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Renewable Energy Option for Socio-Economic Development in Pakistan

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Abstract *An uninterrupted supply and easy access to energy are necessary for the economic and social development of a country. It can only be possible by careful management of available energy and including the increased share of clean, renewable energy (RE) in the overall energy supply. A substantial reduction in the use of fossil fuel can also help to mitigate the global environmental effects. Pakistan has been suffering from a severe energy crisis for the last many years that has badly affected its industrial sector, and consequently, a substantial reduction of economic growth is witnessed in the country. This paper explores the alternative opportunities of energy supply in Pakistan by highlighting the available potential of non-fossil energy resources. It also highlights the present scenario and prospects of RE adoption in the country that will help for socio-economic development in the country..*

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Introduction

Pakistan is among the rapidly emerging countries of South Asia, and due to its industrial growth and rising rate of population, energy security has become one of its major issues these days. The country has been experiencing an acute energy crisis for last many years. There is a significant gap in the demand and supply of electricity and natural gas both for industrial and domestic users (Faheem, 2016; Kashif et al., 2020; Luqman et al., 2019). Roughly 140 million people are living without electricity which is considered a basic facility for a human being all over the world, and those who have access to such facility faces a regular disruption in the electricity for more than 12 hours a day (S. A.A. Shah et al., 2019). The electricity shortfall reached 6000 MW to 7000 MW in 2008 (Lin et al., 2019).

The industrial sector all over the world is considered to be the most energy-intensive sector. In Pakistan, the industrial sector uses more than 37% of available primary energy (figure 1). During the present shortfall of energy, the Pakistani industrial sector has been seriously influenced, resulting in a significant decline in its operational productivity (Asif, 2009; Asif et al., 2007;

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Nadeem, 2014). The shortage of electricity and natural gas is managed by regular disruption in their supply at both domestic and industrial levels. Due to such load management by electricity and gas distribution companies, many industrial units have shut down their businesses, and roughly 500,00 people became jobless (Syed Ahsan Ali Shah et al., 2018).

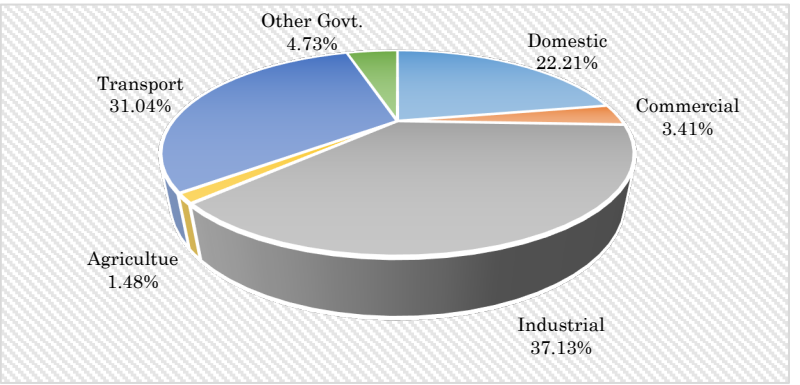

Figure 1: Energy consumption in Pakistan by sector (Hydrocarbon Development Institute of Pakistan., 2019)

In Pakistan, the major demand for primary energy use is mainly fulfilled by conventional fossil fuel, which is not only expensive but also limited in nature and subsequently creates vast financial problems at the national level. More than 70 % of the energy supply mix in the country is covered by oil and natural gas (Hydrocarbon Development Institute of Pakistan, 2019). The gross primary energy supply in the country during 2018-19 has decreased from 86.3 to 83.8 million tons of oil equivalent (MTOE) mainly because of a decline in the supply of oil and LPG as compared to the previous year. Almost 88% of total primary energy was supplied during 2018-19 by fossil fuels. The total energy supply mix (figure 1) of the country includes natural gas 35%, oil 25.7%, Coal 15.4%, LNG 10.6, hydroelectricity 7.8%, Nuclear energy 2.8%, LPG 1% and renewable electricity 1.3% (Hydrocarbon Development Institute of Pakistan, 2019).

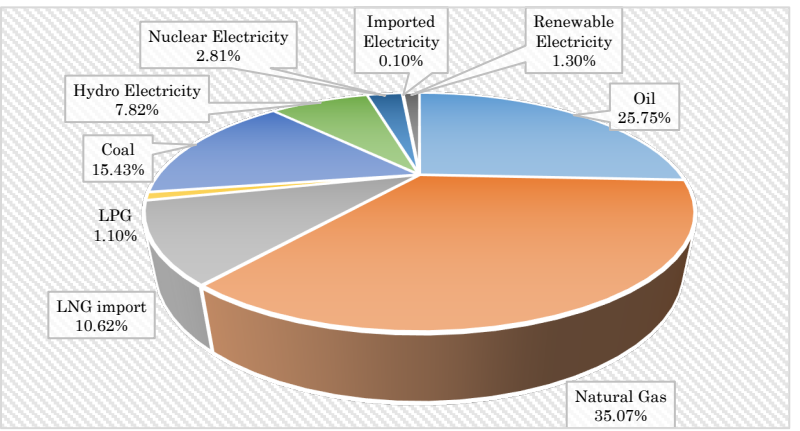

Figure 2: Total Energy Supply Mix of Pakistan (Source: HDIP 2019)

Currently, the RE energy share is less than 2% (figure 2) in overall primary available energy. According to the Hydrocarbon Development Institute of Pakistan (HDIP), 4682 GWh electricity was generated by wind energy (67.6%) followed by biomass (19%) and solar energy (13.4%) during 2018 – 19 (figure 3). Despite the huge available potential, the adoption of RE in Pakistan seems to be relatively slow. The reasons for reluctance to the implementation of such clean and widely available energy may include lack of awareness and relevant technical knowledge, particularly at domestic and small industries level.

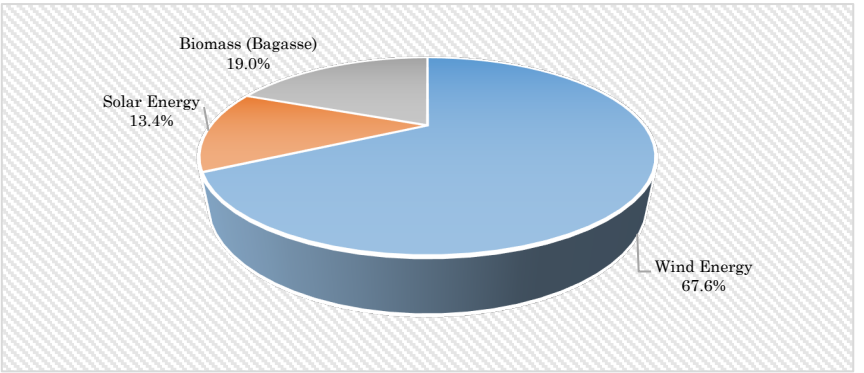

Figure 3: Electricity generation by renewable energy projects (Source: HDIP 2019)

There is a great need of making serious efforts by the Pakistani government to improve infrastructure and encourage investors to invest in renewable energy generation on a large scale.

Overview and Prospects of Renewable Energy Resources in Pakistan

Solar Energy

Pakistan is located in South Asia, and due to its geographic location, it has a great potential for solar energy, but due to several reasons, this opportunity to generate clean energy has not yet been untapped to the required extent. Solar energy is mainly used to generate electrical and thermal energy both for domestic and industrial purposes. Most areas in Pakistan are covered with full sunshine, and an estimated average of 5.5 kWh m^{-2} per day solar energy is available for daytime sunshine of 8 to 10 hours in around 300 sunny days over the year (Ulfat et al., 2012). In a study of design and economic analysis of photovoltaic energy generation for household applications, Ghafoor et al. (2015) found that the unit cost of electrical energy using solar PV system was around PKR 15 per kWh cheaper than the electricity supply from WAPDA.

Solar photovoltaic energy generation is not new technology for Pakistan. A 450 kWh electrical generation system was installed in the 1980s (Kamran, 2018). However, the adoption of solar energy technology could not be successful due to a lack of relevant technical and management skills (Shaikh et al., 2013). The first serious effort in this regard was made in 2003 when the Alternative Energy Development Board (AEDB) started its work in Pakistan. AEDB is a federal body responsible for promoting, encouraging and looking after RE developments in Pakistan. Another body having similar responsibilities called the

Pakistan Council of Renew Energy Technologies (PCRET), was established under the umbrella of the Ministry of Science and Technology, Government of Pakistan, in 2001. The primary objectives of PCRET include coordination of research and development regarding RE technologies and their promotional activities in the country.

After the development of these bodies in Pakistan, a significant improvement in the solar energy infrastructure was witnessed, and the pace of adoption and development of new RE technologies was increased. A solar power plant of 178 kW capacity was one of the initial such projects in the country, successfully installed in 2010 in two building in Islamabad (Kamran, 2018). Another solar system of 2 MW capacity was also installed and in operation at the National Assembly of Pakistan. After the successful commissioning of such projects, private investors found interest in this field and several small solar projects at domestic and industrial scale have been completed in the country during the last two decades. The Alternative Energy Development Board issued letters of interest to several companies in Pakistan, and installation of solar projects are under construction.

For accurate solar data, several solar measurement stations have been installed at various places in all provinces of the country, which covers most of the solar and climate regimes. Table 1 shows the geographical location of various sites of solar measurement (SM) stations in Pakistan.

Table 1. Geographical Location of Solar Measurement Stations in Pakistan.

S. No	Location of SM Stations
1	QA Solar Park.
2	MNS University of Engg. And Tech., Multan.
3	UET Kala Shah Kaku, Lahore.
4	NUST, Islamabad.
5	UET Peshawar.
6	Balochistan UET, Khuzdar.
7	Balochistan University of IT, Quetta.
8	Mehran University, Jamshoro.
9	NED University, Karachi.

A big initiative in this regard was taken by the Pakistani government in 2013 and established an infrastructure called Quaid-e-Azam Solar Park (QASP) near Bahawalpur, having an overall power generation capacity of 1000 MW. In the first phase, a 100 MW pilot project was completed and commissioned in 2015 with a cost of $131.15 million. This initial pilot project intended to seek the attention of domestic and international investors to invest for the remaining target capacity of 900 MW. As a result, three more projects of the same capacity each were developed at QASP and commissioned in 2016, and the park is open for investors for more projects.

Table 2 shows 5 projects completed from 2015 – 2017 with an overall capacity of 430 MW under agreement with the AEDB Pakistan. There are 16 more ventures of 461 MW capacity at various stage of completion.

Table 2. Solar Projects Completed in Pakistan between 2015 – 17.

S. No	Name of Project	Capacity	Location	Date of Completion
1	QA Solar Pvt. Ltd.	100 MW	QASP, Bahawalpur	July 15, 2015
2	Appolo Solar	100 MW	QASP	May 31, 2016
3	Best Green	100 MW	QASP	July 31, 2016
4	Crest Energy Pakistan Ltd.	100 MW	QASP	July 31, 2016
5	Harappa Solar	18 MW	Sahiwal	Oct. 14, 2017
6	AJ Power	12 MW	Pind Dadan Khan	Dec. 13, 2017

The use of solar energy system for thermal energy generation is another application of solar energy and is well proven all over the world. To encourage solar technology in the country, the Pakistani government allowed a tax-free import of solar products in the country and around 15,000 solar water heaters were imported for domestic purposes, and 1400 water pumping projects based on the solar system were completed in 2013 (Kamran, 2018). Various solar thermal energy equipment such as solar water geysers, solar cookers and solar dryers are frequently available in the local market.

Wind Energy

Wind energy is the second most popular form of renewable energy in the world. Various studies have been conducted in Pakistan, and their results demonstrated that a good potential for wind energy is available in the country. In a survey by Pakistan Meteorological Department in 2002, it was concluded the wind corridors at coastal areas of Balochistan and Sindh provinces are the best sites for windmill projects having vast potential of exploiting wind energy. The estimated potential of wind speed at these areas in this study were 4 – 9 m s^{-1} and 12.5 s^{-1} at 10 m and 50 m of heights, respectively (Hashmi, H.N., Malik, N.E. Yousuf, 2007). In a study under the USAID program (2007), it was estimated that around 346,00 MW wind energy potential is available in Pakistan (Farooqui, 2014).

In 2013, a wind power project of 50 MW capacity was established at Fauji Fertilizer Company, and it was one of such initial projects based on wind energy (Farooqui, 2014). According to AEDB, a total number of 24 projects based on wind power with a cumulative capacity of 1235.20 MW have been completed and are operational in the country and adding share to the national grid (see table 3).

In the near future, 16 more wind power projects are expected to start their generation; among those, 12 projects of 610 MW capacity have already achieved their financial closing, and 4 projects of 165 MW capacity are under development phases.

Table 3. Operational Wind Power Plants in Pakistan. (Source: AEDB Pakistan)

S. No	Name of Project	Capacity (MW)	Location	Commercial Operation Date
1	FFC Energy	49.5	Jhampir, Sindh	May 16, 2013
2	Zorlu Enerji	56.4	Jhampir, Sindh	July 25, 2013
3	Three Gorges 1st W. Farm	49.5	Jhampir, Sindh	Nov 25, 2014
4	Foundation W. Energy – 2	50	Gharo, Sindh	Dec 10, 2014
5	Foundation W. Energy – 1	50	Gharo, Sindh	April 11, 2015
6	Sapphire W. Power	52.8	Jhampir, Sindh	Nov 22, 2015

S. No	Name of Project	Capacity (MW)	Location	Commercial Operation Date
7	Yunus Energy	50	Jhampir, Sindh	Sep. 16, 2016
8	Metro Power	50	Jhampir, Sindh	Sep. 16, 2016
9	Tapal W.Energy	30	Jhampir, Sindh	Oct. 07, 2016
10	Tenaga Generasi	49.5	Gharo, Sindh	Oct. 11, 2016
11	Master W. Energy	52.8	Jhampir, Sindh	Oct. 14, 2016
12	Gul W. Energy	50	Jhampir, Sindh	Oct. 18, 2016
13	Hydro China Dawood Power	49.5	Gharo, Sindh	April 05, 2017
14	Sachal Energy Development	49.5	Jhampir, Sindh	April 18, 2017
15	United Energy	99	Jhampir, Sindh	Jun 16, 2017
16	Hawa Energy	49.6	Jhampir, Sindh	March 15, 2018
17	Jhampir W. Power	49.7	Jhampir, Sindh	March 16, 2018
18	Artistic Energy	49.3	Jhampir, Sindh	March 16, 2018
19	Three Gorges 2nd W. Farm	49.5	Jhampir, Sindh	Jun 30, 2018
20	Three Gorges 3rd W. Farm	49.5	Jhampir, Sindh	July 09, 2018
21	Tricon Boston - 1	49.6	Jhampir, Sindh	Aug. 16, 2018
22	Tricon Boston - 2	49.6	Jhampir, Sindh	Sep. 14, 2018
23	Tricon Boston - 3	49.6	Jhampir, Sindh	Sep. 11, 2018
24	Zephyr Power	50	Gharo, Sindh	Mar. 27, 2019

Biomass

Pakistan is an agricultural country, and it is blessed with enormous resources of biomass, one form of renewable energy resources. The key types of biomass available in Pakistan include agricultural stalk, wheat straws, bagasse, rice husk, sugar cane trash, poultry waste and wood chips etc.

In a report prepared by UNIDO under the project title "Policy advisory services for Biomass Energy Conversion technologies in Pakistan", it was found that the overall energy potential through biomass has not yet been determined on a scientific basis in the country. In another report of renewable energy source mapping program (ESMAP) funded by the World Bank, the estimated available surplus biomass for energy generation in Pakistan is shown in table 4.

Table 4. Available Surplus Biomass for Energy Generation in Pakistan (Source: UNIDO, 2016).

Type of Biomass	Available for energy generation (tons)
Agri-based residue	20,494,000
Agro-industrial residue	25,271,000
Wood Based Residue	1,121,000
Total	46,886,000

The use of wheat straw and rice husk for power generation is limited in Pakistan because both are used as the main food ingredients of livestock (Tareen et al., 2020). The widely used type of biomass used in Pakistan as a source of power generation bagasse is a residue of sugarcane and easily available sugar mills.

In Pakistan, out of 83 sugar mills with a projected potential of 3000 MW electrical energy (Kamran, 2018), 8 mills (see table 5) have successfully installed power plants based on their by-product bagasse and are fully operational. The cumulative energy produced by these projects in operation is 259.1 MW.

Table 5. Power Plants Working on Bagasse (Source: AEDB).

S. No	Plant	Total Capacity of Project	Location
1	Chiniot Power	62.4 MW	Faisalabad
2	Layyah Sugar Mills	41 MW	Layyah
3	RYK Mills	30 MW	RYK
4	JDW Sugar Mills- 2	26.35 MW	RYK
5	JDW Sugar Mills - 3	26.35 MW	Ghotki
6	Hamza Sugar Mill	15 MW	RYK
7	Almoiz Industries	36 MW	Mianwali
8	Chanar Energy	22 MW	Faisalabad

There are 16 sugar mills that have received letters of support (LOS) from AEDB and are under completion stages for biomass plants with expected cumulative energy of 563.5 MW. Moreover, 9 more companies with a cumulative energy generation of 314.5 MW received letters of intent from AEDB and are under the development phase. After completion of all these projects, the overall power generation from bagasse (biomass) will reach up to 1137.5 MW in the country.

Micro Hydro

There is a huge potential for power generation through micro hydro-power plants in Pakistan. Due to the geographic location of Pakistan, natural waterfalls available at various sites of the country invite policymakers to develop micro-hydro projects to meet its domestic energy requirements and to address the energy security concerns in the country. According to the AEDB Pakistan, a total of 3100 MW power generation potential is available at various natural waterfalls and rivers at 815 sites in the country (table 6).

Table 6. Estimated Power Generation Potential at Various Sites of Waterfall and Rivers (Source: AEDB)

S. No	Province/Area	Potential Sites	Power Range (MW)	Total Estimated Potential
1	Punjab	Upto 300	0.2 - 40	560-MW
2	Gilgit	Upto 200	0.1 - 38	1300-MW
3	KPK	Upto 125	0.2 - 32	750-MW

4	KPK	Upto 200	0.1 - 38	1300-MW
5	Sindh	Upto 150	05 - 40	120-MW
6	AJK	Upto 40	0.2 - 40	280-MW
Total available potential				3100 MW

Currently, 128 MW is generated using micro/mini hydro-power plants located at various sites in the country, new micro hydro-power plants of 877 MW capacity are under construction, and various sites around 1500 MW capacity are under development phases.

Under provincial government, 7 small hydro-power projects, 3 from KPK with US$ 150.9 million estimated cost and 4 in Punjab with an estimated cost of US$ 138.74 million having 76 MW overall capacity are at completion phases (table 7).

Table 7. Micro-Hydro Power Plants under Completion Phases

Khyber Pakhtunkhwa			**Punjab**		
No.	**Location**	**Capacity**	**No.**	**Location**	**Capacity**
1	Ranolia	17.0 MW	1	Chianwali	5.4 MW
2	DaralKhwar	36.6 MW	2	Sheikhpura	4.1 MW
3	Machai	2.6 MW	3	Pakpattan	2.8 MW
Total		56 MW	4	Marala	7.7 MW
			Total		20 MW

Recently, 9 potential sites for small hydro-power plants of capacities from 11 MW to 36 MW are identified in KPK, and their development through engagement of the private sector is under process.

Conclusions

Keeping in view the geographical context and wide availability of specific types of renewable energy resources in Pakistan, 4 significant RE resources have been discussed in this paper. It can be concluded that the widely available potential of RE resources in Pakistan should be exploited on a priority basis. Through the adoption of clean RE resources, Pakistan can avail its socio-economic benefits, overcome the present energy crisis and significantly reduce greenhouse effects for environmental protection. The government of Pakistan has realized and initiated several projects to utilize the available potential of RE resources. Many projects have already been completed, and some more are at various stages of completion. However, the share of renewable energy in the total primary energy supply is very low, and the pace of adoption of RE technologies is significantly slow. There is a need for serious attention to overcome the barriers to the adoption of RE technology in the country. To create awareness in organizations and the public, a campaign should be devised at various levels. It may include public-funded seminars, conferences and workshops addressing the need, benefits, reluctance, and associated complexities in the adoption of RE technologies. Moreover, renewable energy as a subject should be included in the curriculum at polytechnical institutes, technical colleges, and engineering universities.

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