Improve the Generation and Transfer of Electrical Energy by a High-Power Laser Station and Wireless Networks

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Abstract*−Daily, many people die because of short circuits and many buildings are damaged due to many accidents of the electric short circuit failure. Besides, environmental pollution is soaring due to the electric power stations wastes. In Egypt, with the support of the government, researchers have recently given attention to the problems of electrical power generation. They have also been interested in innovative ways to make electric transmission sustainable as well as wireless. In this invited review paper, we discuss improvements in various methods of global generation and transfer the electrical energy According to this review studies, one of the most efficient and suitable methods depending on generating electric energy from high power laser stations has been reported by the Japanese. Working on solar energy, the Japanese generated about (1 TW/s) from the laser station and this power is far enough to cover the electrical consumption of all the country. In addition, there are promising attempts to convert the electrical energy to electromagnetic waves to make the energy transfer with the help of a wireless network. These would ultimately result in less environmental pollution, death toll, cost, and promoting welfare in Egypt and the world.

***Keywords*−Electrical Energy, Laser, Station, Wireless, Networks.**

I. Introduction

Electricity is perhaps humanity's most amazing and life-changing invention. Survival without electricity is unthinkable now. In general, energy is a vital requirement for a country's economic progress. Many modern-day functions come to a halt when the power source is disrupted. It is nearly difficult to measure the true quantity of energy used in the construction of modern development. Electrical energy is superior to other forms of energy due to its convenient form, easy control flexibility of transformation, and higher transmission efficiency.

The world depends on oil, coal, natural gas, and nuclear energy to produce electrical energy, These energy sources will dwindle and become so expensive, as well as being very harmful to the environment. Every year the world uses about (8×10^6 kg) of carbon coming from about (6.5×10^6 kg) of fossil fuels, and (1.5×10^6 kg) from removed forests. This rapid increase in electrical energy consumption and the increase in the negative side effects resulting from its generation caused great concern. So, scientists looked for viable renewable energy sources. Renewable energy is often referred to as clean energy coming from natural sources or processes that are constantly replenished. Many sources of renewable energy have been discovered, and modern scientific research is still researching and developing this type of energy. The most popular renewable energy sources currently are solar energy, wind energy, hydro energy, tidal energy, geothermal energy, biofuels, and biomass energy [1].

In 2016 the percentage of electricity generation from the unrenewable sources attains about 80%: a) Fossil Fuels 67% such as Coal 41%, Natural Gas 21%, and Oil 5.1%. b) Nuclear Power 13%. In contrast, the percentage of the renewable energy amounts to about 20%: a) Hydroelectric 92%, b) Wind 6%, c) Geothermal 1%, d) Solar 1%, And other sources 4% such as (biofuels, biomass, and other un-identified data) [1].

Today, the world is turning to generate energy from lasers, and this may create a new boom in the world of modern technology. The scientists in China and Japan succeeded in producing energy from the laser.

This review article aims to present a brief overview of the recent methods of electricity generation and their transfer. In particular, the power stations using lasers are highlighted on the basis that they are the future of generating renewable electricity. In addition, the possibility of transmitting this energy through wireless networks is explored.

II. RENEWABLE ENERGY

The importance of renewable energy is highly appreciated to counteract the rapid consumption of fossil fuels which results in an alarming polluted environment. Moreover, the fears about the impending end of fossil fuels due to the increasing demand for them led to thinking about creating everlasting sustainable renewable energy resources. Different types and sources of renewable energy are reviewed in detail.

A. Solar system

After the first oil crisis, the world uses the solar system in the second half of the seventies because the power source is the most abundant. The solar system as shown in Figure 1a [13] provides (150000 TW/y) half of this arrives at the earth and another half reflected on space. Solar energy can be produced via photovoltaic cells directly as concentrated solar thermal energy. Photovoltaic cells depend on the photons of light that knock electrons into the outer energy state. On the other hand, concentrated solar thermal energy is used to produce steam to run turbines and provide electrical energy. The purpose of the concentrator is to achieve high temperatures so high to attain high dynamic efficiency. The concentrators have different geometrical types such as parabolic troughs, solar dishes, linear Fresnel, and solar power towers [2].

B. Biomass Energy

Biomass is an organic material consisting of plants, animals, and microorganisms [3]. Organic waste resources include woody plants, food crops, agricultural crop residues, and forest wastes [4]. Biomass is the fourth largest source of energy in the world after coal, oil, and natural gas, and it is 14% of the world's energy sources [3,4]. The biomass power build is shown in Figure 1e [13].

C. Geothermal power

Geothermal energy uses the heat of the Earth's core to generate electricity [5]. The earth's core temperature increases with depth until it reaches the center and becomes (4473 K). Most of the magma that lies under the earth’s crust heats the surrounding rocks and the groundwater. This method depends on wells being drilled at a depth of a mile in underground reservoirs to reach steam and hot water, which are used to operate the turbines [6]. The geothermal power divides into dry steam, binary, and flash steam. In the case of dry steam, the steam comes out of the ground and to be used directly in the turbine. In contrast, in the binary, plants transfer a secondary liquid through hot water with a lower boiling point which is transformed into vapor for the turbine. In the flash steam, the hot high-pressure water rather moves to cold low-pressure water [6]. The geothermal power systems can operate as closed and open geothermal loop systems. These comprise the horizontal, vertical, and pond closed geothermal loop and the pond and standing well open geothermal loop systems [7].

D. Wind power

The wind is usually used to generate electricity comes as a result of the transmission of the air in the atmosphere from high pressure to low pressure. So, the sun plays a key role as one of the important sources for this process. In addition to the heat absorbed at the surface of the earth helps to heat the air near the surface which in turn expands and produces low pressure [8].

Wind power was considered as one of the most important renewable energy sources in the world and ranked as a second around the world according to the International Energy Agency. Wind energy increased at a rate of 0.2 to 2.3 between 2000 to 2012 [9]. The growth of wind energy in 2006-2007 in the European Union increased by 21% up to about (99430 GW). The wind turbines are shown in Figure 1b [13].

E. Hydroelectric power

In the late nineteenth century, scientists began to find ways to benefit from water energy, after the British-American engineer James Francis developed the first modern hydro turbine in 1882. Hydroelectric power is generated by the gravitational force of falling or flowing water from a high dam as shown in Figure 1c [13]. Hydropower represents 16% of the total energy in the world [10].

III. UNRENEWABLE OR FOSSIL FUELS ENERGY

Coal, crude oil, and natural gas are all regarded as fossil fuels since they are generated from plants, and animals remain buried and petrified millions of years ago. Fossil fuels have a high carbon content because of their origin [11].

A. Coal

It is a solid carbon-heavy rock contain lignite, sub-bituminous, bituminous, and anthracite [11].

B. Natural gas

Under the earth's crust, natural gas was discovered alongside ground crude oil resources. Natural gas comprises methane predominantly but may contain propane, ethane, butane. Being odorless, it is blended with a chemical that gives the natural gas odor to be easily detected in the event of leakage and natural gas extraction. The product is then delivered to propane and butane removal factories [12].

C. Oil

Oil considered as the only unrenewable resource that was extracted in liquid form is crude oil and also known as petrol oil. It is located between the earth's strata or among the rocks, and it is drawn back into the ground and seafloor by piercing a vertical well. The crude oil is subsequently pumped to the surface and sent to refineries [12].

The emission gases emitted by burning fossil fuels consider one of the most dangerous pollinates. Moreover one of the most harmful effects of burning fossil fuels is global warming the carbon dioxide production as shown in figure 1f [13], which leads to global warming and thus climate change. Coal plants emit 42% of mercury and sulfur dioxide, which leads to rain. The oceans are more acidic, as water absorbs about a quarter of carbon emissions. Since the beginning of the industrial revolution, the ocean has become more acidic by 30%. With higher acidity, calcium carbonate decreases, which leads to poor growth of marine organisms and then extinction. The most famous of these organisms is oysters. When extracting natural gas, it is cracked [15].

D. Nuclear Power

The world started with the trend of generating power from nuclear reactors from 1951 until the end of 2020. Nuclear energy is created by breaking uranium or plutonium atoms in a nuclear reactor through chain processes known as nuclear fission. The heat generated by the atoms' dissociation is used to convert water to steam. The steam is then used to power a turbine, which produces useable electricity.

Nuclear energy is considered a double-edged sword with many advantages. It generates energy 10 million times that produced by fossil fuels with no carbon emissions while being inexpensive compared to other energy sources. Besides, it is considered a continuously reliable source of electricity. Yet, the negative aspects of nuclear energy may cause great damage to the world. The impact of radioactive fission leakage on the environment increases the risk of developing liver, bone, or lung cancer for those who are exposed to it. The problem of the world now is to dispose of radioactive waste to avoid pernicious impact on living organisms and the risk of nuclear accidents as in accidents of Fukushima (Japan, 2011) and Chernobyl (Ukraine, 1986). In 1986, the Chernobyl disaster caused the release of large amounts of pollution and pollutants into the atmosphere in the form of radionuclides (radioactive isotopes), molecular and gaseous particles as shown in Figure 1d [13]. Thousands of people died as a result of the Chernobyl disaster, with estimates ranging from 4,000 to 60,000. Furthermore, more than 2 million people continue to suffer from health problems [13,21].

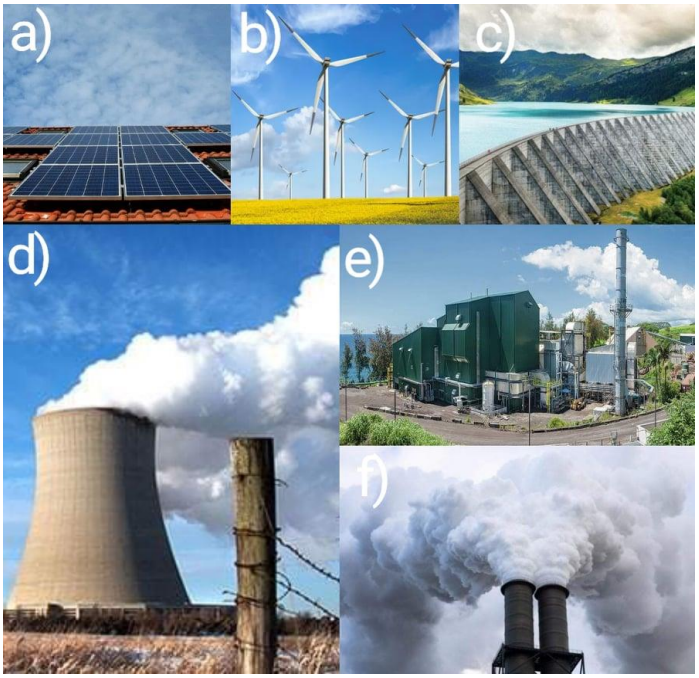

Fig. 1 Renewable and unrenewable energy sources a) solar system, b) wind turbines, c) hydroelectric power dam, d) nuclear power station, e) biomass power builds, and (f) fossil fuel emission gases [13].

IV. LASER POWER

The world is now looking for other solutions to renewable energy, which is not polluting, everlasting and any country can produce it.

Today, the world is turning to generate electrical energy using lasers since 1960. This may create a new boom in the world of modern technology and transfer the world to another electricity production generation.

In this context, scientists in China and Japan succeeded in producing electrical energy from the laser.

Laser means light amplification by stimulated emission of radiation. The operation of any laser system depends on exciting the electrons in a suitable active laser medium to the exited metastable level and getting the population inversion condition. Then, the excited electrons return to the active medium ground state by the stimulated emission of laser photons. These photons will be amplificated by the optical resonator. The most characteristic properties of laser beams are monochromaticity, coherence (spatial and temporal), directionality, and brightness.

Laser is classified into four types according to the type of the active medium such as solid-state laser, semiconductor laser, gas laser, and liquid laser. Moreover, the laser operates as a continuous laser or pulsed laser as a nanosecond, picosecond, femtosecond, and attosecond laser. Besides, the laser covers a very large electromagnetic spectrum from the infrared to the x-

ray where the laser wavelength depends on the active medium of the laser. While the power of the laser depends on the active medium, type of laser, and laser design, the active medium of the laser may be excited optically by flash lamps or another laser system, electrically, and chemically [14].

Physicist Ruxin Li and his colleagues set world records for the most powerful light pulses ever seen in the Shanghai super intense Ultrafast Laser Facility (SULF) as shown in Figure 2. It is a single cylinder of titanium-doped sapphire about the width of a Frisbee. After kindling light in the crystal and shunting it through a system of lenses and mirrors, the SULF distills it into pulses of mind-boggling unprecedented (5.3 PW) power in 2016. Although the pulses are extraordinarily powerful, they are also infinitesimally brief, lasting less than a (T/s). Now, the researchers are upgrading their laser and hope to beat their record by the end of this year with a (10 PW) shot, which would pack more than 1000 times the power of all the world's electrical grids combined. This year, Li and colleagues intend to start building a (100 PW) laser known as the Station of Extreme Light (SEL). By 2030, it will emit powerful pulses produce (100 PW) having a width of (3×10^{-6} m), which is less than 2000 the size of a pencil in a room (20 m) underground. According to that, it is 10 trillion times larger than sunlight whereby achieving vacuum-breaking phenomenon predicted by Albert Einstein according to the equation [15],

$$E = mc^2 \quad (1)$$

The vacuum-breaking phenomenon implies that we can produce energy from a vacuum, i.e., something can be generated from nothing. Although nuclear weapons attest to the conversion of matter into immense amounts of heat and light, doing the reverse is not so easy. Furthermore, physicists in Russia have drawn up a design for a (180 PW) laser known as the Exawatt Center for Extreme Light Studies (XCELS), while Japanese researchers have put forward proposals for a (30 PW) device. Researchers at the University of Rochester in New York develop plans for a (75 PW) laser, the Optical Parametric Amplifier Line (OPAL). It would take advantage of beamlines at OMEGA-EP, one of the country's most powerful lasers. "The Academies report is encouraging," says Jonathan Zuegel, who heads the OPAL [15].

Fig. 2 Laser of SULF (China) [15].

On the other hand, the Japanese at the Institute of Laser Engineering (ILE) at Osaka University succeeded in creating a laser called LEFX that produces power up to (2000 TW) in the duration of one trillionth of one second that is equivalent to 1000 times the world integrated electric power consumption [14].

The use of high-energy lasers may create a new boom in our world. It is now possible to generate all high-energy quantum beams (electrons, ions, gamma-ray, neutron, and positron) with a large current. This helps us in developing all applications in various fields such as medical applications and non-destructive inspection of social infrastructures, which provides us with safety and security. Also, this helps us to achieve laser fusion energy resulting from rapid ignition [14].

Petawatt lasers are used for the study of basic science, generating such high-energy quantum beams as neutrons and ions. So far, Petawatt lasers in the world have had relatively a small output (to a few tens of joules). ILE has achieved the world's largest laser output of dozens of times those at other world-class lasers facilities (1,000 J) or more [14]. This high output has been implemented by a 4-beam amplifier technology and the world's highest performance dielectric multilayer diffraction grating of a large diameter. In addition, to bring out the performance of the Petawatt laser most effectively, the first rising of the laser pulse [14] should be steep enough. For example, the laser pulse is expected to stand steep in its temporal evolution. LFEX laser has thus first succeeded to suppress undesirable extra lights (noise), that exist in front of the main pulse, by a factor of ten orders of magnitudes compared to the pulse peak (10-digit pulse contrast). The height of the noise is equivalent to the size of the influenza virus to the whole height of the Sky Tree [14]. Taking all the advanced high-power-laser technologies, we have completed the Petawatt laser "LFEX", which can be now available to study basic science and practical applications even deeper than earlier [14].

Table I summarizes the advantages, and disadvantages, of each electricity generation source as well as the amount and cost of the electricity generated in some countries.

TABLE I

A COMPARATIVE STUDY BETWEEN THE DIFFERENT ELECTRICITY GENERATION SOURCES

Elect. Source	Main Advantages	Main Disadvantages	Average Cost of this source	Average electricity generate
Solar system	- Available. -Renewable. -Electric bills can save. -Low maintenance cost.	- Not available at night. - High establishment costs. - Amount of electricity generated depends on the weather. - High storage cost	- Average cost of each solar panel system is 15.5 to 20.0 k$ - Maintenance is 150 $ to clean each solar panel system	About 4 kW for each solar Panel
Wind system	- Available - Renewable - Cheap - Space efficient	- Intermitted. - Negative effect of turbines. - Noise and visual pollution.	- Average cost of each turbine is about 2.6 to 4 M$ - Maintenance is 42.000 to 48.000 $/y	About 402,000 kW/h for each turbine
Geo-thermal	- Beneficial for the environment. - Renewable. - High efficiency.	- Emission gases. - Location. - Earthquake	- Average cost of building a geothermal power plant is 42.5 to 67.7 M$.	About 40 MW for each Power build.
Biomass	- Renewable. - Reliable. - Abundant. - Waste reduction. - Less emission	- Expensive. - Require large space. - Greenhouse emission. - Environment impact	- Average cost of build a biomass power plant is 40 to 45 M$.	About (20 MW) for each Power build The largest biomass generates about (205 BW).
Hydro power	- Renewable. - Reliable. - Non Pollutant.	- Expensive. - Limited.	- Average cost of the high dam 1 B$.	More than (10 BW/y).
Oil	- Inexpensive. - Reliable.	- Determination of land. - Pollutant. - Emission of gases. - Global Warming. - Acid rain. - Earthquake.	- Average, production costs are 36 $ for a barrel.	About (1.7 MW/h) for a barrel of oil.
Natural gas			- Average cost of a power plant is 5.3 M$ for 74 generators.	Power plants produce about (6549 MW/h).
Coal			- Average cost is 38.53 $ per ton.	About (2.460 W/h.kg).
Nuclear	- No carbon. - Low cost. - Reliable. - High energy density.	- Environment impact. - Risk of the nuclear accident. - Radioactive waste.	- The nuclear plant costs about 30 M$ for the nuclear station.	About (4,800 MW/h) for the nuclear station.
Laser	- No emission. - Available. - Clean energy. - Gives a lot energy more than other energy sources. - Safety energy. - Has less environmental impact.	- Costly	……	About (2,000 TW/s.)

V. WIRELESS POWER TRANSMISSION SYSTEM

One of the most critical challenges the world is currently facing today is the problem of energy transmission. Transmission by the traditional techniques using wires from the power station to the customer has caused an inevitable loss of energy. Moreover, the greater electricity demand led to an increase in the amount of energy loss through wires. Unfortunately, the power losses from the deployed wire cable ranged from 26% to 30% inherent to wire techniques, whereby, we have retrieved around 70% to 74% of our existing electric distribution system [16]. This is a consequence of wires composed of aluminum and copper, which have a certain degree of resistance, and therefore the transmission and distribution of power lose some of the energy.

Additionally, other problems including friction, corrosion, and erosion in the wires affected the transfer safety of electricity [17].

Maxwell had predicted (1873) the transfer of energy to silica when 30 years later, scientist Tesla transmitted energy wirelessly in his New York laboratory via electromagnetic waves. The Laser was initially used in the 1960s and then became a technique of simultaneous transmission of energy. However, some concepts have to fit in with the basics such as the energy transfer through the atmosphere, the wavelength used, emission potential. There is also the possibility of converting energy from its source (solar energy or wind energy ... etc.) to transmit energy such as microwave, laser, or a sound wave as depicted in figure 3 [18].

Since 1899, research has continued as to how to transmit energy wirelessly, and the scientist Tesla has achieved this. Thereupon, methods of wireless energy transmission can span small distances (electromagnetic induction), medium distances, or large distances.

For instance, inductive power transmission (IPT) depends on electromagnetic induction where the power of the alternating current source is directly proportional to its frequency. Thus, a high AC frequency electromagnetic wave can efficiently transmit electricity for up to a distance of 100 m, However, once a distance of about several meters is surpassed, the efficiency is significantly diminished.

Resonance induction (medium distance), on the other hand, can transmit energy for 3 to 4 m longer distances. Yet, electromagnetic field coupling tension between receiving and transmitting antenna decline at high frequency [17].

Otherwise, using a piezoelectric crystal, we can convert ultrasound waves into electricity and vice versa. Ultrasound (middle distance) waves propagate in a material medium such as air, at a frequency about 20 kHz up to several MHz [19].

In 1899 the scientist Tesla was considered the first to use a microwave to transfer electricity for large distances. This features an electromagnetic wave with wavelengths ranging from (1 mm) to (1 m) and frequency from (0.3 to 300 GHz). Nevertheless, another scientist succeeded in choosing to set up a device that converts the microwave directly into a direct current. However, microwave radiation's relatively long wavelength resulted in a large dispersion with the transmitter at long distances reducing its efficiency. Therefore, scientists thought about the idea of transmitting energy by laser, but still, research is being conducted on how to transfer it [17].

Laser energy transfer is one of the most successful and easiest wireless methods as shown in Figures 3 and 4. In 2017, the patented Power lighting laser technologies succeeded in transmitting hundreds of watts over hundreds of meters using the laser. This technology is targeted at areas in which energy is lost due to natural disasters, drones, communications, and disaster response. Power lighting laser technologies transform energy into light and turn light into a highly efficient receiver over vast distances, converting light back to electricity without reducing the electricity percentage compared to cables. In addition, power lighting laser technology has overcome electricity transfer issues in the deep oceans, at high altitudes, and long distances [20].

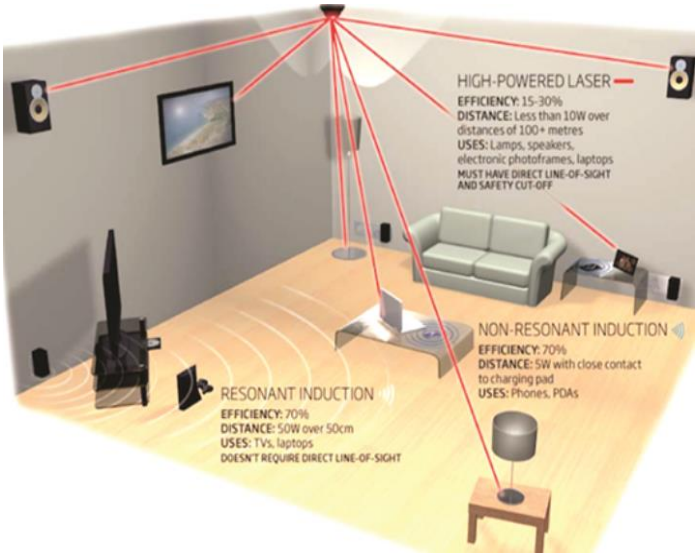

Fig. 3 The wireless power transmission [22].

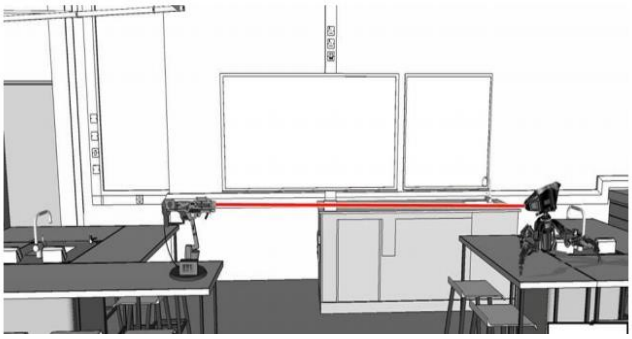

Fig.4 Wireless Power Transmission through Laser [23].

VI. Conclusion

On the light of this review article, the global energy problems to generate and transfer clean, fast, inexpensive energy can be efficiently dealt with by generating energy through lasers. On the other hand, wireless energy transport can reduce energy loss during transportation from power stations to the consumer. Therefore, wireless energy transport together with a viable laser energy generation should provide an uninterrupted potential means for energy generation in the future.

References

[1] team Atomberg Editorial, “Different Types Of Electricity,” Jul. 22, 2016. https://atomberg.com/different-types-of-electricity (accessed Jul. 13, 2021).

[2] E. F. Camacho and M. Berenguel, “Control of solar energy systems,” *IFAC Proc. Vol.*, vol. 8, no. PART 1, pp. 848–855, 2012, doi: 10.3182/20120710-4-SG-2026.00181.

[3] R. Ramakumar and P. Chiradeja, “Distributed generation and renewable energy systems,” *Proc. Intersoc. Energy Convers. Eng. Conf.*, pp. 716–724, 2002, doi: 10.1109/iecec.2002.1392136.

[4] S. Shah and V. Venkatramanan, *Advances in microbial technology for upscaling sustainable biofuel production*. Elsevier B.V., 2019.

[5] Ľ. Csányi, V. Krištof, S. Kušnír, M. Katin, and M. Marci, “Renewable Energy Sources,” 2010, Accessed: Jul. 13, 2021. [Online]. Available: https://otik.uk.zcu.cz/bitstream/11025/22539/1/Csanyi.pdf.

[6] J. unwin, “What is geothermal energy and where is it used in the world?,” Jun. 18, 2019. https://www.power-technology.com/features/what-is-geothermal-energy (accessed Jul. 13, 2021).

[7] “Geothermal Energy: Advantages & Disadvantages (2021) | GreenMatch,” Jun. 09, 2021. https://www.greenmatch.co.uk/blog/2014/04/advantages-and-disadvantages-of-geothermal-energy (accessed Jul. 13, 2021).

[8] P. Breeze, “The Wind Energy Resource,” *Wind Power Gener.*, pp. 9–17, 2016, doi: 10.1016/b978-0-12-804038-6.00002-5.

[9] P. Breeze, “An Introduction to Wind Power,” *Wind Power Gener.*, pp. 1–8, 2016, doi: 10.1016/b978-0-12-804038-6.00001-3

[10] A. Almerini, “Hydroelectric Energy Pros and Cons,” Nov. 29, 2020. https://www.solarreviews.com/blog/hydroelectric-energy-pros-and-cons (accessed Jul. 13, 2021).

[11] M. Denchak, “Fossil Fuels: The Dirty Facts | NRDC,” Jun. 29, 2018. https://www.nrdc.org/stories/fossil-fuels-dirty-facts (accessed Jul. 13, 2021).

[12] “Non-Renewable Resource - Overview, Types, Examples.” https://corporatefinanceinstitute.com/resources/knowledge/other/non-renewable-resource/ (accessed Jul. 13, 2021).

[13] C. Lane, “Nuclear Energy Pros and Cons,” May 11, 2021. https://www.solarreviews.com/blog/nuclear-energy-pros-and-cons (accessed Jul. 13, 2021).

[14] “World-largest petawatt laser completed, delivering 2,000 trillion watts output | EurekAlert! Science News,” Aug. 06, 2015. https://www.eurekalert.org/pub_releases/2015-08/ou-wpl080615.php (accessed Jul. 14, 2021).

[15] E. Cartlidge, “Physicists are planning to build lasers so powerful they could rip apart empty space,” *Science (80-.).*, Jan. 2018, doi: 10.1126/SCIENCE.AAT0939.

[16] S. Pawade, T. Nimje, and D. Diwase, “Goodbye wires: Approach to wireless power transmission,” *Int. J. Emerg. Technol. Adv. Eng. ISSN*, vol. 2, no. 4, pp. 2250–2459, 2012.

[17] Z. Yuwei, H. Xueliang, T. Linlin, B. Yang, and Z. Jianhua, “Current research situation and developing tendency about wireless power transmission,” *Proc. - Int. Conf. Electr. Control Eng. ICECE 2010*, pp. 3507–3511, 2010, doi: 10.1109/iCECE.2010.853.

[18] L. Summerer and O. Purcell, “Concepts for Wireless Energy Transmission via Laser,” *ESA-Advanced Concepts Team*, pp. 1–10, 2008.

[19] M. Etemadrezaei, “Wireless Power Transfer,” *Power Electron. Handb.*, pp. 711–722, 2018, doi: 10.1016/B978-0-12-811407-0.00024-6.

[20] “PowerLight Technologies, formerly known as LaserMotive, is,” Dec. 11, 2017. https://www.globenewswire.com/news-release/2017/12/11/1251099/0/en/PowerLight-Technologies-formerly-known-as-LaserMotive-is-First-to-Market-with-Commercialized-High-Power-Long-Distance-Optical-Power-over-Fiber.html (accessed Jul. 14, 2021).

[21] G. Steinhauser, A. Brandl, and T. E. Johnson, “Comparison of the Chernobyl and Fukushima nuclear accidents: A review of the environmental impacts,” *Sci. Total Environ.*, vol. 470–471, pp. 800–817, 2014, doi: 10.1016/j.scitotenv.2013.10.029.

[22] “Wireless Power Transmission – news.” http://www.electricalpowerinfo.com/2018/02/27/transmission-wireless/ (accessed Jul. 26, 2021).

[23] a Mahmood et al., “A Comparative Study of Wireless Power Transmission Techniques,” J. Basic Appl. Scoientific Res., vol. 4, no. 1, pp. 321–326, 2014.