Elucidation of the Impact of Renewable Energy Power Plants on the Environment

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Abstract

Rapid expansion of renewable energy production can be directly attributed to two factors: The exponential growth of the world's population, and the shrinking supply of fossil fuels. Similarly, impact of greenhouse gas emission is at the forefront from such attributes. As a result, indulge in study aiming at decarbonizing the energy sectors and electrical power plants particularly that are based on renewable energy sources (RES). RES are generally regarded as a clean and environmentally friendly, beside significant number of studies concluded that its expansion has a detrimental effect in preserving natural world. This article provides a comprehensive study on the impacts of RES on the preservation of the natural world and the environment. The research offers an in-depth analysis taking cognizant of the RES that are in use today. To gain a better understanding of the problem, a literature survey on the relevant government and non-profit organizations, were conducted to perform comparative environmental impact analyses and discussions for a variety of attributes on currently operational RES-based. Similarly, impact on human health, noise, pollution, greenhouse gas emissions, the depletion of the ozone layer, toxification, flooding, eutrophication, dried-up rivers, and deforestation was equally attributed as the potential impact recorded. According to the analysis, the impact was manifested in the form of environmental pollution, the loss of biodiversity, the fragmentation of habitat, and the extinction of wildlife. Therefore, as a priority for sustainable development, renewable energy will need to overcome some obstacles.

Keywords: *Renewable energy, Solar energy, wind energy, Hydropower, Geothermal energy.*

INTRODUCTION

The use of fossil fuels in urban areas and the conversion of tropical land to urban usage is responsible for over 70% of the world's carbon dioxide (CO_2) emissions. This makes up 5% of the total annual emissions. By 2050, urbanisation is anticipated to have expanded to every corner of the globe, with Africa and Asia seeing the fastest urbanisation rates. Africa and Asia are expected to have increases in the urbanisation of 56% and 64%, respectively. Around 75% of the energy produced from fossil fuels worldwide is used in urban areas. The production of electricity using fossil fuels is characterised by the release of greenhouse gases (GHG), climate change, and global warming. In 2012, transportation was responsible for 23% of all worldwide CO_2 emissions, while electricity and heat generation contributed roughly 42%. The following sustainability standards are anticipated to be met by urban energy systems as a result of global clean energy trends driven by the United Nations (Ebhota and Jen 2020).

1. Offer minimal or no CO_2 emissions.
2. Maintain a balance between capital-intensive network upgrade investments.
3. Have an impact on network security and local energy independence.
4. Encourage cohesion and social capital.

Studies have also referred to the requirements for a sustainable energy system as an energy trilemma (Gent and Tomei 2017). In order to have a sustainable energy system, three factors must be considered: carbon dioxide emissions, energy security, and the cost of energy. The demands that inspired this investigation are:

1. CO_2 emission reduction—offering energy that is clean, dependable, renewable, and has little to no greenhouse gas emissions.
2. Cost of energy reduction—bettering the commercialization of research and development results.
3. Energy security—better serving urban areas in gaining access to renewable energy sources.

To reduce carbon emissions and fight global warming, it has become significant to use fewer fossil fuels and more RESs in the energy sector. RES are often thought of as clean energy sources that don't harm the environment. Research shows that RES can hurt the environment, even though they are much better than fossil fuels. If the whole point of using RES is to save the environment, then the wrong way to use them could have the opposite effect. From now until 2050, there will need to be an annual investment of US$3.5 trillion in the renewable and sustainable energy sector (Curtin et al. 2019). Power plants that use natural gas put out 50% less CO_2 than those that use other fossil fuels. So, natural gas could be used as a bridge fuel until RES becomes more reliable and sustainable. For a greener environment, the UN has come up with seventeen goals for sustainable development. One of these goals is to provide affordable, clean energy, which is seventh on the list. RESs are considered to have no emissions and are also easy to find in nature. Fig. 1 shows how much power is made by each type of RES-based power plant (Gao, Fan, and Chen 2020).

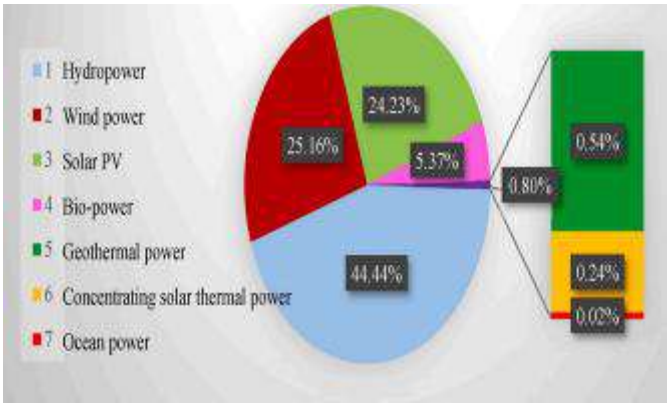

Fig 1. Percentage of power made by each typre of RES-based power plants(Gao, Fan, and Chen 2020)

The main renewable energy sources with their usage in different form are classified in Table 1. Renewable Power Capacity, World and Top Regions/Countries, 2019 is showed in Table 2.

Table 1. Renewable Energy Sources and Usage (Gao, Fan, and Chen 2020)

Energy resource	Energy usage and conversion options
Biomass	Digestion, pyrolysis, gasification, and the production of heat and power

Direct solar	Thermal energy production, photovoltaics, and water heaters
Geothermal	Hydrothermal energy, hot rock, and urban heating
Hydropower	power production
Solar	solar-powered appliances such as cookers and dryers
Tidal	Tidal stream, barrage
Wave	Multiple designs
Wind	power generation, windmills, and wind generators

Table 2. Renewable Power Capacity, World Top Regions/Countries, 2019 (Gao, Fan, and Chen 2020).

Technology	World Total	BRICS[a]	EU-28	China	United States	India	Germany	Japan	United Kingdom
	GW			GW					
Bio-power	130	48	44	22.5	16.0	10.8	8.9	4.3	7.9
Geothermal power	13.9	0.1	0.9	~0	2.5	0	~0	0.6	0
Hydropower	1,150	630	131	326	80	45	5.6	22	1.9
Ocean power	0.5	0	0.2	0	0	0	0	0	~0
Solar PV[b]	627	256	102	205	76	43	49	63	13.4
Concentrating solar thermal power (CSP)	6.2	1.1	2.3	0.4	1.7	0.2	0	0	0
Wind power	651	292	192	236	106	38	61	3.9	24
Total renewable power capacity (including hydropower)	2,588	1,127	502	790	282	137	124	94	47
Total renewable power capacity (not including hydropower)	1,438	597	371	464	202	92	119	72	45
Per capita capacity (kilowatts per inhabitant, not including hydropower)	0.2	0.2	0.7	0.3	0.6	0.1	1.4	0.6	0.7

It is understandable to wonder whether using RESs will have any adverse effects on the environment, even though doing so will help reduce carbon emissions in the power sector and combat global warming. Numerous RESs, according to research, have negative effects on the environment and nature. RESs are used to cut down on harmful emissions and make the environment better. But the same environment can be hurt if the bad effects of RESs aren't considered. In this paper, some of the available RESs are used, and their drawbacks are talked about. The effects of the different RES are summed up and shown in a table for ease of use. Lastly, the right ways to use RESs to reduce their negative effects on the environment are talked about.

SOLAR POWER PLANT

The sun is a great way to make clean, long-lasting electricity without polluting the air or contributing to global warming. Researchers have found that a lot of carbon is released over the course of a photovoltaic (PV) cell's life. The carbon footprints are made when the products are made, when they are shipped, and when they are installed. Carbon emissions can be created by servicing and recycling PV cells over the duration of their useful life. In addition, it has been calculated that, throughout the course of a PV system's lifetime, between 32–82g CO_2 per kWh of electricity is generated. Research and development periods for solar PV cells were lengthy. While PV panels have numerous positive features, there are also some drawbacks that can be harmful to the environment, as evidenced by studies.

A. Effect on Environment

A concrete structure is anchored into the ground at a solar farm's PV panels to keep them at a consistent slant. The soil is not able to evenly distribute heat and water. After the PV panels have served their purpose, the soil has lost some of its fertility, which slows the process of replanting. In addition, a sizable piece of land is needed for PV installations. For a utility-scale PV project, you'll need somewhere between 3.5 and 10 acres of land. Utilising those regions may result in a decrease in the amount of land that is cultivable. However, instead of cultivable lands, it could be a good idea to make use of abandoned mining regions, contaminated brownfields, and transportation corridors. The habitats of adjacent species are impacted by solar photovoltaic systems. Solar farms can't be built in an area where animals can thrive if those animals are relocated elsewhere. Since their ecosystem has been disrupted, the local flora and fauna cannot thrive there. Additionally, many birds have perished in that area due to the high temperatures generated by solar panels and mirrors.

During the process of making PV panels, many flammable and poisonous materials are made, which increases the health and safety risks. In each Copper indium gallium selenide (CIGS) module or Cadmium telluride (CdTe), there are small amounts of toxic materials that don't cause much worry. But when there are a lot of PV modules together, the release of such toxic materials can be bad for public or worker health. If PV modules are not used right, there is a small chance that they will catch fire because they contain some gases that can burn. In large plants with a lot of PV-arrays, a small mistake could cause a serious fire.

Also, if the fluid that moves heat leaks, it could pollute the waterways nearby. During the decommissioning phase of PV modules, toxic dust like cadmium, silica, and arsenic could harm the public's health if they are not handled properly. If you breathe in silica dust for a long time, it can cause silicosis, which makes scar tissue in your lungs.

B. Effect on Human Health

Solar cells made from single-walled carbon nanotubes have many benefits. But there are possible downsides that could lead to many diseases in people. One major problem is that these solar cells cause breathing problems in people. During the manufacturing process, the particles that cause this disease are made. The more these nanoparticles are used, the more likely it is that someone will be exposed to them. If the size of the particles gets smaller, the surface area will go up for the same amount of mass. Solar panel glass is coated with indium-doped tin oxide (ITO), which also makes up about 87% of the total weight of solar glass. The most important part of ITO is indium, which is toxic to humans mainly because sulfuric acid leachate is used in the recovery process. It can also lead to eutrophication, the acidification of the environment, the destruction of the ozone layer, and other problems. Also, Florin doped Tin Oxide can greatly reduce the effects of ITO (Celik et al. 2017).

C. Dependency on batteries

The utility grid is not used in standalone PV systems due to all its demand is met by PVs. PVs are used during the day to charge the batteries while also providing electricity to the loads. Due to the lack of sunlight at night, PVs cannot generate electricity; instead, batteries are used to power the loads. Batteries used in these standalone PV systems contain heavy metals that have a negative impact on the environment. After about 10 years, these batteries' performance starts to drastically decline. Batteries must be replaced twice or three times throughout the course of a solar PV system because the average company offers a warranty on them of about ten years (Zellmer 2022).

HYDROPOWER PLANT

Hydroelectricity is generated by damming a river. A hydro turbine generates electricity by releasing water from higher altitudes. The oldest and most studied RES is hydroelectricity. Hydropower has the most installed capacity of all RESs at 1150 GW as of 2019. Hydropower facilities don't emit greenhouse gases, apparently. However, several studies have found environmental influences. Fish migration is impeded by the dam or barrier that forms the reservoir for a hydropower plant. Also, dams affect both the temperature and the velocity of the water they hold back or release. Additionally, the water and its surroundings undergo a shift in their chemical composition. Both the river's ecology and its physical structure will suffer as a result of these alterations. Negative effects on native flora and fauna are almost inevitable. Moreover, native residents' removal will disrupt their way of life. The flooding and erosion/siltation will also dry up many natural regions and archaeological sites. Steel and concrete are utilised to construct these reservoirs, and the machinery used to do so may produce carbon emissions if fossil fuels are used. These hydro power plants may produce some emissions throughout their operation, but their 50–100 year lifespan makes this a minor issue. Around 5-10% of fish are killed every year by hydropower turbines. The US Department of Energy has proposed cutting that rate to 2%. Many fish, including shad, salmon, and others, migrate upstream to spawn. Dams utilised in hydropower plants block their migration, reducing their chances of successfully reproducing (Fearnside 1989).

D. Land Use

Define The majority of hydroelectric power facilities consist of a dam and a reservoir, both of which require a sizeable area of land. In order to produce 250 MW of electricity, the Balbina hydroelectric power plant, for instance, floods 2360 km^2 of land, whereas a tiny hydroelectric power plant that produces 10 MW of electricity only needs 0.253 km^2 of land. Sometimes, suitable places for hydro plants cover people's houses, significant natural regions, agricultural land, or historical landmarks. These might be undesirable outcomes. Significant changes are brought about in the outward presentation of the natural environment in and around the dam's vicinity (Ezcurra et al. 2019) .

E. Edangering Aquatic Life

Large hydropower plants often alter river flows. It disrupts river flow and fish migration. Thus, impeded

fish migration will reduce fish populations. Fish population declines threaten marine ecosystem stability and human food supplies. Turbines also kill fish. The Energy Information Administration estimates that the best turbines kill 5–10% of fish. Fish ladders may help a hydropower plant. Fish ladders or elevators safely cross dams. It helps salmon and shad spawn upstream. Fish ladders may not support huge migrations. The US Department of Energy is developing turbines to reduce fish mortality to 2%. Due to plastic and chemical pollution, marine life should have a 0% turbine fatality rate (Arent, Wise, and Gelman 2011).

F. Disruption of River Systems

Because of the construction of hydroelectric plants, the habitats of native freshwater species are changed. The river's temperature, flow rate, and nutrient content are all impacted. Lower water quality results from water loss and silt loads in the river's downstream flow. These modifications directly affect the ecological characteristics of rivers, endangering the local plant and fish life. There is evidence that dams reduce estuary production and stability (Michel 2014). Analysis of two dammed rivers on Mexico's Pacific coast uncovered alarming rates of coastal retreat. This resulted in a decrease in aquatic biodiversity as habitats for several species were destroyed.

G. Greenhouse Gas Emissions

The production of hydroelectricity is not 100% emission-free. Dammed river reservoirs generate greenhouse gases, studies suggest. Dead plants and other organic matter in reservoir water degrade and emit methane and carbon dioxide into the atmosphere. Hydroelectric equipment heating and cooling systems can also emit. Hydropower reservoirs emit greenhouse gases depending on location and regional conditions. Small plants release 4.5–13.61g CO_2 eq./kWh. Large semi-arid plants release 27.2g CO_2 eq./kWh over their lifetime. Tropical and moderate peatlands emit more.

H. Social Impact of Hydroelectric Power Plant

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WIND POWER PLANT

Making use of the wind to generate electricity is a viable, eco-friendly option because it doesn't contribute to air pollution or climate change. Due to the fact that it is abundant, cannot be depleted, and has a low cost, wind power is a viable and widespread alternative to the use of fossil fuels. Wind power has a lot of untapped potentials, but there are a lot of negative environmental effects that come along with it that need to be dealt with.

I. Land Use

A Wind power facility has a highly site-specific effect on land consumption; for example, wind turbines positioned in flat locations require significantly more land than those situated in hilly places. On the other hand, wind turbines can't take up the whole field; they need to have a buffer zone of about 5 - 10 rotor diameters (The rotor diameter of the wind turbine blades). Thus, the area taken up by the turbines and the supporting infrastructure (such as roads and transmission lines) represents only a fraction of the overall area used by a wind farm.

According to the findings of a study that was carried out by the National Renewable Energy Laboratory(NREL), the amount of land that is necessary to produce 1 megawatt (MW) of electricity from large wind farms in the United States ranges from 30 to 141 acres (a typical new utility-scale wind turbine is about 2 MW). During construction, less than 3.5 acres per megawatt are disrupted temporarily; however, this number drops to less than 1 acre per megawatt after the project is finished. Livestock grazing, farming, roads, and trails are only some of the additional beneficial uses for the remaining area. There

is a lot less cause for concern regarding land usage when wind farms are placed on brownfields (unused or abandoned industrial land) or other industrial and commercial settings.

The blades and turbines used in offshore wind facilities are far larger than those used on land, hence more room is needed for these installations. These offshore installations may conflict with fishing, navigation, recreation, gravel and sand exploitation, gas and oil extraction, and aquaculture depending on their location. Utilizing best practices in planning and siting can help reduce the potential negative effects of wind energy projects on land use. This applies to both offshore and onshore projects (Gasparatos et al. 2017).

J. Public Health and Community

Headings, Wind turbine visual and noise impact are the key public health and community issues. Aerodynamic turbine blade movement creates most wind turbine noise. Turbines make mechanical noise. Wind speed and turbine design determine sound levels. Industry and government-sponsored studies in Australia and Canada have shown that sound and vibration from wind facilities do not harm public health. However, wind turbine developers must address community concerns by implementing "good neighbour" siting principles and communicating with affected neighbourhood members. The use of sound-absorbing materials and the elimination of blade surface defects are two examples of technological developments that have helped reduce the noise produced by wind turbines (Baqtasch et al. 2006).

Shadow flicker can occur when wind turbines are lit. Planting trees, constructing window awnings, or shutting down wind turbines in particular lighting situations might reduce this irritation. For aircraft safety, the Federal aviation administration (FAA) requires white or red lights on big wind turbines and other structures over 200 feet. The FAA has ruled that multi-turbine wind projects do not need to light each tower if there are no illumination gaps more than half a mile. White turbines eliminate daytime brightness.

K. Bird Fatality

A further concern is the birds and the habitat in which they live. Birds that fly into the blades of wind turbines run the risk of being injured or even killed. In addition, the lights near the wind farm attract the birds that live in the surrounding area, which increases the risk of a collision. However, this topic is controversial because deforestation and urbanization result in more bird deaths. According to reports, barely 20 birds per year per 1000 MW installed capacity of wind turbines are killed. In comparison, approximately 1500 birds every year perish as a result of hunting. An additional 2000 birds per year perish due to electricity and vehicle collisions. Only one bird perishes because of wind turbines for every 250 deaths brought on by people (Baqtasch et al. 2006). Similarly, 9557 turbine checks were performed throughout the course of these eleven years, and a total of 464 carcasses were discovered. Additionally, for the 8 test turbines, 1275 individual checks were performed. According to the yearly fatality report, painted turbines had an average reduction in fatalities of 71.9% compared to nearby unpainted turbines (Nazir et al. 2020).

GEOTHERMAL POWER PLANT

The most common type of geothermal power plant is called a hydrothermal plant, and it is in areas where hot molten rock is close to the earth's crust. This proximity causes the rock to generate hot water. Improved geothermal systems, also known as hot dry rock geothermal, can provide additional access to geothermal energy in certain locations. These systems involve drilling beneath the surface of the earth to reach deeper geothermal resources. Cooling methods and the technology used to transform geothermal energy into electricity (direct steam, flash, or binary) also vary from plant to plant (water-cooled and air-cooled). The effects on the environment will vary with the method of conversion and cooling employed.

L. Geothermal Environmental Impact

Several types of greenhouse gases, including CO_2, nitrous oxide (NH_3), methane (CH_4), and others have been found in Global power plant (GPP) wastes. GPPs release about 380-1045 kg of CO_2 eq/MWh into the atmosphere. In addition, GPPs contribute to acidification since they generate 0.14-44.8 kg of Sulphur dioxide (SO_2) eq/MWh. Additionally, GPPs generate 1.1-31.6 kg of 1.4 DB eq/MWh, adding to human toxicity. In addition, it has been claimed that between 0.086 and 28.94 kg/MWh of ammonia is released from the GPP on Italy's Mount Amiata. In addition to lead (Pb), cadmium (Cd), and mercury (Hg), some GPPs may contain traces of selenium (Se), chromium (Cr), antimony (Sb) and arsenic (As). In

general, the GPP at Amiata has a warming potential of 693 kilograms CO_2 eq/MWh, with a range of 380-1045 kg CO_2 eq/MWh. For comparison's sake, the average values for coal-based and gas-based power plants are 640 and 1068 kg CO_2 eq/MWh, respectively. In this respect, a GPP's effects are like those of other fossil fuel-based power plants (May et al. 2020).

According to Soltani et al. 2021, the number of emissions from GPPs might vary greatly depending on the specifics of each situation. Diesel used for drilling has been identified as a major contributor to this discrepancy. Drilling methods and how long they are employed have a substantial bearing on the environment. Drilling times, depths, and numbers of boreholes vary from site to site due to differences in subsurface qualities. Seismic risk is an additional issue of concern. Seismic events with a Richter magnitude of 3.4 were reportedly recorded after six days of hydraulic stimulation at a planned GPP at Basel. Instead of using diesel for drilling, opt for electrical or thermal spallation methods to reduce negative effects on the environment. To reduce emissions through renewable energy production, it is important to plan for the appropriate number of additional boreholes in advance of their installation. Fewer environmental effects from a 90-kilometer-long borehole can be expected.

M. Geothermal Social Impact

A geothermal plant needs a different amount of land depending on the characteristics of the type of energy conversion system, the amount of power capacity, the resource reservoir, the type of cooling system, the layout of piping and wells systems, and the needs for a substation and auxiliary buildings. The Geysers, which is the biggest geothermal facility in the world, has a capacity of about 1,517 MW and a surface area of about 78 Km^2, or about 13 acres per megawatt. As a result of the fact that many geothermal sites, such as the Geysers, are located in remote and ecologically sensitive places, the developers of projects need to take this into consideration when designing their projects.

On geological "hot zones," which are more likely to experience earthquakes, hydrothermal plants are located. There is evidence to suggest that the presence of hydrothermal plants can increase the frequency of earthquakes. The likelihood of minor earthquakes can also rise with improved geothermal systems (hot dry rock). Like how natural gas hydraulic fracturing works, high pressure water pumps are utilized in this procedure to fracture subterranean hot rock reserves. To lessen the possibility of earthquakes brought on by upgraded geothermal systems, plants must be positioned at a sufficient distance from major fault lines. When a geothermal system is placed at proximity to a highly populated region, additional requirements include constant monitoring as well as open communication with the population that surrounds the system.

Hydrothermal plants are in earthquake-prone geological "hot zones." Hydrothermal plants may increase earthquake frequency. Hot dry rock in enhanced geothermal systems can cause minor earthquakes. Like natural gas hydraulic fracturing, high-pressure water fractures subterranean hot rock reserves. Siting enhanced geothermal plants away from key fault lines reduce earthquake risk. A geothermal system installed at proximity to a heavily populated area requires ongoing monitoring and an open line of communication with the community.

SUMMARY OF RE DRAWBACKS

Referencing the effects being generated from utilization of RES, table 3 summarizes the major problems that need to be addressed for actualizing an optimum operation that features minimal pollution and be eco-friendly.

Table 3. RES Impact

	Negative impact of RES
Hydro	Possible annihilation of freshwater disruption of natural river flow; aquatic biota; possibility of dam structure failure; displacement of residents; Greenhouse gases would be released as a result of a decline in land fertility caused by a lack of sediment deposition, the possibility of flooding, and the decomposition of biomass submerged in water.
Wind	Difficulties for birds and bats, noise and vibration from machinery, a possible change in global climate, and the loss of habitat are all concerns.
Solar	Production of PV cells necessitates the use of rare earth minerals and toxic heavy metals; disrupts local ecosystems; isn't uniformly distributed because different locations receive different amounts of solar radiation at different times of the year.
Geothermal	Could potentially cause water and air pollution as well as micro-earthquakes and land subsidence.

CONCLUSION

When the potential costs and benefits of renewable energy production, the environment, and the preservation of natural areas are weighed against one another, it becomes clear that RE is not automatically environmentally friendly or sustainable, particularly when it is implemented on a large scale, certainly ,this study also discusses the fundamental reasons contributing to the growing of renewable energy, which has been established and will have considerable positive effects on both the environment and the economy. However, we feel it is important to underline that there are certain aspects that are detrimental to biodiversity, and these must be considered when developing laws for renewable energy sources. This is especially pertinent when considering the possibility that non-linear effects will develop during the process of scaling up, as well as the fact that seemingly insignificant impacts can become significant when renewable energy technology is deployed at a scale that is compatible with accomplishing a greener energy transition. Typically, these trade-offs have significant social and economic repercussions, notably for the livelihoods of local communities located surrounding the locations of RE projects. Thus, reflecting the consequence of this phenomenon, it is of the utmost importance to increase public awareness and information regarding the implementation of RE. It is necessary to do additional scientific research and evaluation if we are to improve our understanding of the socioeconomic effects of RE and find ways to mitigate them.

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