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A REVIEW ON THE VARIOUS ENVIRONMENTAL IMPACTS OF RENEWABLE ENERGY TECHNOLOGIES

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Abstract: – This paper deals with the various environmental impacts of renewable energy technologies. Usually all the energy sources have some impact on our environment. Usage of fossil fuels results in serious greenhouse effect and environmental pollution, which have a great influence in the world. Hence it is important to understand the environmental impacts associated with producing power from renewable sources. In this paper the various Environmental Impacts of wind, solar, geothermal, biomass, and hydropower was discussed. This paper would be helpful for the Diploma and UG students to understand the various environmental impacts of Renewable Energy System (RES) also they can get idea how to minimise the various Environmental Impacts of Renewable Energy Technologies.

Keywords: Wind, Solar, Geothermal, Biomass, Solar, RES

1. INTRODUCTION

Renewable energy resources include the sun, wind, moving water such as rivers and tides, and earth's core heat - along with a little human ingenuity these resources are used to produce usable energy in the form of electricity or heat. The most common definition is that renewable energy is from an energy resource that is replaced by a natural process at a rate that is equal to or faster than the rate at which that resource is being consumed. Renewable energy is a subset of sustainable energy.

1.1 Solar

Sunlight, or solar energy, can directly heat and light homes and commercial buildings, be harnessed for generating electricity, hot water heating, solar cooling, and a variety of commercial and industrial uses.

1.2 Wind

The heating and cooling of the Earth by the sun also creates the wind which can be converted into energy by spinning the blades of wind turbines, the modern day wind mills. Wind turbines today range from small to enormous in size, allowing electricity production from home use to an industrial scale.

1.3 Geothermal

In short, geothermal power is energy extracted from heat stored under the Earth's surface. Strategically placed geothermal plants can harness the heat generated from the core of the Earth and convert it into electricity for commercial use through heat turbines.

1.4 Hydropower

Hydropower is power that is derived from the force or energy of moving water. Flowing water creates energy that can be captured and converted into electricity through the use of turbines. The most prevalent form of hydropower is dams, although newer forms harnessing wave and tidal power are becoming more common.

2. ENVIRONMENTAL IMPACTS OF WIND POWER

Wind power is extracted from air flow using wind turbines or sails to produce mechanical or electrical power. Windmills are used for their mechanical power, wind pumps for water pumping, and sails to propel ships.

There are a variety of environmental impacts associated with wind power generation that should be recognized and mitigated.

2.1 Land use

i. The land use impact of wind power facilities varies depending on the site: wind turbines placed in flat areas typically use more land than those located in hilly areas.
ii. However, wind turbines are spaced approximately 5 to 10 rotor diameters apart. Thus, the turbines themselves and the surrounding infrastructure (including roads and transmission lines) occupy a large amount of the total area of a wind facility.
iii. Offshore wind facilities, which are currently not in operation, require larger amounts of space because the turbines and blades are bigger than their land-based counterparts.
iv. Depending on their location, such offshore installations may compete with a variety of other ocean activities, such as fishing, recreational activities, sand and gravel extraction, oil and gas extraction, navigation, and aquaculture.

2.2 Wildlife and Habitat

i. The bird and bat deaths from collisions with wind turbines due to changes in air pressure caused by the spinning turbines.
ii. The National Wind Coordinating Committee (NWCC) concluded that these impacts are relatively low and do not pose a threat to species populations.
iii. By keeping wind turbines motionless during times of low wind speeds could reduce bat deaths by more than half without significantly affecting power production.
iv. Offshore wind turbines can have similar impacts on marine birds, but as with onshore wind turbines, the bird deaths associated with offshore wind are minimal.

2.3 Public Health and Community

i. Sound and visual impact are the two main public health and community concerns associated with operating wind turbines.
ii. Most of the sound generated by wind turbines is aerodynamic, caused by the movement of turbine blades through the air. There is also mechanical sound generated by the turbine itself. Overall sound levels depend on turbine design and wind speed.

iii. Some people living close to wind facilities have complained about sound and vibration issues, but these issues do not adversely impact public health.
iv. However, these community concerns are important for wind turbine developers for siting turbines.
v. Additionally, technological advances, such as minimizing blade surface imperfections and using sound-absorbent materials can reduce wind turbine noise.
vi. Under certain lighting conditions, wind turbines can create an effect known as shadow flicker.
vii. This annoyance can be minimized with careful siting, planting trees or installing window awnings.

2.4 Life-Cycle Global Warming Emissions

i. A global warming emission associated with life-cycle of wind turbine includes materials production, materials transportation, on-site construction and assembly, operation and maintenance, and decommissioning and dismantlement.
ii. Estimates of total global warming emissions depend on a number of factors, including wind speed, percent of time the wind is blowing, and the material composition of the wind turbine.
iii. Most estimates of wind turbine life-cycle global warming emissions are between 0.02 and 0.04 pounds of carbon dioxide equivalent per kilowatt-hour.

2.5 Water Use

i. There is no water impact associated with the operation of wind turbines. As in all manufacturing processes, some water is used to manufacture steel and cement for wind turbines.

3. ENVIRONMENTAL IMPACTS OF SOLAR POWER

Solar power is the conversion of sunlight into electricity, either directly using photovoltaic (PV), or indirectly using concentrated solar power (CSP). Concentrated solar power systems use lenses or mirrors and tracking systems to focus a large area of sunlight into a small beam. Photovoltaic convert light into an electric current using the photovoltaic effect.

3.1 Land Use

i. Depending on their location, larger utility-scale solar facilities can raise concerns about land degradation and habitat loss.
ii. A total land area requirement varies depending on the technology, the topography of the site, and the intensity of the solar resource.
iii. Estimates for utility-scale PV systems range from 3.5 to 10 acres per megawatt, while estimates for CSP facilities are between 4 and 16.5 acres per megawatt.
iv. However, land impacts from utility-scale solar systems can be minimized by siting them at lower-quality locations such as brown fields, abandoned mining land, or existing transportation and transmission corridors.
v. Smaller scale solar PV arrays, which can be built on homes or commercial buildings, also have minimal land use impact.
vi. Unlike wind facilities, there is less opportunity for solar projects to share land with agricultural uses.

3.2 Hazardous Materials

i. The PV cell manufacturing process includes a number of hazardous materials, most of which are used to clean and purify the semiconductor surface.
ii. These chemicals include hydrochloric acid, sulphuric acid, nitric acid, hydrogen fluoride, and acetone.
iii. The amount and type of chemicals used depends on the type of cell, the amount of cleaning that is needed, and the size of silicon wafer.

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iv. Workers also face risks associated with inhaling silicon dust. Hence, these chemicals and other manufacturing waste products are disposed properly.
v. Thin-film PV cells contain a number of more toxic materials than those used in traditional silicon photovoltaic cells, including gallium arsenide, copper-indium-gallium-diselenide, and cadmium-telluride.
vi. If not handled and disposed of properly, these materials could pose serious environmental or public health threats.
vii. However, manufacturers have a strong financial incentive to ensure that these highly valuable and often rare materials are recycled rather than thrown away.

3.3 Life-Cycle Global Warming Emissions

i. A global warming emissions associated with life-cycle of the solar energy includes manufacturing, materials transportation, installation, maintenance, and decommissioning and dismantlement.
ii. Most estimates of life-cycle emissions for photovoltaic systems are between 0.07 and 0.18 pounds of carbon dioxide equivalent per kilowatt-hour.

3.4 Water Use

i. Solar PV cells do not use water for generating electricity. However, as in all manufacturing processes, some water is used to manufacture solar PV components.
ii. Concentrating solar thermal plants (CSP), like all thermal electric plants, require water for cooling.
iii. Water use depends on the plant design, plant location, and the type of cooling system.
iv. CSP plants that use wet-recirculation technology with cooling towers withdraw between 600 and 650 gallons of water per megawatt-hour of electricity produced.
v. CSP plants with once-through cooling technology have higher levels of water withdrawal, but lower total water consumption (because water is not lost as steam).
vi. Dry-cooling technology can reduce water use at CSP plants by approximately 90 percent.

4. ENVIRONMENTAL IMPACTS OF GEOTHERMAL ENERGY

Geothermal electricity is electricity generated by geothermal energy. Technologies in use include dry steam power stations, flash steam power stations and binary cycle power stations.

4.1Water Quality and Use

i. Geothermal power plants can have impacts on both water quality and consumption.
ii. Hot water pumped from underground reservoirs often contains high levels of sulphur, salt, and other minerals.
iii. Most geothermal facilities have closed-loop water systems, in which extracted water is pumped directly, back into the geothermal reservoir after it has been used for heat or electricity production.
iv. In such systems, the water is contained within steel well casings cemented to the surrounding rock.
v. Depending on the cooling technology used, geothermal plants can require between 1,700 and 4,000 gallons of water per megawatt-hour.
vi. However, most geothermal plants can use either geothermal fluid or freshwater for cooling; the use of geothermal fluids rather than freshwater clearly reduces the plants overall water impact.

4.2 Air Emissions

i. In closed-loop systems, gases removed from the well are not exposed to the atmosphere and are injected back into the ground after giving up their heat, so air emissions are minimal.
ii. In contrast, open-loop systems emit hydrogen sulphide, carbon dioxide, ammonia, methane, and boron. Hydrogen sulphide, which has a distinctive "rotten egg" smell, is the most common emission.

iii. Once in the atmosphere, hydrogen sulphide changes into sulphur dioxide (SO2). This contributes to the formation of small acidic particulates that can be absorbed by the bloodstream and cause heart and lung disease.
iv. Sulphur dioxide also causes acid rain, which damages crops, forests, and soils, and acidifies lakes and streams.
v. However, SO2 emissions from geothermal plants are approximately 30 times lower per megawatt-hour than from coal plants, which is the nation's largest SO2 source.
vi. Some geothermal plants also produce small amounts of mercury emissions, which must be mitigated using mercury filter technology.

4.3 Land Use

i. The amount of land required by a geothermal plant varies depending on the properties of the resource reservoir, the amount of power capacity, the type of energy conversion system, the type of cooling system, the arrangement of wells and piping systems, and the substation and auxiliary building needs.
ii. The many geothermal sites are located in remote and sensitive ecological areas, so project developers must take into account in their planning processes.
iii. Hydrothermal plants are sited on geological "hot spots," which tend to have higher levels of earthquake risk. There is evidence that hydrothermal plants can lead to an even greater earthquake frequency.
iv. Enhanced geothermal systems (hot dry rock) can also increase the risk of small earthquakes. In this process, water is pumped at high pressures to fracture underground hot rock reservoirs similar to technology used in natural gas hydraulic fracturing.
v. Earthquake risk associated with enhanced geothermal systems can be minimized by sitting plants an appropriate distance away from major fault lines.
vi. When a geothermal system is sited near a heavily populated area, constant monitoring and transparent communication with local communities is also necessary.

4.4 Life-Cycle Global Warming Emissions

i. In open-loop geothermal systems, approximately 10 percent of the air emissions are carbon dioxide and a smaller amount of emissions are methane, a more potent global warming gas.
ii. Estimates of global warming emissions for open-loop systems are approximately 0.1 pounds of carbon dioxide equivalent per kilowatt-hour.
iii. In closed-loop systems, these gases are not released into the atmosphere, but there are a still some emissions associated with plant construction and surrounding infrastructure.
iv. Enhanced geothermal systems, which require energy to drill and pump water into hot rock reservoirs, have life-cycle global warming emission of approximately 0.2 pounds of carbon dioxide equivalent per kilowatt-hour.

5. ENVIRONMENTAL IMPACTS OF BIOMASS

Biomass is biological material derived from living, or recently living organisms. In the context of biomass as a resource for making energy, it most often refers to plants or plant-based materials which is not used for food or feed, and are specifically called lignocelluloses biomass.

5.1 Water Use

i. Biomass power plants require approximately the same amount of water for cooling as coal power plants, but actual water withdrawals and consumption depends on the facility's cooling technology.
ii. For biomass plants with once-through cooling systems which take water from nearby sources, circulate it through the plants cooling system, and then discharge it water withdrawals range between 20,000 and 50,000 gallons per megawatt-hour with consumption of 300 gallons per megawatt-hour.

iii. Biomass facilities that use wet-recirculation cooling systems which reuse cooling water in a second cycle rather than immediately discharging it withdraw between 500 and 900 gallons per megawatt-hour and consume approximately 480 gallons per megawatt-hour.
iv. In either case, when withdrawn cooling water is returned to its source, it is much warmer than when it was withdrawn, which often has a negative impact on plant and animal life.
v. In regions with sufficient rainfall where irrigation is not required, water use for producing energy crops may be less of a concern.
vi. However, even in water-rich areas, the increased cultivation of energy crops may harm regional water quality as a result of soil tillage and nutrient runoff. Such water quality impacts can be managed through proper harvesting techniques.

5.2 Air Emissions

i. Burning biomass to produce electricity can impact air quality.
ii. The level of air emissions associated with biomass power plants varies depending on the feedstock, combustion technology, and types of installed pollution controls, but the most common pollutants include nitrogen oxides (NO_2), sulphur dioxide (SO_2), carbon monoxide, and particulate matter.
iii. In general, biomass facilities emit less SO_2 and mercury (a neurotoxin) than coal.
iv. NO_2 from biomass are lower than those from coal but higher than natural gas.
v. NO_2emissions causes ground-level ozone, or smog, which can burn lung tissue and can make people more susceptible to asthma, bronchitis, and other chronic respiratory diseases.
vi. Like SO_2, NO_2 also contributes to acid rain and the formations of harmful particulate matter.
vii. Biomass power plants also emit high levels of particulates (soot and ash) and carbon monoxide.
viii. Readily available technologies, such as fluidized bed or gasification systems, and electrostatic precipitators, can help reduce NO_2, CO and particulate emissions associated with biomass power.

5.3 Land Use

i. Using agriculture and forest waste streams for biomass power could lead to land or habitat degradation.
ii. Similarly, harvesting of forest waste products can be done sustainably, but proper forest management practices need to be followed to ensure that wildlife habitat is not destroyed and the forest remains healthy.
iii. Impacts associated with the use of energy crops depends greatly on whether the planting leads to land use change or displaced food production.
iv. Energy crops present many of the same environmental challenges as food crops, and therefore the same principles of sustainable agriculture apply: crop rotation, integrated pest management, and proper soil husbandry to prevent soil erosion.
v. Many energy crops use less fertilizer and pesticides than typical food crops, and perennial grasses do not require annual tilling and planting.

5.4 Life-cycle Global Warming Emissions

i. There are global warming emissions associated with growing and harvesting biomass feedstock, transporting feedstock to the power plant, and burning or gasifying the feedstock.
ii. Transportation and combustion emissions are roughly equivalent for all types of biomass.
iii. However, global warming emissions from the sourcing of biomass feedstock vary widely.
iv. It was once commonly thought that biomass had net zero global warming emissions, because the growing biomass absorbed an equal amount of carbon as the amount released through combustion.
v. When organic waste is disposed of in a landfill, it decomposes and releases methane, a potent global warming gas. Thus, diverting these wastes for electricity production reduces landfill volume and reduces methane emissions.
vi. An estimation of lifecycle global warming emissions of biomass energy is wide. Excluding global warming emissions from land use changes, most estimates are between 0.04 and 0.2 pounds of CO_2 equivalent per kilowatt-hour.

6. Environmental Impacts of Hydroelectric Power

Hydroelectricity is the term referring to electricity generated by hydropower; the production of electrical power through the use of the gravitational force of falling or flowing water. It is the most widely used form of renewable energy.

6.1 Land Use

i. The size of the reservoir created by a hydroelectric project can vary widely, depending largely on the size of the hydroelectric generators and the topography of the land.
ii. Hydroelectric plants in flat areas tend to require much more land than those in hilly areas or canyons where deeper reservoirs can hold more volume of water in a smaller space.
iii. Flooding land for a hydroelectric reservoir has an extreme environmental impact: it destroys forest, wildlife habitat, agricultural land, and scenic lands.

6.2 Wildlife Impacts

i. Dammed reservoirs are used for multiple purposes, such as agricultural irrigation, flood control, and recreation, so not all wildlife impacts associated with dams can be directly attributed to hydroelectric power.
ii. However, hydroelectric facilities can still have a major impact on aquatic ecosystems.
iii. Reservoir water is usually more stagnant than normal river water. As a result, the reservoir will have higher than normal amounts of sediments and nutrients, which can cultivate an excess of algae and other aquatic weeds. These weeds can crowd out other river animal and plant-life, and they must be controlled through manual harvesting or by introducing fish that eat these plants.
iv. In addition, water is lost through evaporation in dammed reservoirs at a much higher rate than in flowing rivers.
v. Reservoir water is typically low in dissolved oxygen and colder than normal river water. When this water is released, it could have negative impacts on downstream plants and animals.
vi. To mitigate these impacts, aerating turbines can be installed to increase dissolved oxygen and multi-level water intakes can help ensure that water released from the reservoir comes from all levels of the reservoir, rather than just the bottom (which is the coldest and has the lowest dissolved oxygen).

6.3 Life-cycle Global Warming Emissions

i. Global warming emissions are produced during the installation and dismantling of hydroelectric power plants.
ii. Such emissions vary greatly depending on the size of the reservoir and the nature of the land that was flooded by the reservoir.
iii. Small run-of-the-river plants emit between 0.01 and 0.03 pounds of carbon dioxide equivalent per kilowatt-hour.
iv. Life-cycle emissions from large-scale hydroelectric plants built in semi-arid regions are also modest: approximately 0.06 pounds of carbon dioxide equivalent per kilowatt-hour.

Conclusion:

In this the various environmental impacts of renewable energy technologies were discussed in simple points. This paper would be helpful for the young engineers to understand the various environmental impacts of Renewable Energy System (RES).

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