Reconsidering the Power Structure of Pakistan

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Abstract- Sustainable economy of a country is owed to the sustainable energy conditions of that country. Pakistan's economic conditions fluctuate as the energy sector swings in an energy deficit and circular debts. This paper gives an overview of the power sector since 1947, energy policies settled since 1994 and the steps to implement these policies to smooth the rise and fall in the power sector. Renewable Energy Policy (REP) and projects initiated are also discussed that advanced the renewable energy resources in the power sector of Pakistan. The study revealed that the energy mix in power sector transferred from hydro domination to thermal under energy policy 1994 and anticipated that transition will be renewed from thermal to renewable domination in view of deep-seated actions taken place under the REP 2006. Currently, grid-connected 100 MW solar, six wind power plants of cumulative capacity 308.2 MW, four bagasse based power plants of summative capacity 145 MW and 98 MW micro hydropower plants are operational while various are at different project development phases. SWOT analysis envisaged a sustainable power sector on the bases of strengths and opportunities that are successfully being availed and the vigilant control over weaknesses and threats will approach sustainability earlier. Some universally recognized and practiced suggestions are made at the end that would create a win-win situation for the private investors and the consumers in generating and consuming electricity from renewable green sources at economical rates.

Keywords: Energy policy; SWOT analysis; Pakistan's power sector; Renewable energy; Pakistan.

1. Introduction

Quantity and quality of energy determine the economic sustainability of a country. Quantity refers to the supply of energy keeping the demand in view whereas quality refers to the source of energy either from conventional extravagant fossil fuels or from renewable and sustainable energy resources. Owing to the industrialization and ever-increasing population power sector of Pakistan could not satisfy the energy demands [1]. In its preliminary years of existence, Pakistan focused on hydropower and met all the energy and irrigation demands by hydropower abundantly available in the country. Till 1994 Water and Power Development Authority (WAPDA) was the sole electricity producer in the country but after the energy policy 1994 [2,3]. Independent Power Producers (IPPs) started working and installed thermal power plants operated on conventional fossil fuels as they followed the phenomenon "dash for gas" for the quick profit from oil and gas power plants [1]. Under the energy policy 1994, Private Power & Infrastructure Board (PPIB) was formed to facilitate the IPPs as a one window organizer [2,3]. The incentives given to the IPPs attracted various investors who installed thermal power plants as shown in Table 5. Every year energy policy was reformed that facilitated the IPPs. Salient features of some of the energy policies are focused in Table 1 [2 - 4]. Introduction of IPPs in the power structure of Pakistan exponentially increased the electricity prices and shifted the energy mix from hydro to thermal but an unswerving supply-demand gap of almost 6000 MW [1,5] could not vanish as shown in Figure 1 [6] for last five years. Energy mix of Pakistan as on June 31, 2015, is shown in Figure 2. In 2006, the Renewable Energy Policy (REP) was announced to introduce renewable energy resources in the energy mix in order to sustain the power sector [4]. Before REP 2006, Alternative Energy Development Board (AEDB) was formed in 2003 to act as a one window facilitator for the renewable energy IPPs [7]. AEDB actively implemented the REP 2006 and managed various renewable energy projects in wind, solar, biomass and biogas as explained in subsequent sections.

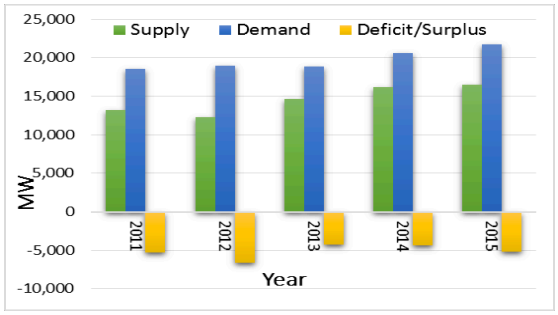

Fig. 1: Energy demand, supply, and gap for 2011-15

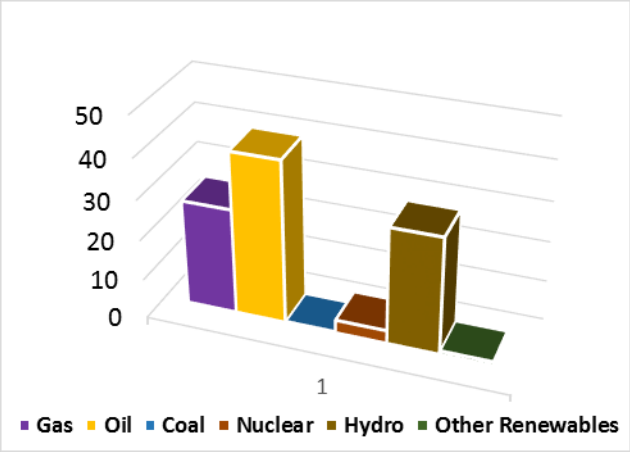

Fig. 2: Pakistan's energy mix on June 31, 2015 [8]

In literature, various authors discussed the renewable energy potential in the country. Baloch [9] and Arshad [10] studied the challenges and future status of wind energy in Pakistan while Bakhtiar [11] identified issues and challenges in way of solar energy in Pakistan and progress in solar energy was studied in [12]. [13-17] have studied in detail the renewable energy potential (wind, solar, biomass and hydro) in Pakistan. Kamran [4] studied the current status of energy and the institutional framework in Pakistan. Qudratullah [18] studied the reforms so far made in the energy sector and also focused critically on the role of IPPs in polluting the environment. Mirza [19] identified the barriers in deploying renewable energy in Pakistan. Yasmeen [20] determined the future energy supply and demand for a sustainable green energy future. This paper scrutinizes the energy policies of the last two decades and then studies the impact of these policies on the power sector of the country and the developments made until now in the power sector under these policies. The paper critically describes the role of IPPs under energy policy 1994 in promoting thermal energy from traditional fossil fuels. Also, the role of IPPs under REP 2006 has been discussed and applauded in introducing renewable energy in Pakistan at competent rates. Conclusion endeavors to retort: How hydro to thermal transition took place? How it can be expected a transition from thermal to renewable? What is the current status of the power sector and what could be in the future?

In the organization of the paper, Section 2 presents a brief overview of the energy policies since 1994. Section 3 discusses how the transition from hydro to thermal in the national energy mix took place. Section 4 discusses the efforts that are being made in promoting renewable energy in Pakistan and the expected transition of energy from thermal to renewable energy in near future. Section 5 discusses the institutional framework of the power sector. Section 6 presents a SWOT analysis of the power sector of Pakistan. Section 7 recommends introducing a more sophisticated REP giving more incentives to IPPs to replace the electricity generation fuel from conventional and imported to renewable and indigenous. Section 4 also performs a SWOT analysis of the power sector of Pakistan. Section 5 gives the conclusion of the paper.

2. Overview of the energy policies

Salient features and objective of various energy policies have been mentioned in Table 1.

Table 1: Salient features and objectives of energy policies since 1994.

Energy Policy	Salient features and objectives
Energy Policy 1994 [2,3]	• Freedom for the investors to propose a site, technology and fuel (furnace oil, diesel, natural gas, LPG, solar, wind and geothermal) for the power projects. • WAPDA/KESC will act as a power purchaser with a bulk tariff of US cents 6.5/kWh for first ten years. • Freedom from sales tax, duty tax, corporate income tax, flood relief fund, import license fee and other surcharges for IPPs. • Fuel supply contract • Foreign exchange risk indemnity • Power purchase contract • One window operation for IPPs by constructing PPIB
Energy Policy 1995 [2,3]	• Focuses on the hydropower projects • Power buying contracts for hydropower projects • WAPDA/KESC will act as a power purchaser with a bulk tariff of US cents 6.1/kWh for hydropower projects • Protection against taxes and duties • Security against exchange rate variations
Energy Policy 1998 [2,3]	• Open bid tariffs in rupees • The tariff will be quoted in two parts: Energy purchase price and capacity purchase price • Protection against taxes and duties • Security against exchange rate variations • Protection against political risks
Energy Policy	• Open bid tariffs in rupees

2002 [2,3]	• The tariff will be quoted in two parts: Energy purchase price and capacity purchase price • Hydropower projects will be on a Build Own Operate Transfer (BOOT) and thermal power projects will be on either BOOT or Build Own Operate (BOO) basis. • Permission to import not locally available plants and equipment exempted from duty.
Renewable Energy Policy (REP) 2006 [2,3]	• Invites private sector to invest for: only grid-connected IPPs, self-consumption or sale to facility, self or dedicated facility use and Islanded power projects. • Except for grid-connected projects all others need no LoI, LoS, and IA from AEDB. • NTDC will be a power purchasing entity from renewable energy power projects. • Provide a net metering facility for power producers to sale and purchase electricity to and from the grid and settle the account. • Provides transparent tariff determination. • AEDB will act as a one window facility in implementing the REP. • AEDB will manage to measure the Meteorological data (wind speed and solar insolation). • Exemption from sale tax or duty tax for renewable energy projects • Freedom from income tax. • Local and foreign financing allowed. • The shift from conventional expensive to local cheaper fuels. • Upgraded efficiency and minimized line losses by governing power theft.
Energy Policy 2013 [2,3]	• Construct a power generation capacity that can encounter Pakistan's energy necessities in a sustainable manner. • Create a philosophy of conservation and obligation. • Ensure the generation of economical and reasonable electricity for domestic, commercial & industrial use. • Minimize pilferage and adulteration in fuel supply. • Stimulate world class standard efficiency in power generation. • Create a cutting-edge transmission network. • Minimize inadequacies in the power distribution system. • Minimize fiscal losses across the system. • Line up the ministries involved in the power sector and improve governance.
Energy Policy 2015 [2,3]	• To encourage local and foreign investors to the energy field. • To provide sufficient power generation capacity at least cost • To ensure exploitation of the indigenous resources • To ensure a win-win situation for all stakeholders

3. The transition of energy mix from hydro to thermal

After coming into being in 1947, Pakistan started fulfilling its electricity necessities from inherited 60 MW electricity. To promote and initiate new energy projects WAPDA was formulated in 1959 that started electricity generation from hydro and thermal power sources. In 1965 total generation capacity was 636 MW that rose to 3000 MW in 1980. In 1960, 70 % of electricity generation was from hydro and 30 % from thermal generation [14]. After ten years in 1990 the capacity inclined to 7000 MW. Because of rapid industrialization and rising population of the country demand drastically increased more than the generation capacity [1, 21]. To meet the rising energy needs Government of Pakistan (GoP) signed Memorandum of Understanding (MoU) and issued Letter of Intent (LoI) to various IPPs who started electricity generation from thermal sources such as oil and gas as can be seen in Figure 3 that thermal share enlarged from 30 % to 68 % in 1980-2015 and hydro share diminished from 70 % to 29 %. It could be admitted that the transition in the energy sector from hydropower to thermal is owing to the IPPs. This transition not only enhanced environmental concerns but also drew the electricity prices out of the purchasing power of the consumers. In spite of shifting energy mix from hydro to thermal a definite demand-supply gap could not be wiped out as shown in Figure 1 a consistent demand and supply gap of almost 5000 MW has been sure for last five years.

Today the generation of electricity in Pakistan is done by four producers. Water and Power Development Authority (WAPDA), Karachi Electric Supply Corporation (KESC), Independent Power Producers (IPPs) and Pakistan Atomic Energy Commission (PAEC) [1]. WAPDA, KESC, and PAEC are the state entities while IPPs are the private power producers that sell electricity to the national grid.

3.1. Water and Power Development Authority

To meet the energy demands of the country WAPDA was established in 1958 through parliament act as a sovereign body whose administrative control is unique with the GoP. Sooner than restructuring in 2007, WAPDA generated electricity with hydropower, steam turbine, gas turbine, combined cycle, and coal. After restructuring in 2007, WAPDA's function was limited to the hydropower generation and O&M of the powerhouses and can be seen in Table 3 that after 2007 none of the thermal power plants was commissioned by WAPDA. Hydro and thermal Power plants constructed under WAPDA are listed in Table 2 and Table 3 respectively. Table 2 is self-evident of the reason behind the decline in hydropower projects as major projects achieved Commercial Operation Date (COD) before 1980.

Table 2. Hydropower plants operated under WAPDA [5]

Hydro Power Plant	Capacity(MW)	COD
Terbala	3478.0	1977
Mangla	1000.0	1967
Warsak	243.0	1960
Chashma	184.0	2001
Ghazi Brotha	1450.0	2003
Dargai	20.0	1951
Shadiwal	13.5	1961
Rasul	22.0	1952
Jagran	30.0	2000
Chitral	1.0	1975
Khan khwar	72.0	2012
Gomal Zam Dam	17.0	2013
Nandi pur	14.0	1963
Renala	1.1	1925
Jabban	22.0	1935
Allai khwar	121.0	2013
Duber Khwar Dam	130.0	2013
Kurram Garhi	4.0	1952
Chichoki	13.2	1959
Jinnah Barrage	96.0	2013

Table 3: Thermal power plants operated under WAPDA

Thermal Power Plant	Capacity (MW)	COD
Gas Turbine Power Station, Faisalabad	244	1975
Gas power station, Multan	195	1960
Steam Power Station, Faisalabad	132	1967
Thermal Power Station, Muzaffargarh	1350	1995
Thermal Power Station, Guddu	1655	1974
Gas Turbine Power Station, Kotri	174	1979
Thermal Power Station, Jamshoro	850	1989
Thermal Power Station, Larkana	150	-
Thermal Power Station, Pasni	17	-
Gas Turbine Power Station, Panjgur	39	-
Thermal Power Station, Quetta	35	1994
Gas Turbine Power Station, Shahdra	59	1969

3.2. Karachi Electric Supply Corporation

Karachi Electric Supply Corporation (KESC) was established in 1913 to satisfy the energy demands of a small town Karachi. On the independence of Pakistan, migration increased the population of Karachi and hence the energy demands. Keeping in view the ever-increasing energy demands GoP nationalized the KESC and again in 2005 privatized the company retaining only 29 % shares with it and transferred 71 % to the Saudi Al-Jomaih Group of Companies and Kuwait's National Industries Group (NIG). The whole journey from KESC to K-Electric (1913-2016) is detailed in figure 4. K-Electric has its own installed capacity of 2262 MW from its four power plants as listed in Table 4. Along with that excess demand is fulfilled by purchasing electricity from IPPs, WAPDA and Karachi Nuclear Power Plant (KANUPP).

Table 4: Thermal Power plants operated under KESC [5]

Power Plant	Capacity (MW)
Korangi Combined Cycle Power Plant	247
Bin Qasim Thermal Power Station I	1260
Bin Qasim Thermal Power Station II	560
Korangi Gas Turbine Power Station	97.5
SITE Gas Turbine Power Station	97.5
Total	**2262**

3.3. Independent Power Producers

Figure 1 indicates a lack of 5000 MW electricity for the last five years and the same was the condition in the 1980s. To eradicate such giant power deficit an amount of almost US$ 6 billion is required that could not be allocated in the federal government's annual fiscal budget. Therefore, GoP decided to invite private investors in the power sector. Under the power policy 1994, Private Power and Infrastructure Board (PPIB) was formed as a one window organizer in order to facilitate, develop and promote private investors in the field of energy. According to power policy 1994 power generated by IPPs shall be purchased by WAPDA/KESC on a tariff set by the government. Under 1994 power policy various private companies invested in the power sector and started generating electricity by constructing thermal fossil fuel based power plants as described in Table 5 but the growing energy demand could not be met under power policy 1994[2]. Power policy of 1998 failed to attract private investors into the power field. A lucrative power policy for private producers was developed in 2002 according to which tariff will be set by the National Electric Power Regulatory Authority (NEPRA) by negotiation between producers and the purchaser and after successful negotiations over tariff power will be sold to National Transmission and Dispatch Company (NTDC). Under 2002 power policy various IPPs constructed thermal power plants and added electricity to the national grid. The projects with COD and capacity are shown in Table 6.

3.4. Pakistan Atomic Energy Commission

Pakistan's nuclear power program is of a small scale generating only 1040 MW electricity from four nuclear power plants. The first nuclear power plant of capacity 137 MW at Karachi started working in 1972. In 2015 share of

nuclear energy in the national energy mix was only 3 %. One nuclear power plant is in Karachi and three plants are in Chashma, Punjab as detailed in Table 7 with their COD and capacity. Chashma III started working in December 2016.

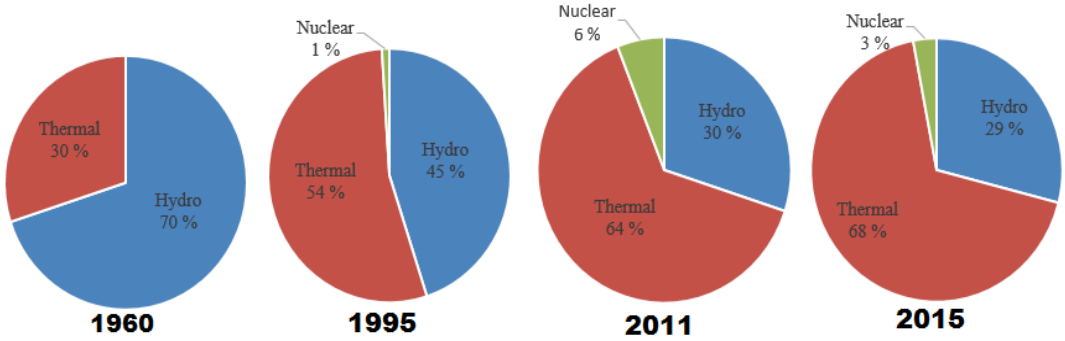

Fig. 3: Transition of energy mix from hydro to thermal 1960-2015

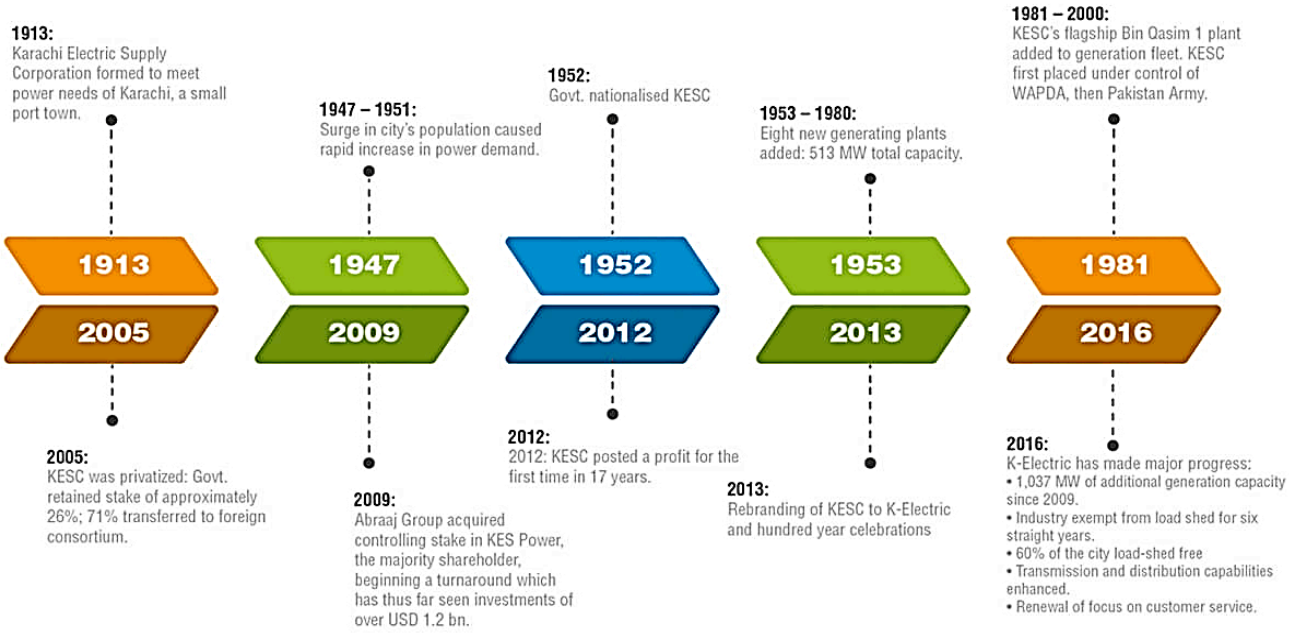

Fig. 4: Legacy of K-Electric 1913-2016 [5]

Table 5: Thermal power plants operated under IPPs as per energy policy 1994 [1]

IPP	Capacity(MW)	COD	Technology
Lalpir Ltd.	362	1997	Oil-Fired Steam Turbine
Pak Gen. (Pvt) Ltd.	365	1998	Oil-Fired Steam Turbine
Altern Energy Ltd.	29	2001	Gas fired diesel engine
Fauji Kabirwala Power Company	157	1999	Combined Cycle + Steam Turbines
Gul Ahmad Energy Ltd.	136	1997	Diesel engine
Habibullah Coastal Power (Pvt) Co.	140	1999	Combined Cycle
Japan Power Generation (Pvt) Ltd.	120	2000	Diesel Engines
Kohinoor Energy Ltd.	131	1997	Diesel Engines
Liberty Power Project	235	2001	Combined Cycle
Rousch (Pakistan) Power Ltd.	450	1999	Combined Cycle
Saba Power Company Ltd.	125	1999	Steam Turbines
Southern Electric Power Company Ltd.	136	1999	Diesel Engines
Tapal Energy Ltd.	126	1997	Diesel Engines
Uch Power Ltd.	586	2000	Combined Cycle
Davis Energen Power Project	10	2013	Combined Cycle

Table 6: Thermal power plants operated under IPPs as per energy policy 2002 [1]

IPP	Capacity(MW)	COD	Technology
Attock Gen Ltd.	165	2009	Diesel Engines
Atlas Power Ltd.	225	2009	Combined Cycle
Engro Energy Ltd.	227	2010	Combined Cycle
Foundation Power Company Ltd.	185	2011	Combined Cycle
Halmore Power Generation Company Ltd.	225	2011	Combined Cycle
Hub Power Project, Narowal	220	2011	Diesel engine
Liberty Power Tech.	200	2011	Combined Cycle
Nishat Power Ltd.	200	2010	Reciprocating Engines
Nishat Chunian Ltd.	200	2010	Reciprocating Engines
Orient Power Company Ltd.	229	2010	Combined Cycle
Saif Power Ltd.	229	2010	Combined Cycle
Sapphire Electric Company Ltd	225	2010	Combined Cycle
Uch II Power Project	404	2014	Combined Cycle
Kot Addu Power Company Ltd.	1638	1996	Combined Cycle

Table 7: Nuclear power plants operated under PAEC [1]

Power Plant	Capacity(MW)	COD
Karachi I, Sindh	137	1972
Chashma I, Punjab	325	2000
Chashma II, Punjab	325	2011
Chashma III, Punjab	340	2016

4. Expected transition of energy mix from thermal to renewables

Power policy of 2002 also failed in providing sustainable and clean energy at a required rate as it leads to only a transition of fuel. In Table 5 and Table 6 it can be deduced that all the IPPs under 1994 and 2002 power policy embraced thermal power plants operated on oil and gas that not only increased the cost of the electricity but also polluted the environment creating serious problems of eyes infection, asthma, and skin diseases. For the same time period, it can be seen in Table 2 that there are few hydropower plants which were constructed after 2002 power policy. In succinct, 2002 power policy brought a transition from hydro to thermal swelling the already existing problems. In searching for a result oriented solution, the transition from thermal to some other energy resources is the high priority constraint. Bearing the available renewable energy potential in the country in mind transition from fossil fuel established thermal energy to renewable energy could be an expected solution of the power sector glitches in the country. Playing its role headed for the development of renewable energy in the national energy mix, Pakistan has taken fundamental steps for the sustainability of the power sector and hereafter the national economy of the country.

As an alternative solution to the power sector, Alternative Energy Development Board (AEDB) was formed in 2003 with an ambition to familiarize Alternative and Renewable Energy (ARE) at an enhanced rate in the country [7]. AEDB is the sole one window facilitator to the private power producers in ARE field. First Renewable Energy Policy (REP) was settled in 2006 that focused to entice the IPPs to invest in renewable energy power projects such as solar, wind, biomass and micro-hydro [4]. REP 2006 provided lucrative incentives to the IPPs in renewable energy as described in Table 1. Under REP 2006 various IPPs showed attentiveness in renewable energy.

4.1. Wind

In the race of development in renewable energy wind energy becomes a pioneer in Pakistan. National Renewable Energy Laboratory (NREL) aided Pakistan Meteorological Department (PMD) in surveying 46 different localities in an effort to search wind corridors in Sindh and Baluchistan. The results found were systematized and analyzed by AEDB that declared the huge area of 9750 km^2 of Kati Bandar, Sindh [17] a perfect wind corridor as shown in Figure 5. The wind corridor has a 25 % capacity factor [9] in Sindh with wind potential of 60 GW [22, 23] out of which 11 GW is exploitable [16]. The wind data provided by AEDB failed in fascinating local and foreign investors as the investors claimed that the wind data was not collected by observing international standards. Therefore, to flourish the wind culture in the country AEDB and United Nations Development Program (UNDP) under Global Environment Fund (GEF) funded wind energy program and installed wind speed measuring masts in the wind potential areas of Pakistan. The data collected showed huge wind potential in the country. Figure 6 shows the average monthly wind speed data for the year 2008-2009 collected from three different masts installed in Babur band, Kati-Bandar and Hawks bay [13, 23]. Figure 7 shows the average yearly wind speed recorded by these masts at different anemometer heights [13, 23]. The exploitation of wind energy in Pakistan started in this wind corridor in 2013 and now 6 wind power plants of summative capacity 308.2 MW are operative as detailed in Table 8 with their status (Letter of Intent: LoI, Letter of Support: LoS, Financial Closing: FC and Feasibility Study: FS) and various projects are at different development phases

with a combined capacity of 663 MW as shown in Table 9 [7, 10].

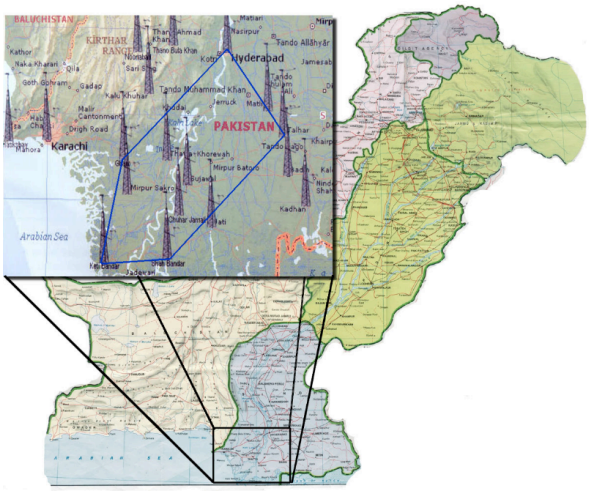

Fig. 5: Wind corridor of Gharo-Kati Bandar, Sindh [17]

Moreover, a combined estimation by NREL and USAID states a wind potential of 346 GW [9] in the country among which 120 GW is technically worthwhile to power the national grid [9]. Pakistan Council of Renewable Energy Technology (PCRET) is electrifying remote villages by installing minor wind turbines extending from 0.49 to 9 kW. To exploit the available wind potential GoP is proposing lucrative incentives to the private local and foreign investors as given in REP 2006 in Table 1. Feed in Tariff (FiT) is one of those incentives given to IPPs shown in Table 10 in last few years.

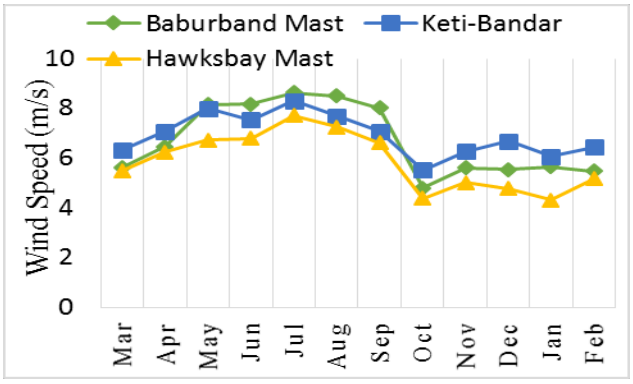

Fig. 6: Average wind speed as in 2008-9

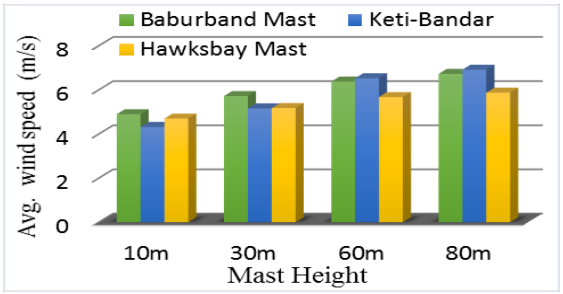

Fig. 7: Average wind speed at different mast heights

Table 8: Currently operational wind IPPs [10]

IPP	Capacity(MW)	COD	Location
FFC Energy Limited	49.50	2013	Jhimpir
Sapphire Wind Power Company Limited	52.80	2015	Jhimpir
Three Gorges I Pakistan Wind Farm (Pvt.) Limited	49.50	2014	Jhimpir
Zorlu Enerji Pakistan (Pvt.) Limited	56.40	2013	Jhimpir
Foundation Wind Energy I Limited	50.00	2015	Gharo
Foundation Wind Energy II (Pvt.) Limited	50.00	2014	Gharo
Total capacity	**308.2**		

Table 9: Wind Power Plants at different stages of development with current status [10]

IPP	Capacity (MW)	Current Status	Location
Yunus Energy Limited	50	FC achieved, under construction	Jhimpir
Sachal Energy Development Pvt. Ltd.	49.50	FC achieved, under construction	Jhimpir
Metro Power company Ltd.	50	FC achieved, under construction	Jhimpir
Tapal wind energy Pvt. Ltd.	30	FC achieved, under construction	Jhimpir
United energy Pakistan Pvt. Ltd.	99	FC achieved, under construction	Jhimpir
Hydro China Dawood Power Pvt. Ltd.	49.50	FC achieved, under construction	Gharo
Master wind energy Ltd.	49.50	FC achieved, under construction	Jhimpir
Tenega Generasi Ltd.	49.50	FC achieved, under construction	Gharo
Gul Ahmad Wind Power Ltd.	50	FC achieved, under construction	Jhimpir
Jhimpir Wind Power Ltd.	50	FiT awarded, LoS issued	Jhimpir
Hawa Energy Pvt. Ltd.	50	FiT awarded, LoS issued	Jhimpir
Hawa Energy Pvt. Ltd.	50	FS approved, FiT awarded	Jhimpir
Hartford Alternative energy Pvt. Ltd.	50	FS approved, FiT awarded	Jhimpir
Three Gorges III Wind Farm Pakistan Pvt. Ltd.	49.5	FS approved, FiT awarded	Jhimpir
Three Gorges II Wind Farm Pakistan Ltd.	49.5	FS approved, FiT awarded	Jhimpir

Tricon Boston Consulting Corporation Pvt. Ltd, A	50	FS approved	Jhimpir
Tricon Boston Consulting Corporation Pvt. Ltd, B	50	FS approved	Jhimpir
Tricon Boston Consulting Corporation Pvt. Ltd, C	50	FS approved	Jhimpir
Zephyr Power Pvt. Ltd.	50	FS approved	Gharo
Western Energy Pvt. Ltd.	50	FS in process	Jhimpir
China Sunec Energy Pvt. Ltd.	50	FS in process	Nooriabad
Burj Wind Energy Pvt. Ltd.	14	FS in process	Gajju
Trans-Atlantic Energy Pvt. Ltd.	50	FS in process	Jhimpir
Shaheen Foundation PAF	50	FS in process	Jhimpir
Total	**663**		

Table 10: FiT for wind power

Year	Upfront Tariff for wind (Rs/kWh)
2012	12.6100
2013	13.1998
2015	10.6048

4.2. Solar

First grid-connected solar system was introduced in the country in 2010 when Pakistan Engineering Council (PEC) installed a solar PV project of 178 kW with the net metering facility providing extra energy to the grid [24]. Because of its unique geographical coordinates and seasonal pattern variations, Pakistan is pro to solar energy. On the average sun shines for 8-10 hours/day for over and above 300 days in a year [25]. According to a careful estimation by AEDB Pakistan contains 2900 GW solar potential [13]. The government of Punjab initiated a major solar power project in Quaid e Azam Solar Park (QASP) that in its initial phase started to generate 100 MW with an expected subsequent capacity of 1000 MW in QASP [4,26]. PCRET has electrified various small homes, mosques, colleges, and streets by installing minor 300 solar systems of 100 kW capacity. Islanded rooftop solar systems have gained popularity in the country and people are investing in electrifying their own houses and facilities with isolated solar power systems. Together with this various grid connected IPPs showed interest in solar power plants and now are under different phases of construction. Some of the projects are explained with their current status in Table 11.

In 2003 government of Punjab propelled a project named "Ujala" to distribute solar system of 30 W [17] to the deserving students on merit in an attempt to reimburse them against the load shedding prevailing in the country. Recently, solar highway lighting systems are being practiced in various major cities of Pakistan. Solar energy can be utilized either for thermal purposes or electricity generation. In spite of the REP 2006, the government needs to announce more incentives to the IPPs to increase the solar PV consumption with the intention of competing for the conventional energy resources and achieve a solar grid parity to replace the conventional expensive energy sources with the solar energy. Solar grid parity also termed as socket parity is a situation when the electricity price ($/kWh) generated from the solar PV system is less than the electricity (kWh) available from the grid [27]. The literature states that the achievement of grid parity accelerates the development of renewable energy.

Table 11: Solar power projects at different phases of development [11]

Company	Location	Tariff awarded	Expected COD	Capacity (MW)
Access Solar Pvt. Ltd.	Pind Dadan Khan, Punjab	Mar.28, 2014	Mar. 2018	11.52
Act Solar Pvt. Ltd.	Sindh Province	N/A	Dec. 2018	50.00
Bukhsh Solar Pvt. Ltd.	Pind Dadan Khan, Punjab	Nov.24, 2014	Dec. 2017	10.00
ET Solar Pvt. Ltd.	Gharo, Sindh	N/A	Dec. 2018	25.00
Jafri & Associates	Nooriabad, Sindh	awaited	Jun. 2018	50.00
Forshine (Pakistan)	Gharo, Sindh	N/A	Jun. 2019	50.00
Safe Solar Power Pvt. Ltd	Bahawalnager, Punjab	Apr.22, 2014	Dec. 2017	10.00
AJ Power Pvt. Ltd.	Adhi Kot, Punjab	Oct.9, 2015	Dec. 2017	12.00
R.E. Solar I Pvt. Ltd.	Dadu, Sindh	awaited	Mar. 2018	20.00
Harappa Solar Pvt. Ltd.	Harappa, Punjab	Jul.2, 2015	Dec. 2017	18.00
Jan Solar Pvt. Ltd.	Sultanabad, RYK, Punjab	awaited	Mar. 2018	10.00
Siddiq sons Energy Karachi	Chakwal, Punjab	N/A	Mar. 2018	50.00
Blue Star Hydel Pvt. Ltd.	Pind Dadan Khan, Punjab	Oct.24, 2014	Dec. 2017	1.00
First Solar Pvt. Ltd.	Makhayal, Punjab	N/A	Dec. 2018	2.00
Access Electric Pvt. Ltd.	Pind Dadan Khan, Punjab	Mar.28, 2014	Mar. 2018	10.00
Janpur Energy Limited	Mehmood Kot, Punjab	awaited	Mar. 2018	10.00
Adamjee Power Generation Pvt. Ltd.	Norsar, Punjab	N/A	Dec. 2018	10.00
ET Solar Pvt. Ltd.	Fateh Jhang Road, Punjab	N/A	Dec. 2018	50.00

Integrated Power Solution	Nooriabad, Sindh	awaited	Jun. 2018	50.00
Asia Petroleum Ltd.	Punjab	N/A	Dec. 2018	30.00
Solar Blue Pvt. Ltd.	Nooriabad, Sindh	awaited	Jun. 2018	50.00
R.E. Solar II Pvt. Ltd.	Dadu, Sindh	awaited	Mar. 2018	20.00
Blue Star Electric Pvt. Ltd.	Pind Dadan Khan, Punjab	Jul.13, 2015	Dec. 2017	1.00
Crystal Energy Pvt. Ltd.	Sambrayal, Punjab	N/A	May. 2019	2.00

4.3. Micro Hydro

Breakthrough in the national power sector occurred in 1967-76 when gigantic twin hydropower plants (Mangla and Terbala dams) came into the system. At that time energy mix was hydropower dominant that shifted to thermal later on in the 90s. Beside hydropower Pakistan is affluent in micro hydropower with an exploitable summative capacity of 3100 MW [4]. This micro-hydro potential is available at natural falls and canal falls in all provinces of the country as detailed in Table 13. Having a vast pre-experience in hydro, micro hydro projects have already been initiated in Punjab and Khyber Pakhtun Khawa (KPK). Micro hydropower projects currently operational are detailed in Table 14.

Table 12: Lavellized Feed in tariff for solar power [11]

Project Capacity (MW)	FiT for North (cents/kWh)	FiT for South (cents/kWh)
1-20	11.5327	10.8920
21-50	11.4460	10.8101
51-100	11.3560	10.7251

Table 13: Power potential of micro hydro in Pakistan [4]

Area	Total potential (MW)	No. of potential sites	Remarks
Punjab	560	300	Canals
Sindh	120	150	Canal falls
KPK	750	125	Natural falls
Gilgit Baltistan	1300	200	Natural falls
Azad Jamu & Kashmir	280	40	Natural falls
Total	**3100**		

Table 14: Micro hydro operational power plants [4]

Location	Remarks	Capacity (MW)
Reshun HES, KPK	Chitral	4.2
Chichoki, Punjab	Upper Chenab Canal	13.2
Renala, Punjab	Lower Bari Doab Canal	1.1
Shadiwal, Punjab	Upper Jhelum Canal	13.5
Dargai, KPK	Malakand	20.0
Pehur HES, KPK	Sawbi	18.0
Rasul, Punjab	Upper Jhelum Canal	13.8
Shishi HES, KPK	Chitral	1.8
Nandipur, Punjab	Upper Chenab canal	13.8
Total		**98.41**

4.4. Biogas/Biomass

Pakistan, an agrarian country whose 70 % population resides in villages [17] which are mostly connected neither to grid nor to the gas pipeline. Therefore, it can be said that almost 70 % of inhabitants of Pakistan rely on crop residues, tree woods and portable small diesel oil-based electricity generators to fulfill their energy demands. Crop residues are burnt in an unproductive way to encounter the cooking requirements while wheat straw is used for animal feeding. Animal dung and crop residue are the chief sources of biogas [17] that can meet the electricity and gas needs of the villages in Pakistan. Pakistan Council of Appropriate Technology (PCAT) now changed to Pakistan Council of Renewable Energy Technologies (PCRET) started working on biogas plants in 1976 and have installed 5357 biogas plants under various stages in all over the country. Now industrial scaled biogas plants are also working in the country, some of them are at Starlet shoes, Ashraf Zia textiles, Tahir dairy farms, Al Hamad exports and JK farms which use the biogas to feed the electricity generators and cocking facilities.

Currently, there are 83 sugar industries working in Pakistan. Raw material from these sugar mills termed as bagasse is an ideal source of electricity. These sugar mills have a potential of 3 GW out of which 4 sugar industries are operational with a summative capacity of 145 MW as illustrated in Table 15. Along with that 18 sugar industry power projects of the combined capacity of 570 MW are at LoI stage by AEDB [7].

Table 15: Sugar mills with functioning bagasse based power plants [17]

Company	Location	Capacity (MW)
RYK Mills Ltd.	Rahim Yar Khan	30.00
JDW Sugar Mills II	Rahim Yar Khan	26.35
JDW Sugar Mills III	Ghotiki	26.35
Chiniot Power Ltd.	Chiniot	62.40
Total		**145.1**

5. The institutional framework of the power sector

In 1998, the power sector of Pakistan was rationalized and WAPDA's wings were made separate distinct entities as

1. Generation companies (GENCOs) from existing thermal, 2. NTDC that purchases electricity from GENCOs and IPPs and transmit to DISCOs, 3. Distribution Companies (DISCOs) to distribute electricity to the end users, 4. WAPDA generating from hydel only [2,3]. Role of WAPDA, KESC, AEDB, PPIB, and PAEC in the power sector has been discussed above in respective sections. Remaining regulator wings of power sectors are as follow. Figure 8 [10] illustrates the organogram of the power sector of Pakistan.

National Electric Power Regulatory Authority. NEPRA was founded in 1997 as a regulatory and license issuing authority for a generation, transmission and distribution of electricity all over the country [2,3]. It also determines the tariff for all conventional and renewable power projects. Power projects desiring a tariff from NEPRA are mandatory to achieve LoI, LoS and Financial Close (FC) from AEDB in renewable energy projects and from PPIB in conventional sources based projects. NEPRA has allocated FiT for wind and solar based power projects shown in Table 10 and 12 respectively.

National Transmission and Dispatch Company. NTDC was assimilated in the national power sector on November 6, 1998, and started operation on December 24, 1998, with an aim to take the control of WAPDA owned transmission lines and grid stations (220 kV and 500 kV). NEPRA issued a transmission license to NTDC on December 31, 2002. It performs the following main functions [2,3]:

- Purchase power from conventional and renewable power plants and dispatch to the DISCOs.
- Regulation and dispatch of generation facilities for safe and sound and reliable operation.
- Planning & Design, Operation & Maintenance and expansion of the 500 kV and 220 kV grid and transmission network.
- Observe and record contracts related to the bilateral trading system.

Private Power & Infrastructure Board. PPIB was established in 1994 to facilitate as a one window organization [2,3] and to intrigue private investors in the power sector. It first implemented energy policy in 1994 that successfully attracted investors and introduced IPPs in the power sector. The main function of PPIB are [2,3]:

- Recommend, facilitate and implement energy policies for conventional energy resources based projects.
- Facilitate private investors in getting a license from government agencies and ministries.
- Execute, implement and issue autonomous guarantees to the investors.

Alternative Energy Development Board. AEDB was established in 2003 to facilitate, promote and encourage the development of Alternative and Renewable Energy (ARE) in Pakistan at an expedited rate. It first implemented REP 2006 that got the ARE projects grounds through IPPs in the country. The main functions of AEDB are [7]:

- To develop and implement renewable energy policies, programs, and power projects through private investors in ARE field.
- Boost transfer of technology and cultivate native technology for ARE projects.
- To act as a one window facilitator in assessing, monitoring and certification of ARE projects and products.

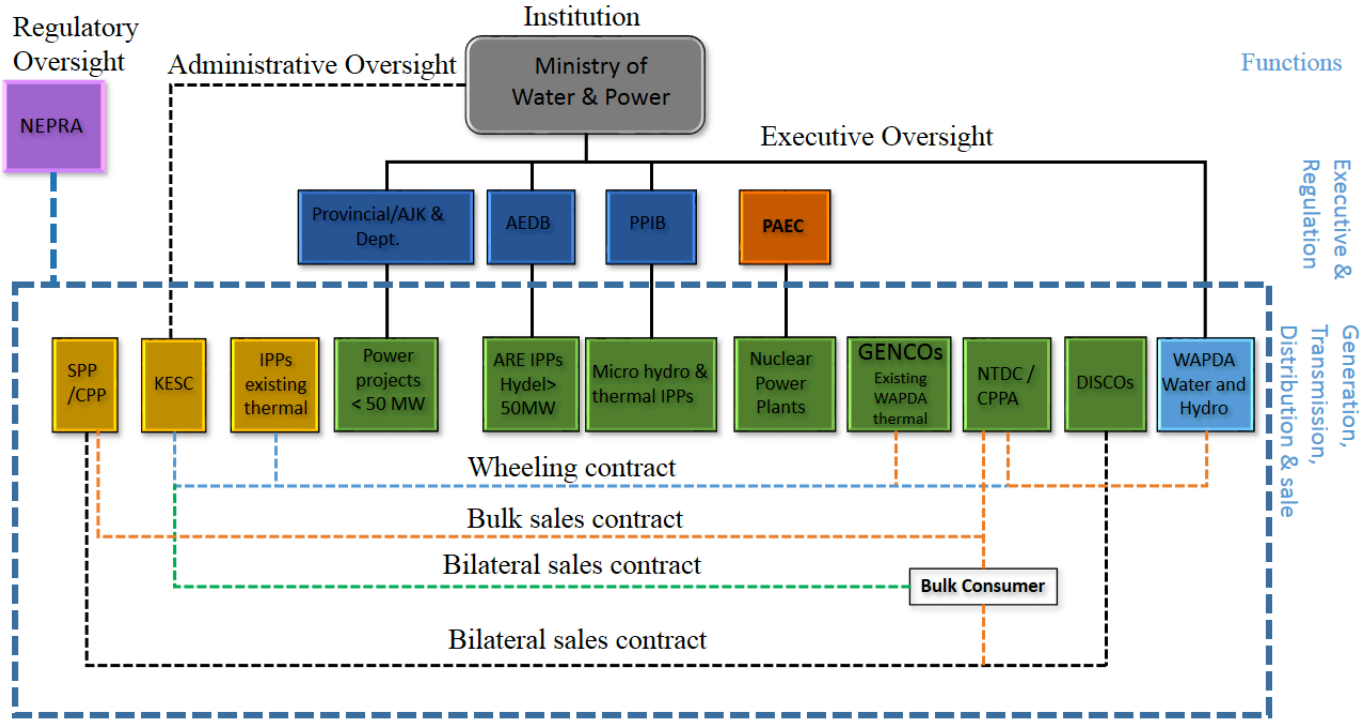

Fig. 8: Organogram of the power sector of Pakistan

6. A SWOT analysis of Pakistan's power sector

A SWOT analysis is performed to identify where the organization stands in the market and where it could be. It determines internal strengths and weaknesses also external opportunities that can be availed and threats that can be avoided. By prudently addressing the weaknesses, threats can be eliminated. A SWOT analysis of the power sector of Pakistan is shown in Figure 9. This SWOT analysis will be handy in the framework of roadmap development of renewable energy in the power sector. Performing a SWOT analysis of a power sector and installing a new project, authors and investors must address the following queries.

- Is the natural conditions of the region is pro to the development of renewable energy sources? [28]
- What are the interests of investors in investing in renewable energy projects?
- Do the natives of that region have knowledge of renewable sources?
- What are the subsidies and profits in renewable energy projects?
- Have the renewable energy achieved grid parity or is it cheaper than fossil fuel-based electricity?
- What is the impact of renewable energy and fossil fuels on the environment?
- What is the demand for electricity in that region?
- How far is the grid from the newly recommended project site?
- What is the security of the availability of renewable energy resources?
- Is there anyone window facilitator in organizing and licensing the projects?
- Which best technology is available and what is the level of knowledge of experts?
- What are the return rates and how much electricity is theft?

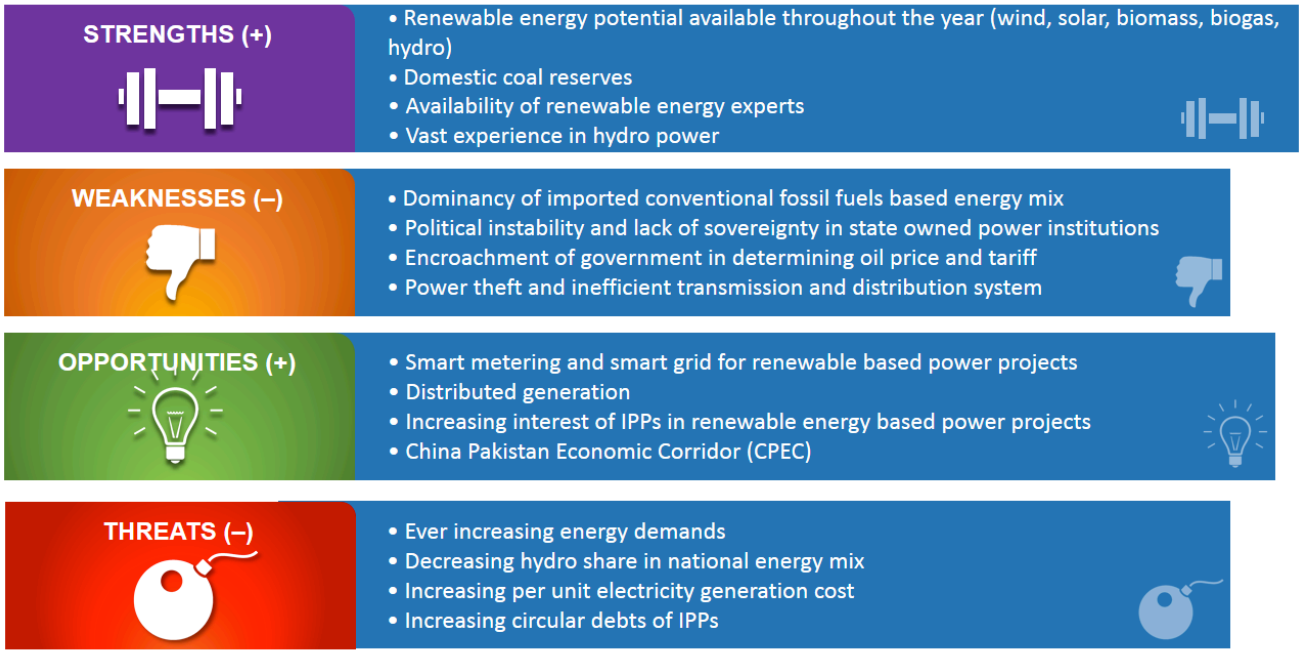

Fig. 9: SWOT analysis of Pakistan's power sector

7. Recommendations

The current state of Pakistan power sector is facing an unswerving energy demand and supply gap of almost 5 GW for the last 5 years and swelling cost of electricity generation. Various energy policies could not provide a sustainable situation for the power sector as it totally relied on the traded in fuel. Here are some suggestions to improve and modify the Renewable Energy Policy (REP) that will draw foreign and local private investors in the power sector of Pakistan envisioning a sustainable energy future.

Renewable Portfolio Standard. Renewable Portfolio Standard (RPS) makes sure the maximum electricity generation using renewable energy resources like wind, solar, biomass and micro-hydro. In order to implement RPS in energy policy salient feature should be pro to the introduction of renewable energy resources, the policy must get rid of the imported fossil fuels and insert indigenous resources, broaden the horizons of the energy mix and reduce carbon secretions [29]. RPS is being practiced in 28 states of the United States of America (USA) [30].

Production Tax Credit. Production Tax Credit (PTC) is the incentive provided by the federal government for the development of renewable energy facilities. This incentive is based on performance and production of the facility so also a partial check on the facilities that are installing nonfunctional renewable projects and taking full benefit of ICT based on FiT capital cost [30]. Mendonça [31] discussed the advantages of PTC by stating a 27 % growth in wind energy

capacity in 2006 and 45 % in 2007. In Germany, PTC brought 200,000 Germans to the wind energy who are somehow or the others are stakeholders in wind energy projects. The USA is currently giving 2.3 cents/kWh of generated electricity for the grid.

Investment Tax Credit. Investment Tax Credit (ITC) is a federal tax credit demanded against the tax liability of commercial, residential and utility financiers in solar energy assets. If a homeowner purchases and installs a solar system in his home he has the right to claim ITC that otherwise would be paid to the government. In the USA investment tax credit is 30 % [30] for solar and wind energy systems.

Feed in Tariff. Feed in Tariff (FiT) is the payment made by the electricity purchasers against each unit (kWh) of electricity generated by IPPs using renewable energy resources such as wind, biomass, micro-hydro and solar [25] at a rate determined by NEPRA. FiT represents a complete compensation to the IPPs against each kWh plus the premium over the market price but not include tax refunds and the government subsidies. This incentive is already being practiced in Pakistan for wind and solar power producers. FiT for solar by NEPRA for the first six months of 2016 is shown in Table 12. The government should give some more lucrative FiT to the sugar industries to urge them to install their own power plants for their own sugar facilities and rest to feed the grid.

China-Pakistan Economic Corridor. Under CPEC various power projects are being installed using indigenous coal and renewable energy resources abundantly available in the country. The government should conduct meetings with Chinese and Pakistani investors offering them above stated handsome and lucrative incentives convincing them to use indigenous coal and renewable energy resources.

Insured Seasonal Parameters. As the wind speed and solar insolation fluctuate affecting the output of wind turbine and solar PV panels. Variation of these seasonal parameters beyond some specified limits must be insured in monetary form by the government or some insurance companies in order to secure the IPPs interests regarding the decrease in output owing to lesser wind and irradiance.

Mitigation in Transmission & Distribution losses. Because of the inefficient T&D system and power theft losses (reported 18.73 % for FY 2014-15) [6] are accruing each year and revenue recovery is also going down. T&D systems must be updated and modified, smart meters/ prepared meters must be installed immediately to put a check on power theft and improve the recoveries.

Energy Efficiency and Conservation. As a short term solution government should familiarize energy conservation measures to the public by declaring energy conservation as a mandatory subject for graduate students, disseminating public messages through utility bills and TV commercials. The government should encourage energy star devices and home appliances from the local market as well as international exported one.

8. Conclusion

The transition from sustainable hydro dominant energy mix to unsustainable thermal dominant energy mix put the economic conditions on a state that the circular debt is accruing every year and government has to take loans to remove the circular debts on electricity generation. Besides this, because of the lack of the electricity industry is either shut or shifting to other countries. Because of poor policies in keeping the hydropower up to date, imported oil-based thermal power projects operated by private investors took place and with the boosting price of foreign oil cost of electricity reached out of the consumer's approach to such an extent that GoP had to give subsidies on electricity putting a burden on already fluctuating economy. Considering the renewable energy potential in the country, energy policy was reformed and Renewable Energy Policy (REP) was introduced in 2006 to incorporate private investors in the alternative and renewable energy field. REP 2006 succeeded in inviting private investors and currently, some grid-connected power projects on solar (100 MW), wind (308.2 MW), micro-hydro (98.41 MW) and biomass (145.1 MW) are operational while various are under different stages of project development. Development under the REP 2006 in the power sector envisages sustainability in the power sector and hence the national economy in near future.

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