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Overview of Pakistan's Electricity Crisis, Generation-Mix and Renewable energy scenarios

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Abstract

Electricity is a basic need of the modern world. It is impossible for an economy to sustain without electricity. Pakistan, despite having the enormous energy resources, is facing acute shortage of Electricity. The Country's electricity demand is rising at the rate of 11% annually, while incremental rate of production is fairly flat. Presently, only 15055MW of Electric Power is being generated while peak demand has reached up to 23953MW. Therefore, nation has to strive for meeting the deficiency of 8899 MW. Installed Power Generation Capacity of Pakistan is approximately 19,855 MW among which 67.2% is generated from thermal sources (oil and gas), 29.4% from hydel, 3.3% from nuclear and 0.1% from coal. Due to increased cost of petroleum products, slow development of hydel and nuclear power generation and negligible development of coal power generation, Country is facing severe electricity crisis. This article provides the overview of electricity shortage, problems associated with energy-mix used for power generation and root causes of electricity shortage in Pakistan. It also highlights the importance and availability of Pakistan's indigenous energy resources, which can be economically used for electric power generation.

Keywords: *Pakistan, Power Generation, Generation-Mix, Electricity shortage.*

1 Introduction

Pakistan is a country blessed with tremendous energy resources, these energy resources are distributed evenly from northern areas where there are a lot of geothermal energy resources [1] and snow covered mountains which are the cause of large rivers that flow down towards the Arabian Sea, in the South. In the southern region, energy resources like crude oil, coal, natural gas, renewable energy resources including solar and wind are present in abundance. If we talk about coal, Pakistan is the 6^{th} coal enriched country, worldwide [2]. It is

anticipated that if properly utilized, Pakistan's Coal resources may generate at least 100,000 MW of electricity, for the next 30 years [2].

Presently in Pakistan, only about 55% population has access to electricity. However, increasing urbanization and industrialization in the country has provided a great opportunity for expansion of the power sector [2]. Country is presently facing a serious energy crisis. There is acute shortage of electric power in the Country. The Nation is currently facing 8899 MW of electric power shortage. This power shortage will become more severe in year 2013 and can reach up to 10785 MW, as shown in "Table 1" [7]. The occurrence of the prolonged and frequent electricity load-shedding has very bad impact on industry operation, especially on small industries which cannot afford excess investment on power generators, for backup power supply. The economy of the Country and the living standard of the Citizens, are in very critical stage. This load-shedding is the major cause of unemployment, especially in cities like Fasalabad, where labor works on daily wages in small industries. This shortage of electric power becomes more severe in summers and as a result of which, load-shedding occurs usually 8 to 10 hours in urban areas while 16 to 18 hours in rural areas [3]. Power shortages are due to many reasons, for example, due to inadequate maintenance, most of the installed power plants are either completely out of order, or not capable to generate rated output power. Due to this problem, despite of the fact that total installed generation is 20922MW (2010 estimate) the firm power supply is only 15055MW, thus there is difference of about 5500MW.

Table 1: Firm Supply verse Peak Demand (MW), in Pakistan

Year	Firm Supply MW	Peak Demand MW	Surplus Power MW
2007	15091	16548	1457
2008	15055	17689	2634
2009	15055	19080	4028
2010	15055	20584	5529
2011	15055	22205	7150
2012	15055	23953	8899
2013	15055	25840	10785

Source: Private Power and infrastructure board.

Another major problem with the power sector of Pakistan is that it depends heavily on fuel-oil imports for power generation. Share of oil in power-generation mix is approximately 37.8%. Fuel-oil is the most expensive mean of generating electric power [8]. Due to the high fuel price and large power losses (approximately 35 %) as shown in "Table 2", generation cost becomes extremely high as compared to electricity tariffs, the utility companies then adds surplus charges on end user, which is a significant burden on the people of Pakistan. "Table 2", projects the power losses reported by Karachi Electric Supply Corporation. The nontechnical losses accounts for the electricity theft, especially in overpopulated areas of large cities, like Karachi.

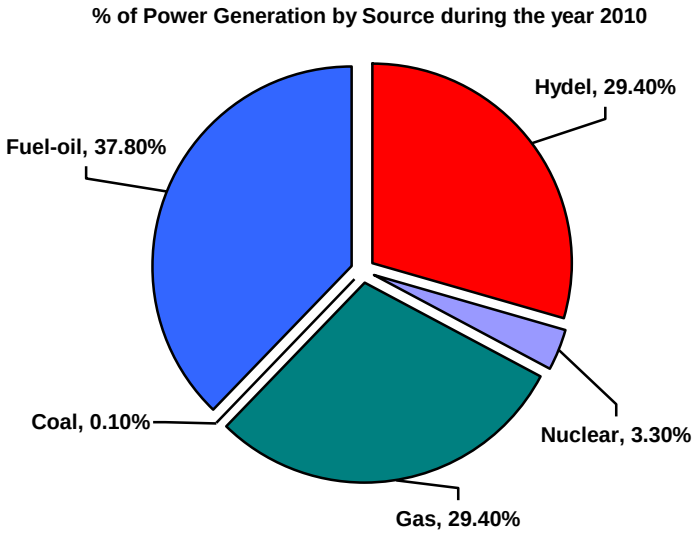
Table 2: Percentage of Network power losses, in Pakistan

Item	2003	2004	2005	2006
Transmission	6.0%	5.8%	5.2%	5.2%
Distribution (Technical)	17.5%	17.2%	15.0%	14.8%
Distribution (Non-technical)	17.3%	14.8%	14%	15%
Total Losses	**40.8%**	**37.8%**	**34.2%**	**35%**

Source: Karachi Electric Supply Corporation Limited.

2 Power Generation-mix in Pakistan

Although, Pakistan has numerous energy resources but energy-mix used by power generation sector in Pakistan depends heavily on fuel-oil imports. "Chart 1", shows energy-mix used for Power Generation in Pakistan. About a decade ago, Pakistan was self-sufficient in natural gas but presently due to economic growth, urbanization, and conversion of thousands of transportation vehicles from fuel-oil to Compressed Natural Gas (CNG), has compelled the Nation towards the import of natural gas, as well. Detail of energy-mix used for power generation in Pakistan is provided as follow.

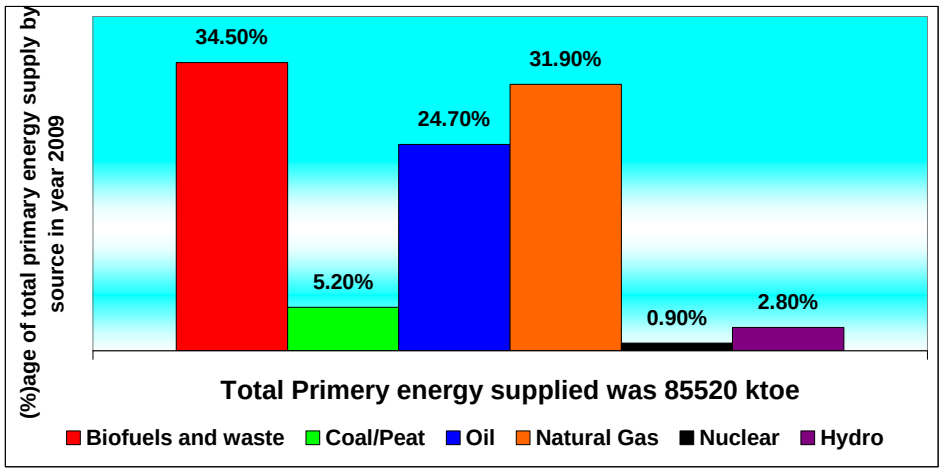


Source: Pakistan energy year book 2010-2011

Chart 1: Energy-mix used for power generation in Pakistan

2.1Power Generation From Natural Gas:

Just like fuel-oil Pakistan is also heavily dependent on natural gas for its energy needs, as shown in "Chart 3". However, domestic production of natural is very high as compared to fuel-oil. Gas contributes 29% of the total electric power generation in the Country and 31.9 % in total energy consumption. Presently, Pakistan consumes all of its domestic natural gas. In near future, Pakistan will become a natural gas importer, due to rapidly increasing gap in production and consumption. As a result, now government is exploring several pipeline and LNG import options to meet the expected growth in natural gas demand. Demand for natural gas in Pakistan has increased by almost 10% annually from the year 2001 to 2008, reaching around 3,200 Millions of cubic feet per day (MMCFD), against the total production of 3,774 MMCFD. But, during 2008-2009, the demand for natural gas exceeded the available supply, with production of 4,528 MMCFD gas against demand for 4,731 MMCFD, indicating a shortfall of 203 MMCFD. The gas supply/demand imbalance is expected to grow every year to cripple the economy by 2025, when shortage will be 11,092, against total 13,259 MMCFD productions [5].



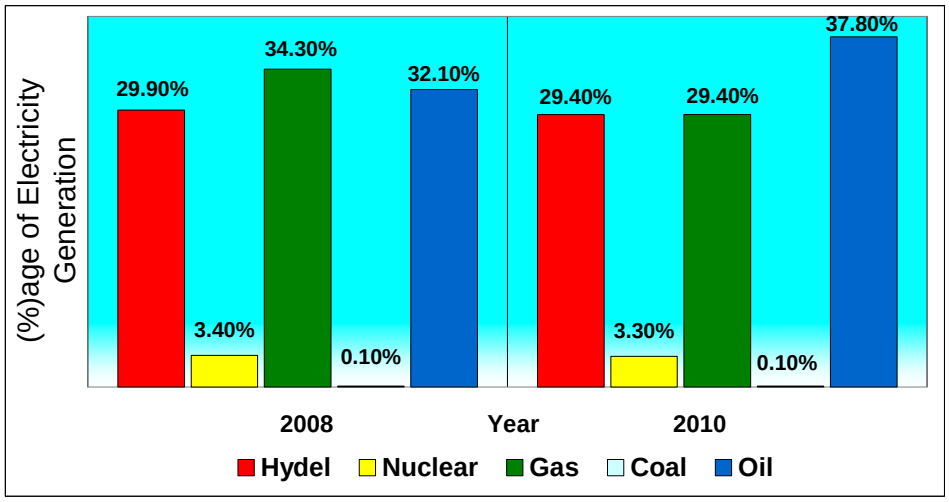
Source: IEA 2011, Note share of under 0.1% are not included.

Chart 3: Total primary energy supply by source in Pakistan, during 2009

2.2Power Generation From Fuel-Oil:

With rising fuel-oil prices in the global market, contribution of oil in power generation has reduced substantially over past three decades, worldwide. In 1970's, the contribution of oil in world's total power generation was almost 25% which has been reduced only to 6.6% in the year 2005 [8]. If we consider Pakistan, share of oil in power generation has increased from 32.2% in the year 2008 to 37.8% in 2010, as shown in "Chart 2". Pakistan has not explored its new oil fields,

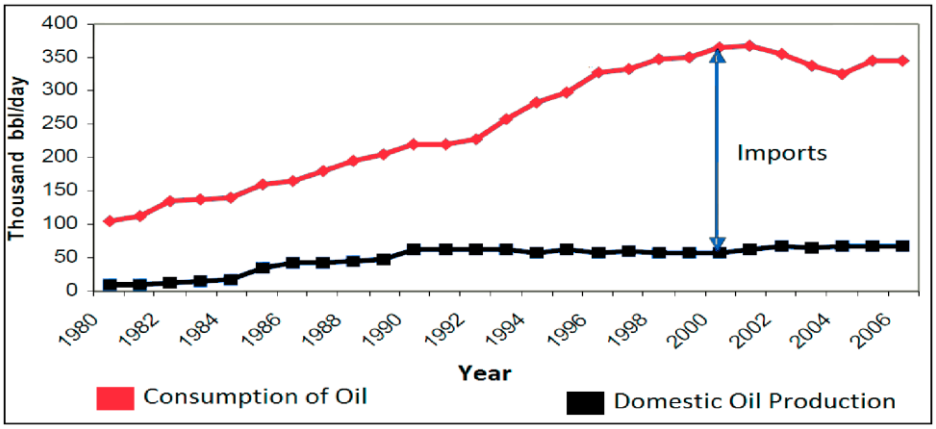
since late 1980s, as a result of which, increment in oil production has remained fairly flat at approximately 60,000 barrels per day [4]. Due to Pakistan's modest oil production, the Country is dependent on oil imports to satisfy domestic oil demand. In the year 2006, Pakistan had consumed approximately 350 thousand barrels of oil and various other petroleum products, of which more than 80 percent were imported [4].



Source: Pakistan energy year book 2008 and 2010

Chart 2: Comparison of energy-mix used for power generation in Pakistan during the year 2008 and 2010

The majority of oil imports come from the Middle East, with Saudi Arabia as the lead exporter [9]. Pakistan state bank paid $6.7 billion for oil imports during the year 2005-2006 [4]. "Figure 1" shows the difference between oil production and oil consumption, in Pakistan.



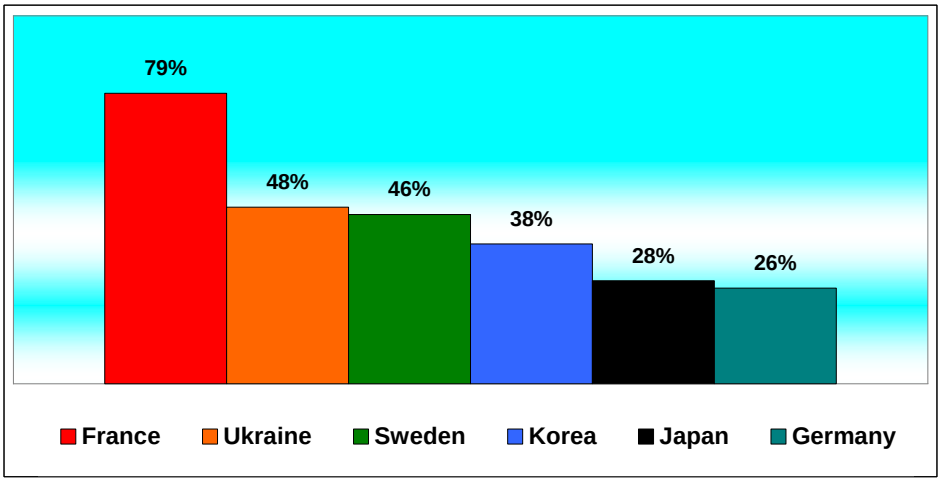
Source: Pakistan energy year book 2006-2007

Figure1: Domestic production, total consumption and imports of fuel-oil in Pakistan

2.3Nuclear Power Generation:

Pakistan is one of the 30 nations in the world, which have reposed confidence in Nuclear Power Plants. Worldwide, total installed power generation capacity of Nuclear Power Plants stood at 375,000 MW, at the end of the year 2010, having 442 operational Nuclear Power Plants [3]. Nuclear power generation has gained significant popularity in recent years. In 1970s only 3.3% of total electric power production was based on Nuclear power, Worldwide. However, presently it has reached to 15%. In recent years China and India have made huge investments in Nuclear Power Plants. China has 11 Nuclear Power Plants with capacity of 9000 MW while India has 20 Nuclear Power Plants having power output of about 4780 MW. Nuclear electricity is the most dominant part of electric energy in France where 79% of the total electricity is generated from Nuclear Power Plants, as shown in "Chart 4".

Pakistan is a country having more than 110 nuclear war heads but unfortunately, only about 3% of the total electricity in Pakistan is generated from nuclear fuel. There are three operational Nuclear Power Reactors in Pakistan namely KANUPP, CHASNUPP-1 and CHASNUPP-2, as shown in "Table 3".



Source: International Energy Agency

Chart 4: Percentage of Nuclear electricity in power generation-mix, in some developed countries

Country has also drawn up plans to import more Nuclear Power Plants from China. Currently, the Country heavily depends upon China for Nuclear Power Generation. In order to make the Nation self-sufficient in nuclear fuel, a facility is being developed, which will use Indigenous Uranium-ore to produce 350 tons of nuclear fuel annually, starting from year 2015 [3].

Table 3: Operational Nuclear Power Reactors in Pakistan

Name	Type	Rating MW	Operational Since	Planned Close
Kanupp	PHWR	125	1972	2019
Chasnupp 1	PWR	300	2000	2040
Chasnupp 2	PWR	300	2011	2051
Total		**725**		

Source: Pakistan Atomic Energy Commission

2.4Coal power generation:

Coal is the world's most abundant and widely distributed fossil fuel with global proven reserves of nearly 1000 billion tones [9]. Due to cheaper price as compared to oil and gas, and easy availability all over the world, coal has been a key component of the electricity generation-mix, worldwide. More than 40% of the world's electricity is fueled by coal. This figure is much higher in some countries, such as South Africa in which almost 93% of the total electricity is generated by coal driven power plants, similarly, 92% in Poland, 79% in China, 69% in India and 49% in US. Moreover, the growing energy needs of the developing world are likely to ensure that coal will remain a key component of the power generation-mix in the foreseeable future, regardless of climate change policy [9]. However, coal currently plays a minor role in Pakistan's electricity generation -mix. Only 0.1% of the total power generation in Pakistan is based on coal which is negligible as compared to the world average of 40%. Although, the Country possess an estimated 185 billion tons of proven recoverable coal reserves but Pakistan still imports coal for industrial sector as well as for power generation. In 2002, Government of Pakistan issued a new policy to promote power generation from indigenously produced coal for a total capacity of 2600 MW but, despite of the large interest from both foreign and local investors, progress seems to be very slow. By 2010, it was targeted to add 900 MW coal-based electric power into the National-Grid but not even a single megawatt has been added till now.

It is imperative therefore, for the government to earnestly review, evaluate and determine the policies. If we talk specifically about Under Ground Coal Gasification (UCG) Pilot Project of 100 MW power plants in Thar area of Sindh province, this project is being implemented and managed under the chairmanship of Dr. Samar Mubarakmand (a renowned nuclear scientist of Pakistan). On 24 January, 2012, Dr.Samar Mubarakmand has said that the finance ministry is not issuing the funds despite the directives of the President and the Prime Minister. He further said that Rs.1 billion has been spent on the projected and Rs.2 billion is needed immediately. The finance ministry has not issued a single rupee during the current fiscal year (2012), [12].

2.5 Hydro Power Generation:

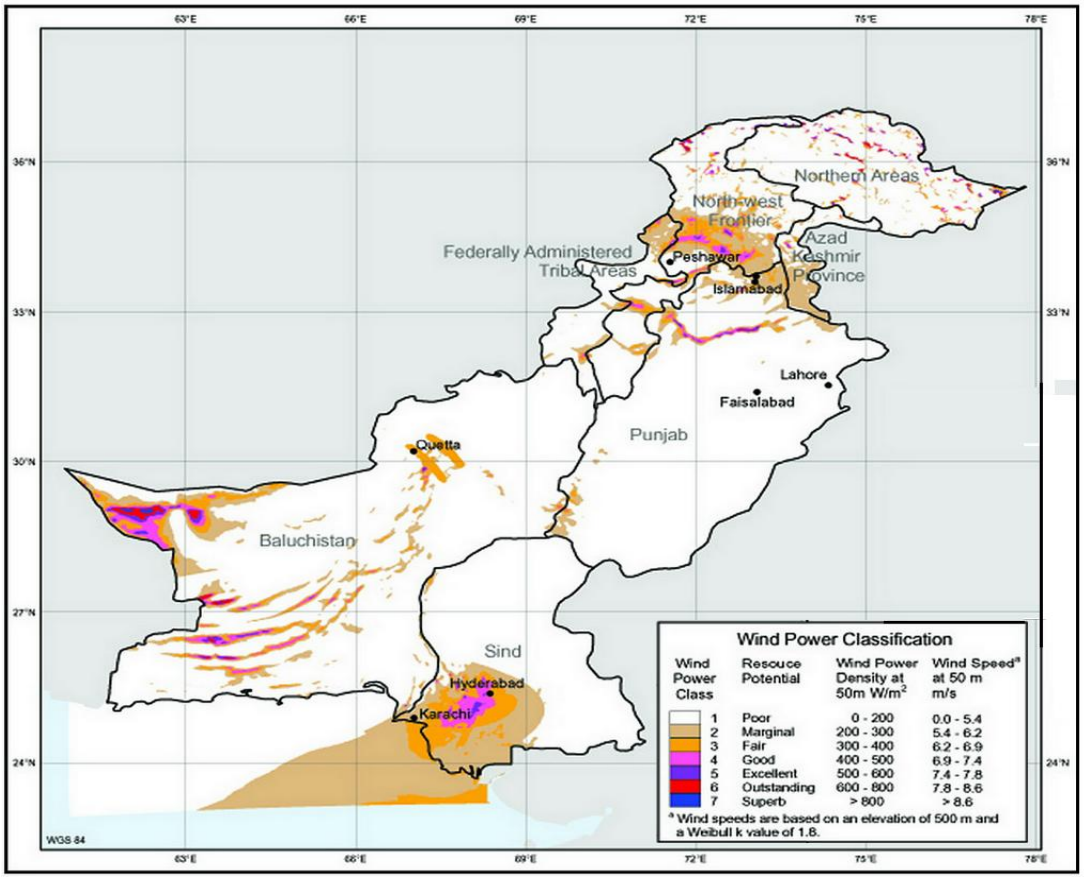
Hydel electricity is considered cheaper source as compared to thermal sources. Currently, in Pakistan, almost, 29% of the total electricity is being generated from this source. Pakistan is blessed with ample water resources. Unfortunately, it could store only 13% of the annual flow of its rivers. The hydropower potential in Pakistan is over 100,000 MW. The total installed capacity of hydropower projects in the Country up till 2010 was 6720 MW. Hydro Power Generation Capability of Pakistan is discussed in detail, in next section.

3 Renewable Energy Potential in Pakistan

Recently, in the year 2006 the government of Pakistan has attempted to promote the adoption of renewable energy technology for electric power generation, by implementing its first renewable energy policy. However, this policy got limited success and faced number of challenges. In order to promote renewable power generation, policy challenges must be clearly identified and addressed. It can be observed from "Chart 1" above that hydro power is the only sustainable energy resource which Pakistan has utilized for large-scale power generation. However, the implementation of the 2006 renewable energy policy has stimulated little interest in wind power generation projects. The potential for renewable energy technologies to bridge the gap between energy supply and demand in Pakistan is significant. Renewable energy projects have the potential to improve energy security, provide socioeconomic benefits, reduce local pollution and mitigate climate change [15]. Furthermore, due to the decentralized nature of renewable energy projects, they have the potential to provide electricity to remote and rural areas without high investment on large transmission networks. Solar, geothermal, wind, biomass and micro-hydel energy resources are widespread in Pakistan. Important renewable energy resources of Pakistan are discussed below.

3.1 Wind Energy:

Wind energy has been shown to have strong technical potential in Pakistan, particularly in the southern regions of Sindh and Baluchistan provinces, as shown in "figure 2". Pakistan has approximately 1000 km of coastline with steady average wind speeds ranging between 5-7 meter/sec. The projected capability for wind energy projects is estimated at 122.6 GW per year, which can provide about 212 TWh of electricity to the Country [16]. Till now this energy source is not utilized however, recently, development of 50MW wind energy project has been started in Thatta district of Sindh province. Project is planned to be operational in June 2012.



Source: Alternate Energy Development board of Pakistan

Figure 2: Map showing regions that are suitable for Wind Power Generation

3.2Solar Energy:

Pakistan lies in a region of high solar irradiance. Therefore, it is ideally very suitable for solar energy projects. Pakistan receives almost 15.5x1014 kWh of solar irradiance each year with most regions receiving approximately 8 to 10 sunlight hours per day. The total power generation capacity of solar photovoltaic power is estimated to be 1600 GW per year, which is 41 times more than Country's present power demand [16].

However, solar power is very expensive choice for Pakistan. Solar power is only suitable for small scale power generation usually in remote villages with small population. The Pakistan Engineering Council (PEC) seems to be very interested in promoting solar power generation in Pakistan. Recently, PEC has launched Pakistan first on-Grid Solar Power System of 178 KW/h, which is planned to become operational in the year 2013 [17].

3.3Energy From Biomass:

As, Pakistan has an agricultural based economy, therefore, the availability of biomass in the Country is widespread. Approximately, 50000 tonnes of solid waste, 225000 tonnes of crop residue and over 1 million tonnes of animal manure are produced daily. It is estimated that the total production of biogas from livestock residue is 8.8 to 17.2 billion cubic meters of gas per year which is equivalent to 55 to 106 TWh of electric power. Additionally, the annual electricity production from biogas generated from the fibrous residue remaining after sugarcane or sorghum processing, is estimated to be 5700 GWh. [16].

3.4Geothermal Energy:

Geothermal energy is thermal energy stored inside the Earth. Earth's geothermal energy originates from the original formation of the planet (20%) and from radioactive decay of minerals (80%) [18]. At the core of the Earth, thermal energy is created by radioactive decay and temperatures may reach over 5000 C^o. Heat conducts from the core to surrounding cooler rock. The high temperature and pressure cause some rock to melt, creating magma convection upward since it is lighter than the solid rock. The magma heats rock and water in the crust, sometimes up to 370 C^o. From hot springs, geothermal energy has been in used for bathing since Pal-eolithic times and for space heating since ancient Roman times, this energy source is better known now for electricity generation. Worldwide, about 10,715 MW of geothermal power is online in 24 countries. An additional 28 GW of direct geothermal heating capacity is installed for district heating, space heating, spas, industrial processes, desalination and agricultural applications [19]. The International Geothermal Association (IGA) has reported that 10,715 MW of geothermal power in 24 countries is online, which is expected to grow more and more in near future [20]. IGA projects growth to 18,500 MW by 2015, due to the projects under consideration [20]. “Table 3”, shows some major countries utilizing geothermal energy for Electric Power Generation.

Geothermal energy resources are also available in Pakistan [1], Geothermal activity in Pakistan originates from the collision of the Indian Plate with the Eurasian Plate [21]. Hot springs have been discovered in Gilgit, Hunza and Yasian vallies in Northern areas. The highest surface temperature recorded in the hunza vally is 210C^o. In the South, the subduction of Arabian Plate beneath the Indian plate has resulted in emergence of Chagai Volcanic arc where quaternary volcanoes are found with evidence of recent tectonism. The third geothermal zone extends from the North-South region to the South-East region of the Country as narrow belt along the Indus basin margin, down to Karachi. A large concentration of geothermal manifestations occurs in Dadu district of Sindh province. The zone

also extends into the main boundary thrust which constitutes the northern limits of the geothermal system. The Power Generation Capability of this energy resource is yet to be investigated. This renewable energy source needs high consideration of Government as well as the private sector.

Table 3: Some major countries utilizing geothermal electricity

Country	***Capacity (MW) 2010***	***%age in total electricity production***
USA	3086	0.3%
Philippines	1904	27%
Indonesia	1197	3.7%
Mexico	958	3%
Italy	843	1.5%
New Zealand	628	10%
Iceland	575	30%

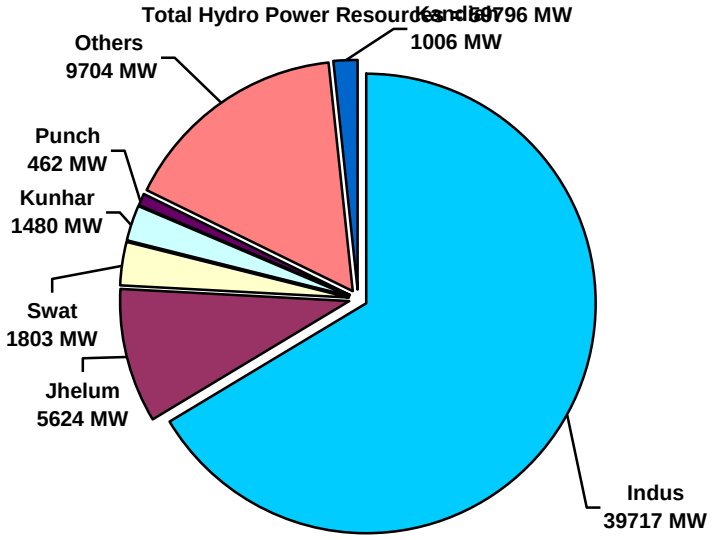
Source: Geothermal Energy Association, 2010

3.5Hydro Energy:

Pakistan’s water resources have rich potential for hydropower generation, it is estimated that 60000 MW of electric power can be generated economically from these resources. But so far only 11% of this cheap resource has been developed [10]. The country is situated between the Arabian Sea and the snow covered mountains like Himalayas, Hindu Kush and Karakoram Mountain Ranges. The hydropower resources in Pakistan are mainly located in the mountainous areas in northern region of the Country. The Water and Power Development Authority (WAPDA) controls the major hydroelectric plants.Hydropower development in the area now in Pakistan started in 1925 with the construction of 1 MW Renala Khurd hydropower station. At the time of independence, Pakistan inherited a very small power base of around 60 MW capacities for its 31.5 million people. At the time of creation of the WAPDA in 1958, the Country's total hydropower capacity was enhanced to 119 MW. With the signing of Indus Basin Water Treaty in 1960, Pakistan was entitled to use Indus, Jhelum and Chenab River. Pakistan is an agriculture based economy, therefore, hydropower is one of the best available option for Pakistan because, apart from electricity, there is acute shortage of water

for irrigation and drinking purposes as well. The total installed capacity of hydropower projects in the Country up till 2010 was 6720 MW out of which 3849 MW is in Khyber Pakhtunkhwa province, 1699 MW in Punjab, 1039 MW in Azad Jammu and Kashmir (AJ&K) and 133 MW in the Gilgit-Baltistan. The largest hydropower plant is Tarbela hydroelectric plant with installed capacity of 3046MW. Other large hydroelectric plant includes Mangla having 1000MW installed capacity, Warsak 240MW and Chasma 184 MW. The WAPDA is vigorously carrying out feasibility studies and engineering designs for various hydropower projects, in different part of the Country, with accumulative generation capacity of more than 25000 MW [10]. Most of these studies are at in advance stage of completion. After the completion of these projects the installed capacity would rise to around 42000 MW by the end of the year 2020 [10].

Hydel electricity is considered cheaper source as compared to thermal sources. Pakistan is blessed with ample water resources. Unfortunately, it could store only 13% of the annual flow of its rivers. The storage is fast depleting due to sedimentation. In contrast, US has developed 497% storage capacity of annual flow of River Colorado, Egypt possesses 281% of River Nile and India 35% on Sutlej-Bias Basin. There is intense need to construction number of dams to enhance availability of water in Pakistan. “Chart 5”, shows the summary of hydropower potential in MW, river wise, in Pakistan.



Source: Hydroelectric potential of Pakistan [10]

Chart 5: Summary of Hydropower Potential in Pakistan (River wise)

Although, the hydropower potential in Pakistan is over 100,000 MW, with identified sites of 59000 MW but, political instability in a country is one of the major causes of slow development of hydroelectric power generation. If we talk specifically about the propose project of Kalabagh Hydroelectric Project (3,600

MW capacity). This Project was designed in 1984, with the assistance of the United Nations Development Program, supervised by the World Bank, for the client WAPDA. Following the submission of its Project Planning Report it was put up to the Federal and Provincial Governments for approval of the launching of this gigantic project. It was estimated to be completed in 6 years, with first generating unit to be commissioned in April 1993. But unfortunately, this program could not be materialized due to opposition from some provincial parties, mainly on political grounds. On May 26, 2008, Federal Minister for Water and Power of Pakistan, Raja Pervez Ashraf said that the "Kalabagh Dam would not be constructed" and the project have been cancelled. However, the large ongoing project of Diamer-Bhasha Dam in northern part of Pakistan and some other medium and small scale hydroelectric projects in some other parts of Pakistan are worthy step of the Government of Pakistan, to overcome shortage of electric power in the Country. Foundation stone of Diamer-Bhasha Dam was laid by Prime Minister, Yousaf Raza Gilani on 18 October 2011. Upon completion, Diamer-Bhasha Dam would be the highest RCC dam in the world. The dam site is situated near a place called "Bhasha" in Gilgit-Baltistan's District. Upon completion, Diamer-Bhasha Dam will produce 4,500 MW of electric power, as well as, 8,500,000 acre feet of water that would be used for irrigation and drinking purposes. [11].

4 Conclusion

By investigating power generation potential of Coal, Hydro, Wind and Nuclear energy resources of Pakistan, it will not be an immoral to say that political instability and lack of good governance is the root cause of electricity crises in Pakistan. As, Pakistan is blessed with plenty of natural resources therefore, country instead of relying heavily on fuel-oil imports for electric power generation, should develop its own resources to satisfy its power demand. It is observed that percentage of fuel-oil in energy mix has increased significantly in past decade, which is not in the favor of the already depressed economy of Pakistan, to limit dependency of the Country on fuel imports, government should have to make a new policy to limit fuel-oil based thermal power plants.

For remote areas, where population is limited, solar power generation on small scale can play the significant role. For large scale sustainable power generation wind and hydroelectric power plants are more economical choice. Meanwhile, indigenous coal is also a self-sufficient choice for large scale power generation. The Government of Pakistan must take bold and sincere steps towards the development of aforesaid energy resources. Financing and technology access must also be addressed. Apart from further power generation, adequate maintenance of previously installed power stations, transmission lines and distribution system is also required to overcome the electricity crises in the Country.

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