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Renewable Energy Potential in Khyber Pakhtunkhwa

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***Abstract*—** Energy is a prerequisite for sustainable development in todays world. Pakistan is a developing country in the South East Asia with a population of more than 210 million. Pakistan is highly dependent on imported oil and gas since a long time. The share of installed renewable energy capacity uptil now is 6%. Khyber Pakhtunkhwa (KP) is one of the four provinces of Pakistan. KP is blessed with a significant amount of renewable energy potential which includes hydroelectric, solar, wind and biomass. This paper starts with Pakistan's energy scenario including the current energy supply and demand gap. It is then followed by a discussion on the renewable energy potential across KP. Hydropower alone has a total potential of around 25000 MW. Average daily solar radiation for KP is found to be 4.99kWh/m^2/day It was found that daily solar radiation remains high in the summer season from April-July and then falls in the winter season. In KP, Mardan receives the highest daily solar radiation in June and Chitral receives the lowest daily solar radiation in December. The province is also blessed with biomass. KP has total livestock population of 43 million including cows, buffaloes, sheep and goats. Waste from animals can be converted into biogas which can be used for cooking and heating purposes. Some parts of the province like Malakand, Buner, Haripur have also some wind potential which is enough to provide electricity to the nearby villages and communites. The paper then discusses reasons for energy shortfall followed by short term and long term measures that can be adopted by KP government to tackle energy crisis.

***Keywords*—** renewable energy, hydroelectric, solar energy, wind energy, biomass, Khyber Pakhtunkhwa

I. Introduction

Energy security has strong correlation with the socioeconomic development of any country. Due to rapid growth in population, industrialization and urbanization Pakistan is facing great energy challenges [1][2]. Pakistan has a population of more than 220 million and is the sixth most populous nation in the world. Pakistan used to be a nation with agrarian economy, but with passage of time, services and industry sector are dominating to the GDP [3]. Pakistan is one of the developing countries in Asia whose energy demand is rising day by day due to increasing population. Pakistan, like many other countries, is oil dependent to meet its energy demand.

In 2015, the two major sources of energy were oil and natural gas. Oil accounted for 36% share and Natural Gas accounted for 43% share in total primary energy supply [4]. Figure 1 below shows total primary energy supply for Pakistan until 2015. From 2006-2015, the production and supply of natural gas did not change and was constant because of no increase in inhouse gas production. But still, natural ga is playing vital role in meeting energy demand of nation. On the other hand, the share of oil in last ten years (2006-2015) has increased with an average of 4.5% per year.

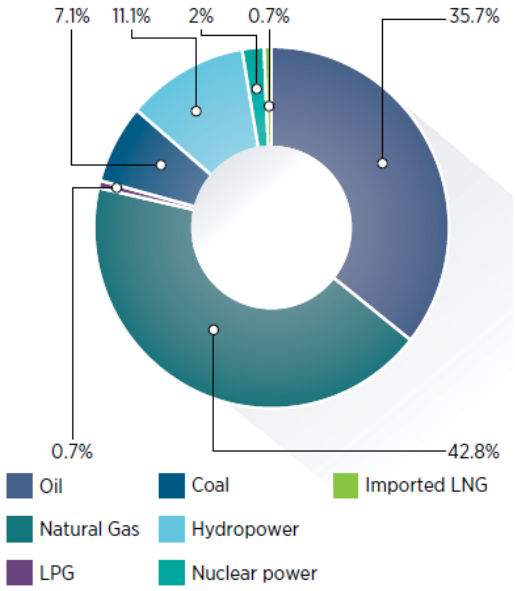

Figure 1 Total primary energy supply by source, 2015 [4]

During last ten years (2006-2015), the population has been increasing at a higher rate as compare to increase in demand. Pakistan electrification rate also increased in that period which resulted in a gap between supply and demand. The electricity defecit started in 2005 with 55MW and is still increasing.
Energy shortfall indicates that current energy resources are unable to meet the electricity demand of Pakistan. The solution to this problem is to harness energy using renewable energy resources which includes solar, hydroelectric, wind energy and biomass. Currently the share of installed renewable energy is 4% [5]. However, the government has plans to increase the share of renewable energy in the total power generation by 30%

[5]. Different form of renewable energy resources are being utilized in other developing countries to increase the share of power generation from renewable energy resources, referring to solar energy, hydroelectric, wind energy, biomass, geothermal and tidal energy.

II. Literature Review

Pakistan is blessed with tremendous amount of renewable energy resources which is a source of power generation. Pakistan has four major renewable energy resources found in excess and this includes solar, hydroelectric, wind and biomass. Small potential of geothermal and tidal energy are also found in the country. Proper utilization of these renewable energy sources can play significant role in overcoming energy crisis.

A. Hydropower

Hydropower is the cheapest source for power generation. This source of renewable energy is available with great potential in country especially in Khyber Pakhtunkhwa. As of 2015, Pakistan was generating 7116 MW of electricity by hydroelectric, most of which is operated by WAPDA [6]. Pakistan has total identified hydro power potential of around 60GW. The province of Khyber Pakhtunkhwa and Gilgit Baltistan have 45GW of the identified potential. Other than large hydropower, Pakistan also has significant potential for development of small scale (1-50MW) and mini/micro (1-1000 kW) Hydel power plants (MMHPP's) [7]. In KP, 142 sites have been identified with a generating capacity of around 25000 MW. In the Punjab province, 296 potential sites have been identified on barrages and canals with a total generation capacity of 7291. In the Sindh province, eighteen hydropower sites have been identified with a total capacity of 193 MW. In Balochistan, there is water scarcity and hardly any hydropower site is identified. Currently, there is no operational project in Baluchistan

B. Solar Energy

Pakistan lies in a geographic region which receives about 2500 hours of sunshine annually. Sheikh [8] in his research concluded that 100 km^2 of area can generate 30 million tons of oil equivalent in Pakistan. Adnan [9] used Hargreave and Agnstrom equation to calculate monthly solar enegy potential using different parameter including sunshine hours, maximum and minimum temperature.

C. Wind Energy

Wind Energy is another useful renewable energy resource which has huge potential in coastal areas of Pakistan including Sindh and Balochistan province. Pakistan has total potential of around 345 GW out of which just 120 GW can be technically extracted as studied by Baloch [10] and Farooqui [11]. Like China and India, Pakistan cal also harness wind energy and tackle energy crisis problem.

D. Biomass

Livestock is building block of Pakistan's economy and contributes significantly to the agriculture sector of the country. Pakistans livestock increases at an annual rate of 4% [12] and 70 million animals (cows and buffaloes) [13] can produce 1140 million tons of dung. Livestock is growing business in developing country where animals are found in great amount as in Pakistan. Livestock can play a vital role in reducing poverty and increase power generation. Iqbal et al [9][14] in his study concluded that by products of livestock business can help in increasing foreign exchange of the nation. Uddin [13] in his paper states that 35.625 million kWh can be generated from biomass on daily use. A complete process for bioenergy has been studied in [15].

III. Renewable Energy Potential In Khyber Pakhtunkhwa

A. Hydropower

Water is the major constituent of our life and is also used as a source for power generation. There are two types of hydropower referred as Small Hydro Power Plants (SHPP's) and Large Hydro Power Plants. The forme has lower generation capacity and the latter has higher generation capacity.

Khyber Pakhtnkhwa (KP) has boundary touching with Gilgit Baltistan and Azad and Jammu Kashmir in its northern side, Afghanistan on its west side, and Punjab and Balochistan on Southern side. The main river that flows in KP are Kunhar, Swar, Indus, Kabul, Kohat, Kurram, Panjkoora, Ushu, Gabral, Tochi and Chital [6].

In KP, there are two major entities working on hydro sector on large scale. Both of them are government entites. The first one is WAPDA and the other one is PEDO. WAPDA is managed by federal government where PEDO is managed by provincial government. There is another department under the ministry of Science & Technology known as Pakistan Council for Renewanle Energy Technology (PCRET). Other than these tow government entities, there are some Non-Government Organizations like Sarhad Rural Support Program (SRSP), Agha Khan Rural Support Program. Table 1 below shows the project that are in operation by WAPDA.

Table 1 Detail of the projects that are in operation by WAPDA [6]

S. No	Project Name	Location	Operated By	Capacity (MW)
A. WAPDA				
1	Tarbela	Tarbela (Reservoir)	WAPDA	3478.00
2	Warsak	Warsak (Reservoir)	WAPDA	240.00
3	Jaban (Malakand-I)	Swat Canal	WAPDA	20.00
4	Dargai (Malakand-II)	Swat Canal	WAPDA	20.00
5	Kurram Garhi	Kurram Garhi (canal)	WAPDA	4.00
			Sub Total	3762

Table 2 below shows list of hydro project executed by PEDO

TABLE 2 LIST OF COMPLETED PROJECTS EXECUTED BY PEDO

Sr. No	Project Name	Location	Capacity (MW)	Status
1	Malakand III Hydro Power Project (HPP)	Dargai	81	Completed
2	Daral Khwar HPP	Bahrain	36.6	
3	Pehur HPP	Swabi	18	
4	Ranolia HPP	Kohistan	17	
5	Machai HPP	Mardan	2.6	
6	Shishi HPP	Chitral	1.875	
TOTAL (MW)			**157.075**	

Other and WAPDA and PEDO, PCRET has also installed 553 Mini Micro Hydro Power Projects across KP with a total generation capacity of 8 MW. SRSP has also installed MMHPP's with generation capacity of 28 MW. AKRSP has installed 147 MMHPP's with a total generation capacity of 13.5 MW.

B. Solar Energy

Solar Energy is the energy received through the solar radiation. This energy can be converted either into heat or electricity depending on the need. The two common methods of generating electricity are solar photovoltaic and solar thermal conversions. Pakistan has a solar PV potential of 2.9 million MW, with annual average temperature of 26-28 degree Celsius [9].

RETScreen software was used to calculate daily solar radiation for 9 cities of Khyber Pakhtunkhwa. Table 16 below shows the data for 9 cities of KP for 12 months. For all the cities, the daily solar radiation increases from January to June. The values are maximum for all the cities in the month of June and July and then start decreasing from June to December.

TABLE 3 DAILY SOLAR RADIATION- HORIZONTAL (KWH/M2/D) FOR 9 CITIES OF KHYBER PAKHTUNKHWA

	Daily Solar Radiation-Horizontal (kWh/m^2/d) for 9 Cities of Khyber Pakhtunkhwa												
Cities/Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average of 12 months
Peshawar	3.08	4.03	4.99	6.11	7.15	7.24	6.55	5.98	5.43	4.55	3.73	3.02	5.16
Mardan	3.08	3.77	4.76	6.18	7.31	7.88	6.96	6.21	5.87	5.02	3.76	2.86	5.31
Kohat	3.18	3.89	4.74	5.92	6.86	6.96	6.12	5.64	5.33	4.86	3.79	2.98	5.02
Doaba	3.24	3.96	4.84	5.85	6.87	7.19	6.55	5.97	5.53	4.89	3.85	3.04	5.15
Dir	2.39	2.9	3.81	4.73	5.93	7.05	7	6.39	5.62	4.27	3.07	2.29	4.62
Abbottabad	2.95	3.57	4.55	5.88	6.99	7.46	6.6	5.94	5.7	4.89	3.69	2.79	5.08
Bannu	3.34	4.09	4.89	6.04	6.46	6.72	5.8	5.51	5.15	4.67	3.81	3.15	4.97
Chitral	2.49	3.2	4.07	4.99	6	7.1	7.39	7.03	6.11	4.38	3.03	2.28	4.84
Tal	2.58	3.13	4.05	5.13	6.23	7.08	6.96	6.23	5.56	4.41	3.27	2.44	4.76
											Annual Average		4.99

Table 3 above shows 9 different cities of Khyber Pakhtunkhwa (KP) for daily solar radiation-horizontal is calculated. It can be clearly seen that solar radiation remains high in summer season from April-July and are lower in other months. In KP, Chitral receives lowest intensity (2.28 kWh/m^2/d) in December whereas Mardan records highest daily solar radiation (7.88 kW/m^2/d) in June.

For all the cities, the solar radiation increases from January to June. The values are maximum for all the cities in the month of June or July and then start decreasing from July to December. As compared to other cities, Chitral experiences less radiation throughout the year.

C. Wind Energy

Wind Energy remained the world's fastest growing energy source until 2016. It is clean, green and renewable source of energy. Pakistan has significant potential for wind energy. As the paper is specific to Khyber Pakhtunkhwa, only wind energy potential in Khyber Pakhtunkhwa will be discussed.

Pakistan Meteorological Department (PMD), a national entity, in coloration of Ministry of Science & Technology (MoST) has completed two wind mapping projects referred to as Phase 1 and Phase 2. The former project is 'Wind Power Potential Survey of Coastal Areas of Pakistan (Phase-I)' completed in June 2005. The latter project is 'Wind Mapping of Northern Areas of Pakistan (Phase II)' and is still an on-going project since June 2010. A wind resource map of Pakistan developed by NREL and USAID is shown in the Figure 3 below.

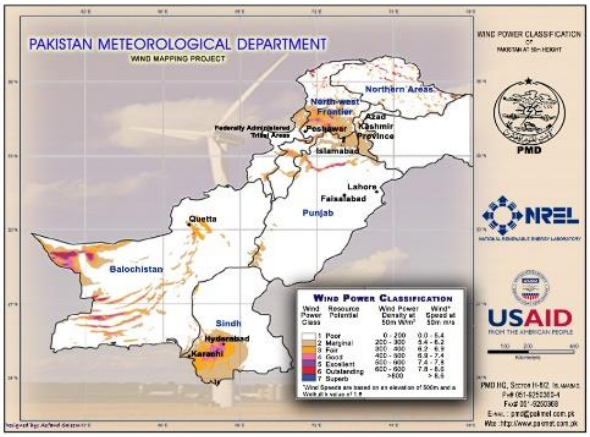

Figure 2 Wind Resource Map for Pakistan [16]

In Figure 3, it can be seen that there exists some areas in Khyber Pakhtunkhwa which have wind energy potential. The violet color areas in the picture are identified as the areas having good wind speed. These violet colour areas are identified as Mardan, Malakand, Buner, Shangla, Swabi and Haripur. These areas in KP are identified to have wind potential that can run small wind turbines to generate electricity for communities.

D. Biogas

Gas produced by decomposition of organic matter in the absence of oxygen is called as biogas. The process of producing biogasis also referred as anaerobic digestion of biodegradable material. 20 kg of animal waste is used to produce 1m^3 of biogas [8] and 2.5 kWh of electricity is generated from 1m^3 [13]. Biogas can be produced from biomass by three techniques:

- Floating Gas Holder Type Plants [17]
- Fixed Dome Type Biogas plant [18]
- Fixed Dome with Expansion Chamber type Biogas Plant [19]

Table 3 below shows livestock population of Khyber Pakhtunkhwa (KP). There were 49.32 million animals in 2006 in the rural areas of KP. As per 2006 livestock census, goats are found in maximum number, followed by goats, cows, sheep and then buffaloes accounting for 9.59 M, 5.98 M, 3.36 M 1.928 million respectively. This data was extrapolated till year 2019 and it was found that number of animals have increased significantly. The total number of cow, buffaloes, sheep and goat were found to be 10, 4, 20 and 10 million respectively. Energy generated from animal waste is not only environment friendly but also highly sustainable and economically viable.

TABLE 4 LIVESTOCK POPULATION OF KHYBER PAKHTUNKHWA FROM 1960 TO 2006 [14]

(000 Heads)

Khyber Pakhtunkhwa	1960	1972	1976	1986	1996	2006
Cows	3206	2962	3000	3285	4237	5968
Buffaloes	651	791	762	1271	1395	1928
Sheep	2432	2455	3675	1599	2821	3363
Goats	3035	3737	4686	2899	6764	9599
Camels	76	101	95	70	65	64
Horses	23	31	29	34	47	76
Asses	306	408	381	446	534	560
Mules	19	32	28	23	60	67
Poultry	4190	4939	9708	17203	22501	27695

About 70% of KP population lives in rural areas. Most of the people living in rural areas have at least two or more cows or buffaloes. The waste of these animals can be mixed with equal proportion of water to produce biogas. This gas can be further used for cooking purposes or other ways to generate electricity. It is estimated that 11.6 GWhr/day of electricity can be generated from 14 million animals including cows and buffaloes.

IV. ORIGIN OF ENERGY CRISIS

1. Poor Management: Pakistan had a population of 210 million [11] in 2017.Energy crisis in Pakistan started in 2000 and got worse in 2006. As top management of the country did not forecast the future of the energy, the country started facing electricity shortfall. Poor planning by the top management of the nation lead to all time worst energy crisis.
2. Policy Problems: Since 1947, policy makers are unable to provide attractive incentives to investors. Other than foreign investors, locals investors are not even satisfied. Pakistan lacks policy makers.
3. Distribution & Transmission Capacity: In spite of the fact that additional transmission and distribution lines would be needed with increase in time, the federal government have remained failed to lay down these lines on proper time.
4. Power Theft: Power theft results when unit price of electricity goes high. Consumers are unable to pay high electricity bills and are forced to steal electricity.
5. Financial Problems: Pakistan is a poor nation. Pakistan takes loan in the form of of aid from other countries and donor agencies to start new power projects. The dependence on foreign investment has damaged our economic system.

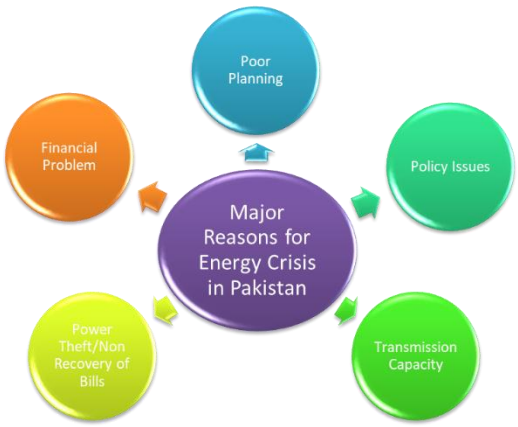

Figure 3 Major reasons for energy crisis in Pakistan

V. SOLUTIONS TO TACKLE ENERGY CRISIS

1. The provincial Government of Khyber Pakhtunkhwa (GoKP) should start solar and mini hydro hydro electric projects across the province. Large hydro electric power palnts and solar parks can be taken into consideration. Where possible, small scale wind turbines should be installed.
2. GoKP should work on weak transmission and distribution network. The network of lines should be strengthened to sustain the electricity generation and transmission needs of the future.
3. All the previous power plants installed in the province should be monitored by GoKP for
4. increasing efficiency. This includes large hydro dams.
5. High wattage electrical appliances should be replaced with energy efficient appliances immediately at every cost. High wattage appliances consumes a lot of electricity. Power theft should be minimised across the province.
6. There should be awareness campaigns in the province to educate the people of Khyber Pakhtunkhwa about renewable energy.

CONCLUSION

Khyber Pakhtunkhwa (KP) is blessed with a significant amount of renewable energy resource. This includes hydroelectric power, solar energy, biomass and wind energy. To conclude; In the hydroelectric sector there is a total potential of

around 25,000 MW out of which only about 4,000 MW of potential is tapped. The amount of solar energy that can be harnessed in Khyber Pakhtunkhwa is $2*10^7$ MWh/m^2 where only around 2 MW of electricity is being generated by solar currently. Similarly in biomass there is a total potential of 3 million biogas plants in the province but only 2000 biogas have been installed so far.

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