POLICY PAPER

DEMAND-SUPPLY GAP ANALYSIS AND POTENTIAL ENERGY RESOURCES OF PUNJAB

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ABSTRACT

Pakistan has been facing severe electricity shortfall since 2007. Having more than 100 million population and economic hub of the country, Punjab province hurts badly from this crisis. The most wanted challenge has been met through investment in power sector especially through CPEC to fulfil the demand without suppress. Large reliance of the power sector on fossil fuels results in high energy prices which then results in economic downturn due to increased cost of production and decreased competitiveness. The economic hub of the country, that is, the Punjab province has been injured the most. It thus calls for attention of the public policy makers to explore the potential of indigenous resources of energy at both federal and provincial tiers of government. The study analyzes the demand-supply gap and potential of energy resources. It is revealed that the province is enriched with solar resources which can be tapped to generate on-grid and off-grid electricity for supplying power to the public at large. Proportion of coal in energy mix needs to be enhanced through utilizing both indigenous and imported coal. The province is blessed with network of canals, barrages watered by five rivers. This potential is available to produce electricity through deploying small power plants at canals and barrages. Wind pressure in the province is not capable enough to produce electricity except small potential in southeastern and Kalar Kahar regions.

Keywords: *Fossil Fuels, Indigenous Resources, Energy Mix, Off Grid Electricity*

1. INTRODUCTION[1]

Economies around the globe are facing high demand of energy to achieve sustained level of economic growth. However, the challenge is to not only meet the rising demand but also put less reliance on the depleting fossil fuels which also cause damaging environmental effects. Volatile price dynamics of fossil fuels and widening demand-supply gap of electricity calls for urgent search of cost effective, environment friendly and reliable energy resources. These factors result in an increasing interest of economies to develop renewable resources. Policy makers globally have largely recognized the significance of relationship between energy and economic progress. That being the case, it is also an agreed fact that economic development and energy reinforce each other. Affordable and sustainable energy supplies not only bring prosperity for the population at large but also helps eradicate poverty through various direct and indirect channels. Pakistan as a country is not an exception. Vision 2025, while accepting energy security as a challenge, aims to achieve Sustainable Development Goal 7 "Ensure access to affordable, reliable, sustainable and modern energy for all" by 2025.

[1] Punjab Economic Research Institute is thankful to Professor Dr. Zafar Mahmood (HoD Research, School of Social Sciences and Humanities, NUST, Islamabad) and Dr. Faisal Jamil (Assistant Professor, School of Social Sciences and Humanities, NUST, Islamabad) for their valuable input and comments on the Policy Paper.

Total primary energy supplies in Pakistan are 70.26 million Tons of Oil Equivalent (TOE). 52.8% of total indigenous production (24.23 million TOE, 34.5% of total demand) is met through net imports (HDIP, 2015). The basic energy products/sources are Natural Gas, Petroleum Products, Liquefied Petroleum Gas, Coal, Hydro, Nuclear and Renewable resources. Major reliance is on petroleum products and natural gas. Out of total energy supplies, 24.5 million TOE are used in transformation and the remaining 42.7 million TOE are used by domestic, commercial, agriculture, industry, transportation and government sectors. Energy is finally used in the form of electricity, natural gas, petroleum products including LPG and coal.

Share of hydel and coal in primary energy supplies is only 11% and 7% whereas their shares in electricity generation comprise of 30.4% and 0.1% respectively. Pakistan is also engaged in energy generation through nuclear (2% of primary energy supplies and 5.4% of electricity generation) and renewable energy resources (0.3% of primary energy supplies and 0.7% of electricity generation). The percentage share of each source of energy in primary energy supply mix is presented in Table-1. The share of hydrocarbons (Oil and gas) is 78.1%.

The increased demand of gas by the transport sector has worsen gas shortage in the country whereas it badly hit the industrial sector of Punjab along with making it unavailable for the household sector during pressure days.

Table 1: Percentage Share of Energy Sources: Pakistan

Primary Energy Supply Mix	Percentage Share
Oil	35.5
Gas	42.6
LPG	0.7
LNG	0.7
Coal	7
Hydro-Energy	11
Nuclear-Energy	2
Renewable-Energy	0.3
Imported-Energy	0.2

Source: Pakistan Energy Yearbook, 2015 (Published in June, 2016 by HDIP)

Overtime, reliance of Pakistan has increased on gas and oil resources in comparison with hydel resources (Figure 1). Main reason behind is the unexplored potential of hydel, coal, renewable and nuclear resources for electricity generation. The share of hydel in primary energy supply is decreased overtime wherein share of thermal (oil and gas) resources is increased overtime.

However, the share of renewable resources is negligible in the country. It requires attention toward abundant resources of water, coal, solar, wind and biofuels etc.

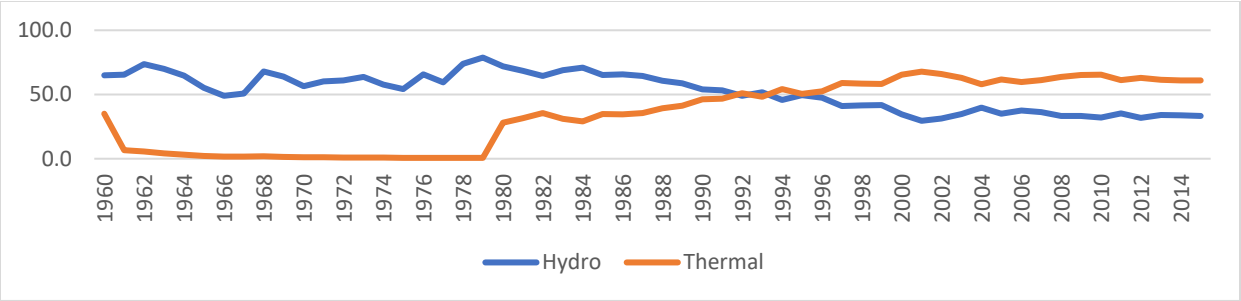

Figure 1: Percentage Share of Energy Generation by Hydel and Thermal[2]

Land of 5 rivers, 17 barrages and 23,712 miles' canal system, the province of Punjab is producing electricity through water resources having capacity of 1,795.3 MW only out of which 1450 MW power plant is installed at Ghazi Barotha only. Electricity production through solar resources also requires attention.

The provincial governments are authorized under the constitution to generate power at provincial level. Accordingly, Power Generation Policy is framed by the Government of Punjab. There is need to work on the less-explored resources for electricity generation by both Federal level and provincial level. In this context, this study aims to identify the potential energy resources of the Punjab province along with analyzing the demand and supply gap in the province.

Section two of the study analyzes the demand supply gap in the Punjab province followed by, in section three, potential of energy resources in the province. Section four concludes the study followed by recommendations in section five.

2. DEMAND-SUPPLY GAP ANALYSIS: ENERGY OUTLOOK

Sustained supply of affordable and environment friendly energy supply to the population at large is the prime concern of policy makers around the globe. Punjab, population-wise the largest province of Pakistan, has been facing severe economic downturn due to unfulfilled energy needs of households and producers. The province is rich in water resources having country's most sophisticated irrigation system. It is potentially viable to implant small capacity water power plants to produce electricity which is the cheapest primary source of energy. Solar radiation intensity, available in the province for more than 3,000 hours in a year, is capable of producing electricity. According to estimates of Punjab Bio Energy Company (Pvt) Limited, minimum 10.9 million tons' biomasses is available for power production in the province which reflects that the potential of power production through biomass can also be explored.

[2] Data Source: NEPRA, 2015

Reliance on expensive resources to produce power is not a rational choice to generate economic activity. Oil price variability in the international market put negative pressures on any oil importing economy primarily due to high import cost. The energy sector of Pakistan has been heavily subsidized up to 2008. Afterwards more deregulated approach and elimination of subsidies by the government of Pakistan results in energy price fluctuations in line with the oil price fluctuations in world oil market. Figure 2 depicts that growth in crude oil prices in the international market results in growth in cost of fuel on electricity generation in Pakistan. Since 2008, growth rate of the cost of fuel for electricity generation has 68% correlation with growth rate of crude oil prices. In this deregulated environment, oil price increases results in rising cost of production. As a result, economy bears high price level, low economic growth and high unemployment, that is stagflation. According to Hamilton (1983), Hamilton and Herrara (2004), Kilian (2008) and Khan (2012), high oil prices have damaging effects on the economy through high inflation and low economic growth accompanied with deteriorating balance of payments and mounting fiscal deficit. High energy prices also erode purchasing power of households because of high energy bills on one hand and low real wages on the other hand (Kilian, 2008).

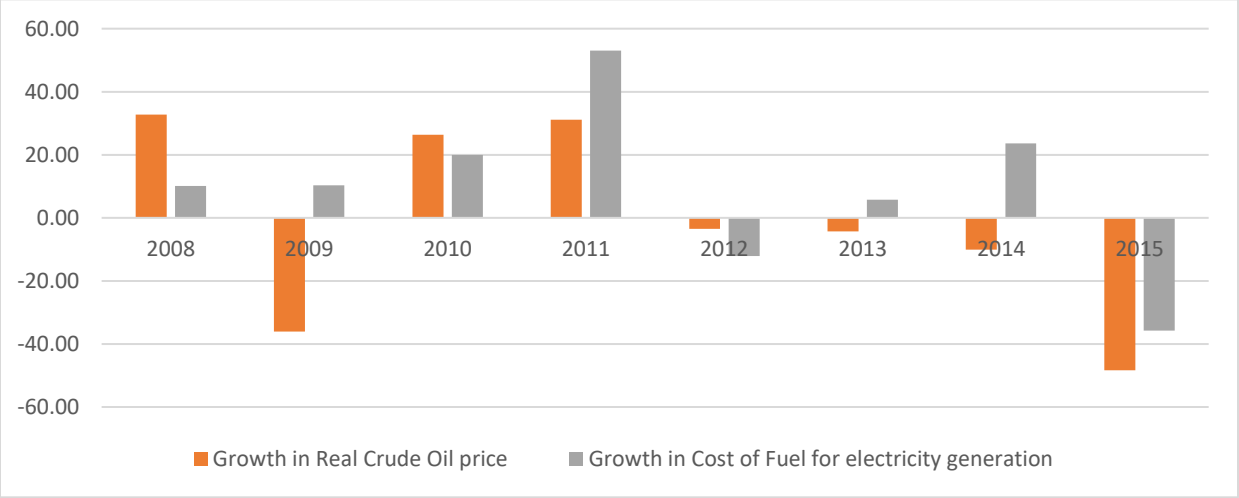

Figure 2: Co-movement of Crude Oil prices and cost of Fuel on electricity[3]

Existing installed capacity of the power projects working in the territory of Punjab is 49.6% of the total installed capacity of the country whereas it will be 62.5% after 2020. Fuel mix in electricity generation, existing and after 2020 is depicted in Figure 3 which depicts that major reliance of power production in Punjab remained at thermal (Furnace Oil, Diesel, Regasified Liquefied Natural Gas(RLNG) and Natural Gas) power. One coal power project, having installed

[3] Data Source: U.S. Energy Information Administration and Power System Statistics

capacity of 1320 MW, will be commission by third quarter of this year. Summary of the installed capacity of the power projects operating in Punjab is depicted at Table 2**.**

Table 2: Source-wise installed Capacity of Power Projects in Punjab

Source	Prevailing Installed Capacity	Under Construction	After 2020	CPEC-Energy Actively Promoted Projects
Hydel	1,795.3	720.0	**2,515.3**	
Thermal	7,953.2	6,425.0	**14,378.2**	1,320.0
Nuclear	990.0	2,340.0	**3,330.0**	
Solar	400.0	842.0	**1242.0**	
Biomasses	282.2	355.4	**637.6**	
Total	**11,420.7**	**10,682.4**	**22,103.1**	**1,320.0**

Source: Latest Reports of Various Relevant Federal and Provincial Government Ministries/Authorities/Departments

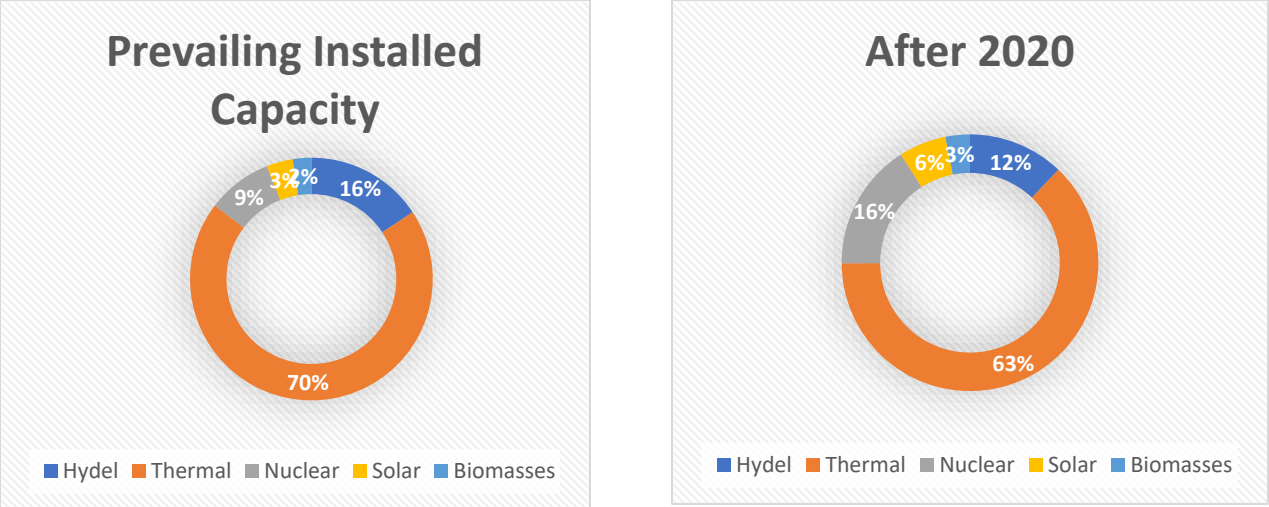

Figure 3: Fuel Mix in Electricity Production

More reliance on resources of energy other than oil can be beneficial both for economic stabilization and competitiveness in the international market. Punjab, being population-wise largest province and the economic hub of the country, is major consumer of all energy products. It consumes 62% of total electricity, 63% of petroleum products, 38% of natural gas and 62% of liquefied petroleum gas. Demand for petroleum products by power plants producing electricity in Punjab comprise 36% of total demand in Punjab and 23% of total country demand. It reflects that demand for petroleum products by power plants operating in Punjab is 57% of total power sector's demand at country level having large reliance on imported furnace oil and diesel. It involves huge foreign exchange expenditures on one hand and high price of electricity for all

consumers including industrial consumer on the other hand. Proportionate shares of demand for major energy products by different sectors of Punjab are not significantly different from that of the country, which is depicted in Table 3.

Table 3: Sectoral Consumption of Energy Products (Unit: Thousand Tons of Oil Equivalent)

Energy Petroleum Products							
	Domestic	Industry	Agriculture	Transport	Power	Other Government	Total
Punjab	77	880	38	7,757	5,048	203	14,003
Pakistan	89	1,300	37	11,373	8,995	365	22,160
Natural Gas Consumption							
	Domestic	Commercial	Gen. Industry	Transport	Power	Cement and Fertilizer	Total
Punjab	3,676	524	1,996	241	859	2,374	9,671
Pakistan	6,507	823	5,606	1,557	6,848	4,173	25,514
Electricity							
	Domestic	Commercial	Industry	Agriculture	St. Lights and Govt.	Bulk Supplies	Total
Punjab	2,010	296	1,440	325	18	247	4,337
Pakistan	3,376	530	2,034	654	42	353	6,989

Source: Pakistan Energy Yearbook, 2015 (Published in June, 2016 by HDIP)

Power plants being operated in Punjab demand 3.3% of total natural gas demand of the country and 8.9% of total demand of Punjab. Original recoverable crude oil reserves in Punjab were 35.8% of total reserves in the country whereas the balance remains at 19.9%. Punjab shares only 7.04% of the balance recoverable reserves of natural gas whereas measured and hypothetical coal reserves in Punjab are only 0.71% and 0.126% of total country's reserves, available at Salt Range and Makarwal (HDIP, 2016). It may be imperative to point out that more than 90% of total measured coal reserves are available at Thar, Sindh.

The major consumers of petroleum products in Punjab are transport and power sectors, respectively; whereas the natural gas is mainly demanded by domestic, fertilizer and industrial sector. Interestingly, the share of natural gas consumption by power sector in Punjab is 12.5% of total demand of natural gas by the power sector in the country as a whole. It depicts that majority share of gas consumption by the power sector is demanded by power plants producing electricity in provinces other than Punjab. Electricity is mainly demanded by two sectors in Punjab, that is by domestic and industrial sectors. The fractions are in-line with that of the country as a whole. The statistics shown for electricity demand does not include electricity demand by the power sector itself. The data depict that change in energy mix through increased reliance on water flow of canal and barrages, indigenous and imported coal, solar and biomass can result in significant

reduction on demand of petroleum products and natural gas. 8.6 million metric ton furnace oil is being demanded in the country which is primarily used for power generation whereas 60% of furnace oil is demanded in Punjab only. Total demand of petroleum products in the country is around 23.6 million Metric ton whereas demand in Punjab is around 14.5 million metric ton (more than 61% of total demand). After the oil embargo and price hike of 1973, the world had shifted its focus from oil and gas to coal, hydel and other renewable resources. Now the share of resources other than oil and gas is dominating the world energy mix (Figure 4). The share of coal, natural gas and renewables is dominating in electricity generation over nuclear resources with negligible reliance on liquids (Oil).

International energy mix depicts that only 4.9% (1.06 kilowatthours[4]) of net electricity is generated through liquids in 2012 whereas it is projected to decrease to 1.55% (0.56 kilowatthours) by 2040. Reliance on renewables and natural gas is expected to increase up to 29.15% and 27.82% respectively. Though the total quantity of net electricity generation through coal is expected to increase from 8.60 to 10.62 trillion kilowatthours but its share will decrease from 39.91% to 29.13%.

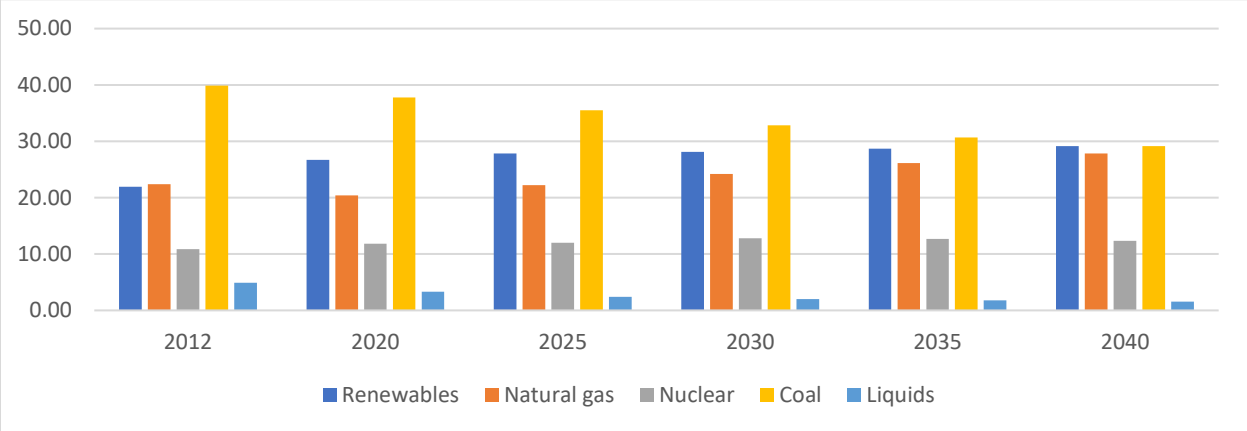

Figure 4: World Net electricity generation (Percent) by energy source[5]

The analysis shows that there is a need to change the energy mix with a shifted focus at provincial level on exploring potential of coal, hydel, solar and biofuels. It will not only enable to produce power at lower cost but also enable the producers to become competitive in domestic and foreign markets.

Further to it, power shortage in the country affected all the economic agents specifically the industrial sector wherein Punjab, being the economic hub, has been injured the most. The estimates of electricity demand are suppressed up to the electricity shortfall witnessed in Punjab and in the country since 2008. In Punjab, at present during peak hours, there is a demand-supply gap of about 4000 MW. During summer season, demand is 30% higher than the total installed

[4] Data on World Net Electricity Generation in Kilowatthours can be seen at Table A-3 of Appendix.
[5] Source: International Energy Outlook, 2016, available at: https://www.eia.gov/outlooks/ieo/world.cfm

capacity in Punjab (ADB, 2014). However, in winter, it decreases significantly. According to figures of Energy Department government of the Punjab, demand-supply gap is 1,366 MW on 16th February, 2017. Punjab with 68% of the consumption of generated power and gas is worst affected and has to endure both power and gas load shedding with adverse social and economic consequences.

Generation capability in the country almost remains same during 2007-2012 which resulted in increasing demand-supply gap from 1.8 GW to 6.6 GW. This widening gap also badly injured the economy. However, from 2013 onwards, generation capability is enhanced due to installation of new power projects. The power projects incepted after CPEC have been proven as a major breakthrough to meet the demand-supply gap. After completion of the power projects under construction, the installed capacity will increase for more than 15,300 MW[6] that will lead to not only meet the gap but will also be sufficient to meet the country's requirement for the next few years. The current projects however are unlikely to meet the country's requirement in the long run; that is, when CPEC will be in full swing. Thus, there is a need to explore the potential of indigenous energy resources to generate affordable electricity in line with the Vision 2025.

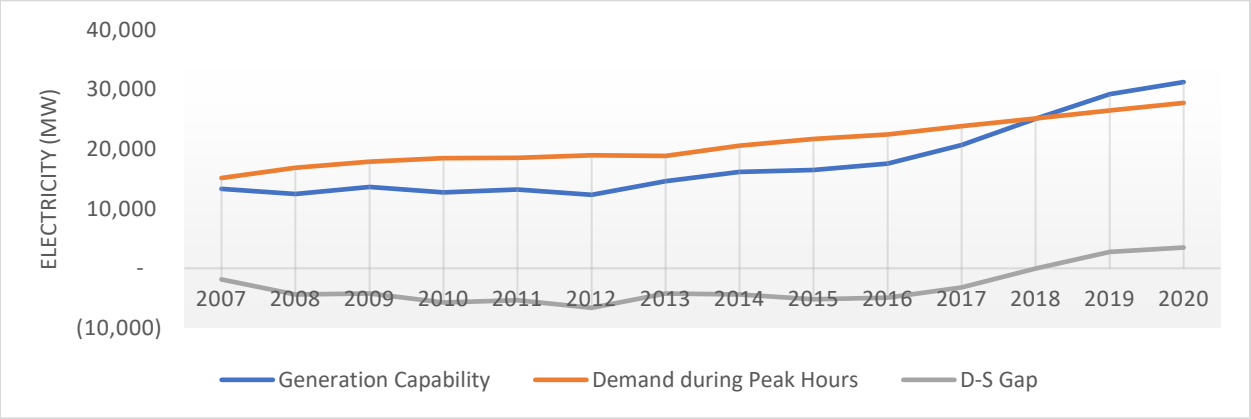

Figure 5: Demand and Supply Gap of Electricity in Pakistan (NTDC only)[7]

In Punjab, the demand-supply gap has decreased from around 5,000 MW to 4,000 MW during first three years of the current government. This gap will vanish by the end of 2018. Political will and vision matter a lot in making appropriate and timely decisions to increase the installation capability in the province. Large potential of producing electricity from solar, biomasses and hydel resources is still awaiting to be exploited. Now is the right time to put appropriate efforts enabling to efficiently meet the electricity demand which must be affordable and environment

[6] http://cpec.gov.pk/energy
[7] Data Source: Various Reports of State of Industry, NEPRA

friendly. It will help to fight against any untoward situation of supply constraint and less reliance on expensive imported fuels.

Table 4: Demand-Supply Gap of Electricity in Punjab Unit: MW

June	Supply	Demand during Peak Hours	D-S Gap
2011	9,499	13,450	(3,951)
2012	8,994	13,985	(4,991)
2013	11,760	15,248	(3,488)
2014	12,451	15,872	(3,421)
2015	11,880	15,737	(3,857)
Projection			
2017	12,760	15,000	(2,240)
2018	18,261	18,306	(45)

Source: Energy Department Government of the Punjab, NEPRA, Author's estimates

As highlighted in Punjab Power Generation Policy (2006, revised in 2009), "In Punjab, only half of the population has access to the electricity. High population density necessitates for appropriate power expansion." However, according to ADB (2014), around 80% (20% (621) un-electrified villages) of rural areas have access to electricity and all cities are electrified in Punjab. According to statistics provided by National Transmission and Dispatch Company[8], more than 31% of villages are electrified from 2009 to 2015.

3. POTENTIAL ENERGY RESOURCES OF THE PUNJAB PROVINCE

The power structure in Punjab is being managed by five DISCOs to which power is supplied by the National Transmission and Despatch Company (NTDC) out of pooled national grid. Tariffs are regulated by National Electric Power Regulatory Authority (NEPRA). The power is supplied by steam power station Muzaffargarh, STPS and GTPS Faisalabad, NGPS Multan, WAPDA [power stations at Chichoki Malian (13MW), Shadiwal (14MW), Renala (1MW), Nandipur (13MW), Ghazi Barotha (1450MW) and Low-Head Chashma (184 MW)]. The power is also generated by Pakistan Atomic Energy Commission (PAEC), IPPs and other small power producers in the province. Punjab Power Development Board (PPDB) is responsible to liaison with Private Power Infrastructure Board (PPIB) on related matters, with NTDC and DISCOs operating in the province regarding sale and purchase of Power and with NEPRA on regulation issues.

Punjab has abundance of renewable resources (small hydel power projects on the irrigated water, biomass and solar projects) but so far, this potential has not been harnessed. The government of the Punjab has allowed the generation and distribution of power to Small Power Producers (SPPs). Furthermore, power generation at raw and solicited sites by the private sector, public sector or public-private partnership is planned in accordance with Hydropower Development Plan-Vision 2025.

[8] http://www.ntdc.com.pk/Files/power2015.pdf

3.1 Hydropower

Hydropower generation had started in Punjab in 1925 with the construction of 1MW Renala Khurd Power project. In Punjab, the main potential for hydropower generation is on barrages and canal falls. More than 300 potential sites with a total estimated capacity of 7291 MW have been identified WAPDA in 2000. 6 projects are under implementation in the public sector and many projects having capacity of around 1028 MW are under implementation in the private sector. Various raw sites are also identified having capacity of more than 238 MW at various canals and barrages. Data are depicted in Table-4. Further, there is a need to develop consensus on Kalabagh dam which will not only enhance the storage capacity of the country but also enhance the capacity to install 3600 MW power plant.

Table 5: Hydropower Projects in Punjab

S. No.	Project Name	Location	Capacity (MW)
		Operational	
1	Ghazi Barotha	Ghazi Barotha, District Attock	1450.0
2	Chashma	Chashma District Mianwali	184.0
3	Rasul	Rasul District Mandi Bahuddin	22.0
4	Shadiwal	Shadiwal near Gujrat	14.0
5	NandiPur	Nandipur near Gujranwala	14.0
6	Chichoki Hydel	Upper Chenab Canal	13.0
7	Renala	Outlet of Cooling Water Disposal channel, Cashnup-1, District Mianwali	1.1
8	Jinnah	Jinnah Barrage, District Mianwali	96.0
9	PAEC Chashma Hydel	Chashma District Mianwali	1.2
		Total	**1795.3**
		Under Implementation	
by WAPDA			
1	Akhori	Indus	**600**
By Punjab Power Development Company Ltd (PPDCL)			
1	Marala	Upper Chenab Canal Lower RD 0+000	7.64
2	Chianwali	Upper Chenab Canal Lower RD 28+000 & RD 164+4500	5.40
3	Degout Fall	Upper Chenab Canal Lower RD 283+100	4.04
4	Okara	Lower Bari Doab Canal RD.199+000	4.16
5	Pak Pattan	Pak Pattan Canal RD.112+350	2.82
		Sub Total	**24.06**
		Total	**624.06**
By Private Sector			
	Many Projects	at various locations at canals and barrages	**1028**

Source: Punjab Power Development Board

3.2 Solar Energy

Pakistan, especially the southern Punjab, Sindh and Balochistan, receives huge solar potential with more than 3 KWH/m²/day of irradiation for most of days in a year. The available potential is feasible for Concentrated Solar Power (CSP) and Solar Photovoltaic (PV), Off-Grid or On-Grid, with financial and technical viability. The direct solar radiation, having potential of CSP and PV, ranges 5-5.5 KWH/ m²/day for more than 300 days a year in Southern Punjab. The range in almost all areas of Punjab is 4-6.5 KWH/ m²/day. Utilizing the available solar potential to produce power not only enable to produce power at lower cost but also enable to conserve the depleting resources and save foreign exchange. It will also help in combating global warming. The map depicting intensity of solar radiations in the country can be seen at Figure 6.

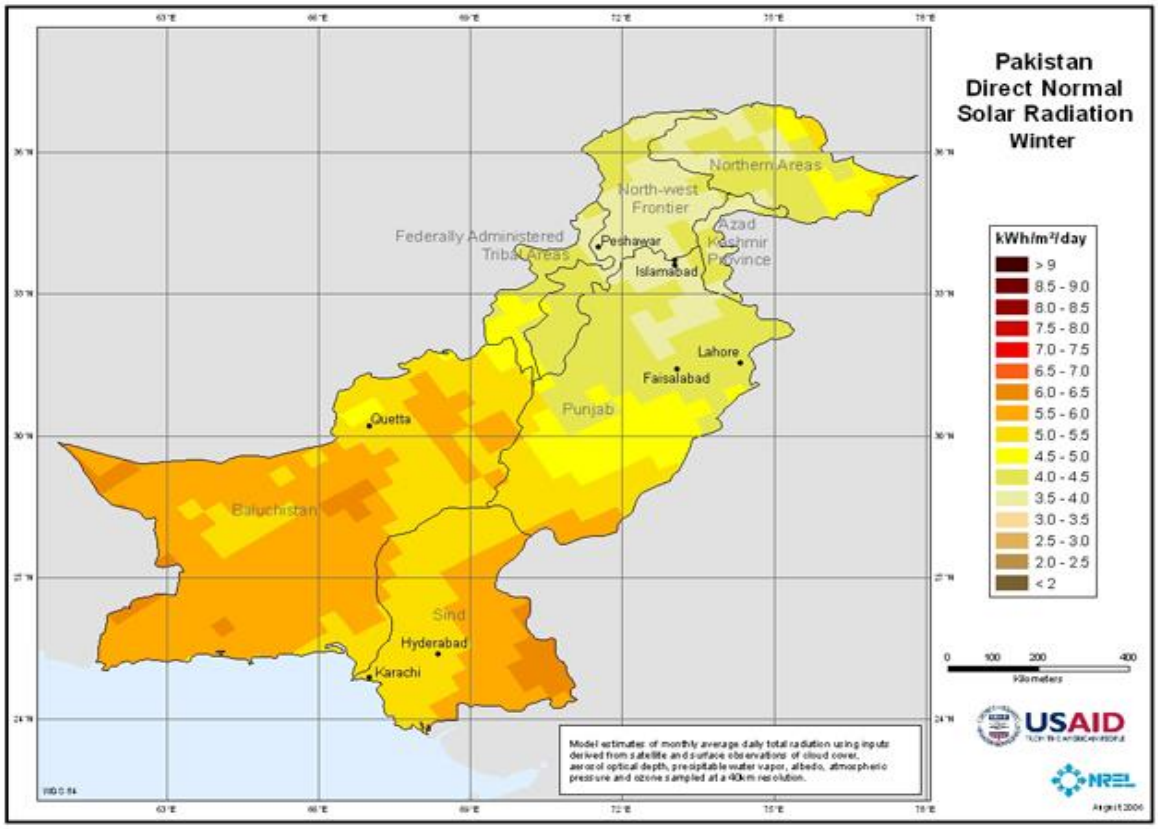

Figure 6: Direct Normal Solar Radiation in Punjab

Quaid-e-Azam Solar Power Park, in Cholistan, Bahalpur, has started producing electricity with generating capacity of 400 MW which will be extended to 1000 MW. In addition, various small solar power projects are under construction in many districts of the province like Chakwal, Jehlum, Sialkot, Sahiwal, Bahawalnagar which will bring installation capacity of 242 MW into the national grid.

Table 6: Solar Power Projects in Punjab by Private Sector

Sr. No.	Company	Project Capacity (MW)	Location
1	M/s Access Solar Pvt. Ltd.	11.52	Pind Dadan Khan,District Jehlum, Punjab
2	M/s Bukhsh Solar (Pvt.) Ltd.	10	Dharanwala, District Bahawalnager, Punjab
3	M/s Safe Solar Power Pvt. Ltd	10	Bhawalnager, Punjab
4	M/s Access Electric Pvt. Ltd.	10	Pind Dadan Khan,District Jehlum, Punjab
5	Janpur Energy Limited SPV: Jan Solar (Pvt.) Ltd.	12	Sultanabad, Rahim Yar Khan, Punjab
6	Janpur Energy Limited SPV:Lalpir Solar Power (Pvt.) Ltd.	12	Mehmood Kot, District Muzafargarh, Punjab
7	Blue Star Hydel Pvt. Ltd.	1	Pind Dadan Khan,District Jehlum, Punjab
8	Blue Star Electric Pvt. Ltd.	1	Pind Dadan Khan,District Jehlum, Punjab
9	Siddiqsons Solar Ltd.	50	Chakwal, Punjab
10	Harappa Solar (Pvt.) Ltd.	18	Sahiwal,Punjab
11	AJ Power (Pvt.) Ltd.	12	Adhi Kot, Khushab, Punjab
12	Adamjee Power Generation Pvt. Ltd.	10	Noorsar, Bahawalnager, Punjab
13	ET Solar (Pvt.) Ltd.	50	Attock, Punjab
14	Crystal Energy (Pvt.) Ltd.	2	Sambrayal, District Sialkot Punjab
15	Asia Petroleum Limited	30	Noorsar, Bahawalnagar, Punjab
16	First Solar (Pvt.) Ltd.	2	Mukhayal, Kalar Kahar, District Chakwal, Punjab
	Total	242	

Source: Alternative Energy Development Board

Power generation through solar radiations is a viable option having lot of potential which can be explored through installation of small solar power projects at public sector buildings. Industries can also be encouraged to install the solar power projects for self-consumption. Further to it, solar power projects to electrify the villages is also an option to focus on. Availability of large potential to produce electricity form solar radiations call for on grid and off grid electrification at community level and household level. It can also help in promoting small scale industry in the country. Aamir Saeed (2015) presented a case study of a women living in village at Bahawalpur who use solar lamp to sew cloths at night[9]. She became capable enough to meet her household expenditures. Indian Punjab Government, in New and Renewable Sources of Energy Policy (2012)[10], put emphasis on Off-grid solar applications, include small powered looms, solar PV pumps, small milk chilling plants, home lighting and hybrid systems for powering telecom towers. Community Development programs, public private partnership or microfinance schemes can be proved as a good source of utilizing solar resources to produce power and fulfil the

[9] http://www.reuters. com/article/pakistan-solar-women-idUSL5N10734920150727

[10] Available at: investpunjab.gov.in/Content/documents/NRSE_Policy_2012.pdf

requirements of households and producers. A solar pumping project was implemented in 2006 for drinking water supplies in 6 villages of FATA by National University of Science and Technology, with the funding of USAID which can be picked as a good example of solar pumping project.

The government of Punjab can use the solar resources to produce off grid energy to increase energy access to unelectrified villages and Public Sector buildings. The analysis shows that all parts of the province have full potential of producing electricity from solar radiations.

3.3 Wind Energy

Wind energy, the fastest growing renewable source of energy globally, has proven to be the cost competitive and environment friendly source of energy. Steady improvement in technology to produce wind power and performance of wind power plants has been witnessed during the last decade. Developing wind energy primarily depends on wind resources. According to wind map of Pakistan, developed by USAID, Coastal belt of Pakistan has good potential for power generation through wind resources.

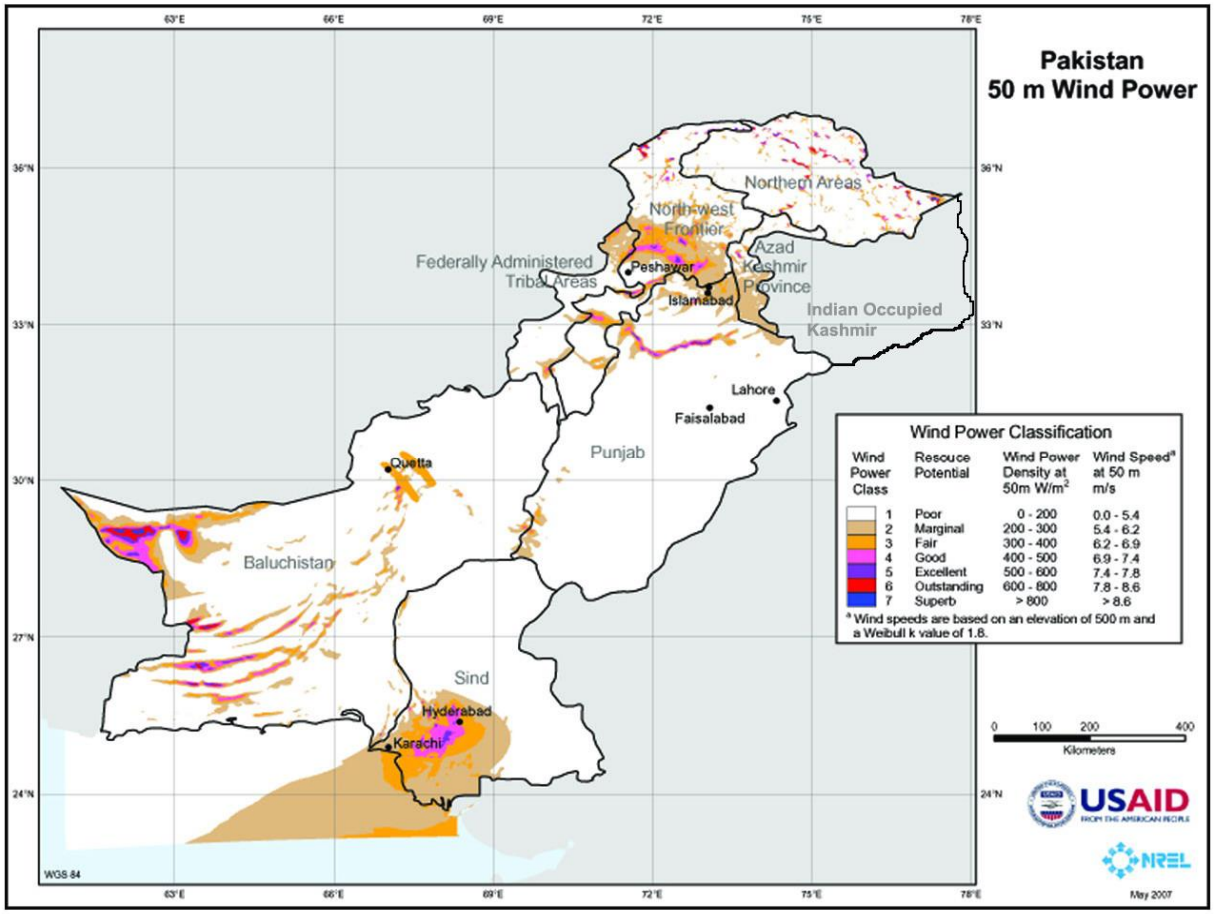

Figure 7: Wind Power Potential in Punjab

Pakistan has potential of producing around 346 GW electricity from wind resources available in coastal areas of the country, according to National Renewable Energy Laboratory, United States (cited in Baloch et al., 2016). Currently, installed capacity of Wind power projects is 504.5 MW and number of projects are under construction having capacity of more than 1100 MW, mostly in Sindh (Jhimpir and Gharo). Letter of Intent to install a wind power project in southeastern part of the Punjab province, of 50 MW installed capacity, has been issued to AM Energy. In Punjab, further potential is available near Kalar kahar, Chakwal district.

Punjab has poor wind resources for power generation with 0-200 W/m² at 50m height. The southern area of Punjab (Rajanpur) has marginal wind power density of 200-300 W/m² at 50m height. It is premature to decide the feasibility of producing power through available wind resources in the province but it seems to be less incentive to invest in exploring the wind power options in Punjab.

3.4 Biomass Energy

An innovative approach in the Punjab province is to produce energy through biomass through utilizing crops residue and animal wastes without any compromise on sustainability of environment and soil health. Feedstock for biomass power production includes agricultural waste, municipal solid wastes, agro-industrial wastes, energy crops and forest wastes. Power production from biomass is an environmental friendly and economically feasible process with negligible carbon dioxide generation. Punjab, having largest agriculture and livestock sector, has huge potential of producing energy by using copious amount of biomass in the form of crop residue and animal waste. According to various estimates, major crops in Punjab are producing 50 million tons of waste every year. Around 7 million tons of sugarcane bagasse is currently being used by the sugar industry to produce power having installed capacity of more than 282 MW and the remaining 43 million tons of crop waste is still available for power production. Various biomass power plants are under construction by the private sector (mostly by sugar mills) of capacity more than 355 MW. The net available waste for four major crops, after excluding commercial and domestic use, is around 11 million tons. According to power sector expert Mohsin Syed, as cited by Shahid[11], "200 MW electricity could be generated from the 5,000 tons of daily municipal waste in Lahore." According to his estimates, "if the solid municipal waste from other big cities of the province is utilized, the electricity generation process could reach 600 to 1,000 MW." The total potential for power generation in the province of Punjab from biomasses ranges from 3,600 to 5,400 MW.

[11] Shahid, Kunwar Khuldune, 28th September, 2015, "Can Renewable Energy Bridge Pakistan's Energy Shortfall?", MIT Technology Review Pakistan, http://www.technologyreview.pk/a-tale-of-two-energy-policies/

3.5 Thermal

Out of total 424.6 million barrels of originally measured crude oil reserves, Punjab now has left with a balance of 76.4 million barrel reserves. The balance natural gas reserves in the province are 1.43 trillion cubic feet. Measured and hypothetical coal reserves in the province are 55 million tons and 145 million tons respectively. The available potential of oil and gas reserves is not sufficient enough to meet the domestic demand that results in reliance on imports of petroleum products and liquefied natural gas. Heavy reliance of power sector to produce electricity through petroleum products (Furnace oil and High Speed Diesel) and gas has put pressure on the domestic consumers in the form of high prices and on the country's foreign exchange reserves, production of less competitive products due to high cost of energy and insecurity of energy. Consequently, the government of Pakistan and the provincial governments especially the government of Punjab has started looking into exploring the alternative cheaper energy resources. However, the focus is still on imported coal and RLNG based power projects. Currently, the ongoing thermal power projects have total capacity of 6,425 MW. These projects will use imported RLNG and coal as primary fuel whereas the benefits of indigenous coal reserves are still need to be harvested. The total installed capacity of thermal power plants (including GENCOs and IPPs) operating in Punjab is 7,953.2 MW[12].

The Punjab Power Generation policy (2006, revised in 2009) seems to be successful in a way that number of power projects, either on grid or off grid, are being installed by the private sector however, there is need to put more focus on renewable resources (specifically hydel and solar) which are cheapest sources of energy. The policy focuses on utilizing the indigenous resources but most of the under-construction power plants are dependent on imported coal and RLNG and indigenous coal reserves still need attention. The policy is successful in attracting the private investors to generate electricity for selling to either the national grid or the bulk consumer. Electricity generation through biomass has been started few years back after the implementation of policy. However mostly sugar mills are involved in this process and a lot of potential is still available there to produce power from biomass.

4. CONCLUSION

Punjab is the major consumer of all energy products in Pakistan. Power plants operating in the province largely rely on petroleum products (furnace oil and diesel). The unwanted electricity shortfall has affected the province most. The shortfall and increased cost of electricity hurt the industrial production as well as the household sector. Underutilization of indigenous resources has affected the energy situation badly. Inefficient planning to timely resolve the energy crisis has set back the economic growth. The increase in demand of energy is natural due to increase in economic activity and population which call for optimizing the energy mix through increased reliance on hydel, coal, solar, wind and biomass. It will ensure less volatile low price of electricity. The province, specially the southern part, is rich in solar resources which can be

[12] Complete list of power plants (including installed capacity) can be seen at Appendix.

utilized to produce electricity; however, due to poor wind, electricity generation from wind is not feasible. Keeping in view the demand for electricity, government of Punjab has already implemented a policy framework wherein every effort is being made to produce electricity through hydel resources of canals and barrages, coal and solar. There is a need to put more focus on exploiting the potential of available indigenous resources with the objective to minimize the role of petroleum products and natural gas in power generation. Large amount of availability of biomass in the province require more and special attention to utilize it for power production.

5. RECOMMENDATIONS

On the basis of above conclusion, we put forward the following recommendations for policy making:

I. The province is rich in solar resource which can be utilized for electricity generation. Government should take initiatives for electrification of unelectrified villages and public sector buildings through small solar power plants.

II. Community level solar power plants can be put in place with public private partnership.

III. Off grid electrification of villages should be prioritized for which microfinance models, as used in many countries of the world like Mexico, Sri Lanka and Bangladesh, should be developed.

IV. Rich canal network and barrages should be utilized efficiently to produce electricity at small scale. Specific lending program can be initiated through commercial banks and microfinance institutions on terms easier than the prevailing commercial terms in the marker. These kinds of programs are implemented in Sri Lanka to bridge the demand supply gap of electricity.

V. Government should focus on developing consensus among provinces to take decision about Kalabagh dam (3600 MW).

VI. Share of coal in power generation should be increased in line with the world energy mix by 2030 through utilizing the indigenous and imported coal. For optimal utilization of indigenous coal reserves, it is imperative to install power plants near Makerwal and salt range, the places where coal reserves are available in province.

VII. Utilization of biomass can be a good option for on grid and off grid electricity generation, having least environmental hazard.

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Appendix

Table A-1: List of Thermal Power Plants Operational in Punjab

IPPs			
Station	**Location**	**Capacity (MW)**	**Notes**
Hub Power Project-Narowal	Narowal, Punjab	225	Furnace Oil
Lalpir Limited	Muzaffargarh, Punjab	362	Oil-fired thermal
Altern Energy Limited	Fateh Jang, Punjab	29	Gas-fired Diesel Engine
Atlas Power Limited	Sheikhupura, Punjab	225	Furnace Oil
Attock Gen Limited	Rawalpindi, Punjab	165	Furnace Oil
Fauji Kabirwala Power Company	Kabirwala, Punjab	157	N. Gas
Nishat Power Limited	Lahore, Punjab	200	Furnace Oil
Nishat Chunian Limited	Lahore, Punjab	200	Furnace Oil
Sapphire Electric Company Limited	Sheikhupura, Punjab	212	Furnace Oil
Saba Power Company Limited	Sheikhupura, Punjab	134	Furnace Oil
Southern Electric Power Company Limited	Raiwind, Lahore	136	Furnace Oil
Japan Power Generation (Pvt) Limited	Raiwind, Punjab	135	Furnace Oil
Kohinoor Energy Limited	Lahore, Punjab	131	Furnace Oil
Sitara Energy Limited	Faisalabad, Punjab	85	HSD, N. Gas
Saif Power Limited	Sahiwal, Punjab	229	HSD, N. Gas
Kot Addu Power Company Limited	Kot Addu, Punjab	1,466	Oil, N. Gas
Pak Gen. (Pvt) Limited Thermal Station	Muzaffargarh, Punjab	365	Oil,
Rousch (Pakistan) Power Plant	Kabirwala, Punjab	450	N. Gas
Halmore Power Generation Company Limited	Sheikhupura, Punjab	225	N. Gas
Liberty Power Tech	Faisalabad, Punjab	200	Furnace Oil, Combined Cycle
Orient Power Company Limited	Kasur District, Punjab	229	Gas Fired, Combined Cycle
Saif Power Limited	Sahiwal, Punjab	229	Gas, Combined Cycle
Davis Energon	Jhang, Punjab	13.2	N. Gas
Total (IPPs)		**5,802.2**	
GENCOs Operating in Punjab			
Muzaffargargh	Muzaffargarh, Punjab	1,350	Gas, Furnace Oil
Faisalabad	Faisalabad, Punjab	376	Gas, Furnace Oil
Nandipur Power Project	Gujranwala, Punjab	425	Oil, Gas
Total (GENCOs)		**2,151**	
Grand Total		**7,953.2**	

Source: Various Reports of Relevant Federal and Provincial Government Ministries/Authorities/Departments

Table A-2: List of Under-construction or Proposed Thermal Power Plants

COAL			
Station	**Location**	**Capacity (MW)**	**Notes**
Grange Holding Group Power Plant	Arifwala, Punjab	152	Furnace oil, by 2019
Sahiwal Coal Power Project	Sahiwal, Punjab	1,320	Coal, 2017
Muzaffargarh Coal Power Project (Proposed)	Muzaffargarh, Punjab	1,320	Coal, Sponsor is to be decided yet

RLNG			
RLNG based Project at Bhikki	Bhikki, Punajb	1,180	Open Cycle, by Jan-17
RLNG based Project at Balloki, Punjab	Balloki, Punjab	800	Open Cycle, by July-17
RLNG based Project at Haveli Bahadur Shah, Punjab	Haveli Bahadur Shah, Punjab	800	Open Cycle, by May-17
RLNG based Project at Balloki, Punjab	Balloki, Punjab	423	Combined Cycle, by Jan-18
RLNG based Project at Haveli Bahadur Shah, Punjab	Haveli Bahadur Shah, Punjab	430	Combined Cycle, by Jan-18
Total (under Construction)		**5,105**	
Total (Proposed)		**1,320**	

Source: Various Reports of Relevant Federal and Provincial Government Ministries/Authorities/Departments

Table A-3: World net electricity generation by energy source, 2010-40 (trillion kilowatthours)

	2012	**2020**	**2025**	**2030**	**2035**	**2040**
Renewables	4.73	6.87	7.89	8.68	9.64	10.63
Natural gas	4.83	5.26	6.30	7.47	8.78	10.14
Nuclear	2.34	3.05	3.40	3.95	4.25	4.50
Coal	8.60	9.73	10.07	10.12	10.31	10.62
Liquids	1.06	0.86	0.69	0.62	0.59	0.56
Total	21.56	25.77	28.35	30.84	33.58	36.45

Source: International Energy Outlook, 2016