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TYPES AND APPLICATIONS OF RENEWABLE ENERGY TECHNOLOGIES AND THEIR EFFECT ON ENVIRONMENT IN PAKISTAN

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ABSTRACT: Use of fossil fuels for power generation has severely damaged the global environment. As Pakistan is suffering from severe energy crisis for past decade, thermal power generation through fossil fuels is increased considerably. This is disturbing the echo system and causing local temperature to rise. In this article global energy consumption is summarized and dependency of different countries on fossil fuel is discussed. A review of the renewable energy production is carried out in different regions of the world and different renewable energy technologies are enlisted like solar, wind, biomass, tidal etc. Applications of these technologies as well as advantages and disadvantages of these are discussed. In the later part of this article effect of renewable energy technologies on environment are discussed. It is concluded that these energy technologies are severely needed, different regions across Pakistan are highlighted that are suited for each type of technology and their suitability regions are mapped.

Keywords: Environment; Renewable energy; climate changes; power plant; Wind.

INTRODUCTION

Energy Demand of the world is increasing every day. An estimated growth of 1.8% per year is recorded in past 10 years and a growth of 1% in 2016. The carbon emission growth in 2016 is increased by 0.1% compared to past years. Still top of the chart in consumption is oil and its growth is 1.2% in 2016 that is 1.6% above 10 years average. Asia pacific region is main contributor in its growth, with China and India are main players.

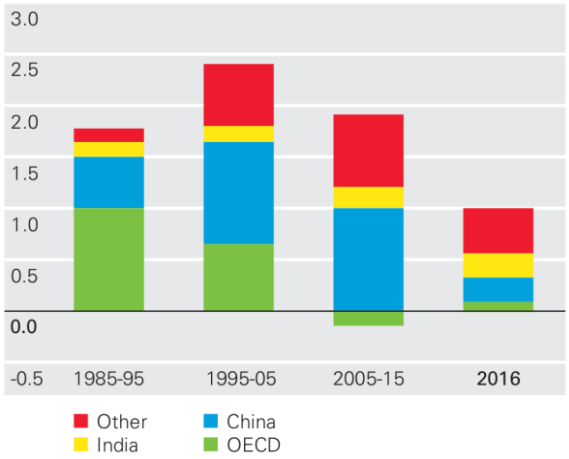

Figure 1: Energy consumption growth, Contributions to annual growth, %.

The natural gas consumption grew by an average of 2.3% in past 10 years but by contrast its growth is 1.5% slower in 2016. A great dip is in the consumption of coal that a decline of 1.7% is in global consumption in 2016.

There was a sharp increase in the growth of renewable power that is grown by 14.1% in 2016. Wind power is the main contributor and cover half of this growth and one third of the growth are by solar energy.

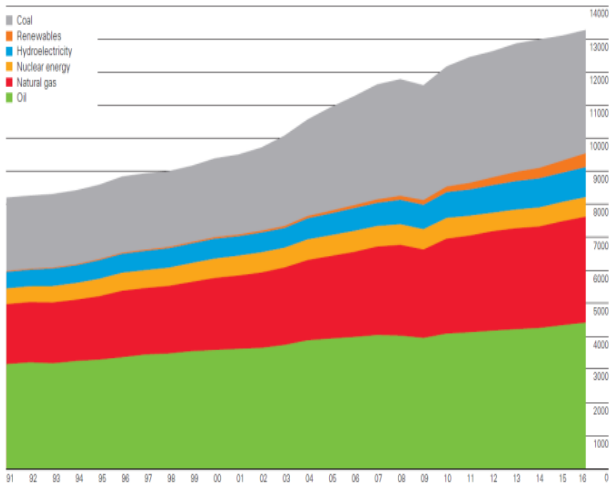

Figure 2: World power generation (Million tonnes oil equivalent)from different resources.

China has become a leader and surpassed USA Eurasia and Asia pacific and is main contributor to this growth. It is evident from Fig. 4 that a sharp increase is there in use of solar energy.

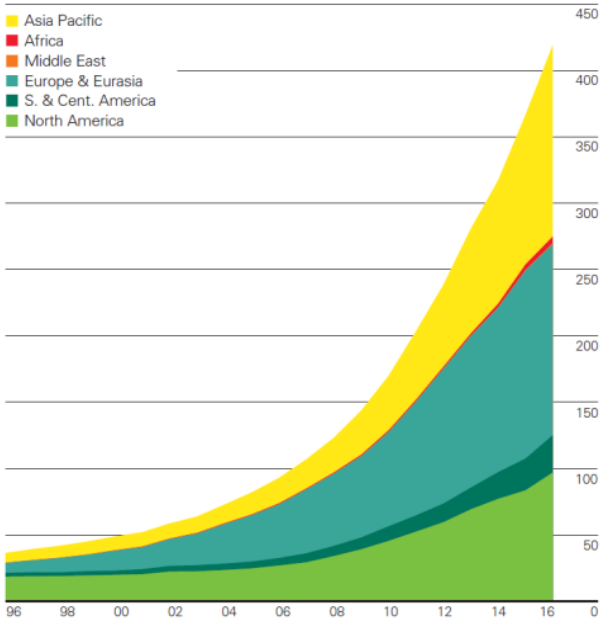

Figure 3: Renewable consumption (Million tonnes oil equivalent) by region.

Two major problems related to each other Pakistan facing from start of this decade is electricity crisis and global warming. Summer is becoming hotter and hotter and it's difficult to meet the peak demand of electricity during this period. Population is also growing at a fast pace and there is continuous increase in the electricity demand. This has forced to erect more thermal power generation plant in Bhikki, Haveli bahadur shah, Sahiwal. Main fuels for generation are Coal, Oil, and LNG etc. It is a need of time to minimize the use of fossil fuel and focus on the other sources of energy for the fast growth of our country. In FY 2012-13 the production of electricity was 67% Thermal, 31% hydro and 5% nuclear but in FY 2017-18 there is a 2% part of renewable energy as shown in figure 1 which is a good sign but it needs to increase.

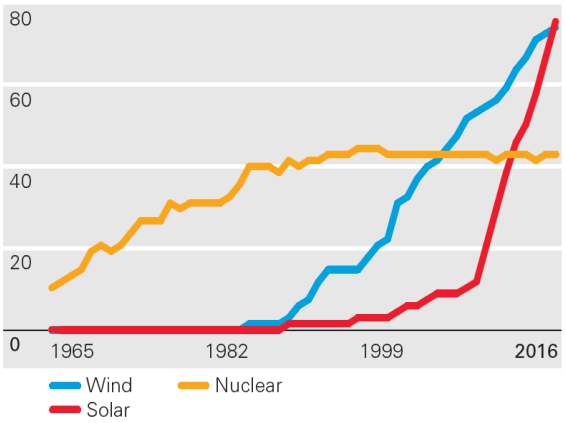

Figure 4: Growth and diffusion of renewable.

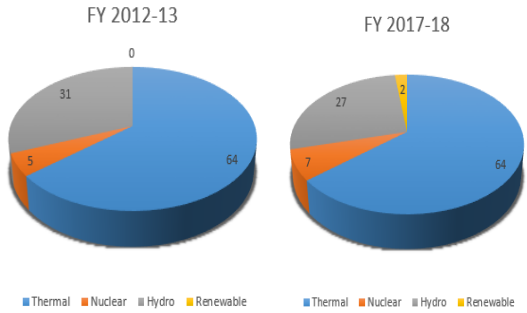

Figure 5: Comparison of electricity generation sources in Pakistan 2012-13 with 2017-18

MATERIALS AND METHODS

Renewable Energy Technologies: The renewable energy resources by which our country is blessed are useful in all the aspects. Using these sources in power production we can save our environment from destruction. Some renewable sources of energy are;

Power Production from Solar Technology: Solar technology converts solar rays coming from sun into useful energy for domestic, industrial and different applications (Mahboob *et al.*, 2018). Solar thermal power plants are feasible and ideal for better and clean energy production. There are various methods to generate electricity from solar radiation. Photovoltaic (PV) is one of the types of solar power plant that produces direct electricity from solar rays falling on the PV panels. The other form of the solar power plant is concentrated solar thermal power plant, in which rays concentrate on the receiver containing working fluid. It produces steam by using heat exchangers and this steam is used to generate Electricity (Bayon *et al.*, 2018). There are three main types of the solar plants (Zhang *et al.*, 2013);

1) Photovoltaic (PV)
2) Line concentrating technology (LCT)
3) Point concentrating technology (PCT)

a) Photovoltaic System: Photovoltaic is a method of direct electricity generation without interfering any steam generation process and engine or generator. Photovoltaic (PV) consist of Photo cell, when solar rays fall on the cell, which is made of semiconductor material, generate electricity by moving electrons.

The designing of the Photovoltaic (PV) system is simple with little maintenance; big benefit of the PV is that it has standalone system, which gives direct output ranges from micro to Giga watts. Due to these features the demand of the PV system is increasing day by day.

Figure 6: Atacama Photovoltaic (PV) solar plant, South America.

a) Line Concentrating Technology (LCT): Line concentrating technology (LCT) consists of rectangular shaped mirrors or parabolic shaped curved reflect mirror or film. It concentrates solar rays towards receiver located at focal line of that trough. Almost 97% line concentrating technology are being used in the world due to feasible features(Parida *et al.*, 2011). LCT plants are divided into two main categories;

a) Parabolic Trough Technology
b) Linear Fresnel Technology

a) Parabolic Trough Technology (PTT): Parabolic trough plant usually comprises of reflector (usually parabolic shape curved) to reflect the DNI radiation towards the receiver located at focal line (AlZahrani and Dincer, 2018; Li *et al.*, 2019) of the parabola having molten salt as a working fluid in it (Mahlangu and Thopil, 2018).

It absorbs heat from the reflector. Thereafter, the superheated molten salt is transported towards heat exchanger to produce steam (Calise *et al.*, 2018; Popov and Borissova, 2018) for steam turbine to generate electricity with generator (Price *et al.*, 2002). This plant has one axis sun tracking system to track the sun throughout the day. Enclosed trough is same plant that has glass envelope on the trough.

b) Linear Fresnel Technology: The linear Fresnel Technology (LFT) plant working is like (PTT) plant, the LFT plant contains rectangular or little curved shape reflector that reflects the solar radiation towards receiver, lies above the reflector at some height (El-Gharbi *et al.*, 2011).

The main difference between linear Fresnel and parabolic trough is that PTT have receiver at focal point of parabola and curved shape reflector while LFT have receiver at above of rectangular shaped reflector.

b) Point Concentrating Technology (PCT): In this type of plants, the solar rays coming from sun are focused at one point to generate heat. Then it is used for different purposes (Carra et al., 2018). Point concentrating type plant achieves highest temperature than LCT. PCT categories in two main types;

a) Central receiver plant (CRP)
b) Parabolic Dish

a) Central Receiver Plant: In this type of plant, there is a tower at or slightly away from center point, encircling by thousands of mirrors called Heliostats (Polimeni *et al.*, 2018; Mahboob *et al.*, 2018). Due to dual axis sun following system, heliostats track the Sun throughout the day (Hu and Huang, 2018; Kribus *et al.*, 2004). These heliostats focused the sun radiation at receiver, located at the top of the tower (Farges *et al.*, 2018; Wagner and Wendelin, 2018; Li *et al.*, 2019).

The molten salt or water is used as an HTF in the receiver to absorb heat reflected by Heliostats, in heat exchanger this heat is used to generate steam which is further used to generate electricity. The temperature of the working fluid reaches at maximum value in PCT as compared to LCT due to focusing the solar rays at one point.

b) Parabolic Dish: Parabolic dish consists of parabola shape curved mirrors mounted at base frame structure that concentrate the solar rays towards receiver located. The reflector of the dish may consist of one compact dish or multiple facets for concentration. The receiver above the dish is supported by dish support which converts solar rays into thermal energy. The working fluid absorbs this heat and converts it into electricity.

Power production from wind: Over centuries windmills were used in different applications like pumping the water and grains crushing. In past few decades, we are seeing wind turbine to produce several KW by using wind power to generate electricity by rotating generator(Bechly and Clausen 1997). The Wind power plant is categories in two types due to their applications and wind sources.

1. Vertical Axis Wind Turbine: In Vertical Axis Wind Turbine, wind direction is at right angle with the turbine or foundation surface. As the turbine is at low elevation, so at low wind intensity electricity can be produced as compared to Horizontal Axis Wind Turbine required high intensity of air flow. Compared to Horizontal Axis Wind Turbine, the installation and maintenance of the Vertical Axis Wind Turbine is lot easier.

The efficiency of the (VAWT) is least. These turbines are used at domestic level and generate low energy. Despite simplicity in the construction, turbine has good torque and work at low intensity of air. There are some advantages of VAWT given as;

a) Usually no needs of tall tower

b) Works at low intensity of air
c) Easy maintenance
d) Low noise pollution
e) Don't need Yaw mechanism for this turbine.

2. Horizontal Axis Wind Turbine: The Horizontal Axis Wind Turbine is used commercially at large scale and has sustainable energy production. In (HAWT) the wind direction is parallel to the rotation of the turbine. Now a day mostly HAWT are being used due to its better performance and high energy production rate. The HAWT have various formations like two blades, three blades and multi blades.

Figure 7: Offshore Horizontal Axis Wind.

Three blades turbine is mostly used due to better performance and a sustainable structure wind turbine.

This type of turbine is widely used throughout the world for optimum production and required more space for installation as compared to (VAWT). Tall towers are required for the HAWT and need high skilled labor. The efficiency of the turbine is better and can generate handsome amount of electricity. There are some disadvantages of the Horizontal Axis Wind Turbine is as follows;

a) Tall tower, blade transportation and installation at height are difficult.
b) Need skilled operator.
c) Building of the tower for supporting heavy components of the turbine.
d) Required Yaw mechanism system to follow the wind direction.

Hydroelectric Energy: It is very old technique to gain some work from water running. Water Wheel and Water mills are used to perform work over 2000 year ago.

Geothermal Energy: Geothermal energy is present in earth's inner side in the form of superheated fluid. The molten fluid magma is under process of cooling and solidification which releases heat. The reservoirs underneath's earth's crust contains steam, and hot water under high pressure. To access these fluids, we drill wells and use them to generate electricity or other industrial applications depend on the temperature of fluid. Due to pressure difference the fluid naturally moves towards the earth surface as the pressure decrease the hot water starts to change in steam and send into a well head separator which separates the steam, liquid and other solids.

Steam is passed through condenser and water is reinjected into the earth's reservoirs for reuse while other earth minerals are collected. Water is reinjected into reservoirs for balancing the reservoir resources, which is also fulfilled by rain water (Moya, Aldás, and Kaparaju 2018). There are three types of geothermal energy power plants.

1) Direct dry steam plant
2) Flash Steam plant
3) Binary cycle plan

Energy form Biomass: Biomass is waste of animals, human beings, plants and other materials i.e. plastic, glass etc. that is used to create some sort of useful energy to perform different works. This useful energy is called biomass energy. Biomass has the following types

1) Wood and Agricultural products
2) Solid Waste
3) Biogas
4) Ethanol
5) Biodiesel

Different process for different types of biomass is as follow;

1. Biomass Digestion: Biomass digestion is low temperature process in which biogas and CO_2 is found. These gases used to generate heat and used to drive steam engines and steam turbines. Wet biomass is more suitable for digestion process. Biomass is stored in digestion tank for 18 days at 35^{o}C for ideal condition and there is flow of materials at constant

2. Biomass Combustion: Biomass combustion is very old process to use the biomass for sake of energy. In this process, the solid type of biomass is more suitable. Biomass combustion process in which biomass is stored for long period for combustion then exhaust gases are used to drive steam turbine to generate electricity. Its electric efficiency rang is 25-30%.

3. Biomass Gasification: Biomass Gasification is more efficient process. In this process, biomass is combusted but in the absence of oxygen. So, it generates CO and H_2 gases. These gases are producer gas. Gasification process efficiency is 35-40%. It is more than

combustion process. But it requires more cost due to cleaning of gases.

4. Co-firing of Biomass in Coal plant: Co-firing is method of mixing of fuel with biomass. Biomass will be in ground form for combustion. It is used for high production of electricity. It's rang is 50-700MWe. Boiler is used to generate steam for driving of steam turbine to produce electricity (Madanayake et al., 2017).

Tidal Energy: The tidal waves from the deep sea contain a lot of energy. This energy can be obtained in a decent manner to run turbines and generate electricity. It is very useful, environment saving and natural process. A tidal turbine works due to the continuous strikes of tides from the ocean. Tides strike on the blades of the turbine and tend it to rotate. Moving blades runs the generator and electricity is produced. There are various types of turbines, which turbine we are going to use depends on the surrounding conditions and depth of sea. The types of tidal energy turbine are;

1) Open-Centre single rotor turbine
2) Floating dual-rotor turbine moved by cables
3) Semi submerged turbine
4) Single-rotor turbine on subsea foundation

A tidal energy turbine named Seagen was first ever turbine installed in Strangford Lough, Northern Ireland. At the time of installation in 2008 it was the largest and most powerful turbine in the world, which was four times more than any stream turbine, generating 1.2 MW of electricity. The upstream and downstream views of Seagen

RESULTS AND DISCUSSION

Comparison of Renewable Technologies with Fossil Fuel: Comparing the energy resources for the production of electricity it becomes clear that the renewable sources of energy are more efficient, cost effective and safe for both health and environment. A solar panel (1 kVA) cost about Rs. 65,000 ($527) with a life span of 25 years, without any maintenance cost, fuel cost and emission of dangerous gases. Similarly, a wind turbine (1 kVA) costs about Rs. 1,20,000 ($970) with a life span of 10-15 years, with a maintenance cost of Rs. 3.5/h only, having no fuel cost, no emission of dangerous gases and unburned particles. But a gasoline generator (1 kVA) costs about Rs. 11,000 ($89), have a life span of only 4-5 years with a fuel consumption of Rs. 114/h, maintenance cost of Rs. 6.5/h and it don't stops here. Moreover, 6.5 g/L carbon monoxide, 0.72 g/L unburned hydrocarbons and 58 g/L nitrogen oxides releases. Renewable sources have a great potential in Pakistan. Total potential of renewable resources in 2010 was, wind power 12,764 MW, Solar PV (decentralized) 9,893 MW, Solar PV (centralized) 116,197 MW, Solar thermal 22,587 MW, biomass 5,420 MW, and small hydroelectric plants has a capacity of 2,658 MW.

Table 1: Estimated electricity production potential of Pakistan from different renewable resources (Rafique and Rehman 2017).

	2010	2020	2030	2040	2050
Wind (grid connected)	12.8	12.8	12.8	12.8	12.8
Solar PV (DCNT)	9.9	14.1	19.1	24.5	29.9
Solar PV (CNT)	116.2	116.2	116.2	116.2	116.2
Solar thermal (CNT)	22.6	22.6	22.6	22.6	22.6
Biomass (field residues)	1.7	2	2.5	3	3.7
Biomass (animal waste)	1.6	2.3	2.8	3.4	4.1
Biomass (MSW)	0.2	0.4	0.7	1.1	1.9
Small Hydro	2.7	2.7	2.7	2.7	2.7
Total	167.7	173.1	179.4	186.3	193.9

Conclusions: Pakistan is situated in South Asia having four seasons in a year, environment in every part of Pakistan is different and suitable for different sources of energy if we talk about solar energy, and nearly all parts of the country are suitable for PV plants. Southern Punjab, Sindh and Southern Areas of Baluchistan are very suitable for CSP technologies due to their hot weather and greater DNI.

Pakistan has a great potential for wind power but the Coastal areas of Sindh and Balochistan are most suitable places in terms of space availability. Also hill station of KPK and Balochistan are also suited for wind technologies. Offshore wind plants can also be installed all along the coastal belt in Sindh and Balochistan.

Hydroelectric sources can be used in northern areas of KPK, due to natural resources of water and suitable locations. Dams can be constructed on all big rivers. Also rivers and canals can be used for micro Hyderal projects in KPK, Punjab and Sindh.

Biomass energy source can be used in rural areas. Majority of the population of Pakistan is living in rural areas, due to excessive presence of waste material including waste of animals and crops. Also the availability of vast land required for the plant.

Pakistan has a wide coastal area from Sindh to Baluchistan. Coastal Areas of Baluchistan are the most suitable place for the Tidal energy production due to the natural deep sea coast.

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