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TRANSFORMING ENERGY SECTOR IMPACT FOR SUPPORTING CLIMATE CHANGE MITIGATION: THE CASE OF PAKISTAN

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Abstract

Purpose of the study: This study attempts to provide an analysis of the energy sector of Pakistan including generation and quality of electricity, and potential of renewables for climate change mitigation.

Methodology: The study used a quantitative approach for analysis. Primary and secondary data sources are used.

Main Findings: According to the quantitative analysis institutions fail to meet the growing demand due to insignificant or no increase in capacity to produce power. CO2 emissions are rising because of increased reliance on coal and other thermal sources for electricity generation.

Applications of this study: It proposes to increase the reliance on renewable resources and align the policy and regulatory framework for setting a sustainable economic system. The government should also plan for a rigorous electric supply system that would ensure the quality and sustainability of the electricity supply.

Novelty/Originality of this study: It sets a benchmark analysis and sets the direction for the policymakers especially at the stage when the country has settled the shortage issue, but at the cost of increasing fossils share in the fuel mix, whereas the transmission and distribution of electricity supply are ignored.

Keywords: *Climate Change, Renewable Energy, Tariff Structure, Electricity Supply, Distribution Losses.*

INTRODUCTION

Energy is an important component of improving competitiveness and investment climate in the economy (Ichord, 2020). The role of government is primarily of key importance to create a predictable regulatory environment, irrespective of the fact that the economy performs well or sustainable in the long run (Jalilian et al., 2007). Regulations have two roles to play. First, market failures (negative externalities, information asymmetries, incomplete markets, etc.) can be corrected and prevented (Bourne, 2019). Second, targeted regulations can be used as an intervention to avoid socially unacceptable outcomes (reducing inequalities and correcting distribution of wealth) (United Nations Development Programme, 2019). Governments can ensure a level playing field for all the economic agents through appropriate design and enforcement of regulations. The shortage in electricity supply can be proved to increase reliance on renewable resources for energy production (Shah and Solangi, 2019). It is also significant for reducing carbon emissions (DeLlano-Paz et al., 2015) and improving competitiveness (Ibragimov et al., 2019). This study aims to analyze electricity generation as a climate change mitigation strategy and quality of electricity supply wherein the regulatory perspective for ensuring sustainability is an integral component (Shaikh et al., 2015).

High transmission and distribution losses, low bill collection rates, and inadequate end-user tariff levels in Pakistan impact the financial standing of utilities and accordingly the reliability of supply (Khan, 2014). Punjab, being the largest province, is most affected by the energy crisis in the country (Nawaz and Alvi, 2018). In this perspective, it is critical to understand that Article 157 (1) of the Constitution of Pakistan empowers the federal government to produce electricity and lay interprovincial transmission lines; however, Article 157(2) authorizes provinces to generate, transmit, distribute and regulate the energy sector (The Constitution of Islamic Republic of Pakistan, 1973). Furthermore, the formation of institutions is possible either through the existing legislation or through creating legal entities under the Companies Ordinance 1984. Different strategies are needed to adopt for the consistent flow of electricity to the end-users such as greening the energy mix and making the electricity affordable (Irfan et al., 2019). Many factors, like a balanced energy mix, sustainable tariff policy, and high operational management, need attention.

The fuel mix for the production of electricity is heavily dependent on imported and expensive fossil fuels. The demand-supply gap in electricity production is now a history due to the inception of CPEC power projects (Mirza et al., 2019). Also, the reliability of electricity supply is influenced by multiple factors such as the condition of power system infrastructure, utility financial performance, adequacy of electricity generation, operational performance, and energy sector regulations (World Bank, 2017). Self-reliance on energy reduces the economy's vulnerability and otherwise, it causes shortages in the commodity market by lowering production (Luft, 2012). Another significantly important aspect, that is, high cost of production due to costly electricity solutions (Ganapati et al., 2016) (in case if the focus is demand-supply gap only and not the cost-effective solution) results in less competitiveness in the global market to lowering the foreign exchange earnings and the employment level in the economy (Valasai et al., 2017). The frequency and duration of power cut are also directly affected by available infrastructure, exogenous shocks to the economy, and weather conditions (Parker and Kirkpatrick, 2012).

It is imperative to change the fuel mix for the generation of electricity which will not only decrease the burden on the national exchequer but it will also improve the energy security in the province (Liu et al., 2017). Further, it is also desired that the quality of the electricity supply should be improved significantly, which would require investment in the transmission system (Powell, 2014).

The objective of the study

To provide an analysis of the energy sector of Pakistan including generation and quality of electricity, and potential of renewables for climate change mitigation.

METHODOLOGY

A quantitative approach was used for the analysis. Both, primary and secondary sources were used for data collection. Primary data collection is done by questionnaire-based survey and secondary data taken by online resources such as Science Direct, Web of Science, and Google Scholar, etc. The energy sector for climate change mitigation data consists of 29 years with the different sectors (urbanization, transportation, industrialization, waste, energy usage, and agriculture). The general public sample size elaborates all provinces and all areas of Pakistan to whom climate change is having direct and indirect effects on the energy sector.

RESULTS/ FINDINGS

POWER SECTOR

After a brief understanding of the institutional structure of the energy sector of Pakistan, holistic analysis of the generation of electricity supply given current and future direction of the policymakers, the state of carbon emission from electricity generation, and the possibility for generation of electricity from renewables. Then, a comparison of tariffs from different fuels and the quality of electricity supply is also discussed in this section.

Institutional Framework

From independence to the 1990s, the electricity generation was owned and operated by the public sector (WAPDA and KESC) only, but these institutions fail to meet the growing demand due to insignificant or no increase in capacity to produce power. In the early 1990s, efforts were started to deal with the growing difficulties of the power sector. A new institutional setup was formed in response to the Regulation of Generation, Transmission, and Distribution of Electric Power Act (1997). In response, National Electric Power Regulatory Authority (NEPRA) was established to play its role as regulator. Four Generation Companies (GENCOs), eleven Distribution Companies (DISCOs), and one National Transmission and Despatch Company (NTDC) emerged from the power wing of WAPDA whereas the KESC was privatized. Further, Private Power and Infrastructure Board (PPIB) was established for facilitating private investment. Overall planning of the sector is primarily the responsibility of the National Economic Council (NEC) wherein among others; the Chief Minister and Finance Minister of Punjab are its members (State of Industry Report, 2020; Parish, 2006). The role of provinces is to carry out a national strategy through their own initiatives or cooperating with the national agencies.

Strategic Analysis

The country has faced a severe electricity crisis since 2007 (Nawaz and Alvi, 2018). The deficient electricity supply has led to socioeconomic consequences. Especially, it compromised the competitiveness due to an increase in the cost of production. However, during the last few years, the energy sector has gone through restructuring to mobilize resources, increased the production capacity, the sectoral efficiency, and widens the consumer reach. Efficiency, sustainability, and competition are claimed as the hallmarks of the National Power Policy 2013 of the Government of Pakistan but the implementation is slow (GoP, 2013a; GoP, 2013b). The only achievement is the increase in electricity generation capacity that is dealt with the investment in power generation under China-Pakistan Economic Corridor (CPEC) projects. However, major reliance remained on imported fossil fuels. For instance, out of the total installed capacity of more than 11,000 megawatts of CPEC-Energy priority projects, coal-based power projects comprise more than 8,000 megawatts (GoP, 2021)[1].

The data show that electricity is a major source of CO2 emissions. Since 1991, CO2 emissions from electricity and heat production is more than 30 percent whereas it remained above 32 percent of total fuel combustion for most of the time. Data after 2014 is not yet available however, it is safe to assume that CO2 emissions are rising because of increased reliance on coal and other thermal sources for electricity generation.

The already dominating fossil fuels in the primary energy supplies share is 87.92 percent wherein the role of oil and gas in percentage terms is decreased since 2013-14 and the share of coal is increased from 5.37 percent to 15.431 percent (Table 1). As such, coal as a source of electricity generation is predominantly adopted along with LNG, which again is a thermal source. Furthermore, the other sources of CO2 emissions are manufacturing and construction industries, the transport sector and residential buildings, and commercial and public services.

[1]Details can be seen at http://cpec.gov.pk/energy.

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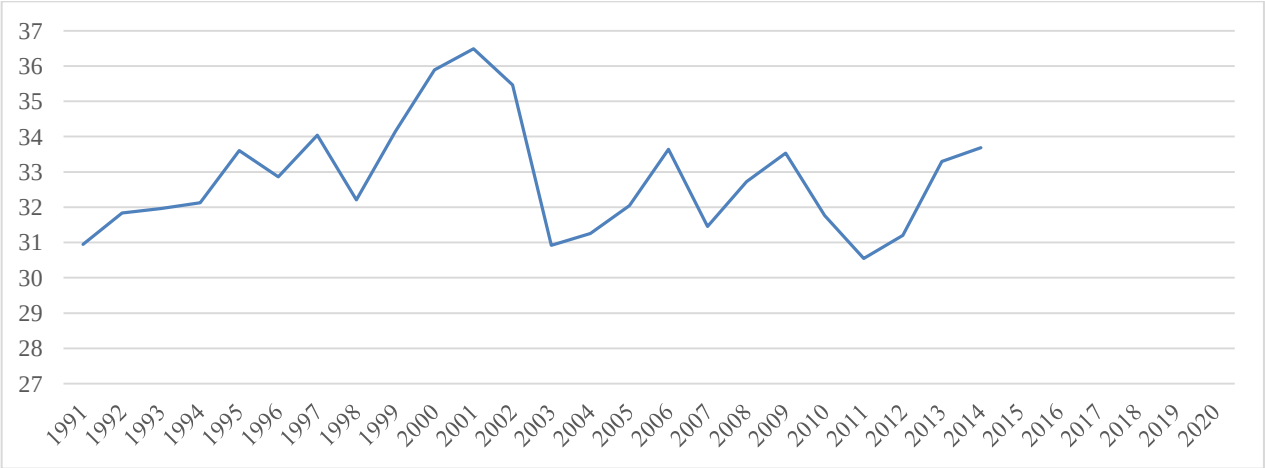

Figure 1: CO2 emissions from electricity and heat production, total (% of total fuel combustion)

Source: World Development Indicators 2020

Table 1: Primary Energy Supplies by Source (Percentage)

Source	2005-06	2009-10	2013-14	2018-19
Oil	28.4	31.4	34.42	25.734
Gas	50.4	48.84	46.32	34.982
LPG	0.4	0.62	0.54	1.138
Coal	4	7.32	5.37	15.431
LNG Import	-	-	-	10.635
Hydro Electricity	7.4	10.62	11.38	7.786
Nuclear Electricity	1	1.09	1.82	2.822
Renewable Electricity	-	-	-	1.333
Imported Electricity	-	0.1	0.15	0.139
Share of Fossil Fuels	83.2	88.18	86.65	87.92

Source: Various State of Industry Reports, NEPRA

The total installed capacity of electricity has remarkably increased after the inception of power generation projects under CPEC which is also reflected in a generation. Pakistan has dealt with the problem of electricity deficit but socioeconomic and environmental sustainability is still at stake due to dominating role of thermal power generation. Table 2 presents the installed capacity and generation of electricity for 2013 and 2020.

Table 2: Electricity Installed Capacity and Generation

Year	2013		2020	
Source	**Installed Capacity (MW)**	**Generation (GWh)**	**Installed Capacity (MW)**	**Generation (GWh)**
Hydel	6,947.00	30,033.00	9,861.00	38,987.96
Thermal	15,941.00	64,034.00	25,244.00	81,554.83
Nuclear	787.00	4,181.00	1,467.00	9,897.89
Renewable	50.00	32.00	2,047.00	4,304.91
Total	23,725.00	98,280.00	38,619.00	134,745.59

Source: Various State of Industry Report, NEPRA

Figure 2 provides electricity demand forecasts for the year 2028 with the base year taken as 2019. It shows that the major share of the increase in demand is originated from the province of Punjab. Therefore, Punjab should move on to a proactive approach by developing closer liaison with the relevant governing bodies of the government of Pakistan for power generation and regulatory matters.

An important lesson to be learned from this long episode of power crisis is the proactive role of provincial governments. The provinces have been accorded the authority to develop a regulatory framework, in the Power Generation Policy 2002. For instance, the Punjab Power Generation policy 2006 (revised in 2009) aims to attract investors to install power projects with a capacity of maximum 50 megawatts. However, failure to implement policies appropriately results in a demand-supply gap in the country that forced the producers to costly solutions and lowered the competitiveness. The coordinated efforts of the provincial government of Punjab with the federal government have been remarkable to end

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this crisis. But it is important to increase reliance on renewable energy resources, especially solar, wind, and hydel, for at least two reasons. First, renewable resources are indigenously available. Second, these are critical for climate change mitigation. Further, less reliance on fossil energy resources put less foreign exchange pressure.

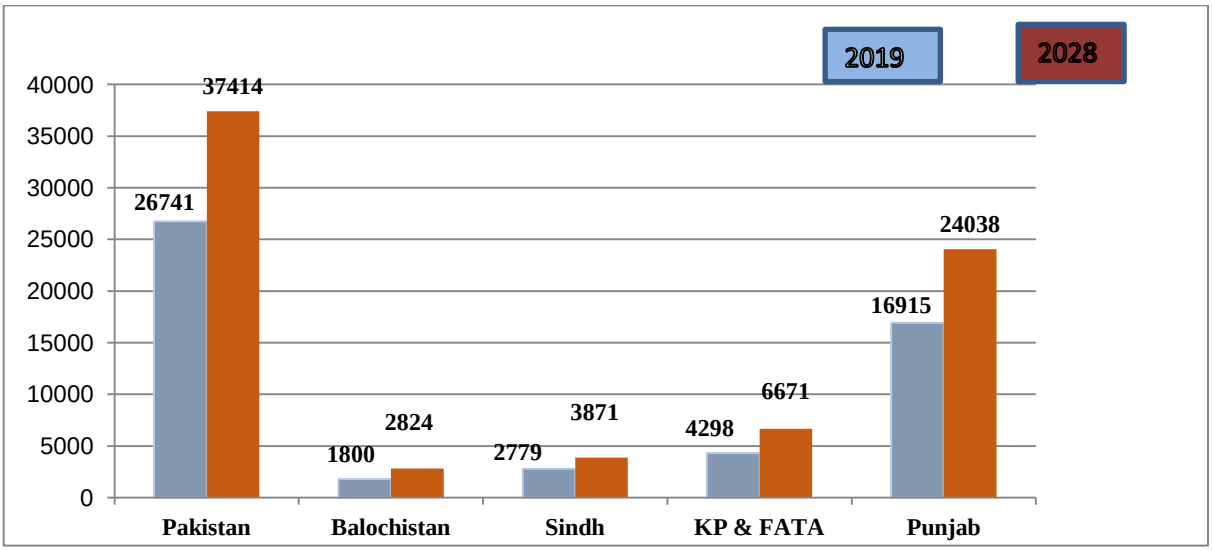

Figure 2: Electricity Demand Forecasts of Provinces (MW)

Source: NTDC (IGCEP-2040/Demand forecast Report 2019-28)

The indicative generation capacity Expansion plan 2047 (IGCEP-2047) of NTDC which is in conformation with the government's policies, latest technologies, and relevant regulatory obligations, devised an expansion plan for meeting the growing electricity demand. Table 3 depicts that the share of thermal power generation will decrease significantly from 65 percent in 2020 to 25 percent in 2030 but it will again increase during 2031-47. Furthermore, the share of renewables will increase from 4 percent in 2020 to 25 percent in 2030 but it again will decrease to 15 percent. On the other hand, hydro electricity's share will consistently increase from 26 percent to 43 percent by 2047.

Table 3: Pakistan's Power Generation Mix within Technical, Economic and Legal Constraints (%)

Year	**2020**	**2030**	**2047**
Thermal	**65**	**25**	**37**
Natural Gas	14	0	0
Local Coal	3	13	36
Imported Coal	18	3	1
Residual Furnace Oil (RFO)	4	0	0
RE-gasified Liquid Gas Based Technologies (RLNG)	26	9	0
Nuclear Plants	**5**	**13**	**5**
Hydro Electric Plants	**26**	**37**	**43**
Renewable Resource Plants	**4**	**25**	**15**
Solar	1	9	8
Wind	2	14	6
Bagasse	1	2	1

Source: IGCEP 2047

As such, the increase in coal power plants at the cost of a decrease in the share of renewables is not a wise option. Keeping climate change policy framework, the international treaties such as Paris agreement and the legal perspective demand more focus for harnessing the potential of renewables. Another aspect is the aggressive and unrealistic target for renewable energy because of its intermittent nature therefore backup generation plan should be in place to deal with any unwanted situation. Given the fact that the tariff for renewable technologies is significantly lower than fossil fuels (Figure 3), therefore NTDC should accept the challenge to deal with the intermittency nature of renewables.

The intensity of solar radiation that is feasible for the generation of electricity is available in most of the regions of Pakistan (Figure 4). Both the on-grid and off-grid solutions should be given due priority at the policy level. Furthermore, the potential of wind energy is also available in the coastal belt of Pakistan (Figure 5).

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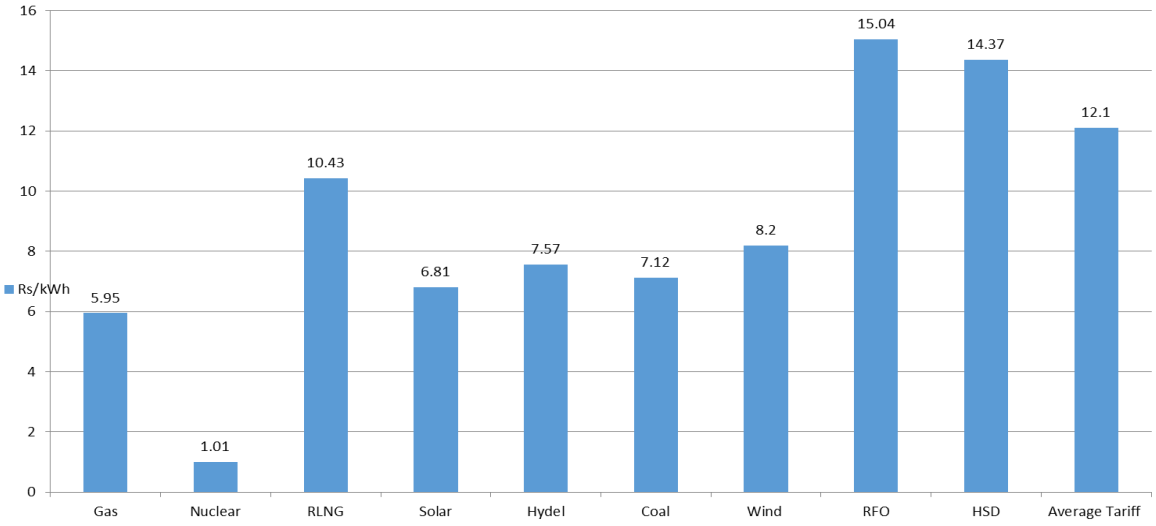

Figure 3: Fuel-wise Tariff Structure

Source: CPPA-G 2019-20

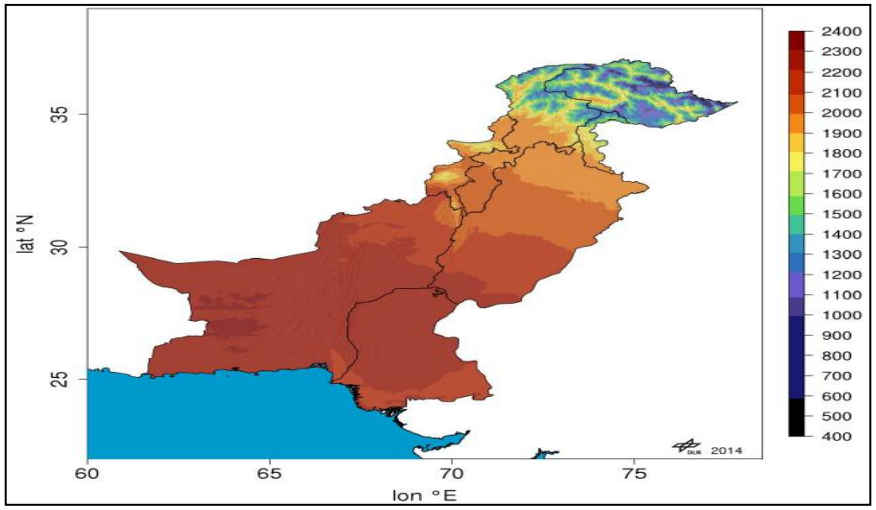

Figure 4: Solar Irradiation Map of Pakistan (kWh/m^2)

Source: WorldBank ESMAP, 2018

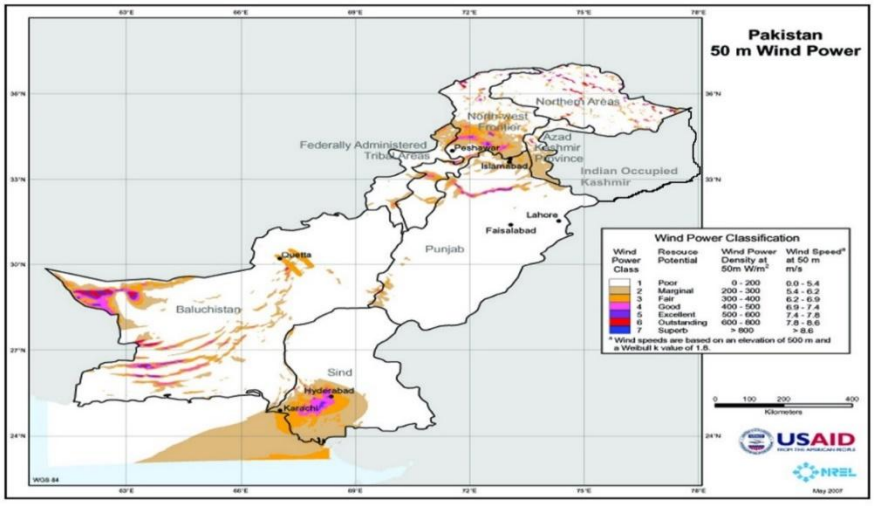

Figure 5: Wind Power Potential in Pakistan

Source: World Bank ESMAP, 2018

The vulnerability of Pakistan's economy to energy price shocks is common knowledge. So far, there has been no steady policy to deal with such shocks. Given the critical nature of reliance on energy, an energy price shock puts pressure on already depleting foreign reserves and creates an issue of circular debt. Particularly the textile sector which had long enjoyed the status of Queen in the industry has been observed to shift their units to Bangladesh.[2] While the industrial sector has shown nominal growth over the years, it could have been much more in absence of cyclical fluctuations elicited by energy price shocks and in the absence of power blackouts. Had there been an adequate long-term policy by the government to deal with it is an important question to answer.

More reliance on modern energy resources is critical for enabling the poor population to participate in economic activities more productively thus it also leads to improve living conditions (Brew-Hammond and Kemausuor 2009; Mondale and Islam, 2010; Zuberi et al., 2013; Nayyar et al., 2014). Rising socio-economic inequalities among the economic agents are the result of the failure of fiscal and monetary policies. Overvalued exchange rates and oscillating energy prices are points of concern for policymakers. An important finding wetted thorough survey of the literature is the cost-push nature of inflation in Pakistan like any other developing economy where capacity utilization is not fully revealed, that is resources are available. Thus, narrowing focus on the cost of different factors of production can help to identify the main sources responsible for rising prices and decreasing world demand for domestic products. Energy plays a vital role in the production of goods whereas its prices are determined in the world market thus controlling prices of energy products is beyond the scope of the government of any energy importing country. In this scenario, efficient use of energy supplemented with energy-efficient technology can settle the problem of macroeconomic instability. Another important dimension is to explore the potential of domestic resources for electricity production to ensure the least reliance on imported fuels.

Quality of Electricity Supply

Transparency of tariff structure and the minimization of transmission and distribution losses are also very important to ensure cost-effective electricity supply to the industrial sector and accordingly to make the climate more investment-friendly. It is, therefore, more important to focus on the electricity reliability index because it captures at least two aspects of SDG 7, that is, reliability and sustainability including quality of electricity supply. Ultimately, it measures the performance of a distribution system. Two indicators are more commonly used to measure the reliability of the electricity supply. These are the System Average Interruption Frequency Index (SAIFI) and System Average Interruption Duration Index (SAIDI). SAIFI serves as a measure of how often a customer would experience a power outage, whereas SAIDI reflects power supply interruption in minutes. According to Performance Standards (Distribution) Rules, 2005, distribution companies are required to ensure that SAIFI and SAIDI do not exceed thirteen (13) and fourteen (14) in numbers and minutes, respectively. However, the performance of all DISCOs is dismal except IESCO. Table 4 provides a comparison of SAIFI and SAIDI among the DISCOs for 2018-19.

Table 4: Comparison of SAIFI and SAIDI 2018-19

DISCO	SAIFI	SAIDI
Punjab		
IESCO	0.05	1.27
GEPCO	27.13	45.19
LESCO	30.19	3,538.93
FESCO	36.86	1,627.99
MEPCO	369.16	31,419.00
Sindh		
HESCO	170.86	10,973.67
SEPCO	516.37	4,306.67
Khyber Pakhtunkhwa		
PESCO	189.01	16,696.51
TESCO	n.p.	n.p.
Balochistan		
QESCO	n.p.	n.p.

Source: State of Industry Report 2019

Table 5 depicts the loading position of 11 KV feeders, and power and distribution transformers across DISCOs and provinces.

[2] As per survey reports, due to energy crisis more than 40 percent of textiles industry and 200,000 power looms have shifted to Bangladesh during the five preceding years 2012 (Sohail, 2012).

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Table 5: Disco-wise and Province-wise Loading Position of 11KV Feeders, Power and Distribution Transformers and losses: FY 2020

DISCO	11 KV Feeders			Power Transformers			Distribution Transformers			Distribution Losses
	Total	Over-Loaded (above 80%)	percent Over-Loaded	Total	Over-Loaded (above 80%)	percent Over-Loaded	Total	Over-Loaded (above 80%)	percent Over-Loaded	
Punjab										
IESCO	1,166	65	5.57	263	9	3.42	50,210	1,663	3.31	8.69
GEPCO	876	57	6.51	173	15	8.67	72,007	1,942	2.70	8.51
LESCO	1,923	458	23.82	404	66	16.34	116,030	25,743	22.19	12.40
FESCO	1,150	56	4.87	236	25	10.59	113,079	652	0.58	9.62
MEPCO	1,508	232	15.38	302	37	12.25	178,730	5,832	3.26	15.23
Total	6,623	868	13.11	1,378	152	11.03	530,056	35,832	6.76	
Sindh										
HESCO	556	69	12.41	122	26	21.31	37,896	1,211	3.20	28.82
SEPCO	541	103	19.04	132	16	12.12	38,616	2,676	6.93	36.27
Total	1,097	172	15.68	254	42	16.54	76,512	3,887	5.08	38.69
Khyber Pakhtunkhwa										
PESCO	1,089	341	31.31	239	86	35.98	77,307	3,477	4.50	38.69
TESCO	245	193	78.78	55	16	29.09	18,903	6,682	35.35	n.p.
Total	1,334	534	40.03	294	102	34.69	96,210	10,159	10.56	
Balochistan										
QESCO	652	652	100.00	177	51	28.81	62,337	6,814	10.93	26.68
Total	**9,706**	**2,226**	**22.93**	**2,103**	**347**	**16.50**	**765,115**	**56,692**	**7.41**	

Source: State of Industry Report 2020

It depicts that improvement in infrastructure for appropriate transformation of electricity to the end consumers is direly needed for improving the quality and sustainability of the electricity supply. Therefore, investment in infrastructure should be taken as a priority. The distribution losses of electric supply companies are also very high ranging from 8.69 to 38.69 percent.

The financial performance of the sector primarily depends on the revenue generation to cover the cost of electricity and the profitability of the producers and other relevant market players. In case of insufficient revenue generation, financial constraints lead to cutbacks on spending on maintenance and on capital investment which increase the production cost and deteriorate the reliability of the power sector. It signifies the tariff structure. Further, proper attention is needed on the operational performance and ownership structure of the sector without which the reliability of electricity supply can be influenced negatively. The role of the regulator is to set the rules of the game for all market players. In this sense, the role of the regulator is most important. For example, this is only the regulator who can control the monopolies in the market and play an important role in supervising the pricing to protect the consumer. Regulators can impose penalties to the supply-side market players or compensation to the customers in case of power outages surpass a certain level. The government needs to ensure the supply of adequate infrastructure facilities and public utilities to avoid the creation of bottlenecks for local and foreign firms. Future endeavours are needed in improving the economy's self-reliance and ensuring the quality of its electricity supply which would reduce its vulnerability and further help in lowering the cost-push inflation due to the lower production costs.

CONCLUSION

Renewable sources, especially solar and hydro should be focused on a long-term solution to not only improving energy security but also for reducing carbon emissions. It is also significant for improving overall sustainability in the country especially to move ahead in terms of sustainable development goals which are correlated with reducing CO2 emissions through adopting green technologies. For instance, CO2 emissions are a major source of all diseases, compromise learning abilities and negatively affect the productivity of human capital, climate change, affect the agriculture sector, and much more. Otherwise, it is a costly solution to mitigate through forestation. An important aspect to understand is that focusing on the reactionary approach only to reduce CO2 emissions cannot be the only solution. A strong regulatory framework and appropriate address of green technology in every relevant policy including climate policy, industrial policy, and power generation policy with a set of incentives and implementation framework are required.

Energy sector reforms are required at two levels, that is, at generation, and transmission and distribution levels. It leads to a lower cost of production of goods and improves competitiveness. More efforts are required to encourage the generation of electricity through renewable resources (both on-grid and off-grid). However, the transmission and distribution issues remained unaddressed which should be taken as a priority for improved quality of electricity supply and competitiveness.

CPEC projects did not change the fuel mix for electricity generation dramatically leaving major dependence on imported oil and coal. Taking into account the inefficiencies of thermal power projects, changing the fuel mix with the majority share of renewables is significantly important for decreasing volatility in overall prices, economic growth, and exchange rate. It also helps in making the macroeconomic policy more effective. Both the provincial and federal governments should focus on reducing dependency on the national grid through promoting off-grid electricity solutions. It is the need of the time that financing models for households, firms, and communities, in close coordination with the banks and relevant federal institutes should be introduced.

LIMITATION AND STUDY FORWARD

The impacts of severe weather circumstances have been less extensively researched unlike gradual improvements in climate change scenarios. This is likely responsible for the higher unpredictability of global warming where the IPCC AR5 assessed the trends of flooding and drought in the future with little confidence. While studies can also evaluate the effects of previous events utilizing available information, it may be difficult to use these results for future climate variability projections because of the great number of parameters.

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AUTHORS CONTRIBUTION

The introduction and literature review of this study was largely conceptualized by Shahzada M. Naeem Nawaz. Zubair Khalid Saleemi has made a major contribution towards the conceptualization of the area of study, data collection from diverse sources, targeted public, discussions, and conclusions. The research concepts of the study and research methodology development and analyzed by Muhammad Nadeem.

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