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Article

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Research paper

An integrated sectoral framework for the development of sustainable power sector in Pakistan

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HIGHLIGHTS

- Up-to-date Review of Electricity Reforms in Pakistan.
- Performance Review of Power Sector.
- Review based integrated framework for sustainable power sector in Pakistan.

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ABSTRACT

To achieve sustainable power sector in Pakistan, several reforms were introduced in last two decades. These reforms included structural transformations, institutional developments and policy advancements. Despite these reform efforts, the performance of overall power sector remained unsatisfactory and ended up in severe crisis. Currently, power sector is confronted with extended blackouts, high tariffs and deteriorated quality of service. To identify the causes of crisis, this article first reviewed the power sector reforms. Secondly, it reviewed the performance of electricity generation, transmission and distribution sectors comprehensively by employing several technical and administrative sectoral variables. Results revealed that biased and undue policy provisions, affected the performance of electricity generation sector. Whereas, poorly planned institutional transformations resulted in deficient performance of distribution sector. In transmission sector the appropriate institutional developments resulted in satisfactory performance of transmission sector. It has been further explored that, for the development of sustainable power sector, electricity generation and distribution sector need serious attention whereas transmission sector only require continuity in its performance enhancement. An integrated sectoral framework is also proposed which provide comprehensive performance enhancement plans for each sector. The proposed framework provides a roadmap for the development of sustainable power sector in Pakistan.

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1. Introduction

For the development of sustainable power sector in Pakistan, several electricity reforms were initiated in late 90's. The primary objective of these reforms was to develop a sustainable power sector in terms of efficiency and social wellbeing that offer affordable and reliable access of electricity. These reforms included structural transformations, institutional developments and policy advancements. Under structural transformation, a state-owned entity was vertically unbundled which resulted in transition of market models i.e. shifting of monopoly model to single buyer model (Qazi et al.,

2017). Whereas, institutional developments resulted in establishment of administrative institutions like market operator and regulator. Apart from these institutions, several functional departments were also established to support the development of sustainable power sector in the country. To fulfill the legal obligations for structural transformations and institutional developments, six energy policies were also enacted by different political governments in last two decades. Despite these extended efforts along with 8th largest private sector investment (Jamasp and Littlechild, 2004), power sector remained under severe stress. Currently, country is facing supply demand deficit of approximately 5000 MW with extended blackouts of 8–12 h, increasing tariffs, extended line losses, burden of circular debt and deteriorated quality of service (Kessides, 2013; Valasai et al., 2017). All these issues affected the overall performance of power sector and disrupted the economic growth as well (Komal and Abbas, 2015; Qazi et al., 2018).

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The existing power situation triggered the need to identify the real causes of power sector crisis in policy and technical concerns. Although, several studies have analyzed the power sector crisis in context of generation and distribution sectors (Alvi et al., 2018; Mirjat et al., 2017; Perwez et al., 2015; Zakaria and Noureen, 2016; Zhou et al., 2017) but separately. Similarly, some studies have also identified the shortcomings of reforms that resulted in power crisis (Mirjat et al., 2017; Qazi et al., 2017; Ullah et al., 2017; Zameer and Wang, 2018).

In this context this research aims to identify the causes of existing power sector crisis by reviewing the power sector reforms and the performance of electricity generation, transmission and distribution sections separately using several sectoral variables for the period of past few years. The review of reforms and performance of power sector entities identified the key issues that resulted in crisis and eventually hurdled in development of sustainable power sector. Based on review of reforms and performance of power sector entities, an integrated sectoral framework is proposed which included performance enhancement plan for each sector i.e. electricity generation, distribution and transmission. The proposed framework is also accompanied with governmental and organizational support plan essential for the execution of sectoral enhancement plan. The integrated sectoral framework not only proposed the solution of existing power crisis, but also provide a structured roadmap essential for the development of sustainable power sector in Pakistan. The study is first of its kind presenting the comprehensive review of power sector reform, policies and performance of electricity generation, transmission and distribution sector. This research also fills the gap by comprehensive assessment of the power sector in both technical (sectoral performance review) and policy (power reforms) concerns. Similarly, the resulting proposed framework contributes as a way forward for all the stakeholders including policy makers, electricity generators and distributors for the development of sustainable power sector in Pakistan. This research will also serve as a base for future studies relating to power sector of Pakistan.

The remainder of this paper is organized as follows: Section 2 presents an overview of power sector of Pakistan Section 3 provides an overview of major reforms initiated over the past 20 years and summary of various energy policies introduced under different political governments. Section 4 reviews performance of electricity generation, transmission and distribution sector. Section 5 discusses the summary of sectoral review. Section 6 explains the integrated sectoral framework and Section 7 provides conclusion.

2. Power sector of Pakistan: An overview

Power sector of Pakistan comprises of 78 electricity generation firms. These firms vary in installed capacities and operating fuel. These electricity generation firms can be segregated in two administrative structures i.e. public (WAPDA and GENCOs) and private (IPPs). The installed capacity of WAPDA, GENCO and IPP is 6902 MW, 6438 MW and 9638 MW respectively. The total installed capacity of power sector is 22,978 MW in which the share of WAPDA, GENCOs and IPPS is 30.04%, 28.02% and 41.94%. The details of existing power sector are given in Table 1.

Table 1 shows that total share of thermal fuels in installed capacity is 63.4% with natural gas (43.9%), furnace Oil (18.7%), coal (0.7%) and HSD (0.1%). Similarly, hydro, nuclear and wind resources contribute 31%, 2.8% and 1.3% respectively. In electricity distribution sector, there are ten public sector DISCOs which serve six consumer categories in their respective regions. The total number of consumer are 24,517 Million. The average loss of distribution system is computed as 19.17. In electricity transmission sector, the total length of the network is 53,005 km with 1111 grid stations and transformation capacity of 92,871 MVA.

3. Review of power sector reforms in Pakistan

In context of global power sector reforms (Nepal and Jamasb, 2015), Pakistan initiated its power sector reform program in late 90's (Qudrat-Ullah, 2015). The reform program consisted of several sub activities which can be segmented into structural transformations, institutional developments and policy advancements. These reform activities were undertaken in parallel manner in different phases, over the period of last twenty years. Fig. 1 shows the time line of sub activities of reforms.

3.1. Structural transformations

In last two decades, power sector of Pakistan has undergone through several structural transformations. The first significant structural transformation took place in 1992 when state-owned natural monopoly namely Water and Power Development Authority (WAPDA), was vertically unbundled. Unbundling of WAPDA resulted in remodeled electricity generation and distribution sector (Qudrat-Ullah and Davidsen, 2001). Fig. 2, presents the pre- and post-unbundling structure of power sector.

Fig. 2 shows that before unbundling, all operations (electricity generation, transmission and distribution) of power sector were solely managed by WAPDA. Whereas, after unbundling, WAPDA was administratively split into separate electricity generation, transmission and distribution sectors. In generation sector, WAPDA was split to WAPDA (hydro) and Generation Companies (GENCOs). WAPDA hydro was given the responsibility to manage the hydro based power plants. Whereas GENCOs were made responsible for thermal power plants. Both WAPDA (hydro) and GENCOs were given the status of public sector. Under this transformation, Independent Power Plants (IPPs) were offered to start their operations in the country in 1994. Initially IPPs could utilize thermal fuels for electricity generation. With the passage of time, IPPs were motivated to utilize renewable energy resources as well. Administrative outcome of vertical unbundling and introduction of IPPs, was development of single buyer market in Pakistan. The second structural transformation occurred in 1998 when distribution sector was split to ten (initially 8) separate electricity Distribution Companies (DISCOs) (Jamil, 2013). These DISCOs still operate under government control but with independent regional jurisdiction and organizational autonomy. The third structural transformation was privatization of State owned enterprises (SOEs) which was initiated in 2005. Under this transformation Karachi Electric (KE) was privatized and was allowed to serve entire area of Karachi independently with its own electricity generation, transmission and distribution network. Another important structural transformation was planned in 2015 i.e. the development of wholesale competitive market. In this regard, private sector was permitted to lay down their own transmission lines. Similarly, net metering was also introduced as preliminary arrangements for the development of wholesale electricity market (Shahzad et al., 2016)

3.2. Institutional developments

Institutional developments involved establishment of various administrative and technical institutions. The aim of establishing these institutions was to provide administrative support to different phases of structural transformations after unbundling and introduction of IPPs. Administrative institutions included Pakistan Power Infrastructure Board (PPIB), National Electric Power Regulatory Authority (NEPRA), National Transmission and Dispatch Company (NTDC) and Central Power Purchasing Agency (CPPA-G). Whereas technical institutions include Pakistan Council of Renewable Energy Technology (PCRET), Alternative Energy Development

Table 1
Details of power sector of Pakistan.

Generation							Distribution & Transmission		
Nature of firms	Installed capacity	% share	Fuel resource	Installed capacity	% share	Generation firms	Distribution		
Independent Power Plants (IPPs)	9,638	41.94	Nuclear	650.0	2.8	IPPs (Thermal)	28	No of Public DISCOs	10
Water and Power Development Authority (WAPDA)	6,902	30.04	Others	339.0	1.5	WAPDA	20	No. of consumer categories	6
GENCOs	6,438	28.02	Wind	305.0	1.3	GENCOs (Thermal)	11	Total no. of consumers (000)	24,517
Total	22,978		Coal	160.0	0.7	Wind	6	Losses (%)	19.17
Fuel resource	Installed capacity	% share	High speed diesel	17.0	0.1	IPPs (Hydro)	4	Transmission	
Natural gas	10,097	43.92				GENCOs (Nuclear)	3	Length of Transmission line (KM)	53,005
Hydro	7,116	30.96				Solar	3	No. of Grid Stations	1,111
Furnace oil	4,304	18.72				Bagasse	3	Transformation capacity (MVA)	92,871

IPPs = Independent Power Plants; WAPDA = Water and Power Development Authority; GENCOs = Generation Companies; DISCOs = Distribution Companies; KM = Kilometers; MVA = Mega Volt Ampere.

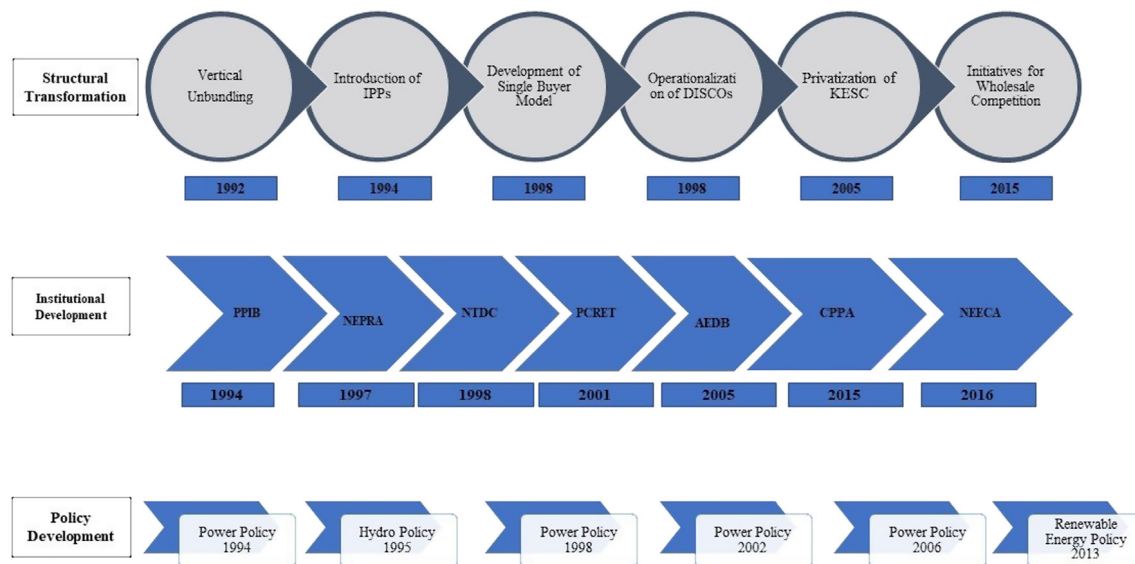


Fig. 1. Segmented time line of power sector reforms in Pakistan.

Board (AEDB) and National Energy Efficiency and Conservation Authority (NEECA).

The institutional development started in 1994, with the establishment of Private Power and Infrastructure Board (PPIB). PPIB was aimed to act as a one window facilitator to promote and facilitate private sector in establishing power projects and related infrastructure. In context of global electricity reforms Pakistan also established power sector regulator NEPRA in 1997. NEPRA was made responsible to regulate the power sector by ensuring the smooth operations (Rauf et al., 2015). In 1998, NTDC was developed with an objective to manage the electricity transmission among public and private sector electricity generators to the national grid and to distribution companies. To reduce the burden of NTDC, another subsidiary namely CPPA-G was developed in 2015. The purpose of CPPA-G was to manage the financial matters involved in sale and purchase of electricity among the generators and distributors. To provide technical support to power sector reforms and associated structural transformations, PCRET was developed in

2001. The prime objective of PCRET was to promote R&D in different renewable energy technologies. In 2005 AEDB was developed to enhance the pace to develop alternative and renewable energy mix in the country. Similarly, in 2016 NEECA formerly ENERCON was developed to motivate and create awareness among public for the utilization of efficient energy appliances/products (Valasai et al., 2017). These departments and institutions were established to develop and promote renewable energy in the country.

3.3. Policy advancement

To provide legal protection, for initiating structural transformations and institutional developments, six energy policies were introduced in last 20 years. Although, these energy policies were introduced for the development of sustainable power sector but there were number of issues with the design and execution of these policies. Up till now, six energy policies have been introduced by different political governments in their respective periods.

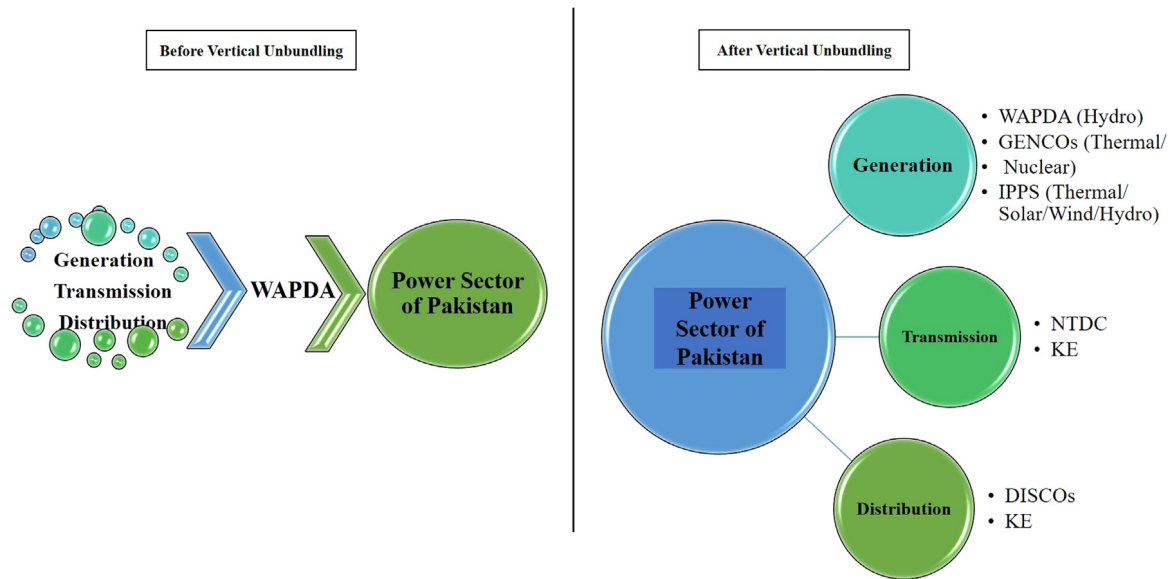


Fig. 2. Pre- and post-unbundling of power sector.

The first energy policy was presented in 1994 which introduced lucrative terms and conditions for private power generators. Private investors were granted full autonomy to propose plant site, technology and type of fuel. Under long term power purchase agreements, private operators were favored as Government of Pakistan (GoP) compelled NTDC to purchase power from private power houses on priority basis instead from public power generators. Various unnecessary guarantees were also provided which included confirm availability of fuel and foreign exchange. Moreover, under this policy private generators were exempted from sales tax and income tax. Due to lucrative terms and conditions this policy attracted many private investors and added approximately 4000 MW of installed capacity. This policy also provided the legal grounds to the development of single buyer model in the country.

In 1995, with the change in government, another policy was introduced which emphasized on the utilization of hydro potential for electricity generation. Various incentives were also offered to investors which included 30% investment from GOP and exemption of sales and income tax. However, due to disturbed political situation in the country, this policy failed to attract foreign investment. No addition of installed capacity was made under this policy. Moreover, various political pressures hindered in the development of public hydro power projects.

In 1998, the newly elected government introduced another policy, to lessen the electricity supply demand gap. This policy also included various incentives for attracting the power sector investments. The major incentive offered to private power houses was permission to conduct pre-feasibility survey of the desired project. In addition to this, thermal and hydro based projects were allowed to operate under BUILT–OWN–OPERATE (BOO) and BUILT–OWN–OPERATE–TRANSFER (BOOT) model at flexible terms and conditions. Under this policy foreign investors were also allowed to issue corporate bonds and shares for meeting their financial obligations. Due to sudden change of government, this policy also failed to be implanted completely.

In 2002 a new energy policy was introduced by military government which included number of provisions for the performance enhancement of the sector. For the first time, public–private partnership energy projects were permitted by GOP. The new policy discontinued the practice of bulk tariff and introduced competitive bidding mechanism for power purchase. Two-part tariff model which consisted of fixed charge and capacity charge was also made

part of this policy. Policy also introduced flexibility to launch power projects after passing through one window qualifying operation. Due to these incentives number of investors rushed in to get the benefits and as a result almost 2500 MW was added in installed capacity. This policy supported the development of AEDB in 2005. Energy policy 2008 was continuation of energy policy 2002 with addition of emphasis on utilization of renewable energy sources. Number of incentives were offered to renewable energy projects which included exemption of taxes on import of equipment.

Energy policy 2013 also offered number of flexibilities for renewable energy projects while introducing upfront tariff model for these projects. This policy also contained provisions for gradual shifting from expensive thermal generation to indigenous and environmental friendly fuels. The last policy supported the development of NEECA in (2015). Table 2 presents the salient features of these policies.

4. Performance review of power sector

In this section, performance of electricity generation, transmission and distribution sector is reviewed by employing several sectoral variables. Data for various sectoral variables was obtained from annual published reports of NEPRA, NTDC and CPPA (NEPRA, 2017; NTDC, 2017a, b). Generation segment sectoral variables include (i). Electricity installed capacity, (ii). Administrative source of energy generation, (iii). Supply/demand deficit, and (iv). Cost of generation and (v). Fuel mix. Transmission segment variables include (i). Expansion of transmission network, (ii). Concurrent growth of consumers and transmission capacity and (iii). Transmission network losses, whereas distribution segment is analyzed by employing (i). Distribution network losses, (ii). Revenue recovery, (iii). Reliability of distribution network, (iv). Time frame for new connections, (v). Duration of load-shedding, (vi). Consumer Affairs and (vii). Compliance with Safety Standards (fatal incidents). The performance review is based on time series data, covering period from 1996–2016 for generation and transmission. Whereas, due to unavailability of data, distribution segment is reviewed for the past five years only from 2011–2016. The period under observation is enough to review the performance for the identification of the causes of crisis.

Table 2
Summary of power policies in Pakistan.

Power policies	Salient features
Power policy 1994	<ul style="list-style-type: none"> ■ Private investors permitted to propose the site, choice of technology and type of fuel for power plant ■ Private investor may propose projects based on hydro, renewable and nonconventional resources. ■ Obligation for WAPDA and KE to purchase power from private power producers under the long-term power purchase agreements ■ Upfront bulk power tariff introduced for private participants ■ Built–Own–Operate (BOO) model to be followed for thermal Power projects ■ Flexibility of draft security agreements by Government of Pakistan (GoP). ■ Guaranteed availability of foreign exchange. ■ 40% of capital cost funding available by GoP. ■ Flexibility introduced in foreign exchange regulation act for private investors ■ Income tax on revenue of electricity sales exempted ■ Sales tax, Iqra, flood relief surcharges exempted ■ Custom duties on import of power plant and associated equipment exempted ■ Foreign lenders of private investors also exempted from income tax.
Hydro policy 1995	<ul style="list-style-type: none"> ■ Much focus on utilization of hydro potential with incentives. ■ Built–Own–Operate–Transfer (BOOT) model allowed. ■ Preference to be given Run-of-River hydro power projects up to 300 MW. ■ Up-front tariff introduce which later shifted to negotiated tariff. ■ 30% of the capital cost of hydro projects being offered by GoP. ■ Income tax on revenue of electricity sales exempted. ■ Sales tax, Iqra, flood relief surcharges exempted.
Power policy 1998	<ul style="list-style-type: none"> ■ Private investors permitted to prepare feasibility reports before bidding. ■ Thermal power plants are allowed to BUILT–OWN–OPERATE while hydro projects allowed to follow BUILT–OWN–OPERATE–TRANSFER model. ■ Execution of terms and conditions of agreement are guaranteed by GoP. ■ Power projects implementation will be through solicited and unsolicited bids. ■ Issuance of shares and corporate bonds permitted to power producers. ■ Facility of uniform tax introduced for private investors. ■ Flexibility introduced in foreign exchange regulation act for private investors. ■ First Year Allowance (FYA) of 90% introduced on machinery and equipment of hydro and local coal based project. ■ Private investors allowed to raise foreign as well as local finance.
Power policy 2002	<ul style="list-style-type: none"> ■ Scope of policy is expanded to public–private, private and public sector projects. ■ International competitive bidding mechanism eliminating bulk power tariff. ■ Permission of involvement of local engineering, design and manufacturing capabilities for the utilization of indigenous resources. ■ Imposition of custom duty on import of plant and related equipment. ■ Imposition of income tax on oil-fired power plants. ■ Provisions for enhancing the share of renewable energy resources. ■ Flexible One-window support introduced to enable the rapid commissioning of power plants. ■ Unsolicited bids are permitted for the raw sites whose feasibilities are not available. ■ Two-part tariff introduced consisting of fixed charge and capacity charge. ■ Any kind of hydrological risk be associated to WAPDA/ NTDC or KEs.
Power policy 2006	<ul style="list-style-type: none"> ■ Renewable energy power projects exempted from customs duty or sales tax for machinery maintenance, replacement, or expansion. ■ Renewable energy power projects exempted from income tax. ■ Permission for deportation of equity along with dividends. ■ Local and foreign finance raising permitted for IPPs especially for renewable energy projects. ■ Non-residents and non-Muslims exempted from of Zakat on dividends of that IPP.

(continued on next page)

Table 2 (continued)

Power policies	Salient features
Renewable energy policy 2013	<ul style="list-style-type: none"> ■ Much focus on utilization of renewable energy resources. ■ Upfront tariff and competitive bidding to lower the cost of electricity. ■ Reduction of subsidies. ■ Provision of shifting swiftly to cheaper fuels. ■ Gradual shifting of fuel supply to IPPs. ■ Improved efficiency and better control of distribution loss/theft.

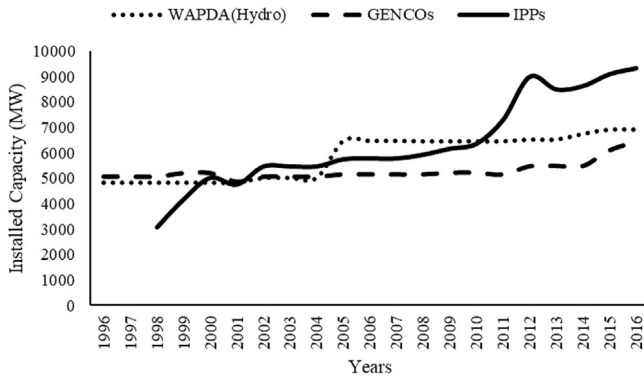


Fig. 3. Progress of installed capacity from 1996–2016.

4.1. Performance review of generation sector

Electricity generation segment is the driver of the entire power sector. Well-structured and technically efficient electricity generation has positive impact on sector's overall performance (Polemias and Stengos, 2017). At present power sector of Pakistan comprises of public and private electricity generation firms. These firms utilize different energy resources for power generation which include hydro, thermal (Coal, HSD, FO, DO), wind, nuclear. This section assesses the performance of generation sector over the 20 years of reforms by employing generation sector variables. These sectoral variables include electricity installed capacity, source-wise energy generation, supply demand deficit, cost of generation and fuel mix.

4.1.1. Electricity installed capacity

Electricity installed capacity is the total installed generation which is measured in kW or MW. The progress of installed capacity is one of the key variable for reviewing the performance of generation sector. Literature witnessed sustainable economic growth in several countries which continued expansion in installed capacity (Mohamed and Lee, 2006). As discussed in Section 3 that, electricity is generated by both public and private electricity firms. Public sector generation firms include WAPDA and GENCOs. Whereas, private sector includes IPPs. Fig. 3 shows the progress of installed capacity by WAPDA and GENCOs and IPPs from 1996–16

From Fig. 3, it may be observed that, initially (from 1996–2003) the hydro installed capacity remained constant i.e. 6463 MW. It was increased to 6733 MW in 2014 after the commissioning of Ghazi Brotha (Hydro Power Project). It is pertinent to mention that it was the only public sector hydro project, commissioned under hydro policy 1995. After that no significant addition was made in installed capacity under WAPDA in power pool up till 2017. This situation affirms the lack of government interest towards the utilization of available hydro potential in the country (Farooqui, 2014). Moreover, due to the lucrative term and conditions of power policy 1994, foreign investors did not show their interest in hydro projects. Same happened in case of GENCOs, where addition in installed capacity remained insignificant. This scenario also provide the evidence of biasedness of political government

which promoted the power policy 1994 and paved the way for the enhancement in share of IPPs. Furthermore, absence of power sector regulator, also surfaced the development of unevenness in generation sector. In 2013–14 and 2015 the share of GENCOs increased suddenly from 4841 MW to 5788 MW, which was the result of operationalization of Nandipur power plant. Several in-operative GENCOs were also upgraded which included Lakhra and Guddu power plants. In case of IPPs, considerable enhancement in installed capacity may be observed in last 20 years. This enhancement can be justified with overwhelming response of private electricity generation firms toward lucrative terms and conditions of 1994 energy policy. Although, 1994 power policy resulted in substantial increase in overall installed capacity but discontinued the motivation of government towards development of public power pool i.e. WAPDA and GENCOs. In 2009–10, a sudden increase in the installed capacity of private electricity firms can be observed clearly. This situation was result of biased decisions of the government which permitted number of private electricity firms purely on political basis. Moreover it also confirms the weakness of the regulator which did not advice government for the enhancement of private power sector while ignoring public sector.

4.1.2. Administrative source of energy generation

Under power sector reforms, structural transformation created private (IPPs) and public segments (WAPDA (hydro) & GENCOs)) in electricity generation side. Both segments participate in power pool to meet the demand. It has been observed that, annually on average, WAPDA (hydro) generates 25,335 GWh whereas GENCOs and IPPs generate 21,826 GWh and 28,652 GWh respectively. It is evident that the share of IPPs is greater than WAPDA and GENCOs. It is pertinent to mention that initially, the share of public and private segments was approximately same in annual electricity generation. An unevenness of shares started after 2005 which may clearly be observed in Fig. 4. Fig. 4 presents the annual share of electricity generated by each source. It can be observed that the share of GENCOs in annual electricity generation has decreased over the period of time which confirm their inefficiency. On the other side, the share of WAPDA in annual generation remained approximately constant even in the presence of mega hydro projects like Tarbela and Mangla power houses. Both entities (WAPDA & GENCOs) are under government control which conveys unsatisfactory performance of public sector electricity generation firms. The reasons for inefficiency included long existing bureaucratic culture and corruption (Naqvi, 2016). Moreover, outdated technology of public thermal units has made it impossible to fulfill the stated needs efficiently (Ali et al., 2018).

In case of IPPs, continuous increase in share of IPPs may clearly be observed. This situation not only confirm the dominance but also validate the efficient performance of IPPs. Although, IPPs have been found productive in terms of catering the electricity demand but their dominance increased the economic burden. Government has an obligation to pay IPPs with capacity charge as well as energy charge. Secondly, most of the IPPs operate on expensive and imported thermal fuels. These factors eventually increase the cost of generation. Inappropriate administrative control and financial constraints make it difficult for CPPA and NTDC to recover the cost which eventually results in accumulation of circular debt.

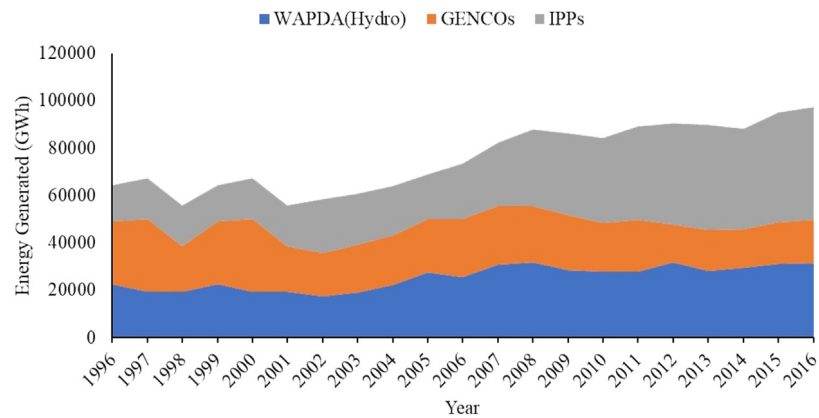


Fig. 4. Trend of source wise electricity generation 1996–2016.

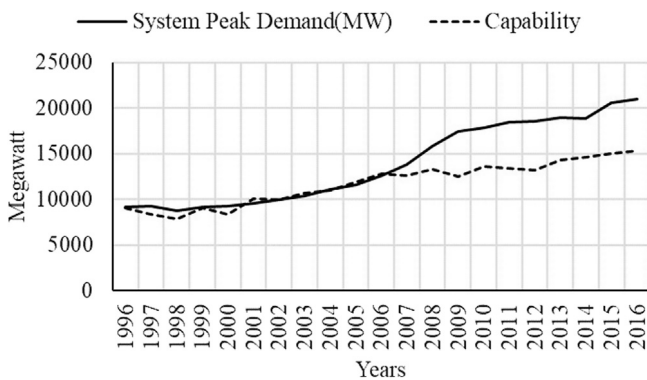


Fig. 5. Progress of supply demand deficit over the period from 1996–2016.

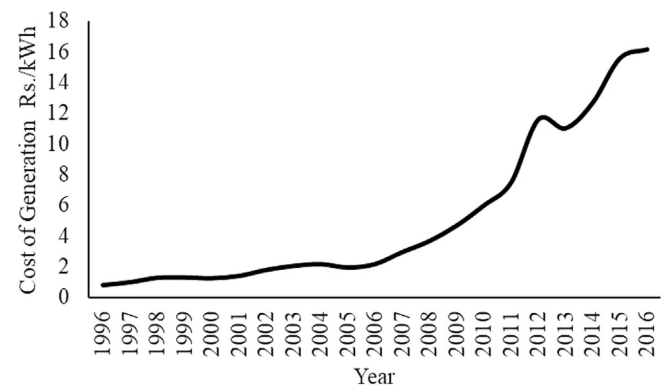


Fig. 6. Cost of generation from the period 1996–2016.

4.1.3. Supply demand deficit

Variance in electricity supply and demand can be used to depict the performance of the generation sector in power sector. The insignificant variation of supply demand deficit can be managed, whereas large difference not only affect the household consumers, industry and also the DISCOs. It has been found that the reserve margin of 18%–25% confirms the reliability of the power sector and ensures the smooth power supply even against any demand elasticity (McPherson and Karney, 2014). Fig. 5, presents the trend of difference of supply demand for last 20 years.

It is shown in Fig. 5, that initially the supply demand gap was negligible. Average shortfall during this period i.e. 1996–2005 was approximately 166 MW. After 2005, the situation deteriorated extensively when supply demand gap started to increase. In 2006, the shortfall was 1247 MW which increased to 5640 MW by the end of 2015. Sudden growth in consumption patterns has made it challenging for concerned institutions to manage this shortfall. The supply demand gap resulted in routine blackouts of 8–12 h a day. In addition to this, economic growth also affected which triggered many industries to shift from Pakistan to neighboring countries. Shortfall and its associated risks also disrupted the trust of foreign investors, who started planning to shift their investments to other countries of the region. The reason for the continuing shortfall was the ineffective institutional development, which resulted in overlapping institutional responsibilities, poor planning and lack of coordination among NTDC, CPPA and NEPRA. Similarly, this scenario also confirmed the ineffectiveness of NEECA (formerly ENERCON) which was unable to motivate the consumers towards utilization of energy efficient appliances (Kamran, 2018; Shakeel et al., 2016).

4.1.4. Cost of generation

Cost of electricity generation directly conveys performance of the power sector. High cost of generation shows the lag in technical efficiency of generation sector (Siano, 2014). The constituents of cost of electricity generation are direct fuel cost, operation and maintenance cost and the initial capital cost of the respective power project.

Fig. 6 shows the trend of average cost of electricity generation from 1996–2016. It is clear from the figure that in 1996, the average cost of electricity generation was Rs. 0.6/kWh, which was increased to Rs. 16.18/kWh in 2015. Overall the percentage increase in cost of electricity generation is quite significant which shows that tremendous increase in cost of generation. The cost of electricity generation mainly depends upon the fuel cost. It has been identified (in Section 4.1.2) that energy mix is dominated by thermal fuels including furnace oil (FO), natural gas (NG), coal and high speed diesel (HSD). Increasing cost of thermal fuels for both public and private generation plants resulted in high over all generation cost. High electricity generation cost ultimately results in high consumer end tariff. Tables 3 and 4 shows the cost of different thermal fuels for public and private power plants respectively. It is clear from Table 3, that the fuel cost of furnace oil (FO) increased six times as it was Rs. 2.7/kWh in 2008 and raised Rs. 18.1/kWh in 2016. Similarly, fuel cost of high-speed diesel (HSD) and natural gas (NG), also increased three times from Rs. 9.9/kWh to Rs. 27.4/kWh for HSD and Rs. 1.8/kWh to Rs. 5.9/kWh for NG respectively. It is also clear from table that cost of generation from coal has also increased five times from Rs. 0.8/kWh to Rs. 3.7/kWh over this period. Although, Pakistan has a large potential for indigenous coal but instead of utilizing local coal GOP has allowed power houses to

Table 3

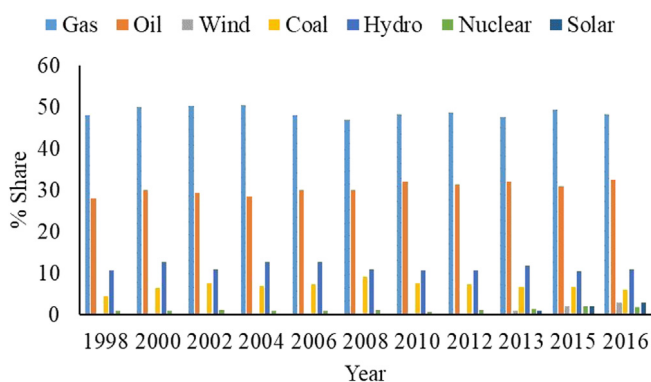
Details of fuel cost (public) over the period from 2003–2014.

Sources	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
NG [*]	1.8	2.0	2.4	2.7	2.6	3.6	3.9	3.9	4.3	4.9	6.0	5.9
FO ^{**}	2.7	3.3	5.0	5.3	8.1	9.1	11.3	11.3	13.7	18.5	18.1	18.1
HSD ^{***}	9.9	11.0	12.6	15.1	18.1	13.5	16.1	16.1	18.4	24.5	26.6	27.4
Coal	0.8	0.9	1.3	1.6	2.0	2.1	2.5	2.5	2.8	3.4	3.5	3.7

^{*} NG = Natural Gas.^{**} FO = Furnace Oil.^{***} HSD = High Speed Diesel.**Table 4**

Details of fuel cost (private) over the period from 2003–2014.

Source	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
NG [*]	3.6	4.2	4.5	4.4	4.5	4.9	5.1	5.3	5.5	6.9	7.2	8.6
FO ^{**}	7.4	7.2	6.7	8.9	9.9	10.7	13.4	14.2	16.5	17.0	19.0	17.3
HSD ^{***}	3.5	4.3	4.6	6.7	7.3	8.3	9.4	10.4	11.4	12.4	13.4	14.4

^{*} NG = Natural Gas.^{**} FO = Furnace Oil.^{***} HSD = High Speed Diesel.**Fig. 7.** Trend of fuel mix situation from 1998–2016.

use expensive imported coal. Although, policy is available to use indigenous fuel but institutions are unable to attract the power plants to use indigenous coal due to less incentives.

Table 4 shows the fuel cost of private thermal units for past 12 years. It is clear from the table that the fuel cost incurred on NG and FO has increased three times from Rs. 3.6/kWh to Rs. 8.6/kWh for NG and Rs. 7.4/kWh to Rs. 17.3/kWh for FO which resulted in high generation cost. Similarly, the fuel cost of HSD has increased up to four times from Rs. 3.5/kWh to Rs. 14.4/kWh which also added in overall generation cost. Another important reason for high cost of generation is inefficiencies in operations of public power plants and dominance of private power sector. Initial power policies contain the provision of commissioning thermal power plants with guaranteed fuel supplies. Continuous increase in fuel cost has resulted in high cost of generation which conveys the unsatisfactory performance of generation sector.

4.1.5. Fuel mix

For the generation of electricity, developed economies are gradually shifting from conventional energy resources to renewable energy resources. The purpose is to develop efficient fuel mix as it enhances sector performance by utilizing inexpensive and indigenous fuel and results in reduced cost of generation.

Although, power sector of Pakistan relies on a diverse, but inefficient, fuel mix which include natural gas, oil (HSD, FO and RFO), hydro, nuclear, solar and wind generation. Fig. 7 shows the fuel mix situation over the last 20 years. The fuel mix in 1998 comprised of

NG, Oil, Coal and hydro with share of 47%, 28%, 4%, 10% respectively. It can be seen that power sector heavily depended on natural gas (NG) and furnace oil (FO) for the generation of electricity followed by hydro and coal. This energy mix is inefficient as Pakistan lacks in NG resources. Unavailability of NG allows utilization of imported expensive oil. In 2016, the fuel mix comprised of NG, Oil, Coal, hydro, nuclear, solar and wind with share 48%, 32%, 5%, 10% and 3%, 1% and 1% respectively. Despite renewable energy policies (1995 and 2006) and development of institutions (PCRET and AEDB), the energy mix remained inefficient during the observed period. The share of renewable energy resources is insignificant. It may also be noted that utilization of renewable energy resources was also ignored. Lack of interest has also been identified from the government for the development of renewable energy technologies for the achievement of efficient fuel mix (Zafar et al., 2018). It may also be observed that the share of oil (furnace, HSD) in 1998 has increased from 28% to 32% in 2014. This situation also resulted in increased overall generation cost (discussed in 4.1.4). Moreover, heavy reliance on these fuel resources also affected the environment. Dominance of thermal fuel resulted as an obstacle in achievement of efficient power sector.

4.2. Performance review of transmission sector

Transmission sector serve as bridge between electricity generation and distribution sector. Sustainable power sector ensures the reliable power supply to the end consumer. In Pakistan, transmission sector is purely under the government control and operated by public sector entity i.e. National Transmission and Dispatch Company (NTDC). NTDC was developed as a result of institutional development. The responsibility of NTDC was not only to manages the transmission but also the sale and purchase of electricity through its subsidiary CPPA-G. NTDC purchase electricity from public and private electricity generation firms and sell it to different DISCOs through its vast network. NTDC's network is comprised of high voltage lines, extra high voltage lines, power transformation stations and real-time control centers. The details of the NTDC is shown in Table 5. This section assesses the performance of transmission sector for past 20 years using transmission sector variable. These variables include expansion in transmission network, concurrence growth of consumers and transformation capacity growth and transmission loss

Table 5
Current capacity of transmission network.

Network component	Capacity
500 kV transmission lines	5183 km
220 kV transmission lines	9104 km
500 kV grid stations	13
220 kV grid stations	35
Transformation capacity	17,400 MVA

kV = Kilo Volt; MVA = Mega Volt Ampere; km = Kilometer.

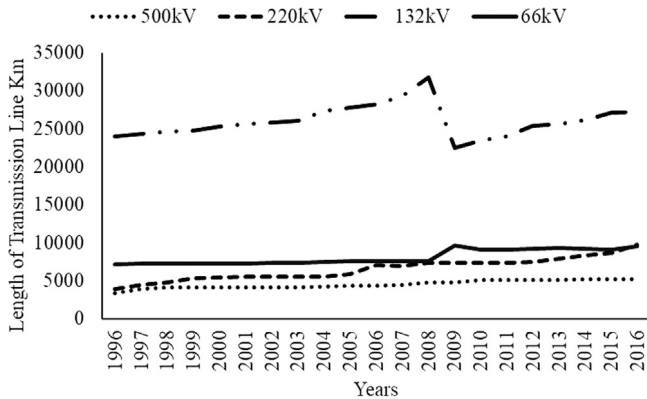


Fig. 8. Expansion of transmission network over the period from 1996–2016.

4.2.1. Expansion of transmission network

Structural transformation and policy advancements in last 20 years resulted in expansion of electricity installed capacity which triggered the expansion of transmission network also. Fig. 8 shows the overall expansion of transmission network over the last 20 years. Continuity in expansion of transmission network has been observed during the last 20 years. NTDC network comprised of 66 kV, 132 kV, 220 kV and 500 kV transmission line. Analysis revealed that the length of 66 kV transmission line was increased to 9563 km which was 7176 km in 1996. Similarly, the length of high voltage transmission lines which include 220 kV and 500 kV lines, expanded significantly from 3848 km to 9867 km (220 kV) and 3315 km to 5187 km (500 kV) respectively. The expansion in length of 132 kV transmission line was smooth till 2008 which was interrupted due several technical and financial constraints. Later in 2010 the expansion in length of 132 kV line was restored. currently, the length of 132 kV transmission line is 2727 km. It has been observed that, in terms of network expansion NTDC has utilized all available resources effectively and catered the growth in installed capacity. Expansion of transmission network conveys better performance of NTDC which is the result of administrative autonomy awarded by GoP right after structural transformation. Moreover, after unbundling of WAPDA many of the technical experts with vast experience of power projects were accommodated in NTDC.

4.2.2. Concurrent growth of consumers and transmission capacity

In past 20 years, sudden growth in population and industrialization has increased the electricity demand (Perwez et al., 2015). This situation necessitated to create a balance between growth in consumption and transformation capacity for smooth and reliable electricity supply. Transmission capacity is series of transmission lines on which electricity flows from generation unit to grid and from grid to distribution node. Fig. 9, shows the relationship of %age growth in transmission capacity along with %age growth in electricity consumers.

Analysis show that initially from 1994–2002, except for the year 1995, 1998 and 1999 there was significant difference in %age growth of consumer and %age growth of transformation capacity.

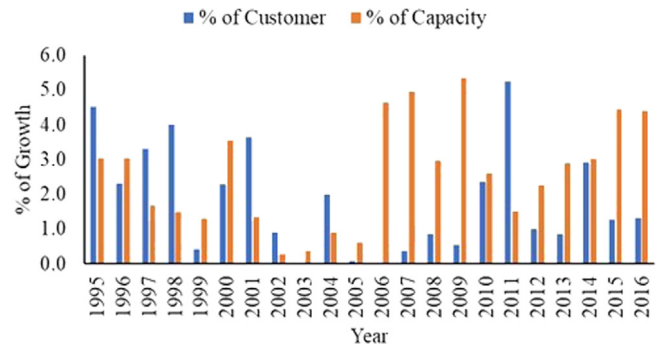


Fig. 9. Capacity and the consumer growth.



Fig. 10. Trend of transmission losses.

In this period, limited efforts were made to enhance the transmission capacity. However, NTDC managed this situation in a structured way and enhanced the network capability/transmission capacity. In later years NTDC has achieved the required concurrence which can be observed from Fig. 9. In context of performance, this enhancement confirms the responsive nature of the NTDC. It has been observed that during the period of insignificant consumer growth from 2004 to 2009, %age of expansion in transmission capacity remained consistent.

4.2.3. Transmission network losses

Transformation loss refers to the energy actually injected into a network and energy actually delivered to points of connection. It is one of the most important sectoral variable to assess the performance of transmission sector. Transmission network losses include losses in transformation of power from sources of supply to points of distribution.

Since establishment, NTDC has made sincere efforts to minimize the distribution losses. Fig. 10 presents the trend of transmission losses over the period of past 20 years. Over the observed period, electricity transmission losses have decreased significantly from 9% to 3%. It is clear from Fig. 10 that, from 1998 to 2005 transmission loss remained constant with negligible variation. The average transmission loss during this period was 7.8% of total transmission. Transmission loss decreased significantly after 2005 due sincere efforts of the NTDC. These efforts included IRP (integrated resource planning) based transmission sector reforms which involved up gradation of existing power transmission lines.

In addition to this, introduction of quality control practices to intelligently monitor and deliver the load has further enhanced the performance of transmission segment (Ahmad et al., 2018).

4.3. Performance review of distribution sector

Electricity distribution sector is the end of entire power chain. Betterment of the distribution sector not only benefits the

Table 6
Current details of distribution companies (DISCOs¹).

DISCO	Service area sq.km	# of consumers	Electricity demand (MW)
IESCO	23,160	2,423,317	2,347
PESCO	77,474	2,618,779	2,798
GEPCO	17,207	2,812,997	2,386
FESCO	36,122	2,445,562	3,091
LESCO	19,064	3,432,160	5,021
MEPCO	105,505	4,989,020	2,892
QESCO	334,616	561,280	1,762
SEPCO	56,300	721,087	1,357
HESCO	81,087	976,923	1,167
TESCO	1,200	390,723	890
Total	751,735	21,371,848	23,711

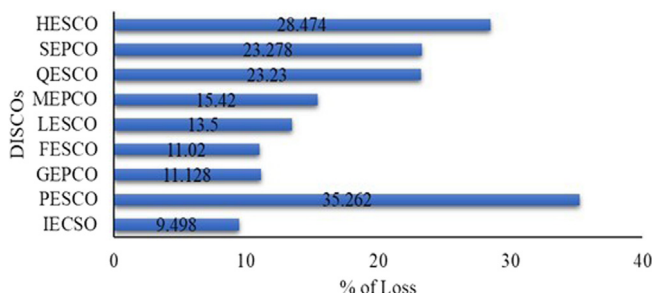


Fig. 11. Average electricity distribution losses.

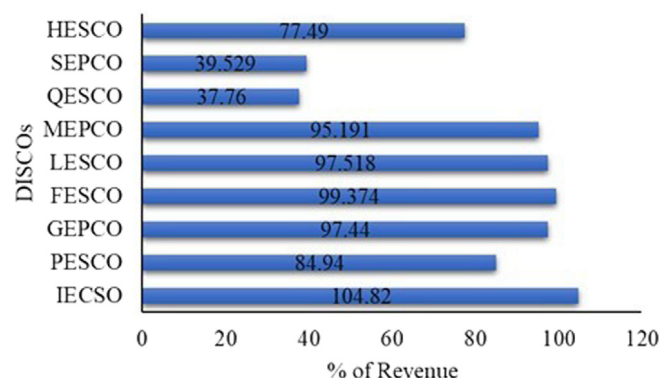


Fig. 12. Trend of revenue recovery of DISCOs.

consumers but other stakeholders of the power chain. Structural transformation of WAPDA initially give rise to eight distribution companies. These DISCOs were responsible for electricity distribution to different consumer categories. Later, two more distribution companies were established (TESCO and SEPCO). Details of each DISCO is given in Table 6. Due to unavailability of sufficient data for TESCO, performance of only 9 DISCOs is reviewed.

This section assess, the progress of distribution sector for last 10 years after the operationalization of DISCOs. Sectoral variable employed for performance review include distribution network losses, revenue recovery, reliability of distribution network, time frame for new connection, duration of load-shedding, consumer affairs, and compliance with safety standards.

4.3.1. Distribution network losses

Distribution network loss refers to the difference between the electricity entering the distribution network and that leaving it at consumer end. It has adverse impacts on efficiency of a distribution company. Due to these losses, it is impossible for DISCO to recover its operational cost effectively. To recover the operational cost DISCOs put extra burden on consumers in the form of overbilling. So, these losses also affect consumers as well. Ineffective recovery due to losses also contribute to circular debt.

Fig. 11, compares the average network losses of all DISCOs after their operationalization. The scenario clearly indicates efficiency differences among these DISCOs. The average network loss of IESCO, PESCO, GEPCO, FESCO, LESCO, MEPCO, QESCO, SEPCO and HESCO is 9.5%, 35.2%, 11.1%, 11%, 13.5%, 15.4%, 23.2%, 23.4% and 28.4% respectively. IESCO, GEPCO, FESCO, LESCO and MEPCO has less distribution losses as compared to PESCO, QESCO, SEPCO and

HESCO which have high distribution losses. These losses included both technical and non-technical losses. Technical losses are due to over-loaded distribution circuits and the high ratio of LT to HT line. In addition to this, inappropriate insulation and outdated wiring also contribute to technical losses. Non-technical losses include high degree of theft by consumers in form of meter tampering, and illegal line taps. Moreover, frauds have been identified in meter reading aided by DISCO's employees. Overall the status of network losses is unsatisfactory and needs serious attention.

4.3.2. Revenue recovery

Electricity cost is recovered from consumers through monthly electricity bills. Inefficient recovery often puts financial and legal burdens on DISCOs, which also contribute to circular debt.

Fig. 12 compares the average revenue recovery of each DISCO. It may be observed that some DISCOs have attained efficiency in revenue collection, whereas some DISCOs still need further improvements. The average collection rate of IESCO, PESCO, GEPCO, FESCO, LESCO, MEPCO, QESCO, SEPCO and HESCO was 104%, 84%, 97%, 101%, 97%, 95%, 37%, 39%, and 77% respectively. Average revenue recovery rate of IESCO, GEPCO, FESCO, LESCO, MEPCO was efficient during the observed period. Interestingly it may be noted that IESCO and FESCO have shown excellent results by achieving revenue collection rate more than 100%. This situation indicates, the strict policy actions taken against defaulters by these DISCOs. On the other side, PESCO, QESCO, HESCO and SEPCO were identified inefficient in revenue collection with recovery rate 37%, 77% and 39% respectively. The reason for low collection rate included accounting regulations that stops DISCOs to collect receivables from government clients. DISCOs with low recovery rate need to implement strict policies to be efficient in revenue collection.

¹ IESCO(Islamabad Electric Supply Company). LESCO(Lahore Electric Supply Company). FESCO(Faisalabad Electric Supply Company). PESCO(Peshawar Electric Supply Company). MEPCO(Multan Electric Power Company). GEPCO(Gujranwala Electric Power Company). QESCO(Quetta Electric Supply Company). SEPCO(Sakhar Electric Supply Company). HESCO(Hyderabad Electric Supply Company) & TESCO(Tribal Electric Supply Company).

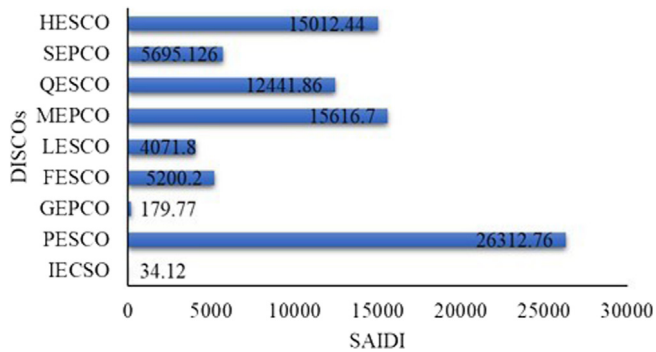


Fig. 13. Average SAIDI value for DISCOs.

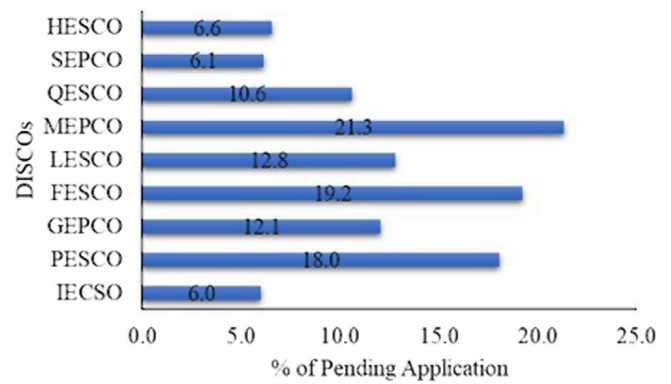


Fig. 15. Status of average %age of pending applications.

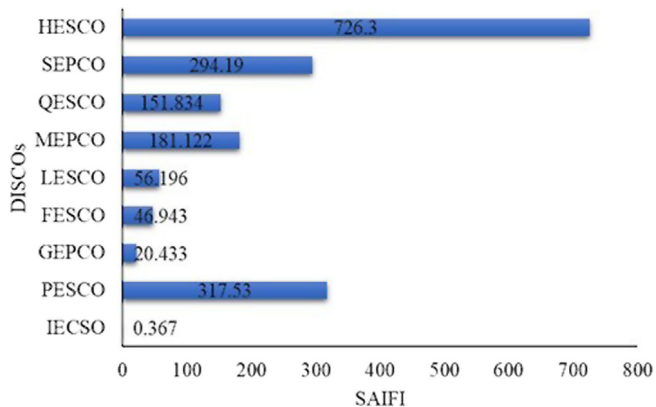


Fig. 14. SAIFI status of DISCOs.

4.3.3. Reliability of distribution network

Satisfaction of electricity consumers depends on reliability of electricity distribution network in terms of uninterrupted power supply. System Average Interruption Frequency Index (SAIFI) and System Average Interruption Duration Index (SAIDI) are the two indicators which are extensively used to gauge the reliability of the distribution network.

SAIDI identifies the duration of the interruptions per consumer per annum whereas SAIFI identifies the total annual interruptions a consumer faced for that particular DISCO. NEPRA has set the standards for all DISCOs not to exceed values of SAIDI and SAIFI 13 and 14 in minutes and numbers respectively. Overall situation that reliability of distribution network is poor and far away from target set by NEPPA.

Figs. 13 and 14, shows the DISCO wise comparison of reliability of distribution companies using SAIDI and SAIFI respectively. Average SAIDI values for IESCO, PESCO, GEPCO, FESCO, LESCO, MEPCO, QESCO, SEPCO and HESCO are 34, 26,312, 180, 5200, 4071, 15,616, 12,441, 5695, 15,012 min respectively. It is pertinent to mention that none of the DISCOs have achieved the desired standard. However, it has been observed that IESCO, GEPCO and FESCO have the potential to achieve the desired standard in near future. All other DISCOs require serious efforts to enhance the system reliability. Moreover, PESCO needs much attention to eradicate unusual behavior of interruptions in electricity supply.

The average SAIFI values for IESCO, PESCO, GEPCO, FESCO, LESCO, MEPCO, QESCO, SEPCO and HESCO are 0.36, 317, 20, 46, 56, 1811, 151, 294 and 726 respectively. It is observed that IESCO, GEPCO and LESCO have achieved the desired standard to some extent. This may be justified by the continuous efforts made by

these DISCOs in utilization of operations and maintenance budget. On the other side PESCO, MEPCO, QESCO, SEPCO and HESCO have large number of interruptions and are far away from desired standard. It has been identified that overloaded transformers and feeders are the significant contributors of interruptions of power supply. Moreover, poor conditions of poles and lines also cause power breaks which results into unreliable power system.

4.3.4. Time frame for new connections

The responsiveness of the service providing entity to customer's requirements directly measures the performance of service provider. Growing population has increased the demand of new electricity connection tremendously. It is one of the key responsibility of DISCO to provide the connections to all consumers within set time standards.

Fig. 15 shows the DISCOs wise percentage of consumers who were not provided electricity connections within a specified time frame. Average percentage of pending application for IESCO, PESCO, GEPCO, FESCO, LESCO, MEPCO, QESCO, SEPCO and HESCO was 6%, 18%, 12%, 19%, 13%, 21%, 11%, 6% and 7% respectively. IESCO, SEPCO, QESCO and HESCO showed efficiency in providing new connections to their customers. Whereas, PESCO, GEPCO, FESCO, LESCO and MEPCO show inefficient behavior in satisfying their customers. Inefficient behavior of these DISCOs is purely due to bureaucratic culture and prevailing corruption in the administrative structure of these DISCOs. Similarly, there were some technical constraints in meeting customer demand in timely and systematic manner which included unavailability of meters, wires and electricity poles.

4.3.5. Duration of load-shedding

Load shedding is one of the practices to manage the supply demand deficit. GoP has allowed DISCOs for load shedding on the basis of performance of DISCO. DISCOs with less electricity theft rate, reduced line lose and high efficient recovery of bills are allowed to blackout for lesser period of time as compared to others.

Fig. 16 provides the comparison of average load shedding made by each DISCO from 2007–16. The average load shedding duration for IESCO, PESCO, GEPCO, FESCO, LESCO, MEPCO, QESCO, SEPCO and HESCO was 5, 5, 3.7, 7, 4, 9, 10, 2 and 4 h per day. It is evident that among all DISCOs only GEPCO, LESCO, SEPCO and HESCO has less duration of load shedding. On the other hand, IESCO, FESCO, PESCO, MEPCO and QESCO still observe more hours for load shedding. The variance in load shedding hours among DISCOs also depicts their performance which needed to be reviewed technically and administratively as well.

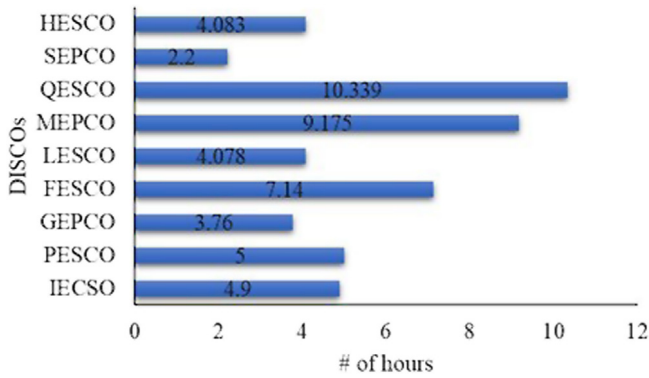


Fig. 16. Status of average load shedding by DISCOs.

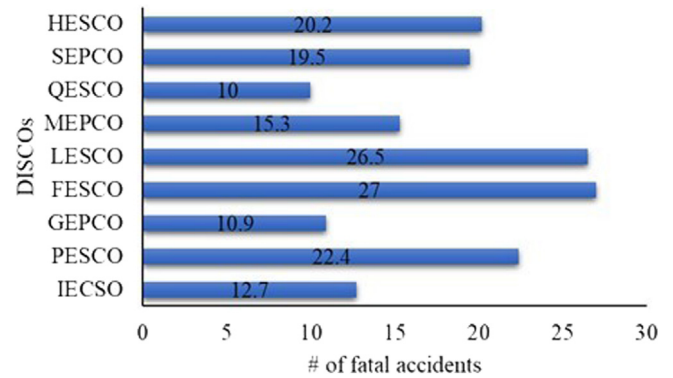


Fig. 18. Average number of fatal incidents status of DISCOs.

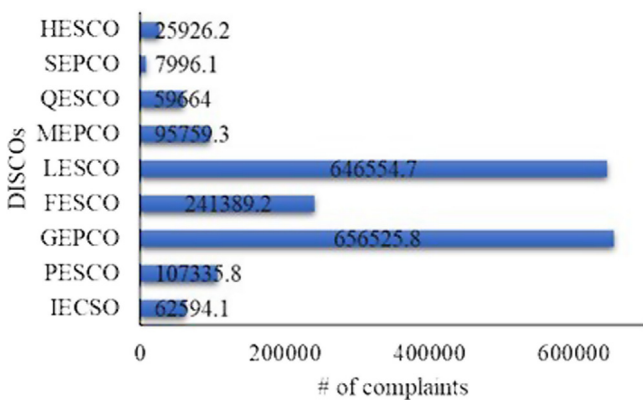


Fig. 17. Average number of complaints of DISCOs.

4.3.6. Consumer affairs

Resolving customer issues in timely manner also serve as one of the indicators to evaluate the performance of the sector. Timely response to the consumer complaints produces satisfied customers which results in positive growth of the sector. It has been reviewed that reforms in the power sector has improved the customer service system. The extensive use of information technology in customer services has made it possible for consumers and service providers to interact electronically. Various initiatives have been taken by DISCOs for the advancements of the consumers facilitation which included online complaint through mobile phone and internet. Similarly, each DISCO has increased customer facilitation centers for resolving customer issues

Fig. 17 compares the average number of complaints of each DISCO during the observed period. Over the period of last ten years the average number of complaints received by IESCO, PESCO, GEPSCO, FESCO, LESCO, MEPCO, QESCO, SEPCO and HESCO were 62,594, 107,336, 656,526, 241,389, 646,555, 95,759, 59,664, 7996 and 25,926 respectively.

The nature of these complaints included incorrect meter-reading, replacement of defective meters, breakdowns of transformer and unannounced load shedding. It can be seen that, IESCO, PESCO, MEPCO, QESCO, SEPCO and HESCO has lesser amount of complaints as compared to GEPSCO, FESCO and LESCO. The lesser number of complaints received by these DISCOs can be explained by the fact that they implemented reforms seriously and enhanced their performance. It is pertinent to mention that GEPSCO and LESCO has performed well in terms of load shedding but number of complaints is still very high.

4.3.7. Compliance with safety standards

Degree of compliance with safety procedures also depicts the proficiency of DISCO and can be considered to assess its performance. Lack of safety culture and the nonexistence of safety management systems often lead to fatal incidents. NEPRA has made standards for all distribution companies to construct, operate, control and maintain according to consumer service manual, power safety mode and power distribution code.

Fig. 18 shows the comparison of average number of fatal incidents for the last 10 years for each DISCO. The number of fatal incidents by IESCO, PESCO, GEPSCO, FESCO, LESCO, MEPCO, QESCO, SEPCO and HESCO were 12.7, 22.4, 11, 27, 26, 15, 10, 19 and 20 respectively. During the observed period the average number of fatal incidents by IESCO, GEPSCO and QESCO was small. It has been observed that these DISCOs have introduced on job trainings for their employees. Moreover, these DISCOs have introduced occupational safety protocols in their working environment. On the other side average number of incidents of PESCO, FESCO, LESCO, MEPCO, HESCO and SEPCO was quite large which conveys that these DISCOs still need to implement the safety procedures.

5. Summary of performance review

Performance review of electricity generation, transmission and distribution sector provided the insights of the overall power sector. The review of the sectors not only identified the shortcomings of the reforms but also high lighted the key improvement areas for the development of respective sector. The summary of performance review is presented in Table 7.

The impact of power sector reforms on electricity generation sector was insignificant. The addition in installed capacity was inefficient and in adequate and resulted in inappropriate fuel mix. Resultantly, high cost of generation and increasing supply demand deficit.

The impact of reform efforts on transmission sector was significant. It can be justified by the expertise and autonomy even under government control being awarded to market operator. Similarly, transmission sector was protected from political intrusions.

The impact of reforms on electricity distribution sector is satisfactory as there is variation in performance of DISCOs. Some DISCOs showed satisfactory performance for distribution sector variables where as other DISCOs show poor performance against these variables.

It has been observed that the existing power sector need serious revolution in its electricity generation, distribution and transmission sectors. However, the level of efforts, required for enhancement of respective sector is different. The review of power sector

Table 7
Summary of sectoral performance review.

Sector	Sectoral variable	Status	Reasons	Impact
Generation	Installed capacity	Limited enhancement in WAPDA & GENCOs Significant addition in IPPs %age Share: Existing Status: IPPs: 41.94% WAPDA: 30.04% GENCOs: 28.02%	Lucrative terms and conditions of 1994 policy. Lack of government interest in hydro policy 1995 In existence of regulatory policy during structural transformation	Dominance of IPPs Dominance of thermal based installed capacity (IPPs+ GENCOs)
	Electricity generation	Continuous increase in share of IPPs Continuous decrease in share of GENCOs Insignificant contribution of WAPDA Progress 2000: IPPs (25%), WAPDA (28%), GENCOs (45%) 2008: IPPs (42%), WAPDA (32%), GENCOs (24%) 2016: IPPs (48%), WAPDA (32%), GENCOs (18%)	Dominance in installed capacity of IPPs. Capacity plus energy charge policy Technical and Economic inefficiency Bureaucratic culture Insignificant addition of mega hydel project in last 10 years. Inefficient utilization of existing hydro projects	Expensive generation Increase in tariff Circular debt Burden on economy Reliance on thermal and private electricity generation
	Supply demand deficit	Continuously increasing Shortfall gap widened Progress: 2000: 857 MW 2008: 2546 MW 2016: 5640 MW	Continuous change in consumption pattern i.e. Increase in demand Overlapping and lack of coordination among power sector institutes Ineffectiveness NEECA	Load shedding of 8–12 h Unsatisfied house hold electricity consumers Shifting of industry
	Cost of generation	Continuously increasing Progress: 2000: 1.2 Rs/kWh 2008: 3.66 Rs/kWh 2016: 16.18 Rs/kWh	Promotion of thermal based power plants in initial energy policies Fuel supply guarantees Dominance of thermal power plants Imported thermal fuel Technical and Economic inefficiency of GENCOs	High consumer end tariff Issues in recovery Undue subsidy offered to consumers
	Fuel mix	Inefficient fuel mix Dominance of thermal fuel Existing Status: Natural Gas: 43.9% Hydro: 30.9% Furnace Oil: 18.7% Nuclear: 2.8% Others:1.5% Wind: 1.3% Coal: 0.7% High Speed Diesel: 0.1%	Lucrative terms and conditions of 1994 policy for thermal based IPPs Ignoring the utilization of alternative and renewable energy Overlooking indigenous fuel Inefficiency of regulatory policies	High generation cost High consumer end tariff Adverse impact on environment and climatic change
Transmission	Expansion of transmission network	Continuous expansion of high and low voltage transmission lines Progress: 2000: 500 kV (4079), 220 kV (5378), 132 kV (25,322), 66 kV (7262) 2008: 500 kV (4712), 220 kV (7318), 132 kV (31,779), 66 kV (7617) 2016: 500 kV (5187), 220 kV (9687), 132 kV (27,272), 66 kV (9563)	Administrative and financial autonomy Availability of local technical experts	Structured transmission system/ready for wholesale competitive market

(continued on next page)

revealed that the performance of electricity generation and distribution has deteriorated considerably over the period of last few years. Whereas, the performance of transmission sector has been found satisfactory over the observed period. The review of power sector also revealed the causes of the crisis.

6. Integrated sectoral framework for the development of sustainable power sector

Review of electricity reforms and performance of electricity generation, transmission and distribution sector provide the

Table 7 (continued)

Sector	Sectoral variable	Status	Reasons	Impact
	Growth concurrence	Aligned and smooth growth Progress: 2000: 3.5% growth in capacity against 2.3% growth in consumption 2008: 3% growth in capacity against 0.9% growth in consumption 2016: 4.4% growth in capacity against 1.3% growth in consumption	Expertise and no political intrusions	Optimistic impact on overall power sector
	Network Losses	Significant reduction Progress of network losses: 2000: 7.93% 2008: 3.83% 2016: 2.73%	Continuous improvement and upgradation	Benchmark for private transmission lines and DISCOs
Distribution	Network losses	Unsatisfactory IESCO <10% GEPSCO, FESCO, LESCO & MEPCO <15% PESCO & SEPCO >20%	Technical losses: Over-loaded distribution circuits High ratio of LT to HT line Inappropriate insulation Outdated wiring Non-technical losses: High degree of theft Frauds in meter reading	Inefficient recovery of operational cost Overbilling Circular debt
	Revenue recovery	Satisfactory SEPCO & QESCO <40% HESCO & PESCO <90% MEPCO, LESCO, FESCO, GEPSCO & IESCO >90%	Flexible accounting regulation for public sector organizations in terms of receivables.	Legal and financial burden on DISCOs Circular Debt
	Reliability of distribution network	Poor SAIDI: None of the DISCOs have achieved the standard SAIFI: Only IESCO has achieved the standard set by NEPRA	Overloaded transformers and feeders. Inappropriate utilization of operations and maintenance budget.	Unsatisfied consumers. Disruption in day to day economic and house hold activities
	Time frame for new connections	Responsive DISCOs: IESCO, SEPCO, QESCO & HESCO Passive DISCOs: PESCO, GEPSCO, FESCO, LESCO & MEPCO	Bureaucratic culture Corruption at lower staff level Unavailability of meters, wires and poles	Unsatisfied consumers
	Duration of load-shedding	DISCOs (Blackout duration <4 h): GEPSCO, LESCO, SEPCO & HESCO DISCOs (Blackout duration >4): IESCO, FESCO, PESCO, MEPCO & QESCO	Supply demand deficit Manual load management	Interruption in day to day activities
	Consumer affairs	DISCOs with small no. of Complaints: IESCO, PESCO, MEPCO, QESCO, SEPCO & HESCO DISCOs with large no. of Complaints: GEPSCO, FESCO & LESCO	Inflexible complaint management system Inefficient technical work force to resolve the problem Lack of resources	Trust on distribution company
	Compliance with Safety Standards (fatal incidents).	DISCOs with small no. of incidents (<15): IESCO, GEPSCO & QESCO DISCOs with small no. of incidents (>15): PESCO, MEPCO, SEPCO, HESCO, LESCO & FESCO	Inexistence of sufficient safety standards Ignorance towards safety measures Use of thumb rule to solve a problem	Loss of human life Loss of assets and resources

causes and detailed insight of power sector. Based on these findings, this research proposed an integrated sectoral performance enhancement framework for the development of power sector in Pakistan. The framework comprised of three segments which include (i). Performance Enhancement Plan, (ii). Government Support Plan, and (iii). Organizational Support Plan. The performance enhancement plan includes the enhancement plans for electricity generation, transmission and distribution sector separately. Whereas, government and organizational support plan describes the required supportive role of government and organization to

achieve the performance enhancement plan effectively. It may be anticipated that operationalization of this proposed framework will enable the smooth achievement of sustainable power sector in Pakistan. Fig. 19 presents the integrated sectoral framework.

6.1. Sectoral performance enhancement plan

Sectoral performance enhancement plan describes the performance enhancement plan for electricity generation firms, distribution utilities and transmission entity. These recommendations

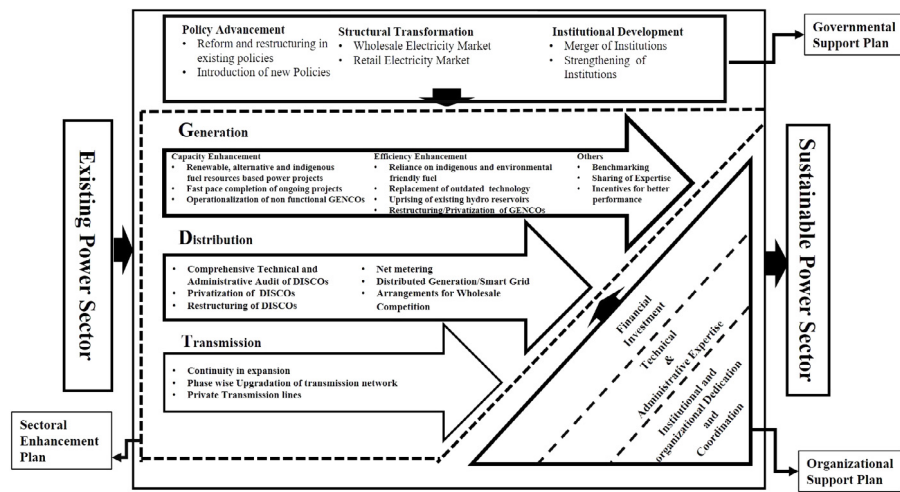


Fig. 19. Integrated sectoral enhancement framework for sustainable power sector.

are based on review of power sector reforms and performance of electricity generation, transmission and distribution sectors.

6.1.1. Performance enhancement in electricity generation sector

For the development of sustainable power sector, electricity generation sector need rigorous performance enhancement. For the purpose, it is essential to full fill the gap in installed capacity by commissioning new power plants. Addition of installed capacity can be done by IPPs, WAPDA and GENCOs. In this context IPPs and GENCOs must be triggered for the development of renewable energy base. Moreover, these generators can also be motivated for the utilization of indigenous fuel. However, WAPDA can help in adding up in installed capacity by utilizing the huge available potential of hydro in the northern region of the country. Timely and fast pace completion of ongoing power projects can also ensure the smooth addition in installed capacity. Peaceful utilization of nuclear energy resources can help in addition of installed capacity as well.

Similarly, the efficiency of existing power plants can be helpful in achieving the sustainability in power sector. Analysis in Section 4.1.2, revealed that the share of GENCOs in annual electricity generation has decreased significantly which was due to economic and technical inefficiencies. Economic efficiency can be improved by organizational restructuring. Similarly, the technical efficiency can be improved by enhancing the technical expertise of human resource and replacing the outdated technology. Non-operational GENCOs can be made functional to contribute in national grid. The efficiency improvements of WAPDA and GENCOs will reduce the reliance on IPPs which in return reduce the financial burden of Government. Another option for performance enhancement of GENCOs is to introduce change in ownership through privatization. Similarly, the efficiency of WAPDA can also be increased by initiating upraising of existing reservoirs. In progress hydro based project either under WAPDA or IPPs must be closely monitored for their timely completion. Efficiency of IPPs has been satisfactory, however to ensure continuity in efficiency, these firms must be offered some incentives. Sustainable performance of IPPs can be utilized to set as a benchmark for GENCOs and for other IPPs as well. Moreover, as good will gesture, IPPs may share technical and managerial expertise with GENCOs. In context of environmental parameters, the enhanced share of thermal fuels must be resolved with utmost priority. The energy mix must contain reasonable share of renewable energy resources like photovoltaic, bio fuels, tidal energy and energy from wastes etc. (Shakeel et al., 2016).

6.1.2. Performance enhancement in electricity distribution sector

Electricity distribution sector also need several improvements for the development of sustainable power sector. Based on the review of DISCOs in Section 5, it is clear that some DISCOs have enhanced their performance however some DISCOs still lack in enhancing the performance. For the purpose a comprehensive and neutral technical, administrative and financial audit of each DISCO must be planned from an independent source. The result of comprehensive audit will enable policy makers to decide among restructuring or privatization of DISCOs. This will also help in deciding which DISCOs have to be restructured and which have to be privatized. In case of privatization, there must be a neutral privatization policy in the best interest of all the stakeholders. Similarly, the mechanism of privatization must be fair and free. In case of privatization, a separate model must be developed dedicatedly for power sector DISCOs. The privatization model must be acquainted with the contribution from cross functional experts of the economic system. In case of restructuring, the senior and middle management of respective DISCOs along with line staff should be involved in designing the restructuring plan. Similarly, case studies of different restructuring plans must be reviewed for identification of challenges in implementation of restructuring. Apart from these structural changes, the DISCOs may introduce technological innovations like smart metering, net metering, distributed generation and pre-paid billing. This will aid in sustainable recovery from consumers and will result in reliable electricity supply. Efficient consumption of electricity can also pave the way for the development of sustainable power sector. In power chain DISCOs have direct access to the consumers so they can better motivate consumers towards efficient energy consumption (Javid and Qayyum, 2014). In this regard several awareness campaigns for the utilization of energy efficient appliances can be launched. Moreover, special incentives can also be introduced for consumers on considerable reduction in their consumption patterns.

6.1.3. Performance enhancement in electricity transmission sector

Although the review of transformation sector presents the satisfactory results, but it is essential to continue the enhancement that must support the development of sustainable power sector. The level of effort required to further enhance the transmission sector will be minimal. It can be anticipated that enhancement in generation and distribution sector cannot stand alone without well-developed transmission sector. Transformational changes in generation sector will increase the burden of transmission sector both in technical and administrative concerns. Based on review the

framework propose that transmission sector should continue the expansion and upgradation of network. Expansion will allow easy transaction among newly commissioned power plants and grids. Upgradation will further reduce the network losses. In order to smoothen the expansion, laying of private transmission networks may be allowed.

6.2. Governmental support plan

The second segment of the integrated sectoral framework is government support plan. This plan describes certain administrative roles of government which are essential to support the sectoral performance enhancement plan. It includes, certain reforms in policy advancement, structural transformation and institutional development.

6.2.1. Policy advancement

Based on analysis, the framework proposes that in the context of energy policy, government has to bring to dimensional change. i.e. reform the existing policies and introduce new innovative energy policies. The existing policies have to be remodeled both on technical and administrative grounds. Technically, existing hydro policy should include the provision of utilization of immense potential in the north by developing small hydro projects. Similarly, the indigenous fuel policy must include the provisions of utilization of indigenous fuel which are environmental friendly, abundantly available and easy to explore. Existing renewable energy policy must be reformed after extensive exploration of wind and solar energy potential. Similarly, co-generation, tidal and geothermal energy provisions should be considered. On administrative grounds, a policy must be introduced for privatization and restructuring of DISCOs.

Introducing new policies include the energy conservation policy. This policy should include flexible provisions of import of domestic and commercial solar panels, batteries and related equipment. Similarly, policy also support the local production of these equipment's. Production and utilization of energy labeled efficient appliance should also be made part of this policy. Net metering and distribute generation also need the development of new policy. Moreover, laying of private transmission lines should also be supported by a policy.

6.2.2. Structural transformational

As reviewed earlier in section that the major structural transformation took place in 1998, when monopoly model was transformed to single buyer model. Several structural transformations were also made which included introduction of IPPs and privatization of KE. After that, the planned transformation i.e. transformation from single buyer model to wholesale competitive market model has not been executed so far. Based on review, it is observed that without competition among electricity generation firms it is not possible to develop competitive power market. This situation necessitates the development of wholesale electricity market. The proposed transformation will aid in achievement of competitive electricity market and hence sustainable power sector.

6.2.3. Institutional development

It has been observed that development of several energy institutions resulted in overlapped roles and responsibilities. To avoid this problem, these institutions can be merged in their administrative and work domain and may be operated under single administrative control. Similarly, the existing important institutions especially NEPRA, must be strengthen by providing them with optimum autonomy in decision making. The organizational support plan propose that all the institutions must work without any political pressures. All institutions must be made responsible for their own actions and decisions towards achievement of sustainability goals. Free and fair mechanism must be introduced for the technical and financial audits of the institutions to enhance their effectiveness.

6.3. Organizational support plan

Organizational support plan includes the provisions related to financial investment, technical and administrative expertise and dedication. All firms of power sector either electricity generation, transmission and distribution require finance for the performance enhancement. For public sector firms the only source of financial support is government. The firms can arrange financials by public-private partnership and selling of unnecessary assets like unused land, scrap etc. Moreover, these firms can also reduce their financial burden by laying off extra staff. Similarly, for enhancement of sectoral performance firms either public or private firms need to enhance their technical expertise. This can be done efficiently by hiring of international experts which train the local employees in technical as well as in administrative concern. The most important thing required for the successful execution of the sectoral enhancement plan is utmost dedication and organizational coordination. This will enable the motivation among the players of the power market and will smoothen the entire process of achieving sustainability in power sector.

7. Conclusions

This study provides a comprehensive review of power sector reforms in Pakistan and assessed the historic performance of electricity generation, transmission and distribution sector. The purpose of this research was the development of a comprehensive roadmap essential for the development of sustainable power sector in Pakistan. It has been found that structural transformations, institutional developments and policy advancements were introduced with anticipation of efficient power sector but the aim remained unachieved as power sector crisis increased day by day. Structural transformation reduced the administrative burden of government but resulted inefficient development separated power sector generation and distribution. Institutional development attempted to fulfill administrative and technical efficiencies but also resulted in overlapping authorities. Similarly, Power policies paved the way for flexible entry of private sector and aided the expansion in installed capacity but in the long run it resulted in inefficient fuel mix. Historic performance review revealed that electricity generation and distribution require serious attention, whereas, transmission sector only requires continuity in improvements. Based on review of reforms and historic performance assessment an integrated sectoral framework is developed that comprised of sectoral enhancement plan, governmental and organizational support plan. The proposed framework describes the required responsibilities by electricity generation, transmission and distribution firms. Moreover, it also explains the role required by government and the respective organization, necessary to successfully achieve the sectoral enhancement plan. The proposed framework serve as a recipe for the development of sustainable power sector in Pakistan.

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