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Social, Economic, and Environmental Impacts of Renewable Energy Resources

Mahesh Kumar

Abstract

Conventional energy source based on coal, gas, and oil are very much helpful for the improvement in the economy of a country, but on the other hand, some bad impacts of these resources in the environment have bound us to use these resources within some limit and turned our thinking toward the renewable energy resources. The social, environmental, and economical problems can be omitted by use of renewable energy sources, because these resources are considered as environment-friendly, having no or little emission of exhaust and poisonous gases like carbon dioxide, carbon monoxide, sulfur dioxide, etc. Renewable energy is going to be an important source for power generation in near future, because we can use these resources again and again to produce useful energy. Wind power generation is considered as having lowest water consumption, lowest relative greenhouse gas emission, and most favorable social impacts. It is considered as one of the most sustainable renewable energy sources, followed by hydropower, photovoltaic, and then geothermal. As these resources are considered as clean energy resources, they can be helpful for the mitigation of greenhouse effect and global warming effect. Local employment, better health, job opportunities, job creation, consumer choice, improvement of life standard, social bonds creation, income development, demographic impacts, social bonds creation, and community development can be achieved by the proper usage of renewable energy system. Along with the outstanding advantages of these resources, some shortcomings also exist such as the variation of output due to seasonal change, which is the common thing for wind and hydroelectric power plant; hence, special design and consideration are required, which are fulfilled by the hardware and software due to the improvement in computer technology.

Keywords: conventional energy resources, social, environmental, economical, hydropower, photovoltaic, geothermal

1. Introduction

Renewable energy is going to be an important source for power generation in the near future, because we can use these resources again and again to produce useful energy. The energy resources are normally classified as fossil resources, renewable, and nuclear energy resources. Different renewable energy resources, like hydropower, wind, solar, biomass, ocean energy, biofuel, geothermal, etc., provide 15–20% of the total world's energy. The world is going to turn into a global village due to more requirement of energy due to fast growing population, which leads to

the use the fossil fuels like coal, gas, and oil to fulfill the energy requirement, which creates unsustainable situations and many problems like depletion of fossil fuels, environmental and geographical conflicts, greenhouse effect, global warming, and fluctuation in fuel prices. Due to environment-friendly and less emission of gases from renewable energy, it is considered as sustainable energy; also supported for the society from each dimensions like economic, social and environmental. “Approximately 1.6 billion people have no access to electricity and about 1.1 billion are without water supply” [1]. Renewable energy resources have an ability to complete the world’s energy demand, protect the environment, and provide energy security. Along with the outstanding advantages of these resources, some shortcomings also exist like the variation of output due to seasonal change, which is the common thing for wind and hydroelectric power plant; hence, special design and consideration are required, which are fulfilled by the hardware and software due to the improvement in computer technology. The main renewable energy sources with their usage in different form are classified in **Table 1**, and it is expected that renewable energy will be one of the important sources for the future; the world’s renewable energy sources scenario by 2040 is estimated as given in **Table 2**.

| Energy resource | Energy conversion and usage option |
|-----------------|---|
| Hydropower | Power generation |
| Biomass | Heat and power generation, pyrolysis, gasification, digestion |
| Geothermal | Urban heating, power generation, hydrothermal, hot rock |
| Solar | Solar home system, solar dryers, solar cookers |
| Direct solar | Photovoltaic, thermal power generation, water heaters |
| Wind | Power generation, wind generators, windmills |
| Wave | Numerous designs |
| Tidal | Barrage, tidal stream |

Table 1.
Main renewable energy sources with their usage form [2].

| | 2001 | 2010 | 2020 | 2030 | 2040 |
|---|--------|--------|--------|--------|--------|
| Total consumption (million tons equivalent) | 10,038 | 10,549 | 11,425 | 12,352 | 13,310 |
| Biomass | 1080 | 1313 | 1791 | 2483 | 3271 |
| Large hydro | 22.7 | 266 | 309 | 341 | 358 |
| Geothermal | 43.7 | 86 | 186 | 333 | 493 |
| Small hydro | 9.5 | 19 | 49 | 106 | 189 |
| Wind | 4.7 | 44 | 266 | 542 | 688 |
| Solar thermal | 4.1 | 15 | 66 | 244 | 480 |
| Photovoltaic | 0.1 | 2 | 24 | 221 | 784 |
| Solar thermal electricity | 0.1 | 0.4 | 3 | 16 | 68 |
| Marine (tidal/wave/ocean) | 0.05 | 0.1 | 0.4 | 3 | 20 |
| Total RES | 1365,5 | 1745,5 | 2964,4 | 4289 | 6351 |
| Renewable energy contribution source (%) | 13.6 | 16.6 | 23.6 | 34.7 | 47.7 |

Table 2.
Global renewable energy scenario by 2040 [3].

2. Background

The economy of Pakistan has been variable and unstable for a long time, but it started to grow somehow since 1990s. Energy demand also increased, as the economy of the country increased. To fulfill the energy demand, oil, natural gas, and coal are used, but due to limited resources, Pakistan is forced to import oil and gases from U.A.E and Saudi Arabia. The location of Pakistan is very good for getting benefit from the sun to generate power, and there are also some places suitable for wind power generation in Pakistan. However, the main problem to generate power is the funding. The energy overview of Pakistan is given in **Figure 1**. Ref. [4] addressed the impacts of renewable energy projects (REP) on the community in Australia. The study focused on four major factors impacting REP: social, political, economic, and environmental. According to one prediction, the world's energy demand will be increased up to 5 times from that of current demand. Currently, three-fourths of that demand is fulfilled by the fossil fuels. On the other hand, the more usage of these resources causes environment pollution and results in more greenhouse effect [5]. For the protection of environment, social development and economics benefits can be get by using renewable energy sources, because there is no requirement of fuel [6]. These resources avoid the fluctuations in prices and importing of fossil fuel. Wind energy has some effects like bird strike and noise etc., which can be mitigated by proper placement of installation. The hydroelectric power may develop slowly with respect to other resources, because a number of people have to leave their homes. But, this may be beneficial for the companies to improve flood control [7]. The increasing global warming effect can easily be prevented with the proper access of renewable energy and by improving the renewable energy technologies [8]. In developing countries like Pakistan, our main focus is to create jobs and the financial development, than focusing on the environment impacts; with the shift of consumers' attention toward renewable energy, society will be more effective and efficient and enhancement in smart grid system [9].

Renewable energy source will be the best option for minimizing pollution, increasing economy, energy security, and job opportunities; also, poverty will be reduced because mostly poor people rely on the natural resources [10]. It is believed that after 2050, 50% of global energy supply will be generated using renewable energy resources; the magnitude of renewable energy sources is 140 times the worldwide annual energy consumption. Renewable energy resources as "job motor for Germany," 55% increase in total number of jobs since 2004, reported in a publication from Environmental Ministry (BMU) [11]. Pakistan has

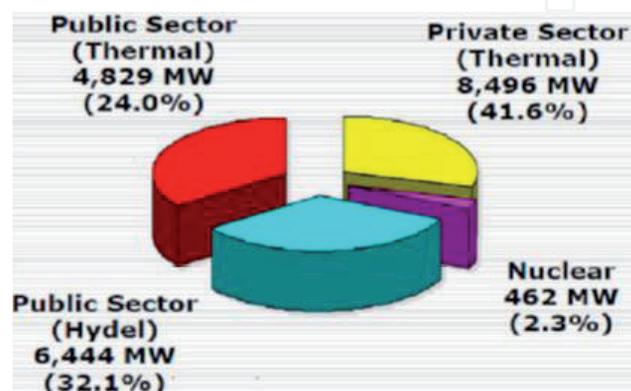


Figure 1.
Energy overview of Pakistan [22].

abundant renewable energy resources and also shows the potential to overcome the energy demand gap, but it is inhibited by some factors like policy, institutional, regulatory, fiscal, social, economic, technical, industrial, and informational barriers [12]. Globally, around three billion people rely on solid fuel mostly fossil fuel, causing health concerns and diseases like pneumonia, chronic respiratory diseases, and lung cancer. It is found that with the 1% increment of growth there will be an increment in CO₂ emission up to 0.84% [13]. Population and GDP per capita have positive impacts on increasing CO₂ emission. Government of Pakistan should initiate, in short run, small dams in the northern area and, in long run, big dams and hydro power projects, and for domestic purposes, coal and hydel resources can be used in small scale [14]. With the proper and efficient use of energy, the culture will be developed [15]. Still most of the northern areas of Pakistan are not electrified and we are under the huge crises of electric power; urban and rural areas experienced 10–12 and 16–18 h, respectively, of load shedding, which is caused direct decrement in the overall economics. With solar cell, electricity can be generated but in small amount, which would be useful as backup during load shedding time. In Baluchistan, there is no scope of grid system because of scattered villages; 77% of the population lives in villages and 90% of them do not have electricity [16]. In Pakistan, big cities produce millions of tons of biomass, but lack of technologies to generate electric power from these wastes is one of the biggest barriers for the improvement in renewable energy resources in Pakistan. Pakistan has potential to produce almost 652 million kg of manure per day, only from cattle and buffalo. It can produce 16.6 million m³ biogas daily, and 21 million tons of biofertilizer can be generated per year. That means 20% nitrogen and 66% phosphorous can be provided to the crop fields. Additionally, 3000 MW energy can be generated from sugarcane industries. A 10 m³ biogas unit can save almost 92,062 PKR per year. Finally, the study concluded that biogas energy system has low initial cost, low operating cost, and positive impact on household income. Biogas energy can do good for almost 70% of the country's population living in rural areas [17]. Nuclear energy can be useful for the development in the long term to meet global increasing demand [18].

Every year, Pakistan spends 3 billion US dollars to import oil to meet the energy requirement, and this ratio is increasing 1% yearly. Decreased efficiencies of thermal plants, periodic changes in water flow, fuel availability, auxiliary consumption and transmission limitations are main cause that Maximum system capability is lower. The main cause of load shedding is the circular debt caused by government institutions, poor revenue collection, insufficient tariff, corruption, losses, theft of electric power, and dispute on tariff with FATA, AJK, and KESC and also due to ignorance of merit, appointments of noneligible employees on political basis, etc. Circular debt can only be improved with the introduction of more and more renewable energy to the national grid [19]. Nonrenewable consumption increases the real GDP rapidly as compared to renewable energy consumption. However, it has 87% variation in carbon dioxide emission, which causes deforestation and dangerous impacts on the human health and the environment. Finally, it was concluded that renewable energy consumption along with nonrenewable energy consumption is the better solution for the GDP growth of the country [20]. It is found that economical, technical, reliability, availability of renewable energy resources, and financial risk are the important factors for selection and ranking of renewable energy technologies. The study prioritizes the renewable energy resources as wind energy, biomass, solar photovoltaic, and solar thermal energy. Further, wind energy and biomass were preferred for power generation in Pakistan [21], and energy review of Pakistan is shown in **Figure 1**.

3. Impacts of renewable energy resources

3.1 Social impacts

These resources also provide social benefits like improvement of health, according to choice of consumer, advancement in technologies, and opportunities for the work, but some basic considerations should be taken for the benefit of humans, for example, climate conditions, level of education and standard of living, and region whether urban or rural from agricultural point of view. Social aspects are the basic considerations for the development of any country. The following social benefits can be achieved by renewable energy systems: local employment, better health, job opportunities, and consumer choice. The study concluded that the total emission reduction is exponentially increasing in different years after the installation of renewable energy projects in remote areas [23]. Social impacts of each resource with its magnitude are listed in **Table 3**.

3.2 Economics

It was discovered that renewable energy projects provide benefits in economic point of view because they utilize local labor from rural areas, local material and business, local shareholders, and services of local banks. In addition, the renewable energy projects have facilitated the communities by establishing a trust fund that aims to invest the money earned by selling electricity in local economy. This makes it easy for a few communities to invest money on any small business of their own choice [4]. Biofuel projects created large number of jobs; however, very low jobs were created by solar power plants, as the ratio of people working in different companies increase that will create more jobs for others by using the part of their economy for entertainment, leisure, restaurant, etc. The consumers will be provided with electric power at a low cost as compared to that of conventional energy sources, and overall economy will be enhanced because there will be multiple options to generate power using different renewable energy sources present in that region [23].

| Technology | Impact | Magnitude |
|--------------|------------------|-------------|
| Photovoltaic | Toxins | Minor-Major |
| | Visual | Minor |
| Wind | Bird strike | Minor |
| | Noise | Minor |
| | Visual | Minor |
| Hydro | Displacement | Minor-Major |
| | Agricultural | Minor-Major |
| | River damage | Minor-Major |
| Geothermal | Seismic activity | Minor |
| | Odor | Minor |
| | Pollution | Minor-Major |
| | Noise | Minor |

Table 3.
Social impacts assessment for different renewable energy sources [7].

3.3 Environmental impacts

Renewable energy projects have also contributed in improving environmental impacts such as reduction of carbon dioxide gas, awakening community about the climate change. The study observed very small impacts on the people living in a particular area, tourism, cost of energy supply, and educational impacts. Significant impacts were observed in improvement of life standard, social bonds creation, and community development. They also observed that the renewable energy projects are complex to install and are local environmental and condition sensitive. Their forecasting, execution, and planning require more consideration and knowledge as compared to other projects [4]. The two main aspects of environment are air and water pollution, normally created by the discharged water from houses, industries, and polluted rain, and discharge of used oils and liquids contains poisonous chemicals and heavy metals like mercury, lead, etc. Along with water pollution, natural resources can be maintained and greenhouse effect and air pollution can be mitigated by the proper usage of renewable energy sources [23] as shown in **Table 4**. Carbon dioxide emission with the generation of electric power using different energy resources is given in **Figure 2**.

Various greenhouse gases in atmosphere is being increased by humankind by doing many economic activities. The role of greenhouse gases and current situation are given in **Table 5**.

3.4 Sociopolitical impacts

Solar panels are usually installed at the roofs of the buildings that increase the job opportunities in the PV system fabrication and installation. This increases the regional development and reduces the usage of energy from nonrenewable energy projects. It is very useful at the regions where there is no access of electricity. The major problem

| Category of impact | Relationship to conventional sources | Comment |
|--|--|---|
| Exposure to harmful chemicals | | |
| Emission of Hg, Cd, and other toxic elements | Reduced emissions | Emission reduced a few hundred times. |
| Emission of particles | Reduced emissions | Much less emission. |
| Exposure to harmful gases | | |
| CO ₂ emission | Reduced emissions | A big advantage. |
| Acid rain, SO, NO _x | Reduced emissions | Reduced more than 25 times. |
| Other greenhouse gases | Reduced greenhouse gases | Big advantage-global warming. |
| Other | | |
| Spouts off fossil fuels | Total or partial elimination of oil spills | Heavy fuel oil and other petroleum product spills. |
| Water quality | Better quality water | Reduced water pollution. |
| Soil erosion | Smaller loss of land | In most cases, there is no penetration deep into earth. |

Table 4.
Summary of environmental effects [24].

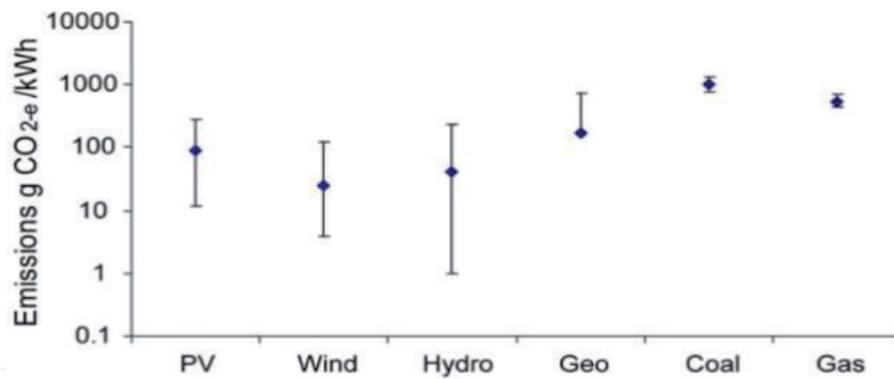


Figure 2.
 Carbon dioxide equivalent emission during power generation [7].

| Substance | Ability to retain infrared radiation compared to CO ₂ | Preindustrial concentration | Present concentration | Annual growth rate (%) | Share in greenhouse effect due to human activity | Share in greenhouse effect increase due to human activity |
|-----------|--|-----------------------------|-----------------------|------------------------|--|---|
| Alpha | 1 | 275 | 346 | 0.4 | 71 | 50 ± 5 |
| Beta | 25 | 0.75 | 1.65 | 1.0 | 8 | 15 ± 5 |
| Gamma | 250 | 0.25 | 0.35 | 0.2 | 18 | 9 ± 5 |
| Delta | 17,500 | 0 | 0.00023 | 5.0 | 1 | 13 ± 5 |
| Epsilon | 20,000 | 0 | 0.00040 | 5.0 | 2 | 13 ± 5 |

Table 5.
 Role of different substances in greenhouse effect [15].

with solar system is the high investment and maintenance cost. Biomass energy projects have great contribution in the local job creation and the development of rural areas. Such types of power plants have large opportunities of jobs in construction of plants, management, maintenance of plants, production, and preparation of biomass. Only the noise production and unpleasant smell are the negative impacts of these plants. Fuel cells have slow implementation because of their high cost of plant construction and energy generation. Their construction and operation create jobs in almost all technical activities. In hydro power plants, the major sociopolitical problem is the shifting of the people from the areas where the plant is going to be constructed. These plants provide significant jobs for local community and also play an important role in the economic development of the community. The construction of tidal energy plants has no effect on humans, and they have better contribution in the local and official employment. These plants are very expensive and are not common. Wind energy projects do not have any emigration problem, and they create large number of job opportunities especially for engineers. Geo thermal energy projects provide the following sociopolitical benefits: improvement in the education of local people, improvement in living standards, and improvement in the care of health issues [25].

3.5 Impacts on grid

When the solar panels are connected to the distribution system, the cost of safety equipment is reduced because their short circuit current is higher than the nominal value. Biomass power plants have the same effects on the grid as do conventional plants. The integration of wind energy plants, tidal energy, and geothermal energy is complex [25].

3.6 Socioeconomic impacts

Three case studies were made to investigate the socioeconomic benefits of renewable energy projects, and the three cases were solar, wind, and biofuel energy projects; empirical method was used to collect data. The basic aim of study was to know the contribution of renewable energy projects to local sustainability, which includes social, economic, and environmental, and to identify the socioeconomic benefits of REPs through the concerned community. It was done by doing survey of the communities. Eleven parameters were used including job creation, impacts on education, easy usage of energy, income development, demographic impacts, social bonds creation and community development, usage of native resources, and tourism. They concluded that the impacts of REPs on employment are positive, and indirect employment is high in comparison with the size of community, whereas direct employment is moderate [26].

4. Availability and technical limitations

One of the important assessing factors to generate power from renewable energy sources is the availability and their technical limitation. Each resource has some limitations; photovoltaic has limitation to generate power only because heat energy from sun can only be received during the day time, except cloudy season. For wind turbine, speed should not increase beyond 25 m/s; otherwise, turbine will be damaged. Also, low speed of wind, that is, <3 m/s, will not be sufficient for the generation of electric power. Geothermal has good ability to generate power throughout the day for 24 h but is geography limited according to the presence of resources. Hydro-electric power plants are easy to start, stop, and operate within minutes; hence, they are considered as one of the highest available, reliable, and flexible renewable energy resources. From efficiency point of view, hydroelectric is classified at the top of the list, and then wind energy, photovoltaic, and geothermal are lowest efficient renewable energy resources. Because of availability of cells in different categories, the efficiency of photovoltaic is very much variable [7]. According to the efficiency, different energy sources are categorized in **Table 6**.

| Technique | Efficiency |
|--------------|------------|
| Photovoltaic | 4–22% |
| Wind | 24–54% |
| Hydro | >90% |
| Geothermal | 10–20% |
| Coal | 32–45% |
| Gas | 45–53% |

Table 6.
Efficiency of electricity generation [7].

5. Conclusion

The conventional energy resources like oil, gas, and coal are very important for the improvement in economics of a country. A country like Pakistan is fully dependent on the conventional energy sources in spite of knowing its bad effects for health and environment like greenhouse effect, global warming effect, etc. Pakistan

is blessed with all the renewable energy sources like hydro, wind, and geothermal, and for solar power generation also, it is a suitable country. But, the main problems to generate power from renewable energy resources are funds and politics. All the factors like emission of greenhouse gases, availability of resources, land requirements, water consumption, social impacts, and price of power generated are taken into consideration for the classification of renewable energy sources. Wind power generation is considered as lowest water consumption, lowest relative greenhouse gas emission, and most favorable social impacts. It is considered as one of the most sustainable renewable energy sources, followed by hydropower, photovoltaic, and then geothermal. Biomass is considered suitable for the small-scale industries because of saving of fuel in considerable amount. Local employment, better health, job opportunities, job creation, consumer choice, improvement of life standard, social bonds creation, income development, demographic impacts, social bonds creation, and community development can be achieved by the proper usage of renewable energy system. Along with benefits of renewable energy resources, these are complex to install and are local environmental and conditions sensitive. Their forecasting, execution, and planning require more consideration and knowledge as compared to other projects.

Acknowledgements

The author thanks the Mehran University of Engineering and Technology, Jamshoro, for providing the necessary facilities for carrying out this research.

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