Issues In Electricity Market Of Pakistan: A Note On Regulatory structure, Sustainability And Policy Choices

Syed Badar-Ul-Husnain Rizvi*

Abstract

This paper reviews Pakistan's electricity market and identifies the problems faced by the sector to suggest policy options to improve its operational and financial performance. Pakistan's electricity market was restructured through WAPDA Act, 1998 however the market is still facing issues in its generation, transmission and distribution segments. The institutional development was planned to strength the technical and administrative efficiency of the sector which could not be achieved with overlapping of functions between different authorities. This has resulted in distorted tariff determination process due to political interests and excessive cross subsidization. The electricity market reforms created investment opportunities for private sector which enhanced the installed generation capacity but due to poor operational management and inefficient fuel mix, the generation sector did not benefit from this expansion. The administrative failures of distribution companies create hurdles in bills collection from end users while mismanagement compromises customer services due to which majority of DISCOs do not meet the performance standards determined by NEPRA. Our analysis proposes that policy makers need to ensure the autonomy of NEPRA in decision making process. The policy actions should focus on administrative and financial strengthening of generation, transmission and distribution network companies to improve the performance of the market in a sustainable manner.

Keywords: Electricity Market, reforms, overview, distribution companies.

Introduction

Structural reforms in electricity markets around the globe started in 1980s which included the unbundling of the state-owned electric utilities, establishment of independent and autonomous regulatory bodies, privatization of generation and distribution companies, creation of market for electricity retail and allowing competition among generation, distribution and retail segments of the electricity markets (Qazi and Jahanzaib, 2018). The reforms process across countries is still in progress as it requires continuous improvements for optimal productive gains (Jamasb et a., 2015). Evidence indicates that an effective implementation of reforms in electricity market results in efficiency improvements through cost reduction, services quality improvements, and attainment of better system reliability and security (Nepal et al., 2016). Similarly, these reforms bring efficiency improvements in transmission systems by substantially reducing the transmission and system losses (Sultana et al., 2016). Like other countries, Pakistan also introduced electricity reforms in 1998 with the aim of developing an efficient power sector that could offer reliable access to electricity at affordable prices.

---

*PhD Scholar, Economics Department, University of Gujrat

In the wake of these reforms, government of Pakistan passed WAPDA Act in 1998 with the underlying objectives to achieve operational, financial and managerial efficiencies by reducing price-cost margins, system losses and sectoral price differences. Furthermore, this Act also aimed at encouraging new investment in the sector which was already undermined due to certain politico-economic issues including overstaffing, corruption, political pressures, poor service quality and poor bills collection mechanism (Malik, 2009). The restructuring of the power sector unbundled WAPDA into four generation companies (GENCOS), one transmission company (NTDC) and eight distribution companies (DISCOs), initially. An independent regulatory body NEPRA (National Electric Power Regularity Authority) was established to promote competition in energy market and to ensure the rights of consumers, producers and the sellers (Malik, 2007). Moreover, Pakistan electric power company (PEPCO) was enlisted as a private limited management company to steer, manage and oversee the corporate and commercial activities of the Government of Pakistan (Ullah, 2013). Similarly, an independent price setting mechanism was made subject to on the rate of return (RoR) regulations for tariff determination. Figure 1 reflects the restructured electricity market in Pakistan.

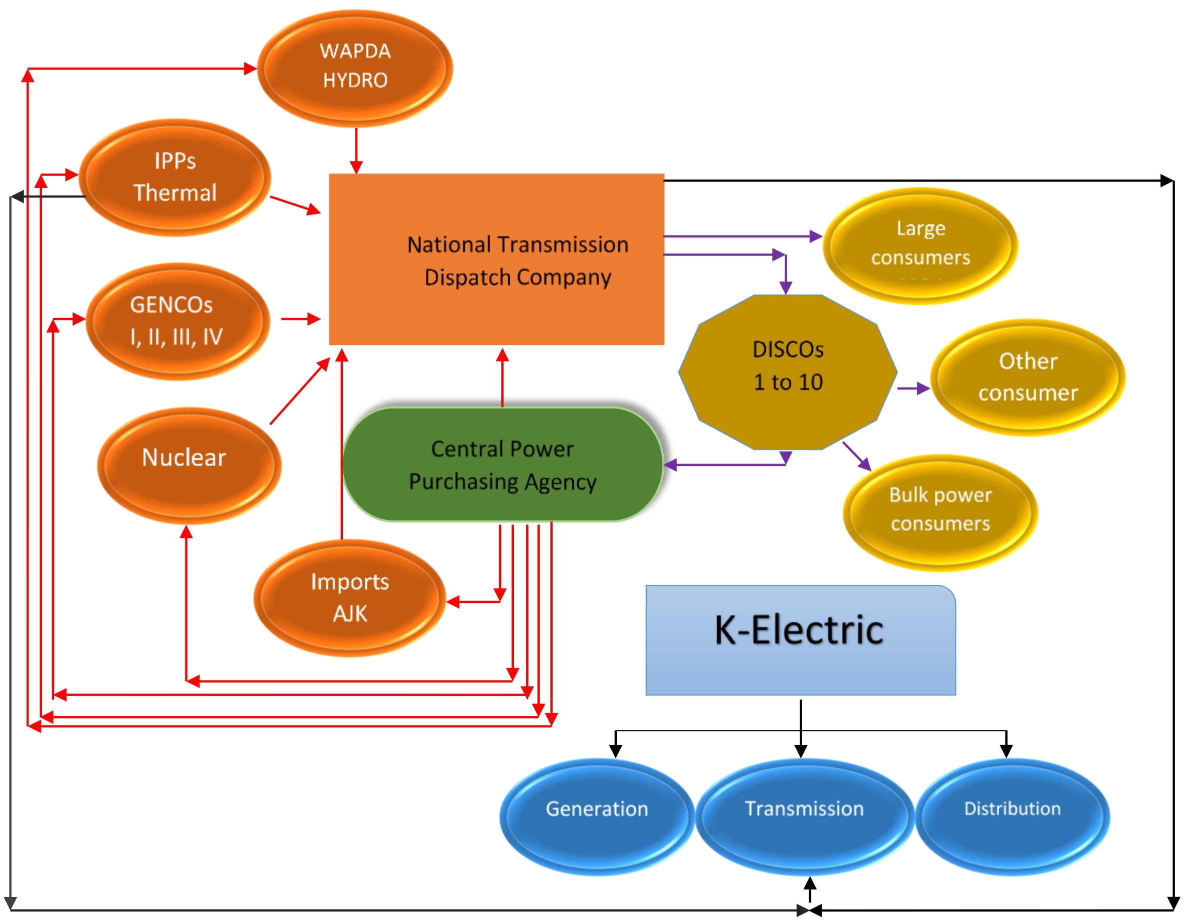

Figure 1: The Post-reforms structure of electricity market in Pakistan (Mirza et al., 2017; Ullah,2013)

The restructuring of the power sector resulted into two parallel systems in Pakistan. Government privatized Karachi Electric Supply Company (KESC) without its restructuring while WAPDA was unbundled (Khan,2014). NTDC is still enjoying its monopoly power due to strict government restrictions on privatization of the transmission system whereas only the thermal generation was opened up for private investment through Independent Power Producers (IPPs) (Figure 1). Moreover, even after passing two decades, the electricity market reforms process in Pakistan is still ambiguous, shaky and slow (Ullah, 2013). Performance of these publically owned companies in all sections of the electricity sector has remained inefficient (NEPRA, 2017) and the power sector of Pakistan has remained under stress. Currently, the country is experiencing a demand supply gap of around 5000 MW, increasing tariffs, huge line losses, poor quality of services and ongoing problem of circular debt (Kessides, 2013; Mirjat et al., 2017; Qazi et al., 2018). These issues not only affect the performance of electricity market but also disrupt the path of economic development (Komal and Abbas, 2015; Qazi et al., 2018) which trigger the need of identifying the technical causes of the crisis in electricity market.

Several studies have examined the potential causes of electricity market crisis and the performance of generation and distribution companies in Pakistan (Khan, 2014; Malik, 2007; Perwez et al., 2015; Zakaria and Noureen, 2016; Zhou et al., 2017; Mirjat et al., 2017; Mirza et al., 2017; Nawaz and Alvi, 2018). Some studies have concluded that poor implementation of reforms has remained a major cause of the crisis in electricity market (Mirjat et al., 2017; Qazi et al., 2017; Ullah et al., 2017; Zameer and Wang, 2018). Therefore, this study aims to review the electricity market in Pakistan by separately analyzing the performance of electricity generation, transmission and distribution segments using sectoral variables. Rest of the paper is organized as follows. Section 2 provide post-reform electricity market structure, section 3 provide genesis of the issue in Pakistan's restructured electricity market and section 4 conclude the paper.

Post-reform Electricity Market

Electricity generation

Prior to the restructuring of electricity market in Pakistan, two vertically integrated electric utilities comprised of the complete market i.e. WAPDA & KESC. Later, WAPDA was restructured into 4 Generation companies (GENCOS), 10 Distribution companies (DISCOS) and 1 Transmission company (NTDC). The electricity market in Pakistan thus now comprises of four major electricity producers namely; WAPDA, GENCOs, IPPs and Pakistan Atomic Energy Commission (PAEC). WAPDA generates electricity using hydro based resources while GENCOs and IPPs generate electricity using thermal based technologies. The share of hydro in electricity generation is 29.29 percent while the share of fossil fuels including gas occupies a share of 65 percent in the overall electricity generation mix where the share of nuclear electricity generation is only 5.85 percent (NEPRA, 2018). Moreover, the share of hydropower generation in overall electricity generation has decreased over time as not much investment in hydropower electricity generation has been made during the last four decades (Qureshi and Akintug, 2014).

WAPDA

Water and Power Development authority (WAPDA) in October 2007 was split into two independent bodies i.e. WAPDA and Pakistan Electric Power Company Private Limited (PEPCO). Pakistan Electric Power Company Private Limited (PEPCO) was established for restructuring and privatizing the generation and distribution companies under the privatization commission of Pakistan (Khan,2014). Hydroelectric power development and its operations are still under the control of WAPDA while PEPCO is responsible for thermal power plants, NTDC and distribution utilities. Due to severe power crisis in April 2012, PEPCO was dissolved and its functions were transferred to Central Power Purchase Agency (Kessides,2013) In order to meet the electricity requirement of the country, WAPDA has planed the construction of four water storage dams namely, Keyal Khwar Hydropower Project with installed capacity of 128 MW, Dasu Hydropower Project with installed capacity of 4320 MW, Kurram Tangi Dam with generation capacity of 83.4 MW (WAPDA, 2019) and Mohmand Hydropower project in Khyber Pakhtunkhwa with installed capacity of 800MW . Alongside, two rehabilitation projects were also planned to enhance the efficiency of tribunes and to increase the generation capacity of existing projects which include Mangla Power Refurbishment and rehabilitation project of Warsak Power Station (WAPDA, 2019). These projects are aimed to harness water resources and to produce clean, cheap and reliable hydroelectricity.

Pakistan has the potential of about 40,000 MW of hydroelectricity but total installed generation capacity of WAPDA was 7116 MW during 2017. The share of installed capacity of hydroelectricity to total installed generation capacity was 67 percent in 1985 which has decreased to 29 percent (NEPRA, 2017). The generation capacity of WAPDA was 34,554 GWh in 2016 which has dropped to 32,079 GWh (See table 1). The generation capability refers to the capacity for meeting demand for electricity in NTDC system. Dropping generation capability of hydro power plants over the years as compared to installed capacity is mainly due to aging and poor utility practices, lower water inflows and reservoir levels.

Thermal Generation

Jamshoro power company limited (GENCO-I)

The Jamshoro Power Company Limited (GENCO-I) was granted license in 2002 by NEPRA and consists of three thermal (gas and furnace oil) power plants in Jamshoro and Kotri. Total installed capacity of GENCO-I is 2344 MWs. Energy generated by GENCO-I was 3153 GWh in FY 2013-14 and 2961 GWh in FY 2014-15. Similarly, during fiscal year 2015-16, the energy generated by GENCO-I was 3828 GWh while it decreased by 6.14 percent and stood at 3593 during fiscal year 2016-17. According to state of industry report 2017, the net efficiency of TPS Jamshoro was 28.42 percent while 27.05 percent for GTPS Kotri. These trends indicate that the generation from GENCO-I has decreased over the recent years. The major reasons for this decline in electricity generation include forced outages, shortage of fuel, shortage of demi water and other rehabilitation activities, showing that the performance is not up to the mark (NEPRA 2017; PER, 2016).

Table 1: Installed and generation capacity

	WAPDA Hydel	IPPs Hydel	**Total**	% Share
Installed generation capacity				
2012-13	6,733	214	**6,947**	29.28
2013-14	6,902	214	**7,116**	30.02
2014-15	6,902	214	**7,116**	30.02
2015-16	6,902	214	**7,116**	30.02
2016-17	6,902	214	**7,116**	30.02
Generation capacity				
2012-13	29,327	706	**30,033**	30.44
2013-14	31,204	1,035	**32,239**	30.5
2014-15	31,525	1,069	**32,594**	29.93
2015-16	33,433	1,121	**34,554**	30.29
2016-17	31,091	988	**32,079**	26.6

Source: State of Industry 2017

Central Power Generation Company limited (GENCO-II)

Central Power Generation Company Limited (GENCO-II) was given license in 2002 which was modified in 2013 allowing GENCO II to increase the installation capacity by 776 MW. Total installed generation capacity of GENCO-II is 2431.7 MW (NEPRA, 2017). It is also observed that various sectors of GENCO-II are out of service due to maintenance issues or not up to date. The power generated by GENCOS-II was 8079MW in financial year 2017-18 while it was 6031MW in 2016-17. The generation capacity of the GENCOS-II has increased by 33.39% as compared to previous year (NEPRA, 2017).

Northern Power Generation Company Limited (GENCO-III)

Installed capacity of GENCO-III is 2291.65MW while dependable capacity is 1925MW. In 2014, installed capacity of GENCO-III increased by 425MW due to installation of Nandipur power project. Total energy produced during 2014-15 was 4627GWh while it was 5307GWh in 2013-14. A decline of 12.81 percent in energy production clearly indicates poor performance of GENCO-III. The generation capacity of GENCO-III has increased by 9.37% in financial year 2016-17 as compared to previous financial years. It was also observed that the performance of the Nandipur, Muzaffargarh and Faisalabad power project was undermined due to forced outages and fuel restrictions, indicating that overall performance of the GENCO-II has not remained satisfactory (NEPRA,2017).

Lakhra Power Generation Company Limited (GENCO-IV)

Installed capacity of GENCO-IV in June 2017 was 150 MW while dependable capacity is 30 MW. It has three units of 50MW but due to poor maintenance only one unit is in working condition which clearly indicates poor performance of Lakhra power generation company ltd as the GENCO-IV is utilizing only 22.68 percent of its installed generation capacity (NEPRA, 2017)

Independent Power Producers (IPPs)

Though the restructuring plans for state-owned power sector were passed in 1992 but first substantial change was observed in 1994 when independent power producers were given the license (Ali and Beg, 2007). Independent power producers (IPPs) were established under the power policy 1994 and later under Power Policy, 2002, Renewable Energy Policy, 2006 and Power Generation Policy, 2015 (NEPRA, 2018). IPPs started electricity supply in late 1990s but a public power plant was privatized in 1996 (Khan, 2014). NEPRA is responsible for determining the upfront tariff for IPPs and for opting any tariff, IPPs have to take approval from NEPRA. According to guidelines for determination of tariff for IPPs (2005), tariff rate of IPPs is determined by Internal Rate of Returns (IRR) which is equal to long term interest rate based on auction during last six months. The installed generation capacity of the independent power producers in PEPCO system increased from 4830 MW in 2000-2001 to 10566 in 2017 (NEPRA, 2017; Malik 2012). Similarly, the installed generation capacity of hydel IPPs rose from 96 MW in 2007 to 214 MW in 2017 (NEPRA, 2017). It was observed that due to the disputes between NTDC and WAPDA, the Japan and Southern electric companies are not generating electricity. If these generation companies start operating, then approximately 270MW of electricity can be added in the system which will help in reducing the demand-supply gap (NEPRA, 2017).

GENCOs also have various issues regarding their performance and efficiency including fuel availability, fuel mix, forced outages, unannounced rehabilitation activities and inefficient actual generation. Furthermore, the fossil fuel is the major impetus for GENCOs of which 80 percent was imported in FY 2015-16 (SBP, 2016). This imported oil results in high electricity generation costs. Keeping in mind the sudden surge in oil prices in 2007 to 2013, substantial measures are required to decrease the share of imported oil in GENCOs. Hence increase in the efficiency of GENCOs is the dire need for electricity market in Pakistan, there are various socio-political barriers that hamper the efficiency associated with GENCOs.

Nuclear Power Plants

Along with two main generation sources, electricity in Pakistan is also generated through nuclear energy. The first nuclear power project was initiated in 1971 in Karachi with total installed generation life time for 30 years and was shut down on December 2002. Followed by three nuclear power projects namely, Chashma Nuclear Power Plant (CHASNUPP-I) in 2000, CHASNUPP-II in 2011, CHASNUPP-III in 2016, the total installed generation capacity of nuclear power plants has increased to 1142 MW in 2017 (NEPRA, 2017).

Renewable energy generation

Pakistan is also using renewable energy resources to meet the domestic demand for electricity. Renewable resources are technologically feasible and do not deplete with the use. Renewable energy refers to clean energy because it is generated through natural resources such as wind energy, tidal energy, solar energy, geothermal energy and bioenergy etc.

Pakistan has the potential of producing 50,000 MW of electricity through wind energy at Coastal Belt of Sindh (NEPRA, 2017). Currently, Pakistan has the installed capacity of 1110 MW in renewable energy resources comprises of wind, solar, bagasse and biomass (NEPRA,2016) which is way below its potential. Pakistan also established the Alternative Energy Development Board (AEDB) in 2003 to attract private investment in renewable energy.

2.2. Transmission network

Transmission network helps to “transmit the electricity produced by the system of generators to the engine to the driving wheels” (Burke and Stephens, 2018). Sustainable and efficient electricity market ensures the reliable electricity provision to end users. The transmission segment in this regard, serves as a bridge between generation and distribution companies. The transmission network in Pakistan is still under the control of government which is operated by the state-owned entity named National Transmission and Dispatch Company (NTDC). The duties of NTDC also include the sale and purchase of electricity which is done through its subsidiary body named Central Power Purchasing Agency (CPPA-G). NEPRA also considers the investment requirements of NTDC regarding upgradation of transmission lines, construction of new grid stations and interconnection between different power plants (NEPRA, 2017).

NTDC uses its vast network for supplying purchased electricity to DISCOs which comprise of high and extra high voltage lines, real-time control centers and power transformation stations. There are thirty-nine grid stations in Pakistan out of which 29 are of 220KV and 12 are 500KV. NTDC has sole right in dispatching electric services and for this purpose, it has 5197 km lines of 500 KV and 9814 Km lines of 220KV.

A reliable transmission system plays a vital role in power supply without tripping but according to NEPRA (2017) transformers are overloaded up to 80 percent and around 11,000 MW to 15,000 MW of electricity is transmitted through these transformers depending on time to time situation i.e. power generation, demand and load. There are many operational hindrances which halt the smooth transmission of electricity to the distribution nodes such as operational mismanagement and insufficient capacity creating imbalances in demand and supply. Deficient electricity induction in the national grid, poor power management and service by NTDC has impaired the transmission system of Pakistan (Lodhi, 2014). Furthermore, because of aging transmission network and its poor maintenance, the transmission network is not secure, safe and reliable due to which duration of outages has increased significantly since 2006. The number of planned outages for the financial year 2017 were 559 and 886 for 500KV and 220KV respectively and unplanned outages were 82 and 287 for 500KV and 220KV respectively. However, number of outages has increased in financial year 2016-17 (NEPRA, 2017).

Similarly, with the increase in electricity demand and rise in expected generation because of upcoming projects, this overloading may rise in future. Additionally, due to inadequate transmission mechanism, frequent tripping and dispersals, the transmission losses are also expected to increase. One of the objectives of the structural reforms in electricity market was to establish a reliable and efficient transmission system but due to eruption in law and order, bureaucratic delays, threats to engineers and technicians, the situation has deteriorated. Therefore, building new transmission lines and grid stations are necessary to avoid frequent tripping in the existing transmission system and improving the energy security. Similarly, transmission losses or technical losses can be avoided by the identifying the weak areas in the transmission system.

Distribution system

Distribution system is crucial part of any electricity market. It contains an extended system of complex lines, transmitting the power from distribution transformers to distribution sub-stations and power points (Meng & Pian, 2015). Distribution segment of electricity market ends the process of supply chain excluding the retail services. Distribution network in Pakistan contains the transformer sub-stations which comprise of 0.4 KV feeders, consumer service lines, meter boxes and handling stations at end user premises (Siddiqi et al., 2012). These feeder networks consist of ABC cables that are fixed over 7m steel poles while meter boxed are the feeder poles which are installed at public places connected with double core service lines that lead the electricity to consumer premises (Sabri et al., 2013).

Due to restructuring of WADPA, eight distribution companies (DISCOs) came into being which were later increased to ten. The distribution companies are responsible for supplying electricity to end users of different categories namely residential, industrial and agricultural. These DISCOs deliver electricity through their network consisting of 132KV to 11KV lines. The DISCOS network contains 25068KM of distribution lines of 132KV (NTDC, 2018). These lines have become unreliable in nature because 38.62 percent of the total transformers are overloaded (Abbasi,2014). More than 50 percent of transformers of FESCO and QESCO are overloaded by 80 percent. This is an alarming situation which requires serious managerial steps by DISCOs.

Genesis of the issue in Pakistan's restructured electricity market

Generation and Installed capacity

Electricity generation sector is an essential component of electricity market and has strong bearings on the performance of the economy. According to Polemis and Stengos (2017), an efficient and well-structured generating unit significantly contributes to the overall performance of electricity market. Currently, the electricity generation segment comprises of state owned as well as private entities, which are using hydro, thermal, wind and nuclear sources to produce electricity. Reforms were initiated to enhance the installed and generation capacity of the electricity market due to which private investors were given license for electricity generation plants. The aim of opening up of the sector to private investment was to ensure that enough generation capacity is available even in the peak hours. But there remains a gap in installed and generation capacity in electricity generation, creating electricity shortages. It also shows that GENCOs are not performing optimally and are not well maintained which reduces their capacity to operate. Figure 2 shows the trend of installed and generation capacity of electricity generation units from 1980 to 2017. It is observed that generation capacity in the market has remained lower than installed capacity. It is clear from the graph that installed and generation capacity gap was small in the beginning but with the passage of time, this gap has widened, indicating that power plants are not being optimally utilized in these years. Moreover, no significant efforts were made to remove this gaps which deteriorated the productive capacity of the plants (KCCI, 2013; GoP, 2014).

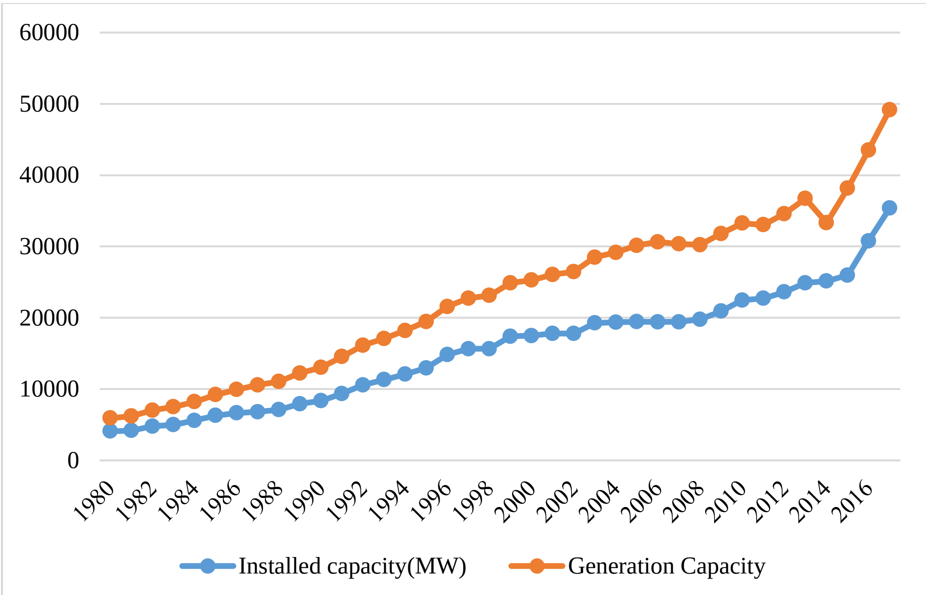

Figure 2: Installed and generation capacity (NTDC, 2018)

Widening Demand-Supply gap

The difference between installed and generation capacity in Pakistan's electricity market is reflected in the difference between demand and supply of electricity. This gap is an important indicator of the performance of generation segment of the electricity market. A large and consistent demand supply gap not only influences the performance of DISCOs but also the residential, commercial and industrial customers in the economy. Figure 3 shows persistent and wide demand supply gap of electricity from 1996 to 2018 for Pakistan economy. Meeting the growth of electricity consumption in the economy has created a challenge for regulatory institutions and the market as the gap between demand and supply has resulted into blackouts for about 8 to 12 hours a day (Qazi & Jahanzaib, 2018). Moreover, shaky economic growth and poor business environment triggered industrialists to shift their businesses to other countries. Shahbaz (2015) found the negative relationship between electricity outage and output. Study found that 1 percent increase in electricity shortage has caused 0.16 percent reduction in agricultural output, 0.70 percent reduction in industrial output while 0.32 percent reduction in the output of the services sector in Pakistan. Similarly, study found a high correlation of 0.80 between electricity shortage and the unemployment.

The reasons for the persistent electricity shortfall include the poor institutional development, lack of coordination between NEPRA, NTDC and CPPA and the incompetence of NEECA (National Energy Efficiency and Conservation Authority) for motivating the end users toward energy efficient appliances (Shakeel et al., 2016; Kamran, 2018; Qazi & Jahanzaib, 2018).

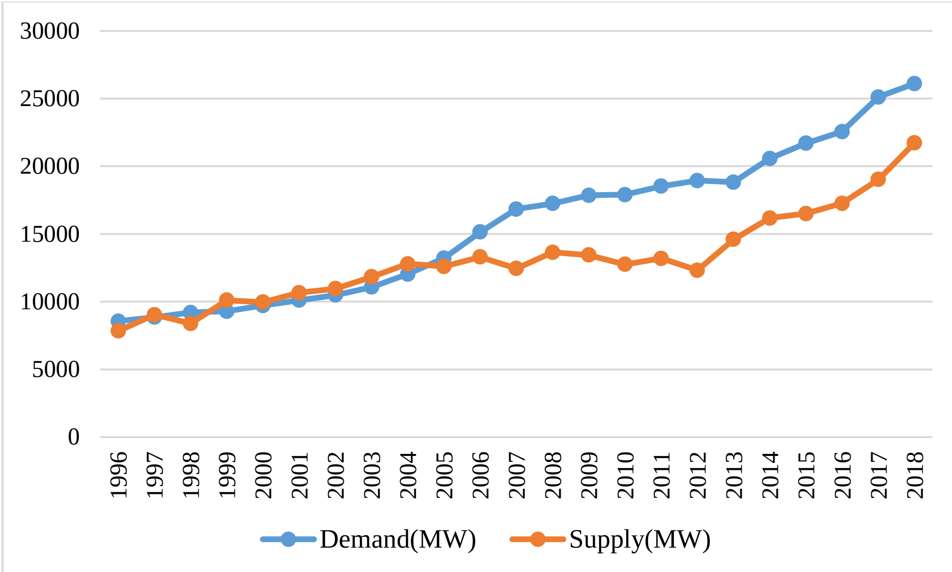

Figure 3: Demand supply gap (NTDC, 2018)

Average cost and Price Margins

According to NTDC report 2017-18, the share of thermal power generation is sixty-seven percent in the overall electricity generation mix where furnace oil is used as a primary source for electricity generation. Pakistan imports the furnace oil for this purpose and as international oil prices remained volatile during the last decade and increased rapidly between 2007 to 2013 resulting a rise in cost of production of generation companies. Prices act as signals for an efficient resource allocation. In a market where the marginal cost of production varies along time, optimal price in each period is where the marginal consumer utility equals marginal production costs. However, the tariff in Pakistan is administratively determined which contributes in piling up of the financial losses, resulting into higher levels of circular debt. Since the end users in Pakistan's electricity market don't observe the prices based on true marginal cost of production, there is a limited response to recurrent variations in prices. This represents an inefficient market outcome as the cost of electricity becomes higher than the optimal since high-cost generators remain in operation for too many hours. Figure 4 shows that average cost of electricity production is always above the average sale price while the gap between the two reflects the subsidy per unit of electricity consumed. The comparison of average price charged by the NEPRA and cost of production clearly reveals that government announces low prices for its political objectives due to which industry faces the losses, hampering the performance of the sector.

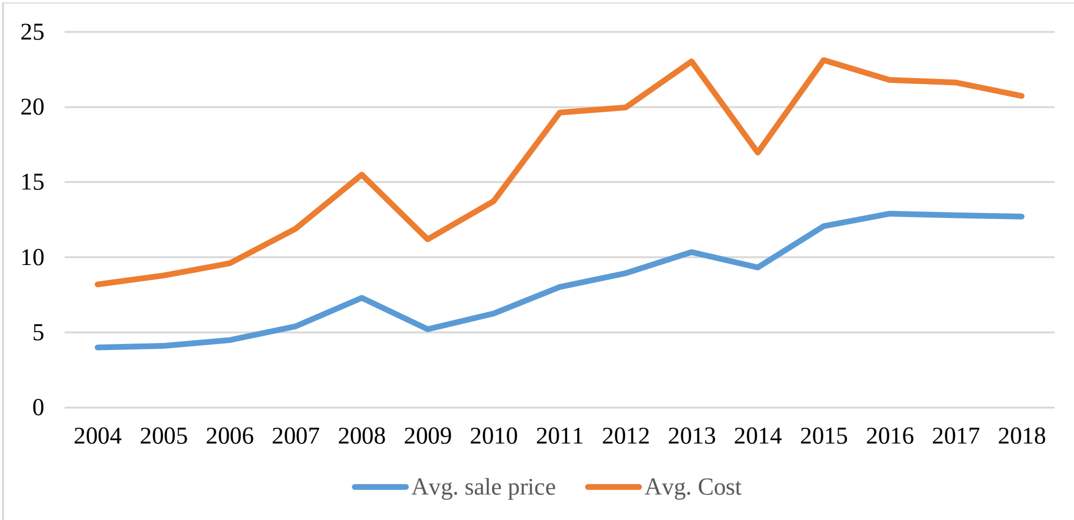

Figure 4: Average cost and sale prices (NTDC, 2018)

Network length

The structural transformation in transmission network resulted in the expansion of installed capacity and network length during 1981 to 2018. Figure 5 shows the transmission network length. The network length in transmission system of NTDC comprises of 66 KV, 132 KV, 220 KV and 500 KV lines. The analysis indicates that the length of 66 KV transmission line increased from 4231 km to 6182 km, the length of 132 KV transmission line increased from 9790 to 26844 km, the length of 220 KV transmission line increased from 2101 km to 10478 km while the length of 500 KV transmission line increased from 524 km to 5618 km from 1981 to 2018. From these statistics, we observe that the length of low voltage and high voltage lines indicates the expansion in installed capacity in transmission network. These expansions in network length were consistent and smooth till 2008, however the rate of expansion decreased due to technical constraints and financial burden in the later years. This analysis implies that NTDC has not been able to efficiently utilize all of its available resources to expand installed capacity from 2007 and onwards.

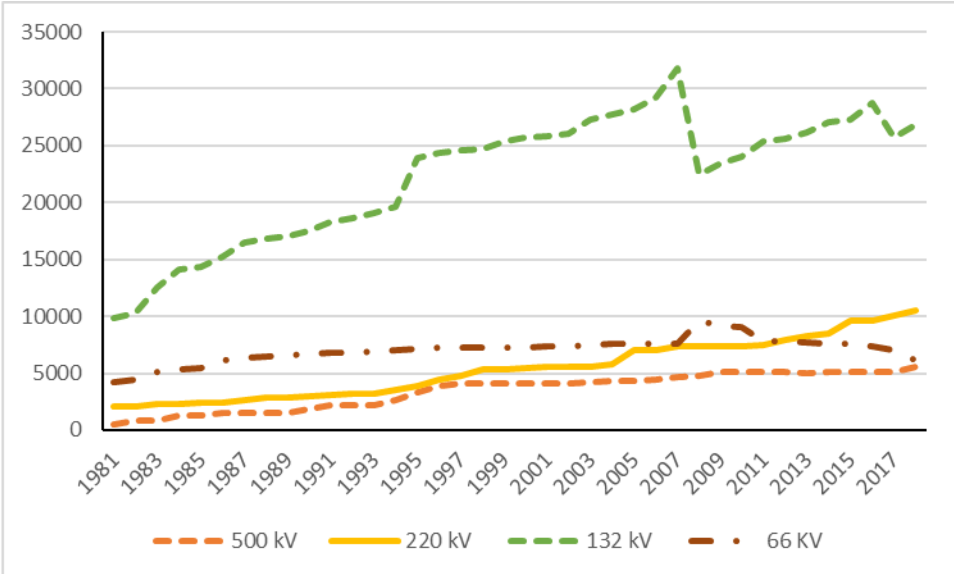

Figure 5: Transmission network length (NTDC, 2018)

Burgeoning operational capacity

The trends in installed capacity in transmission network reflect that further investment is required for the enhancement of reliable and secure electricity transmission. Existing transmission network is sufficient for transferring electricity from generation units to distribution units. However, additional transmission capacity will be required to transmit additional power (Planning Commission, 2018). Therefore, an expansionary policy in power infrastructure development and upgradation of the existing infrastructure is needed (Qazi & Jahanzaib, 2018). For example, there are 129 transformers on 220 KV and 132 KV lines and among them, 90 transformers are overloaded (NEPRA 2017). This requires expanding operational capacity of the NTDC and timely completion of the started projects. Quite a few energy projects will add more than 17000MW of electricity in the system under China-Pakistan Economic Corridor (CPEC) till 2025. But handling this generation will be a challenge as NTDC has limited capacity to carry this amount of electricity to other parts of the country

3.6 Reliability of distribution system

The satisfaction of the consumers depends on reliability and sustainability of electricity distribution which ensures the uninterrupted supply of electricity. The most reliable indicator to measure the performance of any DISCOs in the world is the continuity of electricity supply. There are two indices to measure the reliability of DISCOs namely, SAIFI (System average interruption frequency index) and SAIDI (System average interruption duration index). SAIFI shows the annual interruptions of electricity supply a consumer faces while SAIDI shows the annual duration of electricity interruption per consumer. According to NEPRA’s distribution performance standard rules 2005, a distribution company should not exceed in minutes and numbers from thirteen and fourteen in SAIFI and SAIDI respectively. The SAIFI analysis of distributional companies indicates that IESCO and GEPCO are fulfilling the criteria while the rest of distribution companies are far away from achieving these targets set by NEPRA (see figure 6).

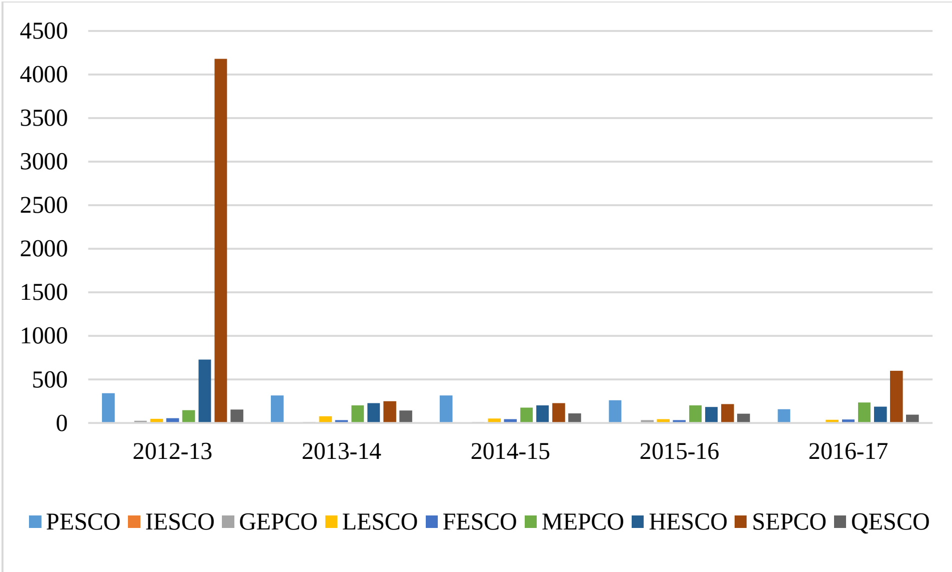

Figure 6: System average interruption frequency index (NEPRA, 2017)

Similar trends are observed for distribution companies in terms of SAIDI. It is observed that only IESCO and GEPCO have shown improvements in their distribution process during financial year 2013-14 and 2014-15 (figure 7). Above mentioned details suggest that distribution mechanism of the companies is far away from its target determined by NEPRA.

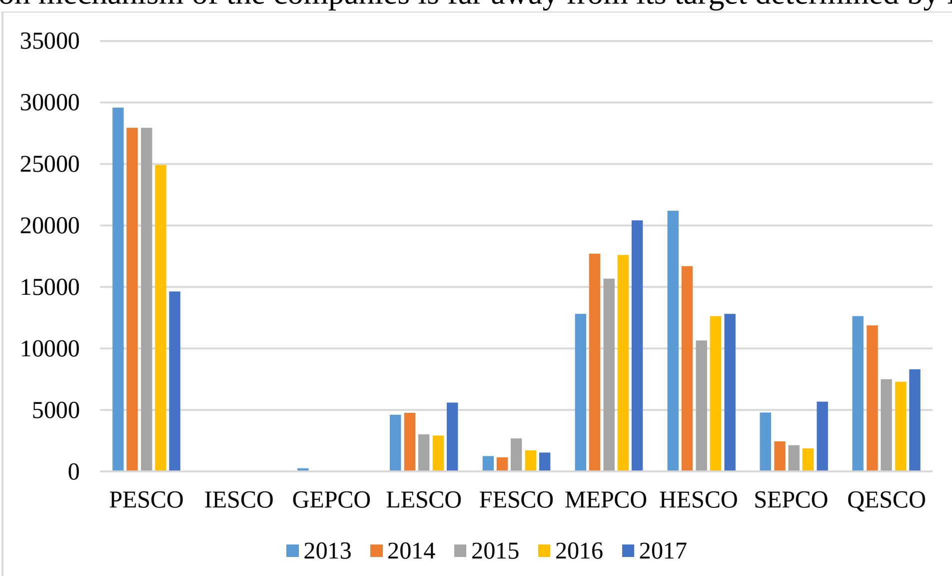

Figure 7: System average interruption duration index (NEPRA, 2017)

Distribution losses

Distribution companies are publically owned entities controlled by ministry of energy of Pakistan. It is important to note that the share of transmission losses is thirty-two percent while the share of distribution losses is sixty-eight percent in overall transmission and distribution losses (NTDC, 2018). The major reasons for the high distribution losses in Pakistan include power theft, overloading of transformers and limited capacity of transmission lines (NEPRA, 2017). It is observed that DISCOs have registered no significant improvement in controlling distribution losses and on average; these losses have remained about eighteen percent of the total electricity injected into the system. Average network loss of distribution companies since their operationalization indicates significant efficiency differences among them. On average, the network loss of PESCO, HESCO, SEPCO, QESCO, MEPCO, LESCO, FESCO, GEPCO, IESCO are 35.2%, 28.4 %, 23.2 %, 23.23, 15.4 %, 13.5 %, 11 %, 11 %, 9.5 % respectively (figure 8). The analysis indicates that PESCO, SEPCO, HESCO and QESCO have been experiencing high distribution losses as compared to other distribution companies. These losses include technical and non-technical losses. Technical losses are mainly because of over-loaded distribution circuits, outdated wiring and inappropriate installation while non-technical losses encompass electricity theft and meter tampering. Distribution utilities are unable to control these losses because of their poor financial position. Stabilization of financial position of distribution companies has become one of the most discussed issues because poor financial position restricts the DISCOs to operate effectively (ADB, 2019). Figure 8 depicts that DISCOs are not performing well because their losses have been increasing at alarming rate. Therefore, urgent improvements are required for developing advanced infrastructure such as enactment of new grid stations, installation of new transmission and distribution lines (NEPRA, 2017).

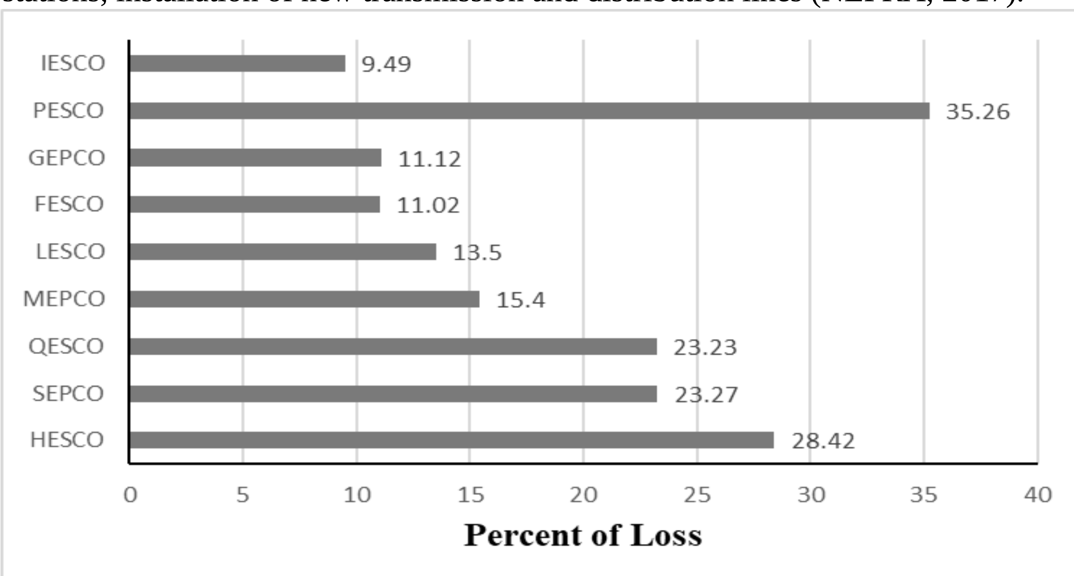

Figure 8: Distribution losses (Qazi and Jahanzaib, 2018)

3.8 Non-Compliance to safety standards

Another measure to assess the performance of distribution utilities is the degree of their compliance with the safety standards. The poor infrastructure, lack of awareness regarding safety measures and non-existence of the safety management system results in fatal incidents at the distribution network (PER, 2015). The code of performance standard developed by NEPRA (2015) instructs all companies to develop, operate, maintain and control distribution channel according to the safety, power standards and customer service manual. The average of the fatal incidents occurred during 2007 to 2016 shows that numbers of fatal incidents are relatively higher for FESCO and LESCO, 27 and 26 respectively. The performance of other DISCOs also remained unsatisfactory. The average of fatal incidents during last 10 years shows that fatal incidents occurred in PESCO, HESCO, SEPCO, MEPCO, IESCO, GEPCO, QESCO, were 22.4, 20, 19, 15, 12.7, 10.9 and 10 respectively. This shows that on average, the numbers of fatal incidents were small for QESCO, GEPCO and IESCO because these distribution companies have used the occupational safety codes at workplace and provided on job training programs to their employees (Qazi & Jahanzaib, 2018). Rest of distribution companies should learn from the experience of others and implement safety standards at their units.

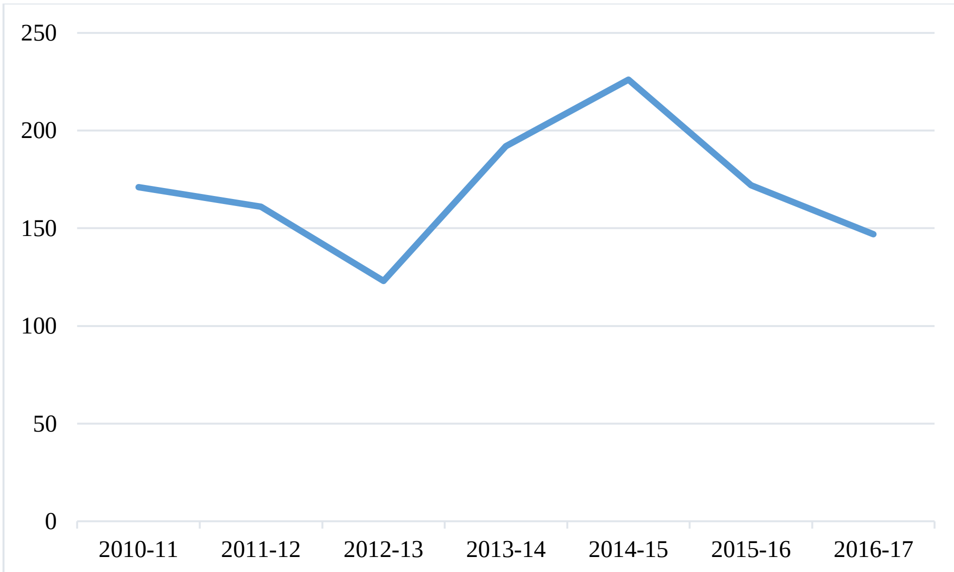

Figure 9: Number of Fatal incidents (NEPRA, various issues)

The frequency of fatal accidents among DISCOs is very high specifically during FY 2014-15 (see figure 9). This shows that DISCOs are reluctant in adopting safety measures. therefore, more attention is required from regulatory body to implement safety rules.

3.9 Consumer affairs

Another indicator to measure the performance of DISCOs is their response to customer applications. Resolving customer complaints in time not only satisfies customers but also contributes in performance of DISCOs. These applications pertain to unannounced load shedding, breakdowns of the transformers, defective meters and incorrect meter readings. Reforms structure has introduced the customer facilitation centers which can improve the service quality while information technology and automation can help in improving the interaction of DISCOs with customers through electronic sources. Figure 10 shows the number of pending applications at each DISCO during 2012 to 2017 indicating that the response of LESCO, FESCO, and MEPCO has remained unsatisfactory as number of pending application were higher for these DISCOs. The less number of pending applications of other DISCOs indicate that they have responded to consumers effectively.

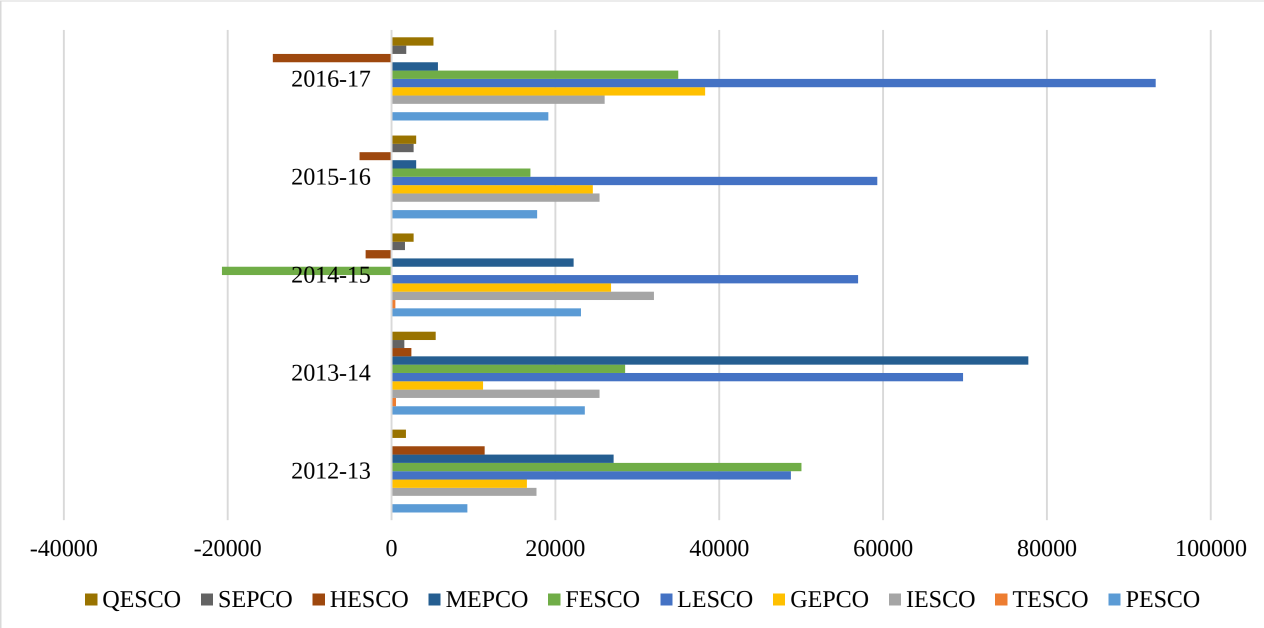

Figure 10: Number of pending applications (NEPRA, various issues)

Circular Debt

"Circular debt occurs when one entity facing problems in its cash inflows holds back payments to its suppliers and creditors. The resulting cash flow constraints have added to the operational inefficiencies of companies in the power sector" (Ali & Badar, 2010). Circular debt was observed for the first time in Pakistan during 2006 when international oil prices started to increase. It was realized that circular debt was not due to the difference in subsidies but due to some other structural problems in the energy market i.e. inefficiency in the electricity market, poor pricing policies, free electricity to WAPDA employees and poor collection of bills (Malik, 2015). As circular debt weakened the financial position of the sector therefore, Government of Pakistan paid all the debt in 2008 but due to non-redressed of structural issues in the market and the existence of technical inefficiencies, it started rising up again and has reached at Rs.1.362 trillion in February 2019 (Business recorder, 2019). Poor collection of bills, units lost in transmission and distribution and power theft in electricity market are still the major issues causing cash flow problems to the DISCOs and adversely affecting the fiscal position of the country. In order to manage circular debt, a comprehensive plan is required to manage subsidy budget, stock and financial flows (GoP, 2017).

Revenue recovery

Figure 11 shows the revenue recovery position of distribution system from 2006 to 2016. It is observed that a huge difference exists between units billed and units received while a large amount of electricity is lost in this process which creates financial burden for DISCOs. Distribution companies recover the cost of electricity from end users through monthly bills. However, the insufficient recovery puts legal and financial burden on distributors which is another reason for accumulation of circular debt. The recovery from domestic and commercial consumers has been improving but to improve the bills collection from industrial and agricultural sectors, strict managerial steps are required.

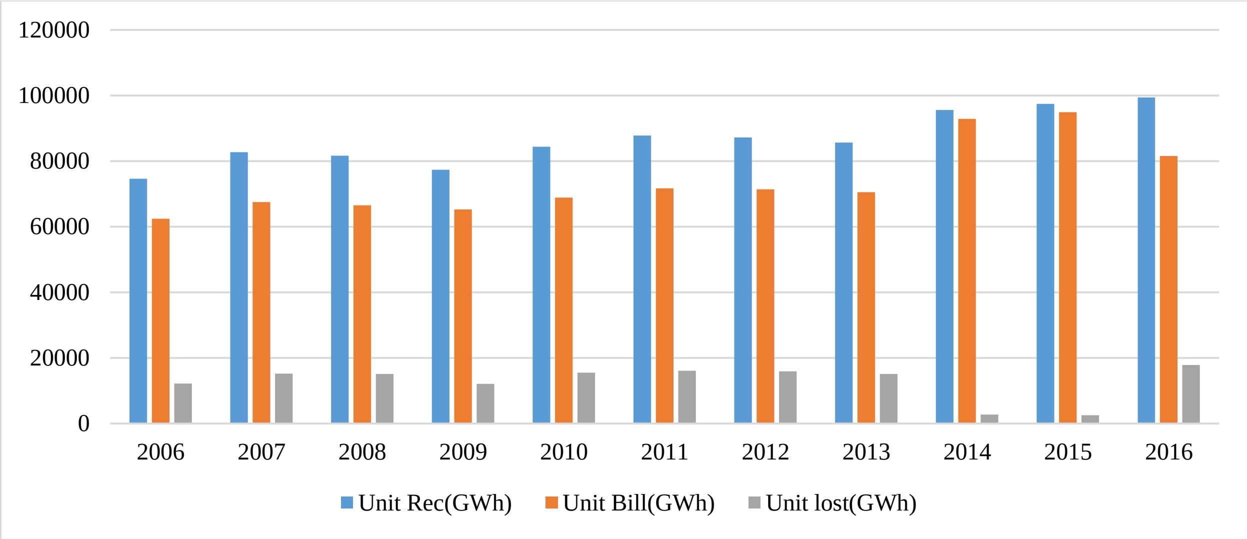

Figure 11: Recovery of bills of DISCOs (NEPRA, 2017)

On average, the revenue recovery of DISCOs shows that some distribution companies have been performing efficiently in bills collection while others are lagging behind (figure 12). On average, bill collection rate of IESCO, FESCO, GEPCO, LESCO, MEPCO, PESCO, HESCO, SEPCO and QESCO was 104%, 99%, 97%, 97%, 95%, 84%, 77%, 39% and 37% respectively. Surprisingly, IESCO and FESCO have shown extraordinary performance with the collection rate of more than 100 percent, indicating that these DISCOs have taken serious actions against the defaulters. The poor administrative performance of PESCO, HESCO, QESCO and SEPCO was the result of poor management which restricts these distributors to collect the bills.

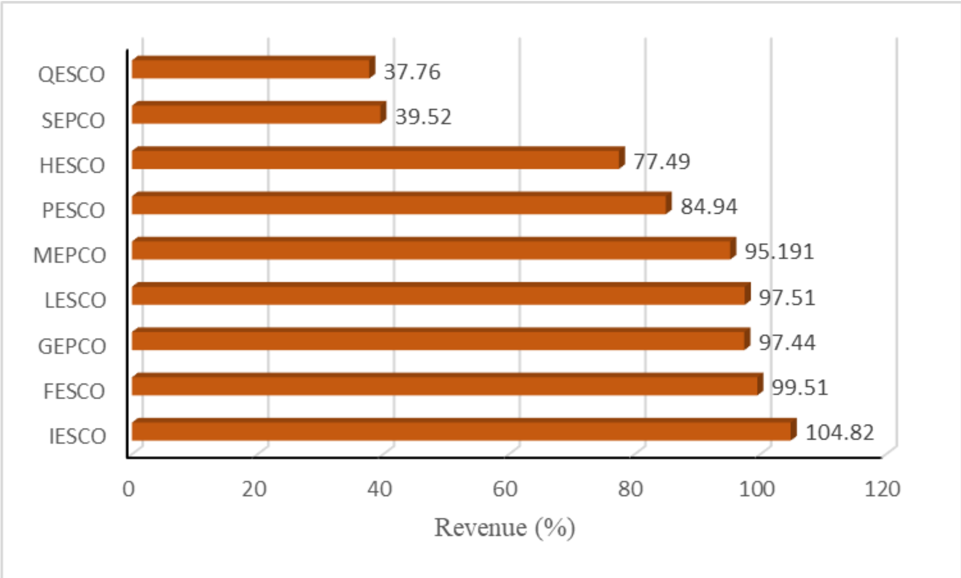

Figure 12: Revenue recovery of DISCOs (Qazi & Jahanzaib, 2018)

Price Determination

The importance of sustainable electricity provision for economic growth cannot be denied. According to an estimate, one percent growth in GDP requires 1.25 percent growth in electricity supply (Lodhi, 2014). In order to attract investment in electricity market, an efficient price mechanism holds the key position which helps in sustaining the operational and managerial cost of business. Ideally, price is determined through demand-supply mechanism but in regulated market, prices are determined by an independent authority. It is the sole responsibility of that authority to determine price/tariff for generation, transmission, distribution and end consumers. There are a number of factors that affect the generation cost and electricity prices include expansion plans, operation and maintenance costs, generation mix and new investments.

Tariff setting mechanism in pre-reforms regime and post-reforms regime is shown in figure 13. In Pre-reforms regime, tariff was determined for vertically integrated utilities WAPDA and KESC. Tariff determination was based on formula of two agreements with donors where 40 percent self-financing was equal to three years' investment multiplied by 1.5 times debt servicing coverage ratio (Lodhi, 2014). This indicates that tariff determination focused on cash recovery for supply chain and government used to notify the tariffs.

In post-reforms regime, WAPDA strategic plan was approved in 1992 and a regulatory body "National Electric Power Regulatory Authority" NEPRA was created. NEPRA, under Electric Power Act 1998 uses the tariff standards and procedure rules 1998 to determine separate tariffs for electricity generation, transmission and distribution companies and consumer end tariff to ensure quality of services and economic efficiency (Ashraf & Khan, 2016). Tariff for generation companies is determined on upfront cost plus and competitive bidding basis. For transmission company, tariff is determined on the basis of annual cost plus and competitive bidding while tariff for distribution companies is based on price cap and revenue cap regulations (Akram, 2018).

Tariff Setting Under Pre Vs. Post-Regulatory Regime

Pre-Reform Regime	Post Reform Regime		
• **Vertically Integrated Utility (WAPDA):** Generation, Transmission, Distribution • **WAPDA deemed License**	NEPRA Regulated Licensees		
	Generation Licensees	Transmission Licensee	Distribution Licensees
	Regulated Tariff	**Regulated Tariff**	**Regulated Tariff**
Costs plus working capital of existing and future facilities to meet the demand: • Generation • Hydel • Thermal (Oil & Gas) • Coal • Nuclear • IPPs • Transmission • Distribution	**Capacity Charge Energy Charge:** • Oil or Gas or Other	**Use of System Charge (UoSC)**	**Distribution Margin (DM)**
	Transfer Pricing Mechanism for Pool Cost • **Generation Pool Costs** • Capacity Transfer Charge • Energy Transfer Charge • **Transmission Costs - UoSC**		↓
	Power Purchase Price (PPPs)		
Fixation of Tariff: Generation Costs + Distribution Costs/Estimated Units Sold	Consumer End Tariff proposed by NEPRA & Notified by GOP means **(PPP+DM)**=Average Regulated Tariff		

Figure 13: Pre-reform and post-reform tariff determination process (Lodhi, 2014)

Some important factors that affect the cost, price and tariff in regulated market include operational and managerial cost, expansion plan, fuel cost and socio-economic goals of the government. Figure 14 depicts the cash flows from one segment to other in post-reforms electricity market. The power and cash flows in the supply chain and entities involving the electricity supply to consumers under single buyer model. NEPRA sets the tariff and allows licensees to recover the costs incurred in generation, transmission and distribution channel for the purpose of meeting consumer demand. NEPRA determines the cost plus rate of return based tariff for each entity in collaboration with relevant stakeholder. NEPRA has prepared the concept paper for determination rate of return which helps to calculate IRR for different technologies and value chains (NEPRA, 2017). The objective of IRR is to depict the tariff against the return risk matrix and adjustment costs.

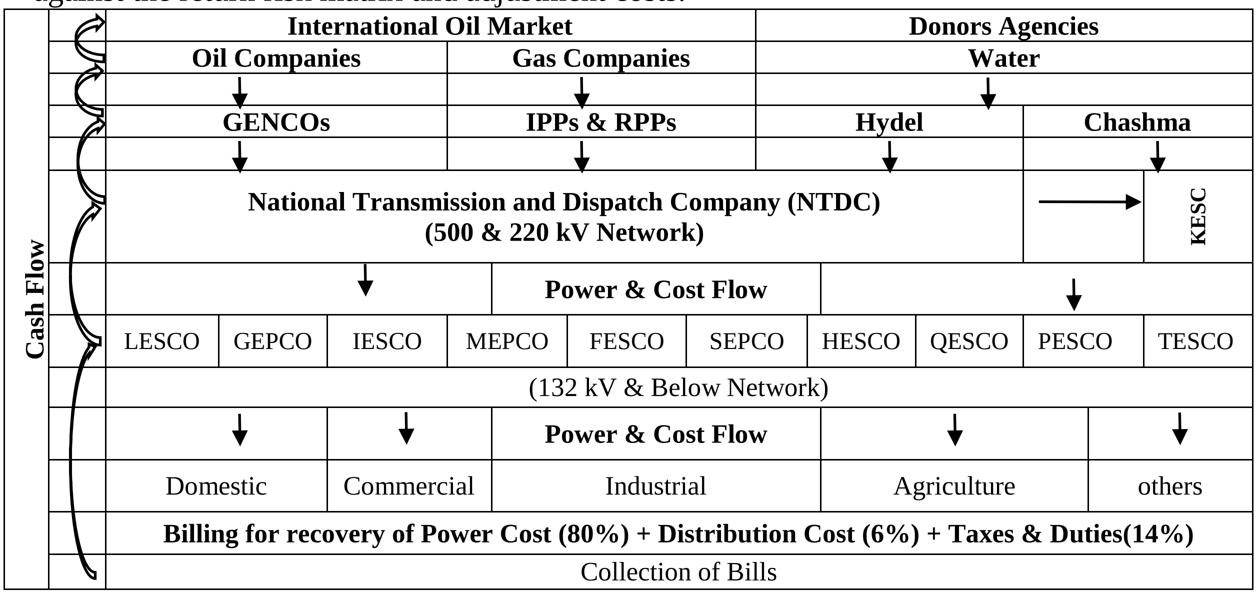

Figure 14. Power sector cash flow process (Source: Lodhi, 2014)

3.13 Tariff Setting of Authority

The generated electricity is procured by National Grid Company (NTDC) through CPPA at tariff rates determined by NEPRA. These tariff rates are separately determined for generation, transmission and distribution segments depending on their different cost structures. NEPRA has classified its tariff determination process into three categories.

(i) Generation Tariff
(ii) Transmission Tariff
(iii) Distribution Tariff

The Generation tariff includes energy charges and capacity charge (NEPRA, 2017). Capacity chargers are fixed while energy charges have variable cost which depends on the energy dispatched. It consists of fuel components such as fuel price, output, partial loading and output whereas variable operational and maintenance costs include the cost of lubricants. NEPRA uses the price of fuel to determine reference price on fortnightly basis. After that, fuel price adjustments are made due to the differences between actual cost of fuel and reference prices. Transmission Tariff includes fixed cost (the use of system charges) and fixed and variables cost (pool generation cost) which is used to transfer pricing for DISCOs and X-WAPDA (Lodhi, 2014). Distribution tariff includes the fixed cost (distribution margins) and power purchase price (pool charge cost).

Figure 15 shows the complete tariff structure of the Regulatory body NEPRA.

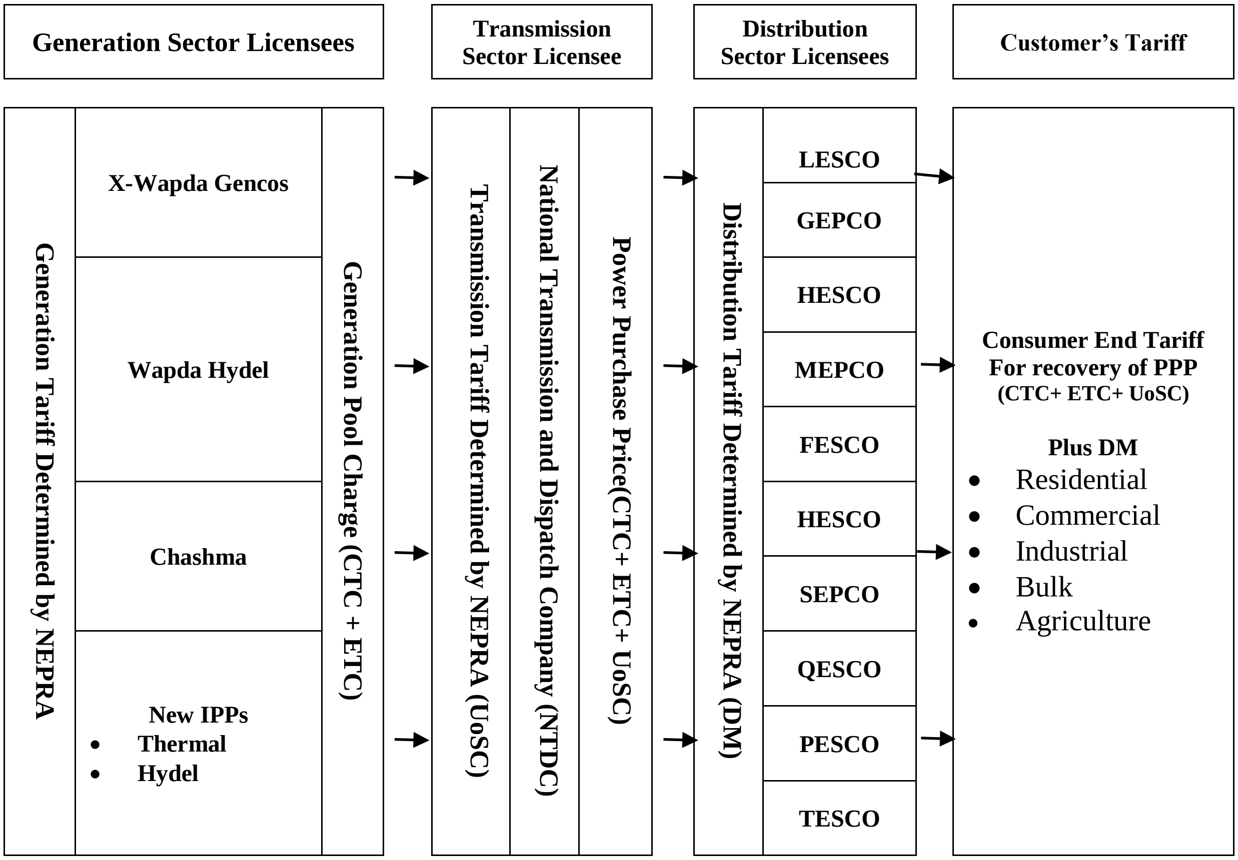

Figure 15. Tariff structure of NEPRA (Lodhi, 2014)

Tariff subsidies

In Pakistan, government sets a uniform tariff for generation, transmission, distribution and end users. As evident above, some distribution utilities are experiencing more losses as compared to others but due to uniform tariff, they receive the same benefits as the better performing DISCOs receive. Due to this tariff determination process, distribution utilities finds no incentive for performing well so they do not given attention toward improving their system which is deteriorating the system. Figure 16 shows different tariff rates proposed for different distribution utilities but government applicable rate is uniform for each DISCO. This difference in proposed and actual tariff rates is known as tariff subsidy which indicates the reconsideration of pricing policy so that prices can be transferred to ultimate users who are taking more advantages

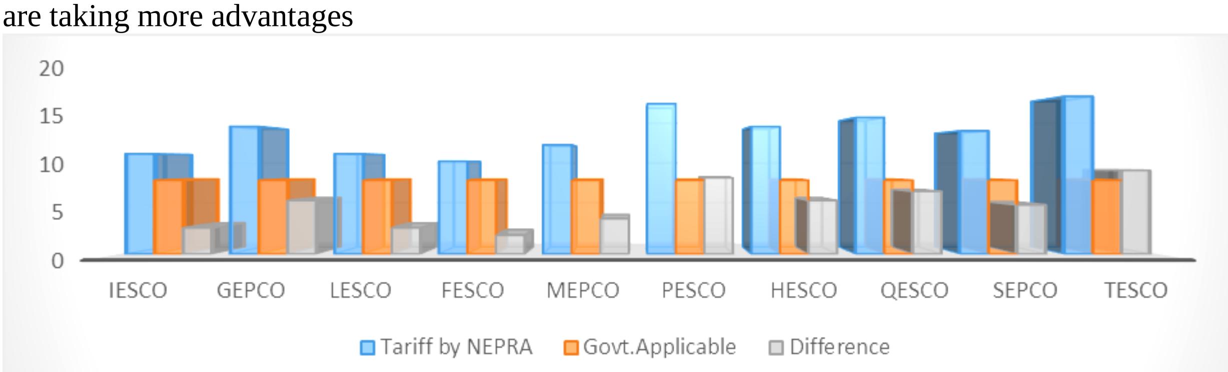

Figure 16. Tariff difference for FY 2017-18 (GoP, 2018)

Sectoral price difference

One of the objectives of the reforms was the provision of electricity at uniform rates between different sectors of the economy. However, significant price discrimination still exists between different sectors of the economy. Sectoral price difference can be calculated by taking the difference between residential and commercial tariff determined by government. Figure 17 shows a clear difference in the sectoral prices which has been increase over the period of time, indicating that no attention has been given to reduce the cross subsidization for reducing the price differentials among different consumer group.

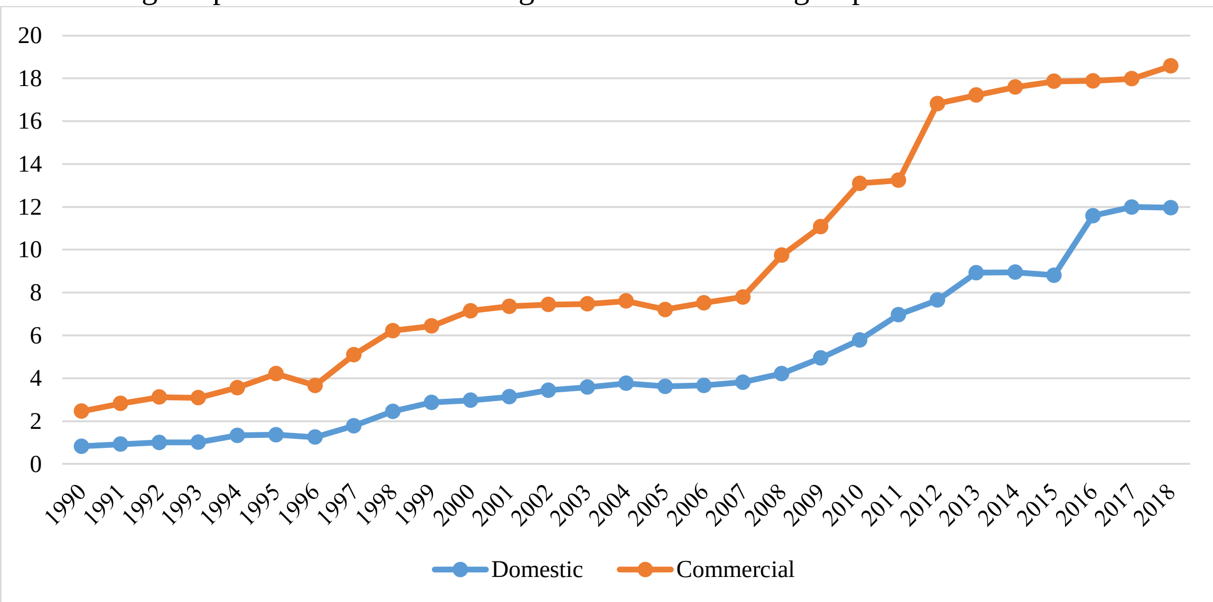

Figure 17. Sectoral price differences (NTDC, 2018)

Fuel mix

At present, almost one third of the total generation capacity (65%) depends on thermal sources (oil, gas and coal based) which is an expensive source of power as compared to hydro power. Alongside, the electricity generated from these thermal sources adversely affects the environment because of high greenhouse emissions (Mufti., et al., 2016; Malik, 2012). Thermal power is attached with oil prices which are increasing in Pakistan due to currency devaluation which implies a per unit increase in the cost of generation. Hydroelectric power stations are considered to be most efficient in power generation as they have 90 percent efficiency (Malik, 2012). Unfortunately, the power policy of 1994 provided plentiful incentives to IPPs while self-interested politicians promoted this IPP induction for their own political and financial benefits.

The power generated by IPPs through oil is very expensive while the tariff structure does not reflect this cost, ultimately it becomes burden on government in the form of circular debt (Saeed, 2013). Moreover, this power policy has encouraged private investors into generation mechanism but no attention has been given toward monitoring the operational performance of publicly owned GENCOs and IPPs. Therefore, it is time to discover the unexploited hydro power projects to meet the energy demand at affordable price as these oil based projects are putting an unrealistic burden on the economy (Kiani, 2013).

Autonomous regulatory body

Restructuring of the power sector was taken place with one of the objective that an independent body will handle all the related issues which must be autonomous in its operations. But it is observed that NEPRA is not autonomous in its decisions and authority has to take approvals from government due to which decision of NEPRA are not truly implemented. Therefore, in order to have true policy implications NEPRA must be strengthen in its decision making process as proposal in organization support plan that every department should work without any political pressure (Qazi and Jahanzaib, 2018).

Conclusion

This paper has comprehensively reviewed the electricity market of Pakistan by separately evaluating the performance of electricity generation, transmission and distribution network. The objective was to design a structured roadmap to develop recommendations for an efficient and sustainable electricity market in Pakistan. The reforms in electricity market were introduced to develop reliable and efficient power system which could result in structural transformation and institutional development of the sector. However, the structural transformation ended up with inefficient and poor performing public and state owned generation and distribution utilities. Although, the sector experienced increase in generation capacity but this advancement in generation is still not enough to meet peak demand creating a persistent demand-supply gap which raises the importance of changing fuel mix and initiation of energy conservation plans. Similarly, the high cost of production from thermal sources and mismanagement in initiation of hydro projects results in poor financial condition that further decreases the investment opportunities in the sector.

Though the transmission network has seen an expansion in installed capacity but the rate of expansion has slowed down from 2007 and onwards. Since then, the operational performance of NTDC has deteriorated showing the flaws in administration of transmission network. As far as performance of distribution utilities is concerned, our analysis indicates alarming situation. DISCOs remained poorly managed in term of operational maintenance, administrative management and customer services response. The reliability of DISCOs measured through SAIFI and SAIDI indicates that only few DISCOs satisfy the reliable provision of electricity to end users. However, their reliability is not consistent over the period of time. Similarly, the administrative failures of DISCOs create hurdles in bills collection from end users while mismanagement creates burden on customer service due to which majority of DISCOs do not meet the performance standards determined by NEPRA.

Other factors affecting the efficiency of DISCOs are electricity theft, circular debt, tariff differential subsidy by government to users and legal proceeding against DISCOs etc. Therefore, to enhance the efficiency of distribution utilities, steps including operational, technical and administrative improvements are required to be taken.

The institutional development was planned to strength the technical and administrative efficiency of the sector which could not be achieved with overlapping of functions between different authorities. This results in sacrificed tariff determination process for political interests and excessive cross subsidizations that further deteriorated the financial position of the sector. The electricity reforms have created the investment opportunities for private sector which enhanced the installed generation capacity but due to poor operational management and inefficient fuel mix, the generation sector did not significant benefits from this expansion. This analysis enriches our belief regarding inefficient electricity generation and distribution system which require serious attention of policy makers. Policy makers need to ensure the autonomy of NEPRA in decision making process. These policy actions should focus on designing separate authorities for generation, transmission and distribution network in order to exterminate the overlay of authorities.

References:

Abbasi, A. H. (2014). Pakistan Energy Vision, 2035: SDPI. *https://www.sdpi.org/.../Pakistan%20Energy%202035-FINAL%2020th%20October*.

ADB (2019). ADB Support Key to Strengthen Pakistan's Energy Sector: Independent Evaluation. https://www.adb.org/news/adb-support-key-strengthen-pakistan-s-energy-sector-independent-evaluation

ADB (2019). Pakistan: ADB's Support to Pakistan Energy Sector (2005–2017). https://www.adb.org/sites/default/files/evaluation-document/397216/files/sape-pakistan-energy.pdf

Akram, S., 2018. Tariff regime in Pakistan. Paper presented at Capacity Building Program for National Electric Power Regulatory Authority (NEPRA) on Tariff Determination (EMP module).

Ali, S. S., & Badar, S. (2010). Dynamics of circular debt in Pakistan and its resolution. The Lahore Journal of Economics, 15, 61.

Ali, F., & Beg, F. (2007). The history of private power in Pakistan: Sustainable Development Policy Institute.

Ashraf, H. F., & Khan, S. (2016). Analysis of Pakistan's Electric Power Sector.

Bertrand, T. J., & Vanek, J. (1971). The theory of tariffs, taxes, and subsidies: some aspects of the second best. The American Economic Review, 61(5), 925-931.

Burke, M. J., & Stephens, J. C. (2018). Political power and renewable energy futures: A critical review. Energy Research & Social Science, 35, 78-93.

GoP. 2014. Economic survey of Pakistan. Islamabad, Retrieved from: www.finance.gov.pk.

GoP. 2017. Economic survey of Pakistan. Islamabad, Retrieved from: www.finance.gov.pk

Jamasb, T., Nepal, R., & Timilsina, G. R. (2015). A quarter century effort yet to come of age: a survey of power sector reforms in developing countries: The World Bank.

Kamran, M., Mudassar, M., Abid, I., Fazal, M. R., Ahmed, S. R., Abid, M. I., . . . Anjum, S. H. (2018). Reconsidering the Power Structure of Pakistan. International Journal of Renewable Energy Research, 9(1), 480-492.

KCCI. (2013). Energy Scenario in Pakistan: The gate way to economic prosperity. www.kcci.com.pk/.../wp.../DW-KCCI-BOOK-ON-ENERGY-PAKISTAN-Aug-2013.pdf

Kessides, I. N. (2013). Chaos in power: Pakistan's electricity crisis. *Energy policy*, *55*, 271-285.

Khan, A. J. (2014). Structure and regulation of the electricity networks in Pakistan. The Pakistan Development Review, 53(4-II), 505-530.

Kiani, K. (2013). "Sold down the River," Dawn, September 08, 2013, http://www.dawn.com/news/1041398.

Komal, R., & Abbas, F. (2015). Linking financial development, economic growth and energy consumption in Pakistan. Renewable and Sustainable Energy Reviews, 44, 211-220.

Lodhi, A.L, (2014). Costing and Tariff Setting in Power Sector of Pakistan - ICMA Pakistan. *https://www.icmap.com.pk/Downloads/Booklet_Power_Sector_in_Pakistan.pdf*

Malik, A. (2007). Effectiveness of regulatory structure in the power sector of Pakistan (No. 2007: 25). Pakistan Institute of Development Economics.

Malik, A. (2009) Power Sector Reforms in Pakistan: A Critical Review.Middle East Business and Economic Review 21:2.

Malik, A. (2012). Power Crisis in Pakistan: A Crisis in Governance? Pakistan Institute of Development Economics.

Malik, A. (2015). Tackling the Energy Crisis. In R. Amjad & S. J. Burki (Eds.), Pakistan: Moving the economy forward (pp. 108-134). Chapter, Cambridge, Cambridge University Press Pakistan. Retrieved from: http://doi.org/10.1017/CBO97813162717.

Meng, X., & Pian, Z. (2015). Intelligent Coordinated Control of Complex Uncertain Systems for Power Distribution and Network Reliability. Elsevier.

Mirjat, N. H., Uqaili, M. A., Harijan, K., Valasai, G. D., Shaikh, F., & Waris, M. (2017). A review of energy and power planning and policies of Pakistan. Renewable and Sustainable Energy Reviews, 79, 110-127.

Mirza, F. M., Mushtaq, I., & Ullah, K. (2017). Assessing the efficiency dynamics of post reforms electric distribution utilities in Pakistan. Utilities Policy, 47, 18-28.

Mufti, G. M., Jamil, M., Naeem, D., Mukhtiar, M. U., & Al-Awami, A. T. (2016). Performance analysis of parabolic trough collectors for Pakistan using mathematical and computational models. Paper presented at the 2016 Clemson University Power Systems Conference (PSC).

Nawaz, S. M. N., & Alvi, S. (2018). Energy security for socio-economic and environmental sustainability in Pakistan. Heliyon, 4(10), e00854.

Nepal, R., Carvalho, A., & Foster, J. (2016). Revisiting electricity liberalization and quality of service: empirical evidence from New Zealand. Applied Economics, 48(25), 2309-2320.

NEPRA (2015). State of Industry report. Islamabad, Pakistan: Ministry of water and power development authority. Retrieved from: http://www.nepra.org.pk

NEPRA (2017). State of Industry report. Islamabad, Pakistan: Ministry of water and power development authority. Retrieved from: http://www.nepra.org.pk

NEPRA (2018). State of Industry report. Islamabad, Pakistan: Ministry of water and power development authority. Retrieved from: http://www.nepra.org.pk

NTDC. (2018). National Transmission and Dispatch Company. Power system statistic 2017-2018 www.ntdc.com.pk/

PER, 2015. Performance evaluation report of all distribution utilities. National Electric Power Regulatory Authority.

PER, 2016. Performance evaluation report of public sector GENCOs based on performance standards (generation) rules (PSGR) 2009. National Electric Power Regulatory Authority.

Perwez, U., Sohail, A., Hassan, S. F., & Zia, U. (2015). The long-term forecast of Pakistan's electricity supply and demand: An application of long range energy alternatives planning. Energy, 93, 2423-2435.

Polemis, M. L., & Stengos, T. (2017). Electricity sector performance: a panel threshold analysis. The Energy Journal, 38(3), 141-158.

PPIB, 2011. Hydel power potential in Pakistan. Private Power & Infrastructure Board. Available at: https://nepra.org.pk/Policies/Hydel%20Potential%20in%20Pakistan.pdf

Qazi, U., & Jahanzaib, M. (2018). An integrated sectoral framework for the development of sustainable power sector in Pakistan. Energy Reports, 4, 376-392.

Qazi, U., Jahanzaib, M., Ahmad, W., & Hussain, S. (2017). An institutional framework for the development of sustainable and competitive power market in Pakistan. Renewable and Sustainable Energy Reviews, 70, 83-95.

Qureshi, F., & Akintuğ, B. (2014). Hydropower potential in Pakistan: sn. https://www.researchgate.net/publication/268224059_Hydropower_Potential_in_Pakistan.

Sabri, P. Z., Afridi, K., & Ali, S., 2013. Transmission & Distribution in Rural Power Supply Systems Design - Specification - Installation. Pakistan Poverty Alleviation Fund (PPAF).

Saeed, K. (2013). Pakistan's Power Crisis: Challenges and the Way Forward'. Criterion Quarterly Magazine, 8(4).

SBP (2016). State Bank of Pakistan. Infrastructure, Housing & SME Finance Department. http://www.sbp.org.pk/smefd/circulars/2016/C3.htm

Shahbaz, M. (2015). Measuring economic cost of electricity shortage: current challenges and future prospects in Pakistan.

Shakeel, S. R., Takala, J., & Shakeel, W. (2016). Renewable energy sources in power generation in Pakistan. Renewable and Sustainable Energy Reviews, 64, 421-434.

Siddiqi, A., Wescoat Jr, J. L., Humair, S., & Afridi, K. (2012). An empirical analysis of the hydropower portfolio in Pakistan. Energy Policy, 50, 228-241.

Sultana, U., Khairuddin, A. B., Aman, M. M., Mokhtar, A. S., & Zareen, N. (2016). A review of optimum DG placement based on minimization of power losses and voltage stability enhancement of distribution system. Renewable and Sustainable Energy Reviews, 63, 363-378.

Ullah, K. (2013). Electricity infrastructure in Pakistan: an overview. International Journal of Energy, Information and Communications, 4(3), 11-26.

WAPDA, 2019. Projects [Online] Available at: http://www.wapda.gov.pk/index.php/projects/hydro-power/under-construction/mangla-rehabiliation [Accessed 27 May 2019].

WB (2017). Implementation completion and results report on a series of credit to the Islamic republic of Pakistan for power sector reform development policy credits i & ii.

Zakaria, M., & Noureen, R. (2016). Benchmarking and regulation of power distribution companies in Pakistan. Renewable and Sustainable Energy Reviews, 58, 1095-1099.

Zameer, H., & Wang, Y. (2018). Energy production system optimization: Evidence from Pakistan. Renewable and Sustainable Energy Reviews, 82, 886-893.

Zhang, J., Hu, Z., Zheng, Y., Zhou, Y., & Wan, Z. (2017). Sectoral Electricity Consumption and Economic Growth: The Time Difference Case of China, 2006–2015. *Energies*, *10*(2), 249.