency (IRENA), the latest global statistics suggest that capturing power has increased 75 times more in the last 20 years from 7.5 gigawatts (GW) in 1997 to 564 GW in 2018. Between 2009 and 2013, wind generation capture recorded twice the output of wind energy output, and in 2016, it was 16% of the total renewable energy generation. The location of wind turbines is very important, and the largest capture of wind power is either remote or offshore, which is a promising sector, as wind turbines have been there for centuries. In the 1830s, engineers tried to extract turbine movement and generate electricity after the electric generator was invented. In 1887 and 1888, wind power was generated in the United Kingdom and the United States, but modern wind power is said to have been invented in Denmark, where horizontal-axis wind turbines (HAWTs) were built in 1891, and a 22.8-meter wind turbine started working in 1897 (IRENA, 2016).

2.2.2 Technology Mechanisms

In the wind, the kinetic energy created by the flowing air is used to generate electricity, which is then converted into electrical energy by wind turbines or wind energy conversion equipment. The blades of a turbine are initially hit by the wind, causing them to rotate and turn the turbine to which they are connected. Kinetic energy is transferred to rotational energy by spinning a shaft coupled to a generator, thereby producing electrical energy through electromagnetic energy. The power that is generated from the wind depends on the size of the turbine and the length of its blades. The output is related to the diameter of the rotor and the cube of the wind speed. The potential for wind energy grows by a factor of 10 (Fig. 5).

Humans have been using the HAWT concept since 5000 B.C. when they used wind energy to move boats down the Nile River, and the design has been continually expanded and upgraded since then. A HAWT is made up of horizontally aligned blades that collect wind and are parallel to the ground. When facing wind flow perpendicularly, the blades rotate due to aerodynamic lift. The HAWT is the most common type of wind turbine and has received more money for research and development because it has a significant advantage over a VAWT in that it is more efficient at extracting energy from the wind when it is placed in a constant wind flow. Its unique design allows it to absorb energy during the whole blade's revolution, as the backtracking effect has no impact. However, one significant disadvantage is that to function properly, HAWTs must always point in the direction of the wind. As wind direction is unpredictable, an additional mechanism is required to guarantee that the blades are always facing the wind to extract maximum power production. Small wind turbines employ a rudimentary wind vane to orient themselves in the direction of the wind, but larger wind turbines need a yaw meter to determine the correct location of the air movement and a yaw motor to position the turbine in the precise

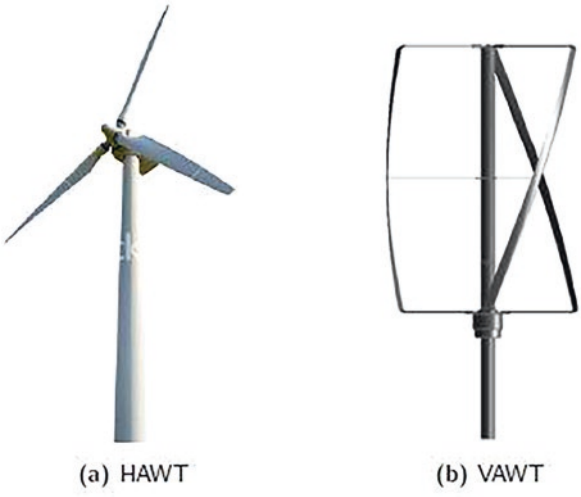

Fig. 5 (**a**) Horizontal-axis wind turbine. (**b**) Vertical-axis wind turbine (VAWT) (https://arivjournal.com/technology/feasibility-study-of-horizontal-axis-wind-turbine/)

direction of the wind. Therefore, HAWTs function best in consistent and low turbulence wind, as they do not need to change orientation as frequently.

In contrast to the HAWT's blades, the VAWT's blades revolve perpendicular to the ground and along a vertical axis. This type of turbine employs drags, lifts, or a combination of both to function. Before HAWTs were developed to become the most common wind turbines, VAWTs were the first windmills that were ever seen. VAWTs are separated into two main designs, each of which follows its own set of rules. The first is Savonius, which uses drag forces to operate like a water wheel, and the second is Darrieus, which uses aerodynamic blades to generate lift and power the turbine. Although VAWTs are less researched and have received less development funding, they have distinct advantages over HAWTs.

VAWTs are omnidirectional and can receive wind from any direction, unlike HAWTs, which must constantly face the airflow for optimal performance. VAWTs can be installed in sluggish and turbulent wind conditions, such as urban areas, because they can start producing power at low wind speeds. The VAWT system, which includes the gearbox and other components, may be bundled together and placed closer to the ground, which lowers maintenance costs and simplifies regulation. Furthermore, VAWTs are quieter than HAWTs.

Nevertheless, the VAWT's disadvantages cannot be underestimated. In high-speed wind settings, the VAWT is inefficient because of its modest beginning torque and worries about dynamic stability. The VAWT's blades are the same as the wind, so it is prone to backtracking because it must return to the flow before being propelled. It is worth mentioning that Johari et al.'s (2018) comparison of VAWTs and HAWTs had mixed results, and possibly, there is not much of a difference between them. "Wind turbine capacity has increased over time. Turbines with a rotor diameter of 15 meters and a rated capacity of 0.05 megawatts (MW) were common in 1985. In today's new wind power projects, onshore turbines with capacities of around 2 MW and offshore turbines with capacities of 3–5 MW are available" (IRENA, 2016).

2.2.3 Advantages and Disadvantages

Various advantages and downsides have been recognized as a result of the greater use of wind power. The low cost of wind energy is one of its most significant advantages, and it is certainly a low-cost alternative. After the production tax credit, a land-based utility-scale wind is one of the cheapest energy sources accessible today, costing 1–2 cents per kilowatt-hour. Wind energy mitigates the price volatility that fuel prices bring to traditional sources of energy because its electricity is provided at a fixed price over a long period (e.g., 20+ years) and its fuel is free. Additionally, the wind energy sector provides new job prospects for those who are currently jobless. Becoming a turbine technician is a rapidly expanding career option in the United States, and over 100,000 people work in the industry, which could actually support 600,000 jobs in production, installation, and maintenance.

Wind energy is a clean form of energy, as it does not pollute the air in the same way as power plants that burn fossil fuels like coal or natural gas do or generate particulate matter, nitrogen oxides, and sulfur dioxide, which are harmful to human health and create economic losses. Pollutants that produce acid rain, pollution, and other environmental issues are not released into the atmosphere by wind turbines. Wind is also a sustainable energy source that may be used in local residences. The good news is that there is plenty of wind in United States, and it may be exploited freely. Wind energy has grown by 15% annually over the previous 10 years, and it is one of the most important sources of renewable energy in the United States because it is a long-term source, with the heat from the sun in the atmosphere being the primary reason.

Wind turbines are frequently installed on farms or ranches. The wind turbine's electricity is sent into the grid and continues to generate as long as the wind blows and the sun shines. This has a significant impact on the economics of rural communities because when it comes to wind, rural areas are the best. Even if the turbines are installed on an existing farm or ranch, the benefit is that they only take up a small amount of space, allowing the farmer or rancher to continue working. They also benefit from the cash generated by renting the turbine's location.

There are downsides to using wind power and issues associated with wind turbines. In terms of cost, despite turbine prices decreasing dramatically over the past decade, wind projects must compete economically to reduce costs and make them feasible when certain areas are less windy than others. It is worth noting that wind projects are typically built on excellent land, which is usually located in remote areas distant from the towns and cities that demand power. Therefore, transmission lines must be built to transport power from the land to the city. Some structures have already made transmission line requests, but if more buildings request lines, the cost will drop dramatically. Unfortunately, erecting a wind turbine on a piece of land might not be the most effective solution. Land space can be used with other methods of power generation that might produce more power on the same piece of land. Turbines with moving parts will create sound pollution when the wind hits and moves the blades. A wind farm might also look aesthetically unpleasant, which causes another type of pollution.

Using wind turbines as a renewable energy source is great; however, they might cause environmental issues. For instance, they can potentially harm local animals, especially birds that fly at the same height as the turbines and could get hit by the moving blades. Bats are also at risk because of the moving blades. A current project is trying to solve this problem by placing wind farms in the right locations (Office of Energy Efficiency & Renewable Energy, 2021).

2.2.4 Latest Technologies

Wind energy has developed throughout the years to try and achieve the most cost-effective solutions. Prototypes of next-generation wind turbines have been developed with a focus on stability and increased power production to megawatt levels. Since 1999, the average generating capacity of turbines has grown, and turbines erected in 2016 averaged 2.15 MW. Longer and lighter rotor blades, higher towers, more dependable drivetrains, and performance-optimizing control systems have been developed as a result of research from the Wind Energy Technologies Office (WETO). Components like control systems, generators, and blades on generations of turbine designs that run to General Electric - GE's 1.5 MW model account for almost half of the nation's installed commercial wind energy fleet and are a key competitor in worldwide markets.

Furthermore, component development is increasing with WETO's collaborations with industry partners to increase system component performance and reliability. The Wind Blade Division of Knight and Carver in National City, California, collaborated with researchers at the Department of Energy's Sandia National Laboratories to create a new wind turbine blade that increased energy collection by 12%. The Sweep-Twist Adaptive Rotor (STAR) blade's main distinguishing feature is a gently curved tip, which, unlike the vast majority of blades, is uniquely engineered to make optimum use of all available angles. An enormous amount of money has also been spent on gearbox enhancement (Office of Energy Efficiency & Renewable Energy, 2021).

3 Conclusion

Renewable energy is the future source of power. After the industrial revolution, more energy and power were generated using fossil fuels, which was an effective source with good power quality. However, fossil fuels are known to be a limited resource, so unlimited resources need to be considered, such as renewable energy, which is a continuous and clean source. Burning fuel is not only problematic because it is limited, but it is also harmful to the environment and human beings; for example, the production of greenhouse gases contributes to global warming. The renewable industry is steadily improving, and two of the main resources, solar energy and wind energy, have been discussed in this article.

PV effects were first discovered by a 19-year-old French experimental physicist who experimented with an electrolytic cell. This marked the beginning of solar panels that use semiconductors to release electricity. Solar energy lasts between 20 and 25 years, and it is sustainable; therefore, users have a sense of independence in terms of generating power. Using solar panels also makes it less expensive when it comes to paying the monthly electricity bill. However, the installation of solar panels can be problematic on certain types of roofs, they also require certain atmospheric conditions, and they have space limitations. Solar energy has grown, and other types of solar panels have been developed using thin films, PSCs, and solar paint.

Wind turbines are becoming more popular sources of renewable energy because of their low cost. When different temperatures around the globe generate high and low pressure, the air moves between the two pressures and creates wind. The mechanism used in wind turbines is easy and has been used for generations, as it converts the mechanical movement of the turbine blades into electricity. Two types of wind turbines are the HAWT and the VAWT, and each has advantages and disadvantages; for example, a HAWT needs height to function properly, whereas a VAWT will work effectively at a lower height. Placing wind turbines on farms and ranches will produce electricity and allow farmers and ranchers to continue working because of the small area needed to house the turbine. Unfortunately, turbines may cause noise pollution and contribute to environmental factors such as killing birds.

It can be concluded that solar and wind energy are a large part of the renewable energy sector. In every renewable project, site conditions and requirements must be identified so that the right technology is used. When implementing projects, experts should be involved to make the right decisions using lessons learned from previous projects. Renewable energy is already applied worldwide as a limitless resource; however, the disadvantages have not yet been revealed, especially in terms of its effect on the environment. Wind turbines are already killing flying creatures, and solar panels are taking up the space of growing trees. The world was excited about the production of energy from fossil fuels without realizing how bad it would be for the environment and potentially the economy. Similarly, research on renewable energy is very important, not only for next-generation development but its effect on the environment. Researchers should also focus on new technologies and how effective it is to use more than one technology to produce energy with fewer effects.

References

Dincer, I. (2000). Renewable energy and sustainable development: A crucial review. *Renewable and Sustainable Energy Reviews, 4*(2), 157–175, www.sciencedirect.com/science/article/pii/S1364032199000118. https://doi.org/10.1016/s1364-0321(99)00011-8. Last accessed 20 Mar 2019.

Ellabban, O., Haitham, A-R., Blaabjerg, F. (2014). Renewable energy resources: Current status, future prospects and their enabling technology. *Renewable and Sustainable Energy Reviews, 39*, 748–764, www.sciencedirect.com/science/article/pii/S1364032114005656. https://doi.org/10.1016/j.rser.2014.07.113

IRENA, Wind Energy. (2016). www.irena.org/wind
Johari, M. K., Jalil, M. A. A., & Shariff, M. F. M. (2018). Comparison of horizontal axis wind turbine (HAWT) and vertical axis wind turbine (VAWT). *International Journal of Engineering & Technology, 7*(4.13), 74. https://doi.org/10.14419/ijet.v7i4.13.21333
Jones, G., & Bouamane, L. (2012). *"Power from sunshine:" A business history of solar energy*. Harvard Business School Working Paper, No. 12–105.
Marks-Bielska, R., Bielski, S., Pik, K., & Kurowska, K. (2020). The importance of renewable energy sources in Poland's energy mix. *Energies, 13*(18), 4624. https://doi.org/10.3390/en13184624. Last accessed 18 Jan 2021.
NASA. (2018). *The causes of climate change*. climate.nasa.gov/causes/
National Geographic Society, Wind. (2012). www.nationalgeographic.org/encyclopedia/wind/
Office of Energy Efficiency & Renewable Energy. (2017). Advantages and challenges of wind energy. www.energy.gov/eere/wind/advantages-and-challenges-wind-energy
Office of Energy Efficiency & Renewable Energy. (2021). *How does solar work?* www.energy.gov/eere/solar/how-does-solar-work