

A Review of Wind Energy Technology

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ABSTRACT:- The global climate change and increasing energy demand has enforced many countries to shift towards renewable energy technologies with an optimistic view for reducing overdependence on fossil fuels for generating electricity. Amongst all of the renewable energy sources available, wind energy is gaining more importance all over the world and is seen as the renewable energy source that can fulfill future energy demand. This paper provides a review of wind energy technology and also discusses the recent technological developments in this technology. Also various issues like strengths, weakness and sustainability of this technology are discussed. Furthermore, this review paper also discusses production capacity and the cost associated with the generation of electricity as well as the energy policies used by many countries that promote use of wind energy systems.

Keywords:- Renewable energy, Sustainability.

I. INTRODUCTION

The fossil fuels are amongst one of the primary sources used by many countries for generating electricity. The fossil fuels are mostly used in developing countries for generating electricity and with the economic growth their energy demand is also increasing, leading to more generation of electricity and releasing more greenhouse gas emissions associated with that generation. If, further this trend of using more fossil fuels continues then the average global temperature will raise leading to various problems that might put life of millions of people at risk [1]. These problems can be avoided by using sustainable energy solutions that have very less impact on environment and these solutions will reduce consumption of fossil fuels as well as save reserves of fossil fuel for future generations. The solutions include use of renewable energy technologies such as wind, solar, geothermal, tidal, wave, etc. [2]. The European Renewable Energy Council (EREC) has predicted that by 2040 half of the total global energy supply will be from renewable sources and the use of renewable sources for generating electricity will increase year by year resulting in reduction of carbon dioxide emissions. [3].

Wind energy can be used for generating electricity, also it is clean, renewable, requires less land area compared to other existing renewable energy technologies and the emissions associated while generation of electricity are negligible. It is estimated that till 2018 the global installed wind energy capacity will reach by 596 GW [4]. Wind energy has an advantage that wind is blowing almost all of the time and because of this advantage the electricity can be produced at a higher efficiency. Although there are some issues associated with the wind speed, but recent technological developments have proved that electricity can be produced at a constant rate when the wind energy facility is properly designed. In 2013, nearly 96 million metric tons of carbon dioxide emissions in United States were avoided because of using wind energy for generation of electricity, so it is proved that the use of wind energy for generation of electricity will help many countries to achieve their targets of reducing carbon dioxide emissions [1].

The main objective of this paper is to review the wind energy technologies as well as this study focuses on energy conversion principles, strengths, weakness, production capacity, sustainability and recent technological developments associated with the wind energy system. The paper also discusses the energy policies used by many countries to promote wind energy technology.

II. WIND ENERGY TECHNOLOGY

The wind energy converts the kinetic energy of wind into electrical energy. The main part of the wind energy facility is the wind turbine that converts wind energy to mechanical power and that can be used in numerous applications. The size and design of the turbine is very important as it plays a key role in generation

of electricity. The turbine diameter and maximum capture of wind are the important parameters that are carefully studied and with that the cost of whole facility is also taken into consideration while designing a wind turbine [1]. The modern design of wind turbine is such that the blades designed are longer, so that the output is also very high [5].

The wind turbines can be divided into two type's i.e. vertical axis wind turbines and horizontal axis wind turbines (HAWT and VAWT).



Fig. 1. Schematic of wind turbines: VAWT (left and center panels) and HAWT (right panel) [6,7].

The horizontal axis wind turbines (HAWT) are used on a large scale than vertical axis wind turbines (VAWT) because of the high efficiency and high energy output. The main problem with vertical axis wind turbines is that they are installed in such a way that they are very close from the ground and because of this they have less contact with wind, so there output is also very low [1]. The VAWTs have advantages such as they can capture wind coming from any direction, also create less noise, have ability to produce electricity in low wind and can be installed on roof top for small scale application [1,5].

The two types of forces are created when the air moves over any surface i.e. first perpendicular to the airflow and second in the direction of air flow and these forces produce the driving torque required to rotate blades [8].

The wind energy technology is improving slowly and because of more research and development in this area, many improvements have been achieved [10]. The power output and efficiency has been increased by technological developments in the wind energy facility [11]. The global installed wind capacity is also increasing year by year and this can be seen from Fig. 2. The Fig. 2 shows the total annual wind capacity and the total installed wind capacity worldwide from 1996–2013 [1].

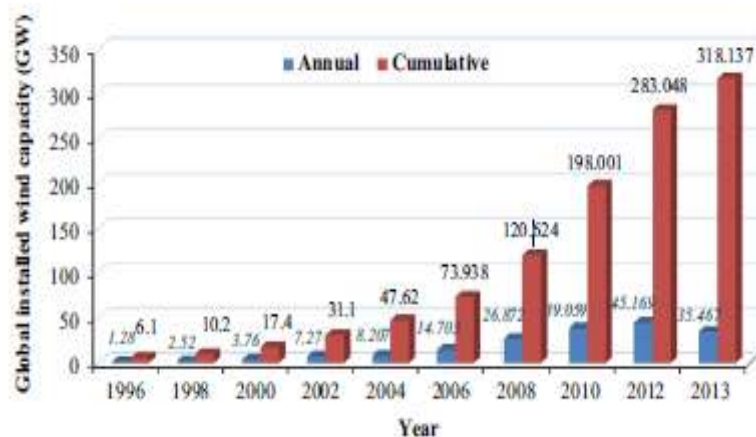


Fig. 2. Annual and cumulative globally installed wind capacity for 1996 – 2013 [1].

2.1. Different parts or components of a wind turbine:

The wind turbine consists of a rotor, a gear box, blades, a tower and a generator. The Fig. 3 shows the different parts or components of wind turbine and all of them are explained below.

Rotor - A rotor consists of blades that look like a wing of an airplane. Generally, there are three blades used in wind energy facility everywhere in the world and these rotor blades very are big in size. The another part or component is called as pitch drive, and this is used because in high wind speed situations the effect of lift forces is high and pitch drive plays an important role in reducing that force, also it leads to smooth operation of facility [1,10].

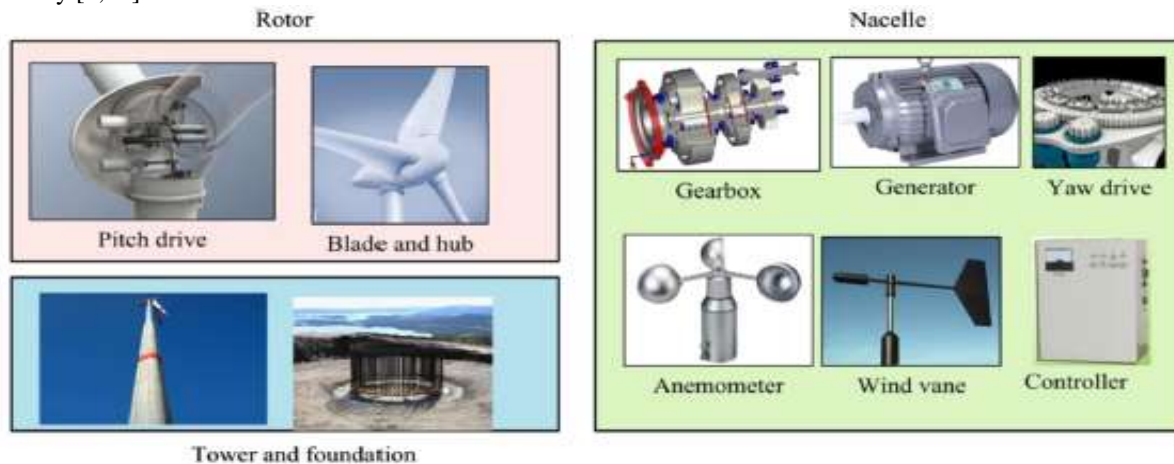


Fig. 3. Schematic of main parts or components of wind turbine [12].

Nacelle - It is connected to rotor and includes main parts such as gear box, rotor shaft and generator, also it plays an important role in wind energy facility [13].

Gearbox - The main function of gear box is to convert lower rotor speed into very higher speed, so that generator will generate electricity. The newly designed wind turbines mostly don't have gearbox [14].

Anemometer - The wind speed is measured by using anemometer and the measured wind speed or value is sent back to the controller.

Wind vane - The wind vane identifies the direction of wind and this helps the wind turbine to adjust according to the wind direction.

Generator - The main function of generator is to produce electricity and electricity is produced when the mechanical energy of rotor is converted into electrical energy [11].

Controller - The controller is a computer operated system and it ensures that the turbine is working properly or not.

Tower - The tower helps the rotor to be placed at high altitudes, so that it can arrest more wind energy. The height of the tower depends upon the wind speed, quality and other factors in that area where wind turbine is going to be installed [1].

2.2. Onshore wind turbines:

The onshore turbines are the wind turbines that are installed on land and have a specific tower height depending upon the location and wind speed. Generally the new wind turbine designs have increased rotor blade length and increased tower height and because of this design the wind turbines can be installed in areas or locations where wind speed is low [11]. Also the newly designed wind turbines have high efficiency and can generate electricity even if the wind speed is low. The new design has facilities that ensure smooth working of wind turbines during storm or even at very high wind speed situations. There are issues related to onshore wind energy systems that they create more noise and because of this people are opposing the use of onshore wind energy systems, but in real the new designs produce very less noise.

The onshore turbines are installed at a very high scale in many countries and the worldwide capacity is increasing. The onshore wind turbine project in China has a capacity of nearly above 5000 MW and the capacity is projected to increase by 20,000 MW by 2020 [1].

2.3. Offshore wind turbines

The offshore wind energy is gaining more importance and offshore wind turbines are installed on a larger scale because the speed of wind is high and the noise is also not a problem. The electricity generated from offshore wind turbines is also very high and all the disadvantages of onshore wind turbines can be eliminated by

installing offshore wind turbines [13]. The largest or major cities around the world are situated near coastal areas, therefore the offshore wind turbines have the capacity to fulfill the energy demand of that cities and the energy generated will be clean, also the distance of transmitting power will be reduced [1].

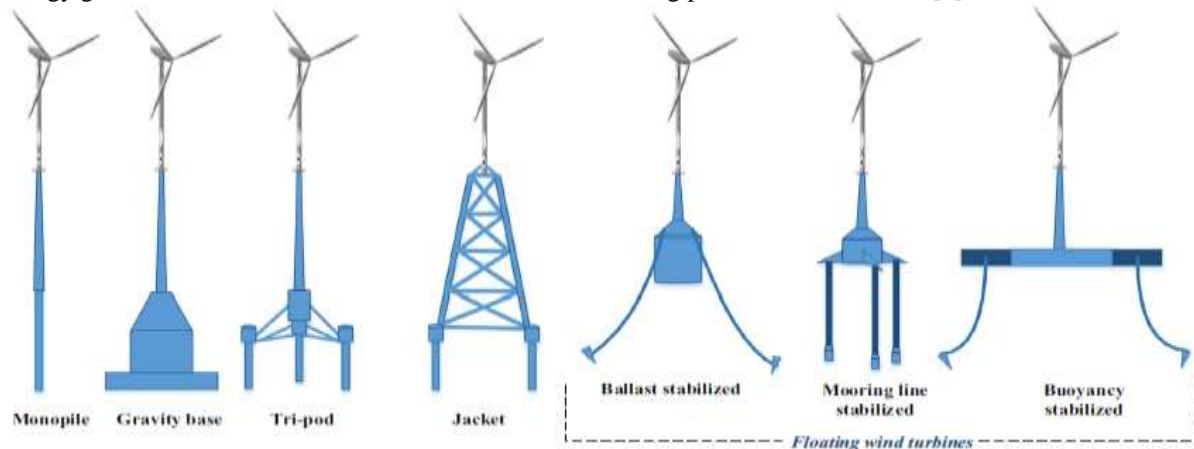


Fig. 4. Schematic of different types of foundation for offshore wind turbines [1].

The major cities in Australia and United States are situated near coastal areas and offshore wind turbine facility has the potential to fulfill their energy demand. Already some of the countries are using offshore wind turbine facility and it is predicted that the use of offshore wind turbines will increase at a higher rate in future [1,13]. The recent technological developments in foundations of offshore wind turbines have proved that the floating wind turbines can also generate electricity and the problems arising from depth of water can be eliminated [1].

III. ENERGY CONVERSION PRINCIPLES

The wind turbines convert kinetic energy of wind to electrical energy and the wind energy of flowing air is calculated as shown below [10].

$$W = \frac{1}{2} \times m \times v^2$$

But, the actual power used by the wind turbine is dependent on different key factors and this is calculated as shown below [10].

$$P = \frac{1}{2} \times \rho \times A \times V^3 \times C_p$$

The different terms mentioned in the above equation are explained as follows [10],

ρ = the density of air (Kg/m³)

A = the total area covered by rotor blades

V = wind speed (m/s)

C_p = power coefficient

The density of air (ρ) is very important parameter and it predicts the amount of power that will be generated from the wind turbine facility. The air density varies according to the location and temperature, so installation of wind turbine facility is finalized depending upon these factors. The modern wind turbines are designed in such a way that the tower height is increased and with that the length of blade is also increased, resulting in more generation of electricity i.e. high output [11].

The Wind speed (V) is also an important factor for predicting the amount of electricity that will be generated. As the wind speed increases the rotation of blades also increases, leading to generation of more electricity. The hub height is also seen as an important factor while designing the wind turbine facility because the wind speed is generally higher at higher height and it goes on increasing with height.

The power Coefficient (C_p) is the efficiency of kinetic energy that is extracted by the wind turbine and the maximum as given by Betz law is 0.59 and the current maximum power coefficient of wind turbine is nearly about 0.40, so it is not very close to the value given by Betz law [10].

IV. RESULTS

4.1. Potential production capacity:

The demand for renewable energy is increasing day by day and new technological developments are reducing the cost associated with the manufacturing, maintenance and installation of renewable energy systems. The wind energy has the potential to fulfill the energy demand as well as it will help the countries to achieve their targets of reducing carbon dioxide emissions. The share of wind energy energy in fulfilling the energy

demands is also increasing every year and by the end of 2013 the total wind power worldwide capacity was reached till 318.1 GW [1]. The European Union countries have already installed offshore wind turbines and are producing high energy from wind turbines and according to a study, the offshore wind turbine installations in European Union increased by 34% in 2013 [1,16]. In United States, nearly 53% of the population is living near coastal areas and installation of offshore wind turbines has the potential to fulfill their energy demand [1].

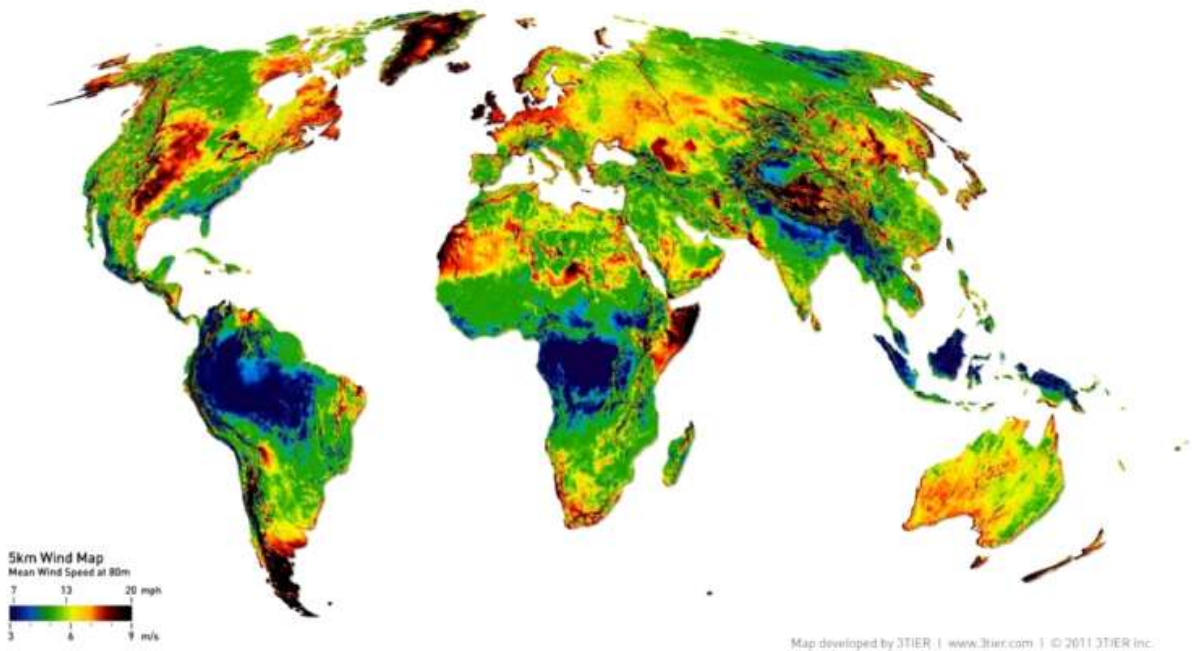


Fig. 5. The wind speed at an altitude of 18m [1].

The growth of wind energy facilities is increasing in developed countries and the state of installations in developing countries is also good. The installations of offshore wind turbines will increase in the countries having less land area and are surrounded by oceans or water [13]. The Fig. 5 shows the global wind speed at an altitude of 18m. The wind speed shows the potential for wind turbine installations in countries where wind speed is good and from Fig. 5 it can be seen that the wind energy has the potential to fulfill the energy demand. The developing countries like China and India are producing more power from wind energy and these two countries are emitting lot of carbon dioxide, so the growth of wind energy will help them to reduce their emissions with economic growth. Also wind energy can play an important role in India because the major populated cities are located near coastal areas.

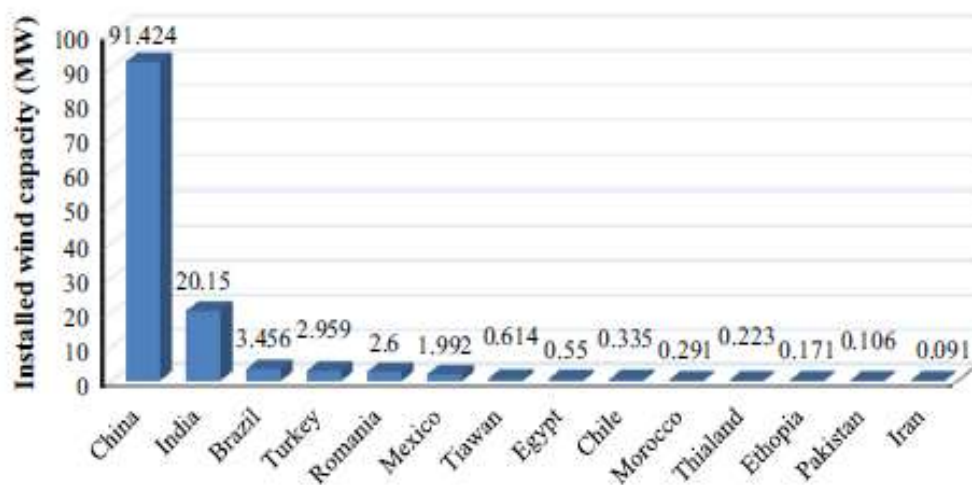


Fig. 6. The installed wind power capacity in developing countries by the end of 2013 [1].

4.2. Strengths of the wind energy system:

The strength of wind energy system is that it is a clean source for power generation and it does not emit any greenhouse gas emissions. The emissions are produced only during the manufacturing, installation and timely maintenance of wind energy systems. The offshore wind energy systems require less land and also produce less noise with high output [1]. The use of wind energy for electricity generation will reduce the use of natural resources such as fossil fuels and from the sustainable development point of view it is very important to make use of renewable energy systems such as wind energy. The small wind turbines can be installed on rooftop and they can fulfill nearly 80% of the electricity demand of that house, so the future scope of wind energy is very high and its use will help many countries to reduce their carbon dioxide emissions.

4.3. Weakness of the wind energy system:

The wind energy is considered to be clean source for electricity generation but still there are some economical, technical, environmental issues associated with it. The installation cost is very high and the investors are confused to invest in wind energy, because the payback period is very high and profits start very late [1]. The main technical problem is integration of large scale wind energy systems to grid and even after connecting to power grid, it is necessary to maintain it properly because the flow of wind is intermittent and it may lead to instability of grid. These fluctuations may also cause power losses i.e. in transmission lines [1]. The people complain that noise produced by wind turbine is very high, but in actual the noise produced is less and people think that the noise may cause stress or sleeping disorders, so wind turbine projects are opposed by people. There are other issues that the birds get killed due to wind turbines i.e. due to hitting or by coming in contact with blades of wind turbine. According to a study approximately 20,000 to 29,000 birds are killed every year in Canada due to wind turbines [15], but because of new designs the number of accidents or number of death of birds is reduced drastically [3]. There are other issues that the number of accidents occurred every year are very high and many people die or get injured while working at wind energy facility [1]. The majority of accidents occur because of fire, blade failure and structural failure. The Fig. 7 shows the number of accidents occurred from 2000 to 2013 due to wind turbines [1].

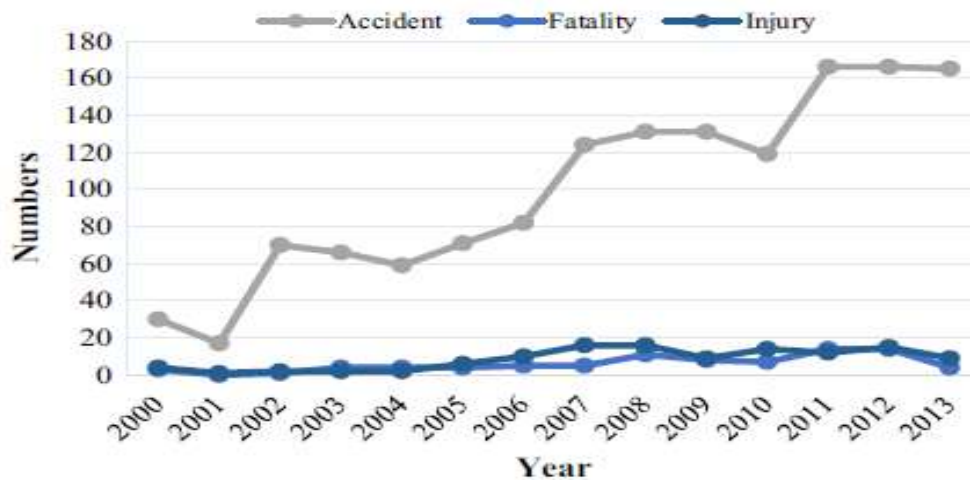


Fig. 7. The wind turbine accidents, human fatalities and injuries in United Kingdom from 2000- 2013 [1].

4.4. Recent technological developments:

The modern wind turbines are designed in such a way that they should generate more power and because of that the height of wind turbines is also increased leading to increase in their power output [1]. The floating wind turbine is also a new development and still continuous research is going on related to this technology and some companies have already installed floating wind turbines and they are generating electricity, also the main reason for installing floating wind turbines is that the foundation of wind turbine is difficult to build or maintain in deep sea waters and also the cost is very high and to avoid this problem floating wind turbines are designed [1,13]. The major oil companies are also doing research that how floating wind turbines can supply electricity to offshore petroleum facilities. The problems associated with gear box can be removed by using variable speed drive also known as direct drive and by installing this there will be no need of gear box and it will help the wind turbine to work smoothly, but the cost of installing this is very high and still research is going on related to this new technique.

V. DISCUSSIONS

5.1. Energy policy and sustainability:

Energy policy of a country shows their strategies related to energy development and the development of their energy industry to withstand its economic growth and all the areas such as energy distribution, production and consumption are covered [17]. The energy policy may also include international treaties, legislation, incentives for investment, guidelines or plans for conservation or efficient use of energy, taxation and focus or development of policies related to use of renewable energy sources [17]. Many countries do not have their policies related to wind energy, but the global climate change and other environmental issues have forced them to develop policies related to renewable energy or wind energy in order move towards sustainable development. The wind energy policy must be developed in order to reduce carbon dioxide emissions and with that the depletion of natural reserves will also be reduced [17].

Table 1. Wind energy policy implemented in different countries [17,19,20,21,22].

Country	Investment support (For e.g. subsidies)	Energy tax exemption	Public loans i.e. financing	Legislation (e.g. CO ₂ emission)	Target implementation	Research and Development Support
USA	Yes	Yes	Yes	Yes (25%, 2025)	Yes (25% of supply, 2025)	Yes
Denmark	Yes	Yes	-	Yes (50%, 2030)	Yes (200 GW, 2030)	Yes
Canada	Yes	-	Yes	Regulatory framework in 2008	Yes (12 GW, 2016)	Yes
Germany	Yes	-	Yes	Yes (20%, 2020)	Yes (30 GW, 2010)	Yes
Australia	Yes	-	Yes	Yes (60%, 2050)	Yes (10 GW, 2020)	Yes
China	Yes	Yes	Yes	-	Yes (total capacity 30 GW, 2020)	-
Japan	Yes	-	-	Yes (6%, 2012)	Yes (3000 MW, 2010)	Yes

As shown in Table 1, the countries who have implemented energy policy are also focusing more on research and development because the new developments will reduce the cost and increase the power output and when the production cost gets decreased then people can afford it and it also fulfills the sustainability principle. Many countries have given subsidies for wind energy and this is promoting the growth of wind energy for electricity generation in their country [17]. To promote the growth of wind energy the developing countries are also preparing their policies in order to reduce carbon dioxide emissions. The targets set by countries to produce a specific amount of electricity from wind energy and reduce emissions have stimulated them to prepare policy that will promote the growth of wind energy and also follow sustainability principles [17].

VI. CONCLUSIONS

The growth of renewable energy sector is very important and in order to fulfill the increasing demand of energy the countries should implement policies that will promote the growth of renewable energy. Wind is a clean and renewable source for generating electricity and it has the potential to fulfill the future energy demand and the new technological developments and continuous research has decreased the cost and eliminated all other problems related to wind energy facility. The environmental, social and economic problems associated with the wind energy system are very less compared to losses generated from combustion of fossil fuels. The growth of technology will allow the transmission of continuous power from offshore wind turbines and this will prove to be a sustainable solution. The Table 1 shows that the growth of wind energy in those countries was achieved because of policies that were promoting the growth of wind energy systems. The developing countries are also preparing policies to promote the growth of wind energy and the worldwide installation capacity is going to increase at a higher rate.

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