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Environmental Impacts of Renewable Energy Technologies

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Abstract. Nowadays, fossil fuels are the main sources energy from which electricity is obtained. But these sources will not last forever, so in due course renewable energies will have to replace them in this role. All energy sources have some impact on our environment. Fossil fuels — coal, oil, and natural gas — do substantially more harm than renewable energy sources by most measures, including air and water pollution, damage to public health, wildlife and habitat loss, water use, land use, and global warming emissions. A brief overview of the potential for release of some global warming substances, hazardous materials into the environment and the land and water use for different renewable energy utilization devices is presented.

Keywords: Renewable energy, environmental impact, hazardous materials, global warming emissions, land and water use.

1. Introduction

Today, renewable energy provides only a tiny fraction of its potential electricity output worldwide. But numerous studies have repeatedly shown that renewable energy can be rapidly deployed to provide a significant share of future electricity needs, even after accounting for potential constraints.

In accordance with *REN21 Renewables 2010 Global Status Report* renewable energy replaces conventional fuels in four distinct areas: electricity generation, hot water/space heating, motor fuels, and rural (off-grid) energy services:

1. **Power generation**. Renewable energy provides 19% of electricity generation worldwide. Renewable power generators are spread across many countries, and wind power alone already provides a significant share of electricity in some areas: for example, 14% in the U.S. state of Iowa, 40% in the northern German state of Schleswig-Holstein, and 49% in Denmark. Some countries get most of their power from renewables, including Iceland (100%), Norway (98%), Brazil (86%), Austria (62%), New Zealand (65%), and Sweden (54%).
2. **Heating**. Solar hot water makes an important contribution to renewable heat in many countries, most notably in China, which now has 70% of the global total (180 GWh). Most of these systems are installed on multi-family apartment buildings and meet a portion of the hot water needs of an estimated 50–60 million households in China. Worldwide, total installed solar water heating systems meet a portion of the water heating needs of over 70 million households. The use of biomass for heating continues to grow as well. In Sweden, national use of biomass energy has surpassed that of oil. Direct geothermal for heating is also growing rapidly.
3. **Transport fuels**. Renewable biofuels have contributed to a significant decline in oil consumption in the United States since 2006. The 93 billion liters of biofuels produced worldwide in 2009 displaced the equivalent of an estimated 68 billion liters of gasoline, equal to about 5% of world gasoline production.

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2. Types of Environmental Impacts

It is important to understand the environmental impacts associated with producing power from renewable sources such as wind, solar, geothermal, biomass, and hydropower. The exact type and intensity of environmental impacts varies depending on the specific technology used, the geographic location, and a number of other factors.

Various aspects of the impact of renewable energy sources can be analyzed, including, among others: air and water emissions, waste generations, specially hazardous materials, noise generation, land use, global warming emissions.

By understanding the current and potential environmental issues associated with each renewable energy source, we can takes steps to effectively avoid or minimize these impacts as they become a larger portion of our electric supply.

A whole series of determinants are favouring the development of the energy sector based on renewable resources: increasing social awareness of the need to limit emissions of harmful substances, legislation, pro-environmental policies of governments, by-laws, support in the form of programmes and financial mechanisms, not to mention the rising costs of energy from conventional sources and the need to ensure energy security.

Because the environmental performance of renewable energy systems is greatly improved by: increased efficiency and longer lifetimes, both should be stimulated for the devices and whole systems.

What does it mean: environment? The *Oxford dictionary (Brown, 1993)* defines environment as "*the set of circumstances or conditions … in which a person or community lives, works, develops, etc, or a thing exists or operates; the external conditions affecting the life of a plant or animal*". In most countries, industrial development is contingent on the developer obtaining a permit from a regulatory authority which involves assessing the impact the development may have on the environment. Preservation of the environment is not merely a local issue but an international concern.

The brief comparison between environmental benefits and costs of the use of different types of RES is presented in the Fig. 1 and Table 1.

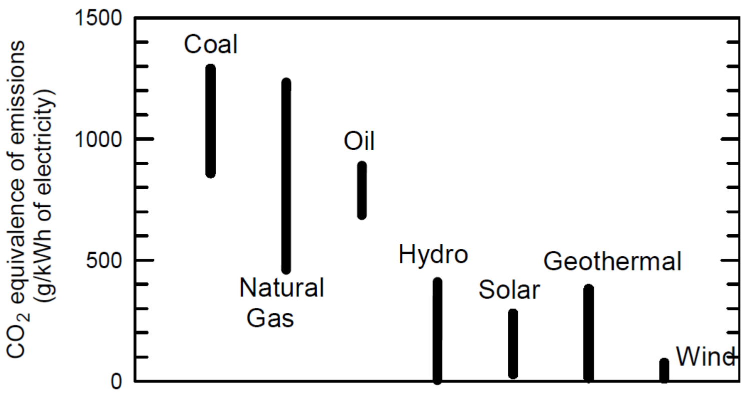

Fig. 1: Relative amounts of greenhouse gas emissions from various types of electricity generation methods, data expressed as CO_2 equivalents [1]

Table 1: Comparison between environmental benefits and costs

Environmental benefits	Environmental costs
1. Energy produced by the renewable energy systems 2. Greenhouse gas savings	1. Production of devices and BOS • Greenhouse gas emissions • Heavy metals emissions • Energy used (Energy pay-back time[1]) 2. Wastes generated by different RES industry

[1] Energy Payback Time - EPBT is the time necessary for a system to generate the energy equivalent to that used to produce it.

3. Environmental Impacts of Different Technologies

3.1. Environmental Impacts of Wind Power

A wind farm, when installed on agricultural land, has one of the lowest environmental impacts of all energy sources: it occupies less land area per kilowatt-hour (kWh) of electricity generated than any other energy conversion system, apart from rooftop solar energy, and is compatible with grazing and crops; it generates the energy used in its construction in just 3 months of operation, yet its operational lifetime is 20–25 years; greenhouse gas emissions and air pollution produced by its construction are very tiny and declining. There are no emissions or pollution produced by its operation; in substituting for base-load (mostly coal power) wind power produces a net decrease in greenhouse gas emissions and air pollution, and a net increase in biodiversity; modern wind turbines are almost silent and rotate so slowly (in terms of revolutions per minute) that they are rarely a hazard to birds [2].

Modern wind turbine designs have significantly reduced the noise from turbines. Turbine designers are working to minimise noise, as noise reflects lost energy and output. Noise levels at nearby residences are managed through the siting of turbines, the approvals process for wind farms and operational management of the wind farm. The noise limit for wind farms is 35 A-weighted decibels, which is usually around 5 A-weighted decibels above a quiet countryside. Alternatively, the limit is 5 A-weighted decibels above the level of background noise (i.e. without wind farm noise), if that is greater than 35 A-weighted decibels [3]. Low frequency sound and infrasound (ie usually beneath the threshold of human hearing) are everywhere in the environment. They are emitted from natural sources such as wind and rivers and artificial sources such as traffic and air conditioning. Modern turbine designs which locate the blades upwind instead of downwind have significantly reduced the level of infrasound. Scientific and health authorities have found the low level of infrasound emitted by wind turbines pose no health risks [4].

Wind turbines may create shadow flicker on nearby residences when the sun passes behind the turbine. However, this can easily be avoided by locating the wind farm to avoid unacceptable shadow flicker, or turning the turbine off for the few minutes of the day when the sun is at the angle that causes flicker. Shadow flicker is considered in the NSW development assessment process to ensure potential impacts are addressed [3]. Many energy policy studies have noted how wind turbines present direct and indirect hazards to birds, other avian species, and bats [5], [6]. Birds can directly smash into moving or even stationary turbine blades, crash into towers and nacelles, and collide with local distribution lines. These risks are exacerbated when turbines are placed on ridges and upwind slopes or built close to migration routes. Some species, such as bats, face additional risks from the rapid reduction in air pressure near turbine blades, which can cause internal hemorrhaging [7].

Comparative assessment of avian mortality for fossil fuel, nuclear, and wind power plants in the United States is presented in [8]. It was stated that for wind turbines, the risk appears to be greatest to birds striking towers or turbine blades. For fossil-fueled power stations, the most significant fatalities come from climate change, which is altering weather patterns and destroying habitats that birds depend on. For nuclear power plants, the risk is almost equally spread across hazardous pollution at uranium mine sites and collisions with draft cooling structures. Yet, taken together, fossil-fueled facilities are about 17 times more dangerous to birds on a per GWh basis than wind and nuclear power stations.

Timely decommissioning of turbines that are no longer in use is a standard condition of consent for wind farms in NSW. Decommissioning wind farms is a straightforward task. In Europe many older wind farms are being re-powered with new turbines; this could also be expected to occur in New South Wales. Existing wind sites have considerable value – the wind resource is well understood and structural foundations, electricity transmission and local community acceptance are already in place [3].

3.2. Environmental Impacts of Solar Power

Photovoltaics is now a proven technology which is inherently safe, as opposed to some dangerous electricity generating technologies. Over its estimated life a photovoltaic module will produce much more electricity than was used in its production. A 100 W module will prevent the emission of over two tonnes of CO_2. Photovoltaic systems make no noise and cause no pollution while in operation. PV cell technologies that have relatively lower environmental risks compared to other types of electric sources. However, chemicals used in PV cells could be released to air, surface water, and groundwater in the manufacturing facility, the installation site, and the disposal or recycling facility [9]. The production of photovoltaic devices involves the use of a variety of chemicals and materials. The amounts and types of chemicals used will vary depending upon the type of cell being produced. Based on a review of the chemical information reported in the U.S. EPA's Toxics Release Inventory System (TRIS) database for six photovoltaic companies producing solar cells, it appears that most of the chemicals used by the manufacturing companies are not released in reportable quantities. The releases of chemicals to the air from the photovoltaic facilities were reported as both air stack emissions and fugitive air emissions. All six of the photovoltaic companies reviewed reported air stack emissions of some compounds used for cleaning and etching. The chemicals released in the largest quantities in air stack emissions included 1,1,1-trichloroethane, acetone, ammonia, isopropyl alcohol, and methanol [10]. The scale of the system plays a significant role in the level of environmental impact. Depending on their location, larger utility-scale solar facilities can raise concerns about land degradation and habitat loss. and impacts from utility-scale solar systems can be minimized by siting them at lower-quality locations such as abandoned mining land, or existing transportation and transmission corridors [11].

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. Concentrating solar thermal plants (CSP), like all thermal electric plants, require water for cooling. Water use depends on the plant design, plant location, and the type of cooling system.

3.3. Environmental Impacts of Geothermal Energy

Geothermal power is a relatively benign source of energy. For the most part, the impacts of development are positive. Worldwide geothermal energy utilization increases yearly because it is an attractive alternative to burning imported and domestic fossil fuels.

Electricity generation from geothermal resources involves much lower greenhouse gas (GHG) emission rates than that from fossil fuels. According to the International Atomic Energy Agency (IAEA), replacing one kilowatt-hour (kWh) of fossil power with a kilowatt-hour of geothermal power reduces the estimated global warming impact by approximately 95% [1].

However, geothermal development could have certain negative impacts if appropriate mitigation actions and monitoring plants are not in place. Any large-scale construction and drilling operation will produce visual impacts on the landscape, create noise and wastes and affect local economies. Some countries have strict environmental regulations regarding some of the impacts associated with geothermal development, and others do not. Environmental issues usually addressed during the development of geothermal fields include air quality, water quality, waste disposal, geologic hazards, noise, biological resources and land use issues [12].

The protection of groundwater is important during the drilling phase. The groundwater is to be managed sustainably. It is part of the ecosystem, is a habitat for animals and plants, and has a role in the livelihood of local residents. The main visual impact during the construction phase is the presence of a drilling rig, but once a project is in the production phase the rig is not required and the energy centre footprint is very small. Because of low emissions, the geothermal power plants also meet the most stringent clean air standards. It should be noted that all geothermal plants have to meet various national and local environmental standards and regulations, although emissions are not routinely measured below a certain threshold, and emissions from geothermal plants typically fall below this threshold [13].

The list of barriers resulting from environmental regulations can be rather long. Environmental regulations should include groundwater protection incl. pressure issues, soil protection but also protocol on micro-seismicity, and surface issues. For work safety, construction and traffic, any legislation applicable for similar activities in mining, drilling, construction, etc. should be applied.

3.4. Environmental Impacts of Biomass

Biomass power plants share some similarities with fossil fuel power plants: both involve the combustion of a feedstock to generate electricity. Thus, biomass plants raise similar, but not identical, concerns about air emissions and water use as fossil fuel plants. Biomass power plants, like coal- and natural gas-fired power plants, require water for cooling. Land use impacts from biomass power production are driven primarily by the type of feedstock: either a waste stream or an energy crop that is grown specifically for generating electricity. There are global warming emissions associated with growing and harvesting biomass feedstock, transporting feedstock to the power plant, and burning or gasifying the feedstock. Transportation and combustion emissions are roughly equivalent for all types of biomass. However, global warming emissions from the sourcing of biomass feedstock vary widely. 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, but now it is understood that some biomass feedstock sources are associated with substantial global warming emissions. Beneficial biomass resources include energy crops that do not compete with food crops for land, portions of crop residues such as wheat straw or corn stover, sustainably-harvested wood and forest residues, and clean municipal and industrial wastes [14].

3.5. Environmental Impacts of Hydroelectric Power

Although hydropower has no air quality impacts, construction and operation of hydropower dams can significantly affect natural river systems as well as fish and wildlife populations. Assessment of the environmental impacts of a specific hydropower facility requires case-by-case review.

Negative impact of dams are as follows: in flat basins large dams cause flooding of large tracts of land, destroying local animals and habitats; people have to be displaced causing change in life style and customs - about 40 to 80 million people have been displaced physically by dams worldwide; large amounts of plant life are submerged and decay anaerobically; the migratory pattern of river animals like salmon and trout are affected; dams restrict sediments that are responsible for the fertile lands downstream; salt water intrusion into the deltas means that the saline water cannot be used for irrigation; large dams are breeding grounds for mosquitoes and cause the spread of disease; dams serve as a heat sink, and the water is hotter than the normal river water - this warm water when released into the river downstream can affect animal life [15].

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