Prospects of Renewable Energy in Pakistan to Meet INDC Commitments

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List of Acronyms

NCCP	National Climate change policy
NPP	National Power Policy
PCRET	Pakistan council of research in renewable energy technologies
CCS	Carbon capture and storage
CDM	Clean development mechanism
RFO	Residual furnace oil
NDC	Nationally determined contributions
SEA	Strategic environmental assessment
PPDB	Punjab power development board
AEDB	Alternate energy development board

Section 1: Introduction

Economic growth scenario of Pakistan

Since Fiscal year (FY) 2014 Pakistan's economy has been witnessing an impressive turnaround with GDP growth crossing 4 percent in a challenging environment. Over the last four decades, the composition of Pakistan's GDP has undergone considerable changes. During the past five years, the economy continued to benefit from growth-oriented initiatives, including higher development spending, low inflation, vigilant monetary policy, and CPEC related investment providing impetus for economic recovery.

The key feature of 2017-18 economy growth is the high and broad-based growth in agriculture, industrial and services sectors. Percentage growth in each of these sectors and their sub-sectors is shown in figure 1 [1].

At an average economic growth rate of 4.9 percent from 1952 to 2015, current gross domestic product (GDP) of Pakistan stands at nearly US$ 284 billion. This classifies Pakistan as a lower middle-income country. Vision 2025 sets the target rate of economic growth to be, on the average, seven percent until the year 2025 and well above that level for subsequent years.

Investments in power generation, energy distribution and 'China-Pakistan Economic Corridor' (CPEC) will provide significant boost to the economy. Several large-scale infrastructure investments, energy and industrial growth projects currently in the pipeline, are expected to further accelerate the targeted economic growth. CPEC alone is expected to trigger an additional GDP growth of 1.5 percent from 2016 to 2020 and a further 1 percent increase for the period 2020 to 2030. Research studies suggest that CPEC will substantively boost growth and job creation. It will also accelerate urbanization and attract local as well as foreign direct investment in the country.

Projects under the CPEC portfolio are broadly categorized into 'Early Harvest' projects with completion by 2018, Short- and Medium-Term projects, which are aimed for completion by 2020 and 2025 respectively. Under the CPEC Long Term Plan, sectors of cooperation include energy sector, infrastructure development, establishment of industrial

parks and improving IT connectivity. CPEC is a major breakthrough in the development of the country's energy sector, under which financial outlay of around US $ 35 billion has been made for Energy sector projects including power generation and transmission projects. A total of 17,045 MW will be added to the system with 10,000 MW expected in 2018. Also, shift of energy mix from oil to coal, significant relief is also expected to be passed on to domestic as well as commercial consumers.

Growth Rates (%)

Sector	2012-13	2013-14	2014-15	2015-16 F	2016-17 R	2017-18 P
A. Agriculture	2.68	2.50	2.13	0.15	2.07	3.81
1. Crops	1.53	2.64	0.16	-5.27	0.91	3.83
Important Crops	0.17	7.22	-1.62	-5.86	2.18	3.57
Other Crops	5.58	-5.71	2.51	0.40	-2.66	3.33
Cotton Ginning	-2.90	-1.33	7.24	-22.12	5.58	8.72
2. Livestock	3.45	2.48	3.99	3.36	2.99	3.76
3. Forestry	6.58	1.88	-12.45	14.31	-2.37	7.17
4. Fishing	0.65	0.98	5.75	3.25	1.23	1.63
B. INDUSTRIAL SECTOR	0.75	4.53	5.18	5.69	5.43	5.80
1. Mining & Quarrying	3.88	1.40	4.97	6.19	-0.38	3.04
2. Manufacturing	4.85	5.65	3.88	3.69	5.82	6.24
Large Scale	4.46	5.46	3.28	2.98	5.62	6.13
Small Scale	8.28	8.29	8.21	8.19	8.15	8.18
Slaughtering	3.63	3.38	3.34	3.61	3.55	3.52
3. Electricity Generation & Distribution & Gas Distribution	-26.38	-0.74	13.48	9.39	5.82	1.84
4. Construction	1.08	5.96	7.26	13.68	9.84	9.13
COMMODITY PRODUCING SECTOR (A+B)	1.73	3.49	3.63	2.92	3.79	4.84
C. SERVICES SECTOR	5.13	4.46	4.36	5.72	6.46	6.43
1. Wholesale & Retail Trade	3.53	4.77	2.60	4.73	7.46	7.51
2. Transport, Storage & Communication	4.03	3.90	5.07	4.89	4.44	3.58
3. Finance & Insurance	8.32	4.31	6.35	6.42	10.78	6.13
4. Housing Services (Ownership of Dwellings)	4.00	4.00	3.99	3.99	3.99	4.00
5. General Government Services	11.32	2.86	4.82	9.72	5.95	11.42
6. Other Private Services	5.26	6.22	6.06	6.77	7.98	6.15

Figure 1: *Percentage growth rate of different sectors*

Source: Pakistan Bureau of Statistics

Pak-INDC/ Commitments of Pakistan to UNFCCC

INDC essentially indicates a country's contribution to achievement of the universal target set in the Paris Agreement and the accompanying compliance mechanism at country level. Pak-INDC (Pakistan's Intended Nationally Determined Contribution) is rooted in the country's strategic plan 'Vision 2025'. Vision 2025 is a blue print for a future-oriented and growth-centric roadmap for Pakistan, it clearly recognizes global warming and climate change as priority areas for effective action by the Government.

INDC is aligned with the respective policies, plans and sectoral growth targets set by various ministries and other government entities. Similarly, potential impacts of key development plans and projects, such as measures being undertaken to address current energy shortages and contributions to economic growth partly due to China-Pakistan Economic Corridor (CPEC) have been taken into consideration. Pak-INDC presents the overall GHG emissions profile and future emission projections, by considering both the present and future socio-economic parameters, changes in the demographic dynamics and emerging energy needs. It also describes mitigation and adaptation measures already being implemented in Pakistan and discusses the challenges and difficulties being faced and those likely to be confronted in coming years. According to Pakistan's INDC statement, considering the existing potential for mitigation in the country, Pakistan intends to reduce up to 20% of its 2030 projected GHG emissions subject to availability of international grants to meet the total abatement cost for the indicated 20 percent reduction amounting to about US$ 40 billion at current prices. Pakistan's adaptation needs range between U$ 7 to U$ 14 billion/annum during this period. Pakistan reiterates its commitment and obligations towards the United Nations Framework Convention on Climate Change and Paris Agreement, and the objective to limit the average global temperature increase to 1.5 to 2.0 degrees Centigrade [3].

Major GHG emission sectors as per INDC document

Over the years 1994 - 2015, coinciding with GHG inventory preparation activities in the country, an increasing trend in emissions in all sectors of economy has been observed. Overall increase in emissions over the period of twenty-one years is approximately 123 percent. The average annual increase works out to 10 MT CO2 equivalent, which represents annual growth rate of 3.9 percent. The historical trend of increase in emissions

has so far been fairly consistent; however, the envisaged economic growth and increasingly conducive macro-economic environment are likely to boost future emissions. Greenhouse Gas Inventory Commitments in Pak-INDC in response to the Paris Agreement are based on socio-economic realities and their impact on the country's current and future GHG emissions. The emissions have been quantified on the basis of the latest available data and recently completed national GHG inventory for 2014-15. Based on the National GHG Inventory for 2014-15, the total GHG emissions of Pakistan add up to 405 MT CO2-equivalent. Five key GHG contributing sectors of the economy are energy, agriculture, industrial processes, land use and forestry, and waste [3].

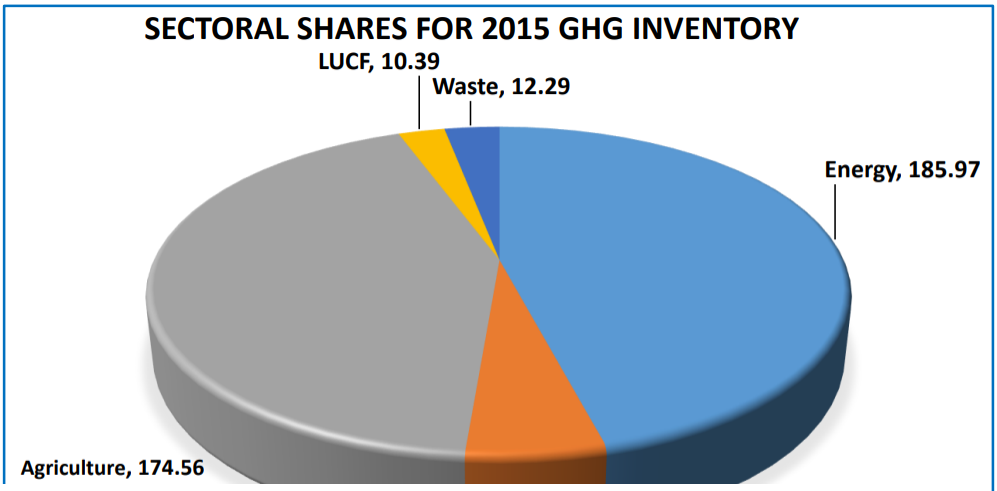

Figure 2: *Sectoral share for GHG inventory*

Though the historical trend of increase in emissions has so far been fairly consistent. However, with the priority of the government to eradicate energy crisis and harness economic dividend from the potential CPEC opportunities, the share of emissions from the industrial sector is expected to grow exponentially. Similarly, with the rapid increase in urbanization, the share of the waste sector is also expected to increase in the coming years. Future projections for the period 2015-30 show a steady increase in emissions due to expected

economic activity brought by large-scale investments in energy, communication and industrial infrastructure.

Projected levels of GHG emissions and their comparison with the last two GHG inventory years (1994 and 2015) are shown in Figure 3. Though from 1994 to 2015 the emissions increased by about 123 percent, the total emissions are expected to increase by about 300 percent for the projected period (2015-2030) [3].

Sector Wise Projection of Emissions (*MT CO2-equivalent)*

Sectors	1994	2015	2030
Energy	85.8	185.97	**898**
Industrial Process	13.29	21.85	**130**
Agriculture	71.63	174.56	**457**
Land-Use Change and Forestry	6.52	10.39	**29**
Waste	4.45	12.29	**89**
Total	**181.7**	**405.07**	**1603**

Figure 3: *Sector wise projected Emissions in MT CO2 equivalent*

Climate change profile of Pakistan and impacts on energy and health sectors

GHG emissions contribute to global warming and climate changes. Pakistan's vulnerability to adverse impacts of climate change is well established and widely recognized. Despite Pakistan's diminutive contribution to global GHG emissions, it is among the top ten most climate-affected countries of the world. Moreover, these adverse impacts of climate change are not in the distant future but are imminent. Pakistan has started suffering with ever-increasing frequency and ferocity of climate-induced catastrophes. Studies and assessments undertaken by the National Disaster Management Authority (NDMA) show that extreme climate events between 1994 and 2013 have resulted in an average annual economic loss of almost US dollars 4 billion. The last five floods (2010-2014) have resulted in monetary losses of over US$ 18 billion with 38.12 million people affected, 3.45 million houses damaged, and 10.63 million acres of crops destroyed. Likewise, over 1200 people lost their lives due to the unprecedented

heat wave in Karachi in 2015 [3]. Past observed trends and future projections of climate change are summarized in figure 4 [4].

Climate change has drastic effects on the economy and well-being of people. According to climate change profile of Pakistan, Projected Climate Change Implications for energy sector are alarming and include [4]:

1. Reduction in water availability for hydropower generation. The most likely impact of global warming is the recession of Himalayan glaciers that is the largest source of fresh water supply in the country, and this would very likely affect the country's power generation systems.
2. Extreme climate events damaging oil, gas, and power infrastructure. The other major likely impact on the energy sector is damage to oil and gas infrastructure due to heavy precipitation leading to flooding.
3. Hotter temperatures increase energy demand. Due to increase in air conditioning requirements particularly in summer, energy demand is expected to increase. Further, climate change induces higher temperatures, and evaporation will increase electricity needs for pumping water for agriculture irrigation.
4. Warmer air and water temperatures may affect efficiency of nuclear and thermal power plants. Increase in water temperatures used for cooling of nuclear and thermal power plants will affect the power plants' efficiency.

Apart from energy sector, climate change finds implications in health sector as well. Climate change has the potential to affect both environmental and social determinants of health including safe drinking water, clean air, enough food, and secure shelter. Climate change can impose detrimental effects on health and general wellbeing through extreme heat events, natural disasters, and variable rainfall patterns. Heat wave events are projected to increase both in frequency and duration. The heat wave of Karachi in June 2015 took more than 1,200 human lives in Karachi alone, and about 200 lives in other parts of the Sindh Province [5]. In Karachi, a maximum temperature of 44.8°C was recorded which is the second highest temperature after 1979. In Pakistan, heat waves are common in the pre-monsoon months (May–June) in the plains of the country. The variations in rainfall and temperature were correlated with the spread of different

infectious diseases and food security [4]. During the floods in 2010, in a preliminary study by UNDP, it was found that the proportion of population below the minimum level of dietary energy consumption increased by 3%, thereby adding an additional 5 million to the population of undernourished people [6]. Similarly, extreme events are correlated with the mental health of the affected population, i.e., extreme events generally cause depression, distress, aggression, etc. [4].

Climate change brings global warming and with the rise of temperature, the risk of water-borne and vector-borne diseases also increases. Higher numbers of dengue and malaria cases are due to changes in temperature and heavy precipitation, possibly resulting in the increased number of breeding sites for mosquitoes [7].

Mitigation potential of Pakistan

As explained in the Pak-INDC, several mitigation and adaptation measures and actions are already being undertaken with domestic resources. These measures and actions can be intensified in coming years with expected availability of international climate finance, technology development and transfer, and capacity building. Pakistan is on the verge of embarking on an unprecedented phase of economic growth and development with large-scale investments in high emissions sectors, providing an opportunity for realizing the obvious mitigation potential. The national government is committed to exploring all sources of energy to resolve the prevailing crisis. The sector also offers the most promising mitigation potential, which can be realized by making available required funding and technologies.

According to the INDC document, mitigation potential and options exist in both energy supply sector and energy demand sector. Mitigations options of high priority in energy supply sector include: Increase in grid efficiency, Improvement in coal efficiency, and large scale and distributed grid connected solar, wind and hydroelectricity. Mitigation Options of high priority in Energy demand Sector include: more efficient irrigation motors and pumps (electric), Replace incandescent bulbs with LEDs Efficient stoves, efficient water heaters, and Replacement of Boilers/ Furnaces. These mitigation options have the potential to reduce both the cost and GHG emissions of the energy sector.

Key Findings of Past Observed Trends of Climate Change Indicators and Future Projections for Pakistan

1. During the last century, Pakistan's average annual temperature increased by 0.57°C compared to 0.75°C for South Asia, and average annual precipitation increased by 25%. The warming is mainly due to increase in winter temperature.
2. Heat wave days per year increased by 31 days in the period 1980 to 2007. Cold waves decreased in northeastern and southern parts, and increased in western and northwestern parts of the country.
3. Observed sea level rise along the Karachi coast was 1.1 millimeters per year in the past century.
4. During 1960–2007, the following changes were noted:

- An increase of 0.6°C to 1.0°C in the mean temperature over the hyper arid plains, arid coastal areas, and mountains regions of Pakistan;
- A decrease of 10%–15% in winter and summer rainfall in the arid plains and coastal areas;
- A rise of 18%–32% in the summer rainfall over the core monsoon region of Pakistan;
- A decrease of 5% in relative humidity over Balochistan province;
- An increase of 0.5%–0.7% in solar radiation over the southern half of the country;
- A decrease of 3%–5% cloud cover over central parts of Pakistan, and a consequent increase of 0.9°C in temperature;
- The northern parts of the country outside monsoon region have suffered from expanding aridity;
- A decrease of 17% to 64% in rainfall observed during the seven strong El Niño events in the last 100 years;
- The minimum temperature in summer over central parts of Pakistan has shown a pronounced warming trend while in the extreme north and south have shown a slight cooling trend in some climatic zones; and
- The coastal belt in general and the Indus delta in particular have not shown any significant warming or cooling trends.

Future Projections

- Pakistan's projected temperature increase is expected to be higher than the global average.
- Projected temperature increase in northern parts is expected to be higher than the southern parts of the country.
- The frequency of hot days and hot nights is expected to increase significantly.
- Pakistan's rainfall projections do not indicate any systematic changing trends.
- Major crop yields such as of wheat and rice are expected to decrease significantly.
- Water availability per capita is projected to decrease to an alarming level.
- An increasing trend in the rainfall over the Upper Indus Basin and decreasing trend in the Lower Indus Basin.

Figure 4: *Past observed trends and future projections of climate change*

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Section 2: Support of Pakistan National Policies and potential impact on future energy mix

Climate change is being considered as developmental and environmental issue. The two key strategies that are adopted to tackle climate change are adaptation and mitigation. These two constituents must be mainstreamed into all developmental programs and policies as well as in funding decisions and allocation. In this regard, The Government of Pakistan has developed various policy drafts and passed the legislation bills to address climate change and challenges associated with it.

National Environmental Policy (2005):

The environmental policy overall goal is to protect, conserve and restore Pakistan's environment for the improvement of citizen's life quality by means of sustainable development. The policy document incorporated sectoral and cross-sectoral guidelines and laid it out for federal and provincial governments to address environmental concerns effectively and ensure environmental management of natural resources. The sectoral policy guidelines covered issues regarding water supply and management, air quality and noise, waste management, Forestry, biodiversity and protected areas, energy efficiency and renewable, agriculture and livestock and multilateral environmental agreements [1]. The NEP drafts also realized the climate change as an emerging environmental issue and its sixth unit of sectoral guidelines is dedicated exclusively to the climate change and ozone depletion. The direct and indirect measures to curb climate change in this policy are presented in the table 1.

Some of the noticeable achievements under sector 7 of climate change and ozone depletion is the formation of National climate change policy in 2012 and establishment of clean development mechanism authority. Apparently, some efforts have been made for the promotion of green technologies under CDM mechanism. According to ex-climate change Minister Mushaid Ullah Khan statement, most of the 75 CDM projects registered under CDM are renewable and clean energy projects which are in different implementation stages. Furthermore, collaboration with CDM regional collaboration

center in Bangkok has also been started in terms of capacity building and identification of potential CDM projects in Country [2].

Table 1: *Direct and Indirect measures associated with climate change mitigation in National Environment Policy 2005*

Direct Measures	1. Devise and implementation of National Climate Change policy and Action
	2. Establishment of National clean development mechanism authority
	3. Development and implement policy and operational framework for effective management of CDM process
	4. Promote the use of ozone friendly technologies
	5. Phase out the use of ozone depleting substances in line with the provision of Montreal protocol
Indirect Measures	1. Promote integrated watershed management
	2. Enact National clean air act
	3. Ensure enforcement of NEQs and reduction and control of harmful emissions through regulatory programs
	4. Regulate vehicular emissions
	5. Implementation of National forest policy
	6. Promotion of social, farm forestry and irrigated plantations, development of action plan for rehabilitation of mangrove forests
	7. Sustainable Management of riverine forests, preservation of unique forests eco system and conservation of protected areas
	8. Promotion of renewable forms of energy (hydro, wind, solar, biogas-etc.) at all levels, encourage the use of waste resources for energy production
	9. Development of strategies and programs to tackle desertification and drought

According to a report, functioning of CDM cell was also affected in the past due to devolution of Environment Ministry and its changing affiliation with different government institutions like with Enercon and later with Ministry of Climate change adversely affected its working capacity [3]. In addition, the absence of mechanism for the promotion and implementation of renewable energy technologies and failure to include the food security issue are some of the short comings of this policy with respect to the climate change.

National Climate Change Policy (2012):

The development of national climate change policy (NCCP) is a major initiative in responding to the vulnerabilities posed by the climate change. NCCP contains more than 120 policy measures covering various areas like vulnerable ecosystems, consideration of socioeconomic issues, capacity building, institutional strengthening etc. The main goal of this policy is to make Pakistan economic and social development more robust towards the effects posed by climate change by mainstreaming it into the vulnerable sectors of the country, thus we can say it is implemented within the framework of the sustainable development goals. The climate change policy has some ambitious objectives like sustainable economic growth, food security, water availability and adequate energy for the region. The policy also stresses on raising awareness, technology building, cross-ministries coordination, active engagement with international institutes, participation in international conferences and to avail any opportunity of international funding for the ease in implementation of adaptation measures. The NCCP document also highlight some critical climate change inducing factors that threatens Pakistan's water sector, food and energy security. Main climatic threats which are focused in this policy are extreme weather events, erratic rainfall patterns, glacial melting, siltation in water dams, low forest cover, vulnerability of mangroves forest, higher sea levels endangering coastal areas and intrusion of saline water in Indus delta. NCCP Policy has categorizes policy measures in to two main sets i.e. adaptation and mitigation bit it has mainly prioritize adaptation measures. Proposed adaptation measures are related to water resources, agriculture, livestock, human health, forestry, biodiversity and other vulnerable ecosystems. Moreover, adaptive measure under the sub category of water storage and infrastructure

has specifically emphasized on development of new hydroelectric dams and identification of new potential sites.

The mitigation section of the NCCP document has explicitly mentioned the energy sector to be the main source of GHG emissions. The mitigatory measures pertaining to this sector are as following;

- Development and promotion of hydropower generation, and its consideration on top priority
- Proper assessment of negative impacts on environment and local communities generated because of hydro power projects
- Promotion and development of renewable energy resources and technologies such as solar, wind, bioenergy and geothermal
- Encourage the incorporation of solar photovoltaic technology in building designs to make them self-sufficient in energy
- Expansion of nuclear power while ensuring highest safety standards
- Exploring the possibilities of clean coal technologies and their transfer for installation in Thar coal reserves.
- Ensure that new coal fired plants works at high efficiency level and can easily be modified to install carbon capture and storage technologies
- Install waste to energy plants for power generation
- Carbon tax on fossil fuels
- To prioritize liquified natural gas (LNG), Liquefied petroleum gas (LPG) import over oil and coal import.

In addition, mitigation measures are also proposed for other sectors like agriculture, livestock and forestry. All in All, NCCP is a very comprehensive document that effectively encapsulates the all key aspects required to tackle climate change ranging from sectoral adaptation and mitigation measures to strengthening of institutions. However, some concerns are being reported about the policy. Despite of the fact that objectives and goals are stated clearly, it seems hard to evaluate them especially by means of quantitative assessment tools [4]. In addition, the utilization of coal reserves has been encouraged in the policy draft and it is also reflected same from the INDC's which is not viable in the

longer run (discussed in Section 2 of this report). Furthermore, after the devolution of this subject to the provincial governments, its implementation mechanism has been affected and got slow in process. The National Climate Change Policy Implementation Committee (NCCPIC) failed to take solid steps to influence the provinces, ministries and divisions in making medium or long-term plans for adaptation measures to tackle with climate change issues under the NCCP [5]. So main challenge that hampers the implementation and execution of NCCP is conflicting or overlapping objectives, priorities and responsibilities between provinces and federal agencies. Also, there is need to improve the data on climate change in Pakistan. access to information is another challenge that is faced by this policy [6]. In a nutshell, ex-government has been failed to translate this policy into concrete actions even though several environmental issues had been highlighted during that tenure.

National Power Policy (2013):

National power policy was formulated in 2013 to address the long-standing issues related to subsidies, unsustainable electricity and hue gap between demand and supply. The vision of the policy was “Pakistan will develop the most efficient and consumer centric power generation, transmission and distribution that meets the needs of its population and boosts its economy in a sustainable and affordable manner” [7]. The policy envisages to improve existing generation capacity to meet the energy needs in a sustainable manner; to promote a culture of energy conservation and responsibility; dependence on more indigenous resources such as coal and hydel; improving efficiency in the power supply chain and enhancing the governance through better co-ordination at federal and provincial levels. To improve energy supply, the 2013 power policy stresses on generation of affordable electricity by using local coal resources such as Thar coal (Goal 3) and run of the river projects. NPP has also highlighted the development of coastal energy corridors based on imported coal, rapid propagation of coal mining especially at Thar and conversion of expensive RFO plants to coal. One of the rationales was that power generation from coal fired plants would not be costly as compared to oil-based generation and easy availability of coal in international market. In addition, this policy also underscores on building medium and long-term hydel capacity in the country.

It is quite evident that NPP is coal oriented policy and it is keen on producing electricity using the imported and domestic coal reserves. Therefore, we have seen that coal projects in the recent years have materialized much earlier completely overlooking the important factor environmental impacts and it will lead to high greenhouse gases emissions. With the advent of this policy, few projects proposals that were started in overzealous way like Gaddani power project was later had to be terminated because of the transmission system augmentation, land acquisition environmental impacts and coal transportation issues [8]. When it comes to implementation of this policy it has faced several setbacks, for example the initiative for conversion of existing furnace oil fired power plants did not achieve any success. According to the study performed by (H. Ishaque) using leap tool, coal based powerplants in Pakistan will become the biggest emitters of greenhouse gases emissions by year 2035 [9]. However, by switching to renewables these emissions will decrease at rapid pace as compare to business as usual scenario. Solving the energy crisis in a resource constrained economy urged us to construct thermal power plants because they have smaller gestation periods and required low investments. Also, it seems plausible in the short run. However, in the long run, renewable energy resources in Pakistan have the potential to become economically viable not only in terms of generation cost due to fuel savings but also in terms of GHG emissions.

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Section 3: CPEC Coal Power Projects and their environmental implications

Harnessing energy from indigenous renewable energy resources and conventional fuel resources (i.e. Coal) is made to be an integral objective of CPEC project. A lion's share of CPEC investment that is approximately $33 billion is to be invested in power generation sector to overcome the energy shortfall of 4,500 MW. This will eventually address the critical energy shortages in Pakistan and will flourish the country's economy growth. The construction of energy projects is to be carried out by private independent Power producers (IPP) rather than the governments of China and Pakistan. Finance of these investments will come mainly from China Development Bank (CDB), Industrial and Commercial Bank of China (ICBC), Asian Infrastructure Investment Bank (AIIB) and Silk Road bank. As Beijing claimed, financial investment in these projects will not lead to any new debt on Pakistani government. If the CPEC plan undergo smooth sailing, 21 new projects will produce around 17,000 MW of energy and will twofold the Pakistan's installed capacity. Out of total twenty-one CPEC energy projects, it is expected that 14 "early harvest" prioritized projects will add 10,400 MW to the national grid by early 2019.

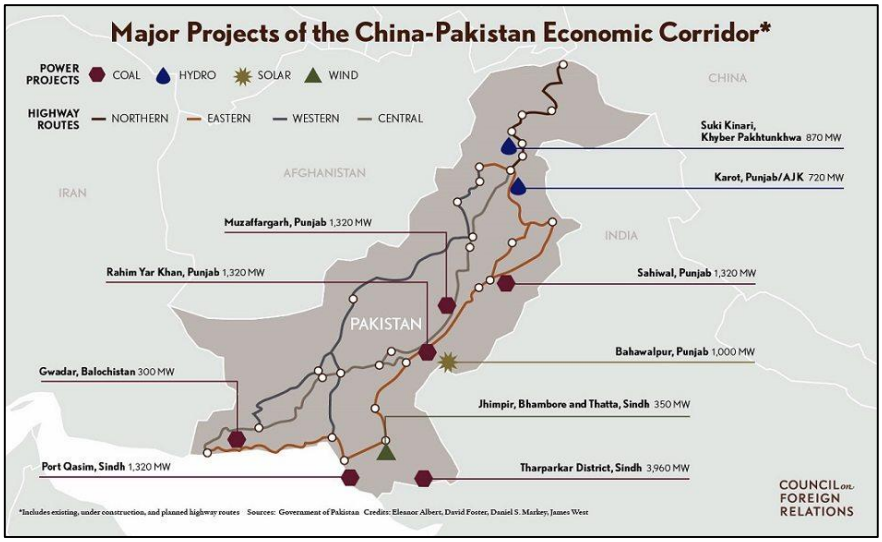

Figure 5: ***Major CPEC energy Projects [1]***

Pakistan current energy mix is mainly dominated by natural gas and imported furnace oil followed by hydropower. Aggregate energy contribution from Furnace oil and natural gas in energy supply mix is around 65% and 31.5% is from hydropower followed by Nuclear 3% and renewables (wind, solar) 0.5% [2]. Exorbitant cost of imported fuel and Pakistan's increased dependence on it had greatly hemorrhaged its economic growth. According to a source almost half of Pakistan's annual income of $12 billion was spent on imported fuel [3]. Therefore, under the umbrella of CPEC country's current energy mix will be projected to modification as CPEC aims to tap the indigenous energy resources including Coal.

The share of coal was trivial over the last few decades and the main reason was high dependence on the Arab crude oil. Pakistan has the largest reserves of the lignite coal in Thar, but it has been untapped since 1990s which clearly indicated the reason behind the lowest share of coal in energy mix as compare to other countries. In the recent era many industrial units like textile mills, small steel enterprises and urea plants have incorporated coal gasification technology and coal-based oil heaters to fulfill the energy demand. Furthermore, cement sector and brick kilns sectors are the highest consumers of local and imported coal consuming about 4.7 million tons and 3 million tons respectively [4]. Traditional Brick kilns utilizes coal under highly energy inefficient conditions which lead to the consequences of air pollution as black smoke, particulate matter and carbon dioxide is discharged into atmosphere. In addition, brick kilns also degrade the soil fertility causing fertile soil degradation and biodiversity loss. The need of the hour is to adopt the efficient measures for making this sector more climate friendly and efforts should be made to convert the conventional brick kilns into "environmentally friendly zig zag brick kilns". Emphasis should be made on assessing the economic viability of smart brick kiln technologies like Bull's trench kilns (BTK), modified Bull's trench kilns, Vertical shaft Brick kiln, Hoffman kiln as these economizes the fuel consumption and greatly reduces the air pollution. CPEC prioritized in adding the bulk of coals fired plants for the improvement of Pakistan's energy system. These plants will have cumulative capacity of 6,900 MW with the total worth of $5.8 billion and they are to be completed by December 2020. The detail description of these coal-based power plants is provided in Table 1.

Table 2: *Details of Coal fired Power Plants under CPEC Project [5]*

Sr No	Project Name	Energy Input	Capacity (MW)	Estimated Cost (USD Million)	Technology	Status
1.	2x 660 MW Coal based Power plants at Port Qasim Karachi	Coal (Imported)	1320	1912.2	Super-Critical	Operational
2.	Sahiwal 2x660 MW Coal fired Power Plant, Punjab	Coal (Imported)	1320	191.2	Super-Critical	Operational
3.	Engro Thar Block II 2x330 MW Coal Fired powerplant Tel 1x330 Mine Mouth Lignite Fired Power Project at Thar Block II ThalNova 1x330 MW Mine Mouth Lignite Fired Power Project at Thar Block II, Sindh, Pakistan	Coal (Local)	660 330 330	2000	Sub-Critical	Construction work in progress
4.	SSRL Thar Coal Block-I 6.8 Mtpa	Coal (Local)	1320	2000 + 1,300	Sub-Critical	Expected Commercial

	& SEC Mine Mouth Power Plant (2x660MW)					operation date 2018/2019
5.	CPHGC 1,320 MW Coal-Fired Power Plant, Hub, Baluchistan	Coal (Imported)	1320	1912.2	Super Critical	Expected Commercial operation date Dec 2018/ Aug 2019
6.	330 MW Imported coal-based power project at Gwadar, Pakistan	Coal (Imported)	300	Yet to be determined	Sub-Critical	NEPRA's Tariff determination is in process
7.	Surface Mine in Block II of Thal Coal Field, 3.8 Million tons/year	N/A	-	1,470	Open Pit Mining	Mining work in Progress
8.	Thar Mine Mouth Oracle Power Plant (1320MW) and surface mine	-	1320	Yet to be determined	-	Shareholding agreement on new equity partners in process

Overview of the Technologies Involved in CPEC Coal fired power Plants

Pulverized Coal Combustion is the widely known technology that is employed in coal-fired power plants worldwide. It utilizes coal that is crushed into a fine powder (about 70% of the coal is typically sized less than 75 μm) and is introduced into the burners with pressurized air. This technology is primarily involved in improving thermal efficiencies by raising the range of steam properties like pressure and temperature. It is further divided into 3 categories depending upon the pressure and temperature of steam.

1. Super Critical Steam plant technology
2. Ultra-Super Critical Steam plant technology
3. Sub-Critical Steam Plant technology.

The first two technologies come under the category of efficient Coal Power technologies. These technologies for low emissions of greenhouse gases can somewhat resolve tensions between environmental impact on local population and reliance on coal-energy generation. So far, these technologies are considered favorable for accomplishing the goal of meeting energy demands through coal utilization but in an “innocuous and cleaner way”.

a) Super Critical Steam Plant Technology:

This technology is considered as preferable choice for most new coal- fired power plants as it provides greater efficiency than old sub-critical plants thereby leading to low emissions i.e. NOx, SOx and particulate emissions. “Supercritical” is a thermodynamic expression relating the state of a substance where there is no clear difference between the liquid and the gaseous state (i.e. they are a homogenous fluid). Water reaches this state at a pressure above 22.1 MPa. In this technology development of various steel alloys is required that can tolerate high temperatures (580 degree centigrade), corrosion and pressures (23 MPa). Super Critical Steam plant technology is mature and reliable form of technology that can greatly enhanced the thermal efficiency up to 42%. Highly efficient coal power plant has the potential to generate lower price per unit of electricity [6]. Coal Consumption is

also inversely proportional to efficiency, highly efficient plants consume less coal as compare to Sub-critical technology.

b) Ultra-Super Critical Steam Plant Technology:

Ultra-Super Critical power plants are run at higher steam temperature (above 593-621 degree centigrade) and pressure (28.4 MPa). New materials that can withstand high temperatures are used in boilers. High temperature means greater efficiency, high energy but low consumption. By comparison, ultra-supercritical Power plants can convert up to 45% of energy of coal to electricity.

Advanced ultra-supercritical coal technology is expected to convert over 50% of the gross energy of coal to electricity, but the costly alloys required to withstand the very high temperature requirements do not make the plant financially viable. Before advanced ultra-supercritical technology can be deployed in plant, new design changes like this definitely require to be tested and evaluated at a pilot level [7].

c) Sub-Critical Coal Plant Technology:

Sub-Critical Coal Plant Technology constitutes of conventional coal plants that have a thermal efficiency range between 32%-37%. In Sub-Critical Coal Plant Technology boilers are operated below the critical pressure and temperature of water. These types of boilers have an operational pressure limit up to 19MPa [8].

Table 3: *Comparison of the sub, super and ultra-super critical technologies*

Parameters	Sub-Critical	Super-Critical	Ultra-Supercritical
Pressure (kg/cm^2)	< 225	250-270	>270
Temperature (^0C)	540-565	565-600	>600
Efficiency (%)	35-38	42-47	48-55

Will an abundance of Coal fired Power Plants under CPEC project is a viable option in a longer run?

Although CPEC project is responsible for burgeoning economic growth and energy sector development by commissioning and executing the various nature of energy projects, but still it is hard to ignore that responsibility of deliver massive energy supply is on the shoulders of coal generation power plants. Coal is expected to make up 69% of added capacity. Therefore, these projects materialize much earlier than a normal gestation period of coal project occurring anywhere in the world. The ground reality is that most of coal fired plants are dependent on the imported coal from Indonesia unless Thar coal reserves undergo full exploitation and made coal readily available for the energy input to these plants. Coming towards the technologies that are incorporated in these plants, only 3 projects i.e. CPHGC 1,320 MW Coal-Fired Power Plant in Baluchistan, 2x 660 MW Coal based Power plants at Port Qasim Karachi Hub and Sahiwal 2x660 MW Coal fired Power Plant in Punjab is using the super-critical coal technology (Table 1). Super Critical coal technology is already termed as efficient technology as it utilizes less amount of coal. Remaining power projects operation will be just like any other traditional coal power plant resulting in increased emissions and high consumption of coal.

Ironically, while supporting the development of coal fired plants in Pakistan, China itself is liquidating and cancelling the coal projects at home to tackle the problem of air pollution. For example, in January 2017 China has ceased its plans for developing 103 new coal power plants of net value of $62 billion in eleven provinces eventually rejecting at least 120 GW of country's future coal-fired capacity [9]. The Environmental Protection Ministry has banned the use of coal in 28 cities, including heavily polluted regions like Beijing and Tianjin. Executing Beijing's clean plan, the last coal-fired power station of 845MW capacity had terminated its operations in last year, while three other coal-based power plants were shut down in the years 2014 and 2015. Currently, Beijing has 27 power plants, all clean and renewable energy, with total installed capacity of 11,300MW.

Paradoxically, China does not strict apply its stern standards to the market abroad. China is building or planning to develop more than 100 new coal-fired power generation plants in as many as 21 countries, overlooking the grave concerns of smog and climate change.

Besides Pakistan, these coal-based power plants are being constructed in Bangladesh, Indonesia, Vietnam, and the African countries. In addition, plant machinery for the construction of various coal projects at different stages is readily available because of cancellation of enormous orders in China. Therefore, technology and machinery are directed towards the foreign market, despite being an obsolete in nature.

The plants being installed in Pakistan are of the modules 330/300MW and 660/600MW, which are no more being established in the developing countries. For many years, a module of 1,000MW coal-fired power plant is globally considered technically viable and economically feasible, under the current conditions. Incongruously China itself plans in the years to come to replace the old-technology based coal-fired power generation capacity with ultra-supercritical technology that it has already mastered, having acquired it in the late 1990s. Another quite interest fact is that all large-capacity coal-based power plants in China have incorporated the ultra-supercritical steam generating units. The Zouxian power plant of 4,400MW combined capacity in Shandong province operates two ultra-supercritical units of 1,000MW each since 2006-2007. The Shanghai Waigaoqiao coal-fired power plant of total 5,000MW capacity had commissioned two ultra-supercritical units of 1,000MW each in 2008.

Despite of the claims given by the both countries, only a few powerplants have state of the art “super critical Technology” and other plants are much relying on “sub-critical technology”. All Thar based coal projects will be employed with above mentioned technology (Sub-critical) same in the case of Gwadar Coal Project. Sub-Critical technology means low efficiency and high emissions, leading to adverse environmental impact and impact on human health. To thwart these emissions, Carbon capture and storage technology (CCS) will be highly ill-suited for these coal fired power plants. This is attributed to the fact that energy input in these plants is Thar lignite coal which is low quality coal having high sulfur content. For CCS technology to be highly efficient only advanced quality of coal must be used as energy input which in this case is highly impracticable. Presently it is not an economic viable option because of high cost of carbon capture together with transport and storage costs. Even if power plants can use the technique of Flue gas desulfurization (FGD) and electrostatic precipitator to eradicate

sulfur from the flue gas and particulate matter, some emissions are unavoidable. These sulfur dioxide emissions will contribute to acid rain formation, smog formation and health issues like respiratory illness. Moreover, to dig Thar coal fields water is pumped out of the land exhausting the underground water to dangerous levels hence disturbing natural aquifers and water tables.

Energy sector in Pakistan is recognized to be on top position that contributes to total greenhouse emissions of the country. It is quite evident that in future these bulk coals fired plants will increase the GHG emissions substantially. Despite the claims provided by the supporters of Coal power projects that deploying super critical technology won't affect the environment as it will have low emissions, but these emissions still have a potential to impact the environment. Besides, ash handling and its disposal will also worsen the negative impacts on environment. The chances of occurring extreme climatic events like changing precipitation patterns, droughts, glacial melting and extreme heat waves etc. would be much higher in future. These coal projects, when operational will have a life expectancy that can stretch over decades hence they will trap the energy mix of Pakistan in a system of carbon-intensive use. In addition to these negative environmental impacts, power generations from coal fired plants will also lead to the issue of water quality. This debacle is also on the end of Provincial EPAs as they are utterly failed in sharing the Environmental Impact assessment (EIA) or Strategic environmental assessment (SEA) report with the public. Hence it raises concerns among the environmentalists that either they have performed these assessments in actual or just rubber-stamped these coal power projects. In a nutshell, there is going to be a significant mismatch between Pakistan's current domestic energy realities and the NDCs submitted towards the Paris Agreement that proposed the mitigatory measures towards reduction of emissions. This significant new coal expansion under the umbrella of CPEC in Pakistan future energy mix will put the strength of its INDC in doubt.

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Section 4: Taping the Indigenous Renewable energy Resources, The Wave of the Future

Fuel consumption trends for Pakistan reflects the configuration of energy mix dominated increasingly by dirty fuels (oil, coal), and gas. Modern energy supply must be based on goal 7 of Sustainable development which is “Ensure access to affordable, reliable and sustainable and modern energy for all” [1]. It will deliver not only the benefit of energy security but also strengthen the Pakistan climate pledge in the perspective of global climate cooperation. Renewable energy solely can accomplish these criteria. Utilization of these resources will have a minuscule impact on global warming and insignificant effects on air pollution. Furthermore, these harnessing these resources will incur no fuel cost in contrast to fossil fuels and nuclear energy. Besides, the indigenous nature of renewable technologies made them quite eligible to be cost effective without incurring high costs for the extension and maintenance of the power transmission grid. Pakistan’s power transmission and distribution system is not only terribly inept but also it does not cover the geographical area. Small and medium sized wind power, small hydropower, and solar power projects can easily meet the local demand without inducing much pressure on the grid.

In the light of this, resources that are present in abundance in Pakistan are Solar, wind, hydro and biomass. Their substantial potential will provide solutions to overcome the long-term energy shortage issue but in an environmentally friendly way. Cognizant of this fact, Pakistan and China has incorporated some wind, hydro and solar projects in energy sector development scheme to shift Pakistan’s energy system towards the sustainable and clean source of energy.

Solar energy Potential in Pakistan:

The most tantalizing aspect of solar energy is its abundancy. The total solar energy intercepted by the earth is 1.75×10^{17}W or an annual total of 5.52×10^{24}J. it is a reliable source that has the capacity of producing substantial energy with creating adverse impact on environment. Pakistan with a land area of 796,096 km^2 is located between longitudes

62° and 75° east and latitudes 24° and 37° north. Its location is ideal to take benefit from solar energy boom. According to Energy Information Administration (EIA) daily solar energy potential for Pakistan is 5.3 KWh/m^2 (1.93 MWh/m^2 annually). This unique geographical position and climate conditions is advantageous for the exploitation of solar energy. Figure 2 illustrates the annual solar radiation map of Pakistan [2].

According to available statistics, the south-western province of Baluchistan receives the

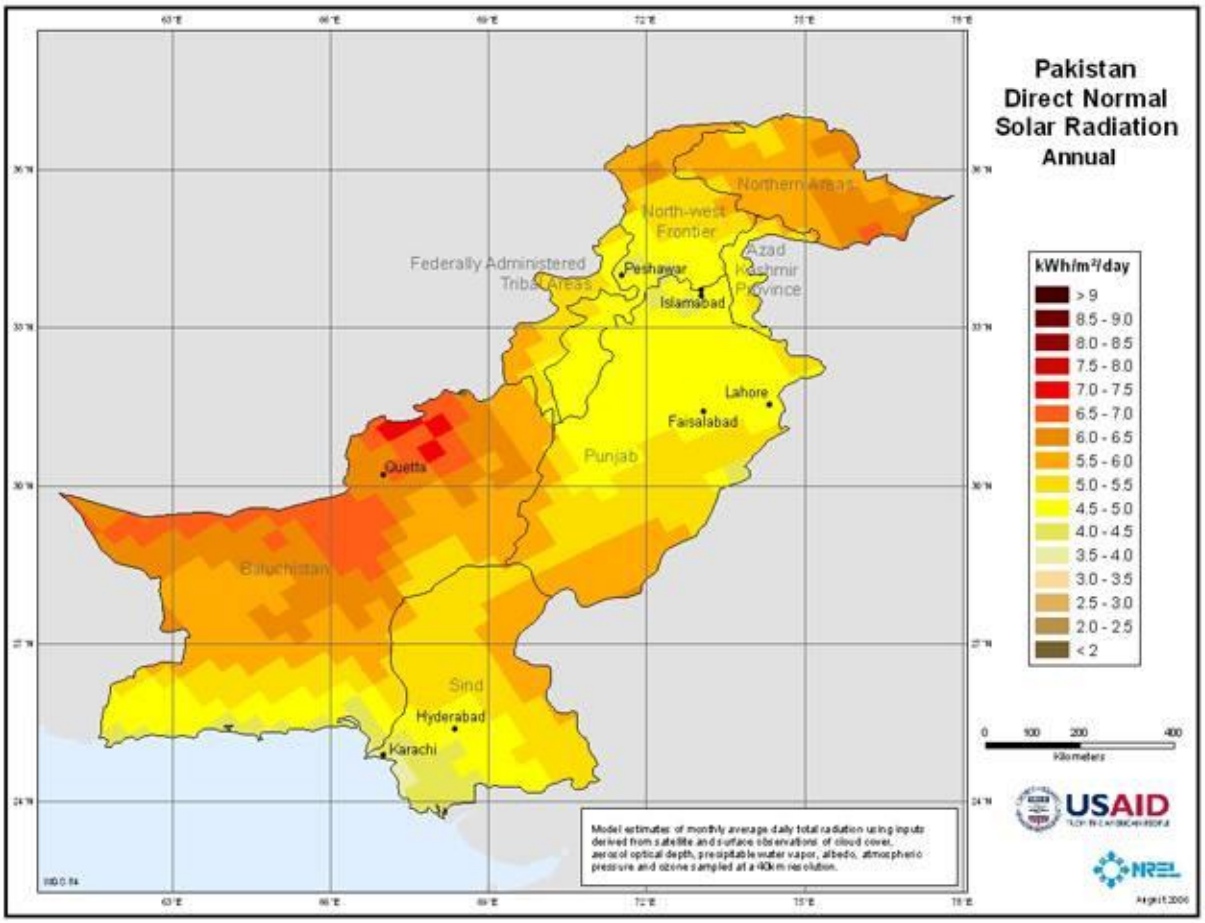

Figure 6: ***Pakistan Direct annual normal solar radiation***

largest portion of solar energy with an average daily global insulation of 19–20 MJ/m2 a day with annual mean sunshine duration of 8-8.5hrs. These conditions are well- suited for Photovoltaic and other solar energy applications to produce electricity particularly for off-grid localities in western and southern deserts [3]. In the rural and far off remote areas, access to electricity is considered as on top priority as compare to other solar thermal heating technologies. Therefore, the use utilization of photovoltaic technology will play a

vital role in decentralizing the electricity generation as well removing the needs for transmission and distribution. AEDB in this regard has started another program to provide solar power electricity for the development of rural areas. In the first phase, solar systems are planned to be set up in 100 and 400 villages of Sindh and Baluchistan respectively. In Sindh, 3000 solar home systems have already been installed [4].

In addition, the 178 MW solar PV plants at Pakistan Engineering Council (PEC) and Planning Commission are the only on-grid solar pilot plants in the country. Pakistan Council of Renewable Energy (PCRET) have installed thirteen solar panels of total capacity 26.5KW which is providing electricity to 124 community centers, schools and houses. PCRET have specially manufactured three thousand solar lanterns to supply electricity to rural areas.

Solar Project under CPEC:

For the development of energy sector CPEC has made effort to harness the solar energy source of country by establishing the Quaid e Azam Solar power park. The project was constructed in Bahawalpur as Pakistan's first utility-scale, grid-connected solar photovoltaic plant. It is only large-scale solar power generation project in Pakistan with capacity of 100MWp in first phase, 300 MWp in second phase and additional 600MWp in third phase. The estimated cost of this project is about 1,302 US $ Million. The project has started its operation in 2015 and has been under the supervision of Alternate energy development board and Punjab Power development board (PPDB) [3]. Despite being a great source of providing clean and green energy, this project is subjected to great ridicule as the cost per unit of electricity coming from this project is too high thus raises concerns of its affordability and lower power output. Despite all the negatives, experts are sure that as energy storage technology advances and economies of scale kick in, the costs will get lower and eventually solar power will have the lower tariff.

Wind energy Potential in Pakistan:

Pakistan is fortunate to have something many other countries do not, that is high speed of wind near major centers. Pakistan has perfect wind corridor in Karachi, Islamabad and Thatta region. Near Islamabad, the wind speed is anywhere from 6.2 to 7.4 meters per second (between 13.8 and 16.5 mph). Near Karachi, the range is between 6.2 and 6.9 (between 13.8 and 15.4 miles per mph) [5]. Figure 3 illustrates the complete wind map of Pakistan wind corridors [6]. In only Sindh and Baluchistan provinces, ample wind energy exists for provision of electricity to every coastal village in the country.

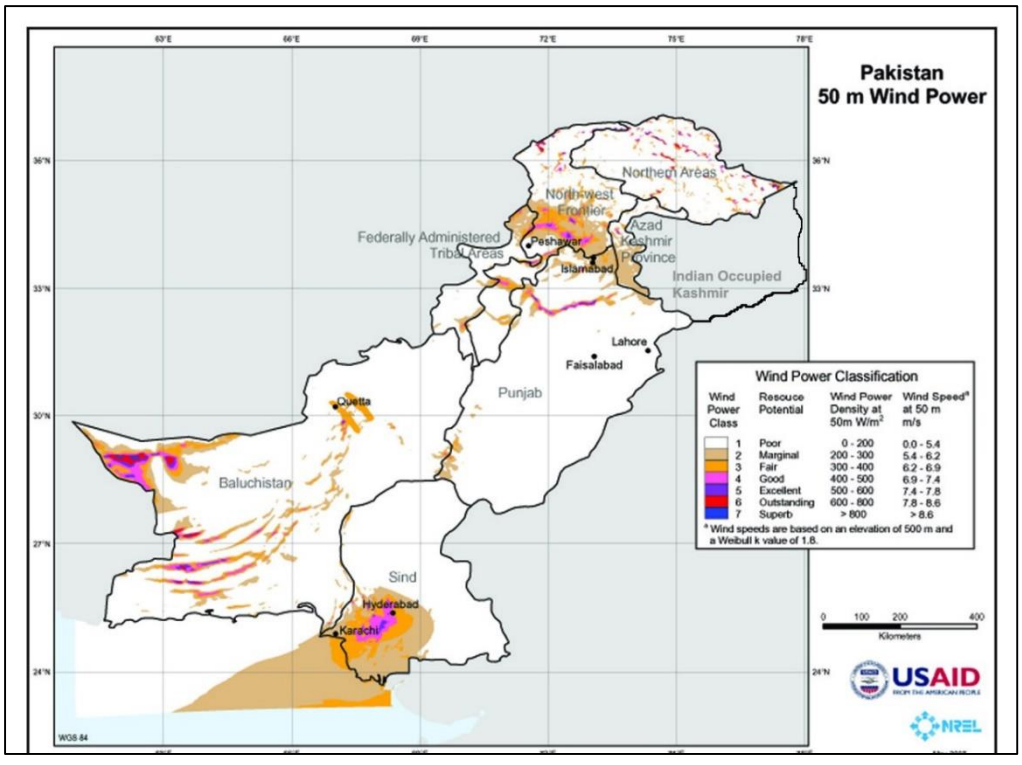

Figure 7: *Wind Map depicting wind corridors of Pakistan [14]*

In the past Pakistan Meteorological Department (PMD) had work together with National renewable energy Laboratories (NREL), USA to perform the wind speed survey of 46 different locations in Baluchistan and Sindh province with height ranging from 10-30m. The data attained from this assessment was analyzed by Alternate energy development Board (AEDB) and it was discovered that Gharo-Corridor in Sindh has a huge wind potential or producing 50,000 MW of electricity. But only 25% area can be utilized to harness this source as other economic activities are also taking place in the same region [3].

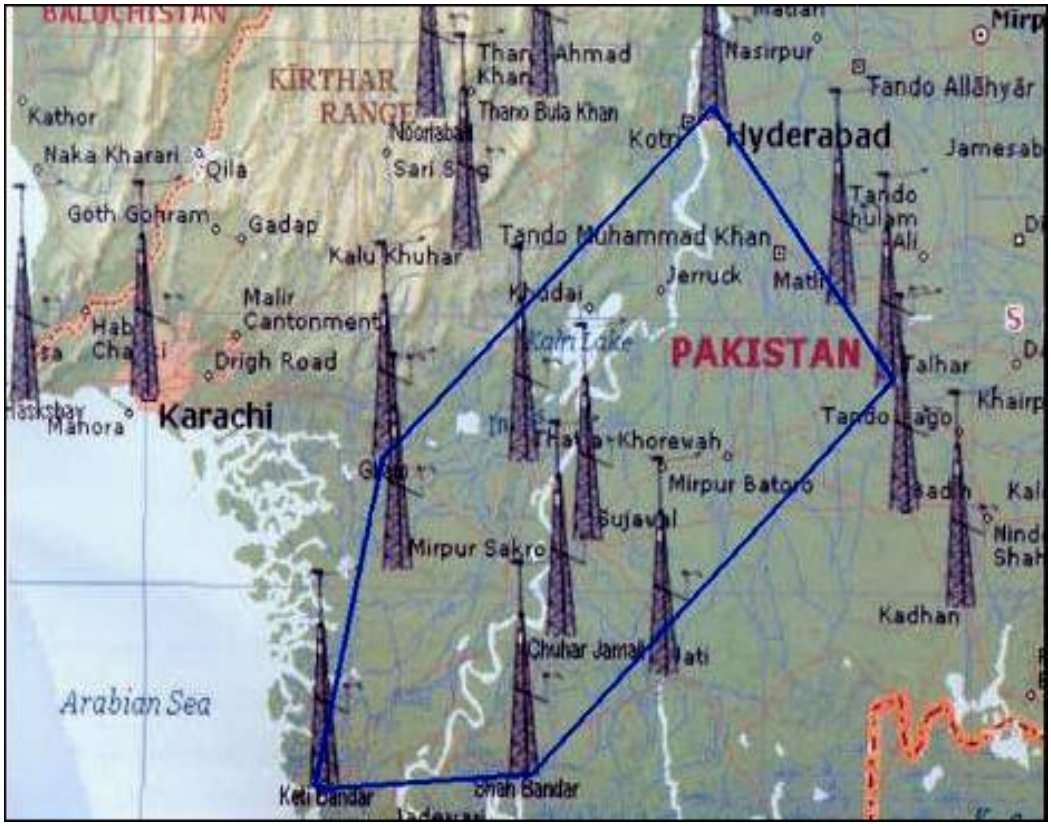

Figure 8: *PMD assessment of wind potential in "Gharo-Corridor", Sindh [5]*

Wind Projects Under CPEC:

Four Wind energy Projects under CPEC early harvest projects scheme is included for promotion of green energy in Pakistan. Three wind power projects Dawood wind farm in Bhambore, UEP wind Farm, J and Sachal wind farm in Jhimpir are already operational providing total energy of 200MW to the grid (Details are in table 3). The construction of wind power project has been touted as a major achievement of the CPEC and the larger One Belt One Road (OBOR) initiative The Jhimpir wind farm has been developed by Sachal Energy Development and financed wholly from the Industrial and Commercial Bank of China. This company will provide electricity to grid over the course of 20 years [7].

Hydro Power Potential in Pakistan:

There is a significant hydro power potential present in Pakistan. The total Hydropower resource in Pakistan is estimated about 50,000 MW. Most of the resources are present in Northern region of the country, which offers sites for large scale (100 MW to 7,000 MW) power projects (Figure 5). Smaller (< 50 MW) sites are available throughout the country. Out of estimated power generation only 16% i.e. 6758 MW has been exploited so far. The potential sources of hydroelectric generation are at the river Indus, Jhelum and Chitral. In addition, canal system with total of 58,450 km watercourses, farm channels and field ditchers running another 160,000 km in length has a huge potential to provide energy at numerous sites/locations.

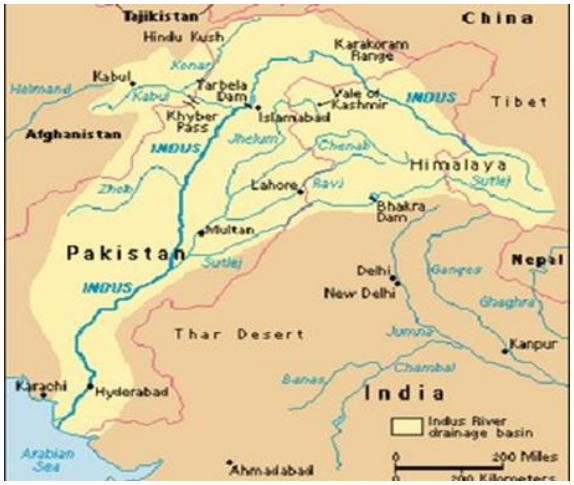

Figure 9: *Hydel Map of Pakistan [9]*

These sites can install 1 MW to more than 10 MW hydro plants [8]. Figure 5 illustrates the hydro power potential based on available basins, rivers and small hydel sites present in the country.

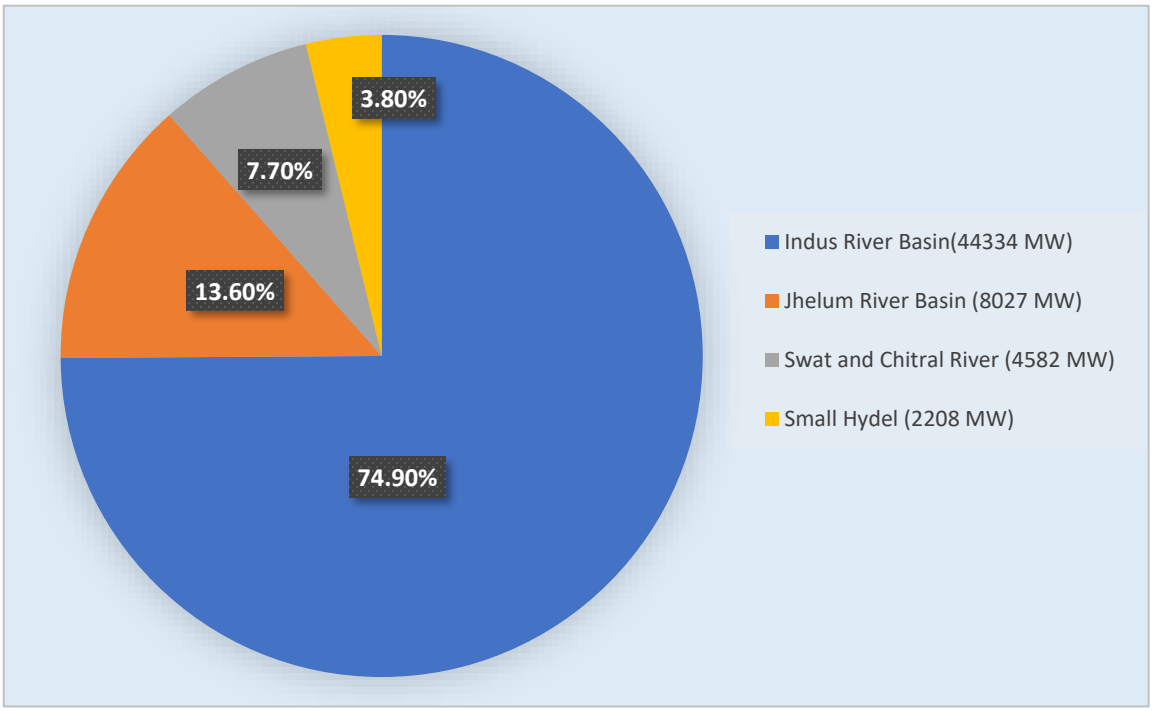

Figure 10: *Hydropower potential Distribution in Pakistan [10]*

Besides having potential of construction of mega hydroelectric power projects, Pakistan can also exploit its resources for the construction of 'Run-of-river' hydropower plants in KPK and AJK. Run-of-the-river hydel projects hold great potential to diversify energy mix of Pakistan in favor of cheaper hydro power in the country. In this regard, Neelam-Jhelum

Hydroelectric Plant has been under construction near Muzaffarabad. The project estimated cost is 4.5$ US billion and has an installed capacity of 969 MW. This powerplant

Sr. No.	Province	No. of Potential Sites	Potential Range (MW)	Total Potential (MW)	Remarks
1.	KPK	125	0.2-32	750	Small/ Micro Based on Natural Falls/Flow
2.	Punjab	300	0.2-40	560	Canals
3.	Gilgit-Baltistan	200	0.1-38	1300	Natural Falls
4.	Sindh	150	5-40	120	Canal Falls
5.	AJK	40	0.2-40	280	Natural Falls

is designed to divert water from the Neelam River to a powerhouse on the Jhelum River. In addition, there are definite prospects of establishing mini and micro hydro power. Small hydro power plants are considered as one as the lucrative option for power generation and also to accomplish the goal of improved energy access. The sector has been mainly handled by the provincial governments. At present 128 MW is operational in the country; 877 MW is under implementation and around 1500 MW is available for development.

Table 3 showed the potential of these hydro projects in 4 provinces of Pakistan [11].

Table 4: *Potential of Small-Micro Hydro plants in Pakistan [11*]

Hydroelectric Projects under CPEC:

CPEC has also placed Hydro projects on the forefront. It has also encouraged Pakistani government to complete the current Hydropower Projects. In the light of this, Three Gorges Corporation (TGC) has taken the responsibility of constructing three main hydro power projects comprised of Karot hydro project (720 MW), Mahl (590 MW) and Kohala (1100 MW). In Mansehra region of KPK, Suki Kinari hydro power plant with total capacity 870MW worth US $1802 Million is also an integral part CPEC energy sector development program. The Karot and Suki Kinari are expected to be operational in 2020.Kohala and

Mahl Hydro project will be completed in 2022-2023 [12]. Table 4 present the details of renewable energy projects under CPEC.

Table 5: *CPEC Renewable Power Projects*

Category: Priority					
Sr. No	Name of Project	Province	Capacity	Estimated Cost US $ M	Status
1.	Quaid-e-Azam solar park, Bahawalpur	Punjab	1000	1350	COD of 3 x 100 MW attained in August 2016.
2.	Dawood wind farm, Bhambore	Sindh	50	125	Operational
3.	UEP wind Farm, Jhimpir	Sindh	100	250	Operational
4.	Sachal wind farm, Jhimpir	Sindh	50	134	Operational
5.	Suki Kinari Hydro Power Station	KPK	870	1802	Construction work under way Expected Commercial Operation Date (COD): December 2021
6.	Karot Hydropower Station	AJK & Punjab	720	1420	Construction of access road/bridge, concrete batching plant, diversion tunnel and spillway, etc. are in process Operation Date (COD): December 2021
Category: Actively Promoted					
1.	Kohala Hydel Project	AJK	1100	2355	Land Acquisition process started
2.	Cacho Wind Power Project	Sindh	50	-	LOI stage

Biomass Energy Potential in Pakistan:

The potential to harness energy from biomass resources is very promising in Pakistan. Being an agricultural economy, more than 60% of country's population is involved in agricultural activities in the country. As per World Bank statistics, around 26,280,000 hectares of land is under cultivation in Pakistan. Broadly, Biomass is categorized in to four major groups i.e. Agricultural wastes (crop residues), Livestock waste (animal manure) municipal solid wastes and forest residue [13]. Technically these products can be converted into various energy products by means of biochemical and thermochemical methods. Solid wastes in Pakistan amount to 50,000 per day, agricultural residue 225,000 per day and approx. 1 million tons per day of animal manure.

- **Agricultural Residue:**

An agricultural residue is a by-product from harvesting and processing crops like wheat straw, rice straw, rice husk, bagasse, cane trash and cotton straw. Pakistan is also fourth main produce of sugar from sugar cane and generates bagasse and cane trash as a waste from sugar mills. During the year 2010-11, around 63,920,000 metric tons of sugarcane was grown in Pakistan which caused waste generation of around 5,752,800 metric tons. As per conservation estimates, the bioenergy potential of cane trash is around 9,475 GWh per year [13]. Bagasse has the highest potential as fuel for cogeneration plants at the existing sugar mills. Bagasse contains the highest potential as fuel for cogeneration plants at the existing sugar. The new high-pressure cogeneration plants at the country's 84 sugar mills could have a combined power capacity output of 1,844MW based on bagasse of about 17.1m tones a year generated by these mills. Moreover, Cotton is another major cash crop in Pakistan and is grown on around 11% of the total cropped area in the country. The major residue from cotton crop is cotton sticks which is the left-over material after cotton picking and comprised 3 times of the cotton produced. The production of cotton sticks during 2010-2011 was approximately 1,474,693 metric tons which is equivalent to power generation potential of around 3,071 GWh [14].

Forest residue consists of small branches. Tress, tops and unused wood left after the cutting of tress. People in Northern areas specifically used forest wood for burning wood stoves and for space heating purposes. This is a traditional use of biomass resource which is not sustainable in nature. Hence, People should be discouraged on utilizing this form of waste instead they should be facilitated in getting access to clean fuel like biogas.

Figure 11: *Agricultural residues in Pakistan*

Figure 12: *Forest Residues in Pakistan*

- **Animal Manure:**

Animal manure is used as energy source for burning or cooking purpose. It has high organic matter content and can be biochemically processed to produce the clean fuel known as biogas. The cattle and dairy population are around 67,294,000 while the animal manure generation is estimated to be 368,434,650 metric tons. The Cattle Colony in Karachi, which is home to one of Asia's largest milk producing area, produces thousands of tons of bio waste from cattle. Converting this waste to energy can generate up to 3,000 MW of power. Pakistan council of renewable energy technologies (PCRET) is technically and financially assisting in developing Small scale anaerobic digestors for provision of affordable and reliable energy to farmers particularly living in rural areas of Punjab and KPK [14].

Figure 13: *Animal manure in Pakistan*

- **Municipal wastes:**

Wastes under this category have both organic and inorganic matter but they can be processed through various means to generation electricity. Industrial, municipal, and commercial wastes come under this category. Mostly big cities like Karachi, Lahore, Multan and Faisalabad are major contributor to these wastes. The generation or solid wastes in 9 major urban centers is around 7.12 million tons per annum which is growing by 2.5% per year due to high rate of industrialization and increasing population. The average calorific value of MSW in Pakistan is 6.89 MJ/kg which implies power generation potential of around 13,900 GWh per annum [15].

Figure 14: *Municipal Solid waste in Pakistan*

Biofuels:

Biofuel is the advanced form of bioenergy produces from highly efficient technologies. A significant potential in Pakistan in present to produce biodiesel by using castor bean. It is a self-grown crop and is estimated to produce more than 1180 kg oil per hectare in comparison to soybean, sunflower and corn. Hence, this untapped resource must be subject to exploration for generation of biodiesel to shift transportation industry reliance from liquid fossil fuels to environmentally friendly bioenergy fuels.

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Conclusion:

Impact of Renewable energy deployment on Sustainable development and Environment in Pakistan

The impact of climate change is not localized rather it is global in scope targeting every region of the world. Developing Countries present in Africa and Asia are more vulnerable to its impact as compare to developed one. Pakistan itself is the 7th most vulnerable country in the long-term climate risk Index and its vulnerability is going to increase in the long run. The likelihood of Natural disasters will be escalated by climate change thus making Pakistan more vulnerable to climate change. In past few years noticeable change in Pakistan's water cycle has been observed in the form of changing precipitation patterns, floods, unprecedented heat waves, droughts, lack of fresh water availability and extreme weather events. Although Pakistan only contribute 0.80% to total global Greenhouse gas emissions, but still this does not justify its increasing reliance on fossil fuels predominantly natural gas, imported oil and now Thar coal. These resources will eventually run out and then take millions of years to be replenished again. Moreover, adding increasing number of coal power projects in its energy system will lead to adverse local environmental and human health impacts. The need of the hour is to skewed energy mix in favor of renewable energy by exploring indigenous clean energy resources. Pakistan should also utilize its climate finance as an anchorage to modify its energy mix and focus on using renewable energy resources. Harnessing energy from these resources will not improve energy access but also it will be a significant factor in curbing climate change as encompassed in sustainable development goal 13 on climate action and Paris climate agreement 2015.

Development of Renewable energy projects will strengthen the Pakistan climate pledge on international forefront and will be subject to admiration for its greenhouse gases mitigation efforts. Clean air and Low Carbon footprint are concomitant benefits that comes with solar and wind energy. Burning of fossil fuels will lead to increased carbon levels. So, depending on green energy that is solar is an efficient of reducing carbon foot print. Pakistan being already affected by massive water crisis According to UNDP report

Pakistan will reach absolute water scarcity by the year 2025 and huge masses of population will be affected by lack of available water. In the light of this, constructing coal power plants is not a feasible option as they are considered as guzzlers of freshwater. Thermoelectric power plants need water both in extraction and refining process but also in power plant operations for cooling purposes. In contrast, wind and solar Photovoltaic systems uses 200 times less water in operation. Considering the water crisis in Pakistan fossil fuel power will be short lived investment and with the prospect of growing water scarcity transitioning to low water consuming renewable energy will make ensure the availability of adequate water resources in future.

Renewable energy provides remote rural areas with an opportunity to produce their own energy (electricity and heat in particular), rather than importing conventional energy from outside. Being able to generate reliable and cheap energy can trigger economic development in these areas of Pakistan. Large opportunity of new job and business arises, when the Renewable Energy activity is embedded in the local economy. It can create some valuable job opportunities for people in regions where there are limited employment opportunities. It can create direct jobs, such as in operating and maintaining equipment. However, most long-term jobs are indirect, coming along the renewable energy supply-chain specialized services), and by adapting existing expertise to the needs of renewable energy. Off-grid renewable energy solutions can also install for productive uses, like solar-powered irrigation on farms, thus increasing yields and incomes, reducing vulnerability to erratic precipitation patterns. In this way, renewables not only help societies access modern and sustainable energy, but also in building climate-resilient infrastructure, protecting and restoring ecosystems in rural areas.