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Impact of Reforms on Capacity Adequacy, Resource Mix, Efficiency and Emissions in the Power Sector of Pakistan

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ABSTRACT

This paper analyzed impact of reforms on the generation capacity adequacy, resource mix, efficiency, and carbon emissions of the power sector in Pakistan over the past two decades. Operating results for the period 2000–2013wereanalyzed. The results showed that although there were sufficient capacity additions during the early part of this period, long-term increases were not sustained and this resulted in a shortfall in capacity. Furthermore, yearly demand increased by 6.3%, whereas the capacity increased by only 2.7%.In the pre-reform period, the hydel was sharing 70% in the overall mix. However, this mix was worsened over this period reversing the pre-reform hydel dominance to sharing only30% in the overall mix. In addition, no significant gains in efficiency or environmental benefits were observed. We conclude that the sector reform model is acceptable, but suggest changing the regulatory framework to improve the operation of the power market in terms of the associated risks, and ease of doing business, to achieve the desired results of sector performance.

KEYWORDS: Market Model, Policy, Regulation, Hydel Ratio

1. INTRODUCTION

Historically, Pakistan's power sector has been served by two vertically integrated utilities: the Karachi Electric Supply Corporation (KESC)served the metropolitan area of Karachi, and the Water and Power Development Authority (WAPDA) served the rest of the country. However, the country has been facing constraints on the public financial resources available to provide the additional capacity required to meet demand. During the late 1980s,to bridge this gap in the public finances, Pakistan invited Independent Power Producers (IPPs) to provide additional capacity based on 100% foreign ownership. However, only one IPP (Hub Power, 1250MW) was found to develop new generating capacity to add to the system [1].

Pakistan could not attract sufficient private sector investment in the power sector through incentive policies in a vertically integrated utility model. Therefore, decided to reform the sector to create a competitive market environment. Accordingly, WAPDA's Strategic Plan for the Privatization of the Pakistan Power Sector 1992 was devised [2]. The restructuring and reform process was initiated in 1998 through the Pakistan Electric Power Company (PEPCO), which was created specifically for this purpose. The vertically integrated WAPDA was separated into generation, transmission, and distribution businesses, which were corporatized to create financially viable companies capable of operating in a market environment. WAPDA's strategic plan for the privatization of the Pakistan power sector envisaged a fully competitive market beyond 1996, and planned to allow supply and demand to be controlled by market forces. However, to address the transition period before the market became fully competitive, the Pakistan government commissioned an energy task force that was to manage the growing energy demands during the transition phase, but without placing any additional strain on overstretched public resources.

The task force recommended a multi-part strategy that included the framework for an incentive scheme for private sector participation, improvements in sector efficiency, and the development of indigenous resources [3].Accordingly, to attract the private sector to power generation, a policy framework and package of incentives was devised and announced in 1994 [4].This policy offered an internationally competitive upfront tariff; free choice in the selection of sites, technology, and fuel; blanket exemption from duties and taxes; and an off-take guarantee for the power generated. The projects were offered on a first-come first-served basis, and bypassed bureaucratic hurdles through the use of a one-window facility for investors. Potential investors approved of this approach, and there was an overwhelming response from the private sector, which applied to develop 26,000MW of thermal capacity. However, despite this enthusiastic response, projects totaling only 3000MW of capacity were successfully added to the system [5].

While this policy was partially successful in that it mobilized much needed private capital into power generation, it also resulted in a power mix dominated by fossil fuels and burdening import bill. To correct the power mix, in 1995, a hydel policy was announced to incentivize hydel generation by the private sector[6]. However, this policy did not succeed because it overlooked the risks typically

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associated with the construction, operation, and financing of hydropower projects. Therefore, although investors with 1385MW of capacity had shown interest, only one project with a capacity of 84MW was successfully developed.

As a result of this poor response, the government decided to let the generating companies set the level of hydropower power pricing and planned to invite prospective investors to enter a bidding process. Subsequently, in 1998, a new power generation policy was announced [7]. However, the government again failed to achieve its desired aim of exploiting the abundant hydel potential of Pakistan, and not a single project was developed. Therefore, in 2002, this policy was revised and opened up to other conventional technologies and fuel choices[8].The focus of this policy was to encourage site-specific projects based on indigenous resources, and determining project-specific tariffs through negotiation or competitive bidding. The policy also allowed development of projects based on imported fuels as a secondary option. After consecutive policy failures, this policy was again a partial success in attracting projects based mainly on imported fuels; however, it was not sufficient to address the problem of insufficient capacity. Furthermore, the additional capacity was based mainly on fossil fuels, which led to an increase in Pakistan's carbon footprint, but a decline in the security of its energy supply.

Despite these difficulties, Pakistan has acknowledged that economic growth is linked to both environmental sustainability and energy security, which can only be achieved through the deployment of clean energy resources and efficient operation of the existing system. Accordingly, Pakistan announced an environmental policy that aimed to facilitate energy efficiency projects under the Clean Development Mechanism (CDM) and so contribute to the Kyoto Protocol initiative [9, 10]. To complement this policy, the government decided to develop and deploy renewable energy resources for power generation projects and launched an incentive scheme to this end in 2006 [11]. So far, this policy has been successful, and has added 50MW of generating capacity to the grid.

The international experience exhibits that power sector reforms cost billions of dollars to achieve efficiency gains and adequacy but the results are a mix with limited success [12]. The generation security is difficult to achieve through market but requires regulatory interventions. However, regional interconnection can help to achieve the security and adequacy [13,14]. Similarly, Latin-American countries also show no significant environmental benefits and emission reductions during post reform [15]. However, the China experience is a success, resulting in generation adequacy, production and efficiency gains in its public-sector fossil-fuel fired projects [16,17]. Pakistan power sector reforms for a competitive market, and the transition incentive policies were used to attract the private sector aimed to mobilize market resources to maintain adequate generating capacity, efficient operation, and a sustainable generation mix and emission levels. This paper analyses the post-reform period (2000–2013) to assess the impact of these reforms on the power sector using historical operating data [18–20] to analyze the trends in capacity, demand, generation mix, fuel efficiency, and emission levels.

Pakistan's electrical energy needs are met through power generation facilities based on hydel, fossil fuels (gas, diesel oil, fuel oil, and coal), nuclear, and renewable energy resources (mainly wind). In 2013, Pakistan's total installed capacity was 23,617MW, of which 29.3% was hydropower, 30.4% was public thermal, 36.7% was private thermal, and 3.3% was public nuclear.

PEPCO, in accordance with the 1992 strategic plan for power sector reforms, restructured WAPDA's power wing into 15 distinct corporate entities, comprising 4 generation companies to manage the existing thermal facilities, 1 transmission company, and 10 distribution companies, whereas the Karachi Electric Supply Company (KESC) remained as a vertically integrated utility. All of the WAPDA companies remain in government ownership, while KESC was privatized as a vertically integrated utility. The 10 distribution companies are responsible for distributing power and serving retail consumers. The transmission company is responsible for transmission and the generation facilities. An independent regulator, the National Electric Power Regulatory Authority (NEPRA), was established to regulate the power business, including standards, services, and pricing. No new thermal power in the public sector. So, new generation plants were established as IPPs through the private sector.

The commercial market model used for the power sector reform was single-buyer plus, except KESC, which remained a vertically integrated utility(Figure1).The single-buyer National Transmission and Dispatch Company (NTDC) buys the power from the generating companies (public thermal, IPPs, public hydropower, public nuclear power, and imports) at a price determined through competitive bidding or determined by NEPRA, and sells it to distribution companies and bulk consumers connected at the transmission system. The distribution companies buy the power from NTDC and sell it to consumers. The public and private generation companies buy their fuel, including oil, gas, and coal, from the respective fuel suppliers, both through a spot market and under long-term contracts. The gas price is still regulated by the Oil and Gas Regulatory Authority (OGRA), whereas the oil sector is deregulated and the price is left for the market to determine.

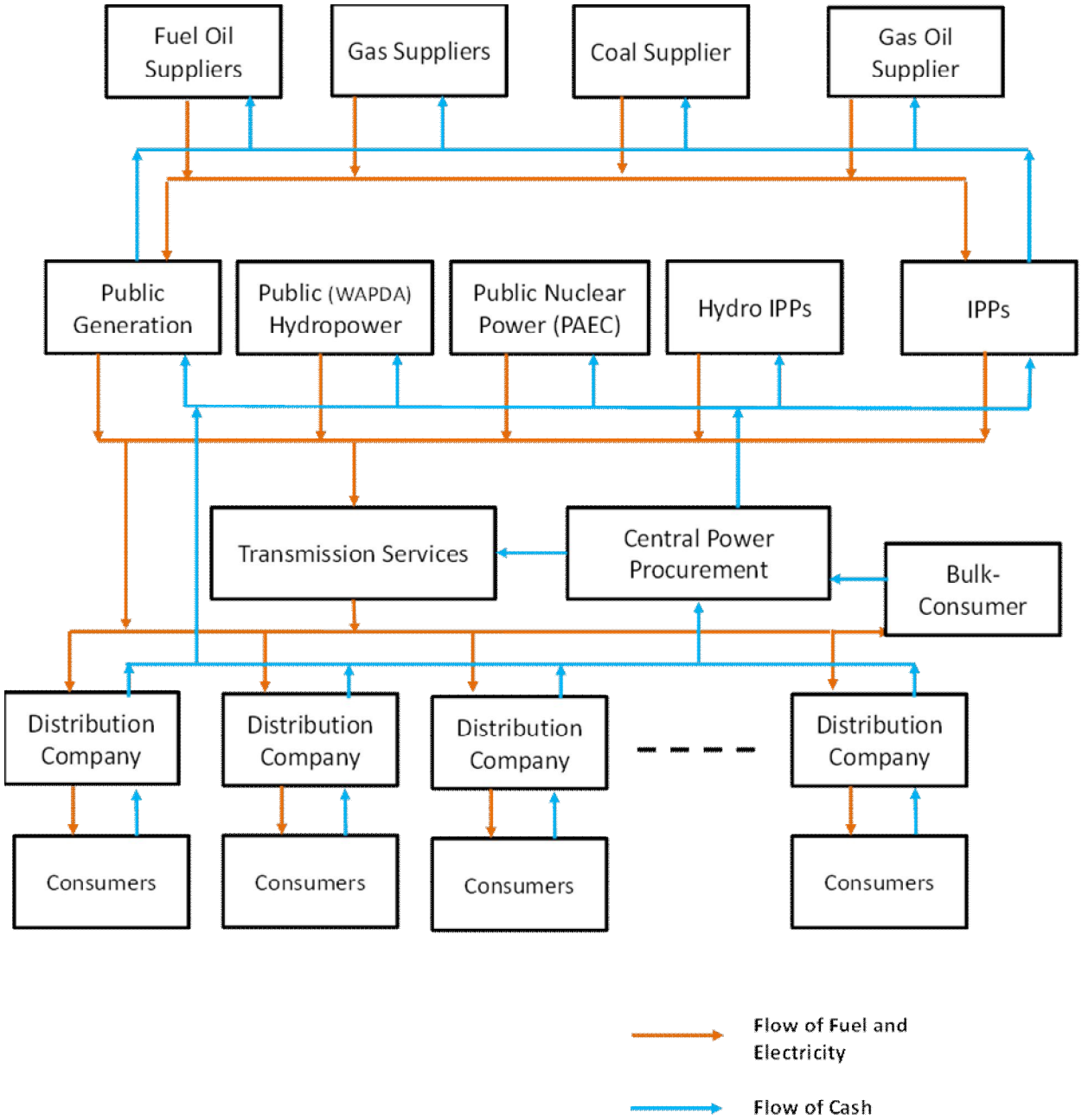

Figure1. The structure of Pakistan's power sector.

2. METHODOLOGY AND CALCULATIONS

Operational data were analyzed from 13 years of the post-reform period (2000–2013). During this period, the power sector was reformed into disintegrated corporatized structure, and power generation was deployed procuring IPPs. The operating data for capacity addition, power mix, efficiency gains (public sector generation only), and emission levels were analyzed.

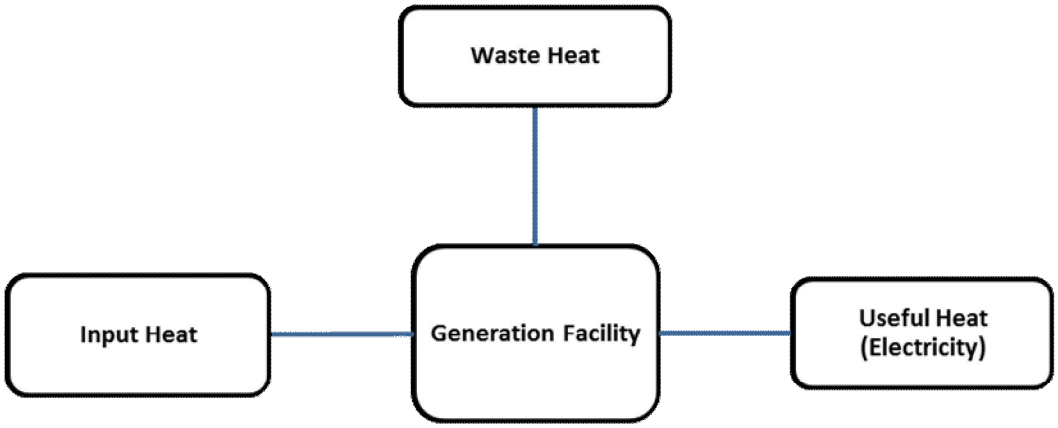

Figure2. Heat flow in a power generation facility.

In power generation facilities, the useful fraction of input heat issued for electricity generation and drives the efficiency of the facility, while the waste heat is emitted to the atmosphere leading to greenhouse gas (GHG) effects (**Figure2**).

We used a linear method to calculate the specific heat and efficiency [23] over the study period (2000–2013). Electricity generation is converted to useful heat by multiplying by a conversion factor of 3412Btu/kWh. The thermal efficiency is calculated from the ratio of useful heat to the actual input heat, and the specific heat rate is derived from the ratio of electricity generated to the actual input heat. The reference or base year for the comparison was 2000.

Greenhouse gas emissions, predominately carbon dioxide (CO_2),were calculated by multiplying the Intergovernmental Panel on Climate Change (IPCC) tier 1 default emission factors for the combustion of gas, diesel, fuel oil, and coal, by the annual fuel ratio and the gross fuel consumption figures recorded.

3. Results and Discussion

4.1 Capacity Adequacy

The real test of the reformed market and the addition of power capacity through the private sector began in 1999–2000. The load demand during this post-reform period increased at a yearly average of 6.3%, but the capacity only increased at a yearly average of 2.7% (**Table1; Figure 3**); i.e., the growth in capacity lagged significantly behind the increase in demand. Although there was sufficient capacity in the early years, this could not be sustained. Calculating the required capacity using are serve margin of 15%gives a capacity shortfall of approximately6.5GW,and a corresponding required investment of $6.5 billion (US). Comparing these results with the similar market in the Abu Dhabi Power sector [23] shows that in spite of the similarities in the reform structure, in contrast to Abu Dhabi, the Pakistan power market failed to maintain adequate capacity. Although both markets adopted a similar reform model, World Bank indicators of the market environment highlight why Pakistan was unable to attract private capital for new generation, while Abu Dhabi was. The report compares the ease of doing business index, in which, for the period 2009–13, the United Arab Emirates, with Abu Dhabi as its capital, stands at 23, with Pakistan at 110 [21]. Local capital market development and contribution is the key to success in business through the private sector. The report also compares the local capital market contribution for 2013, which was 59.1% of GDP in the United Arab Emirates, but only 16.9% for Pakistan [22]. These contributions have declined continuously from the 2004 figures. Similarly, in Pakistan, the ownership structure is hindering the development of local capital market [26] and the level of development of international finance is showing underdeveloped if compared to other OIC countries like Turkey, Indonesia [27],

Table 1. Installed vs. required capacity during the post-reform period (2000–2013).

Year	Installed Capacity	Firm Capability	Actual Peak Load	Computed Load	Spinning Surplus/ (Deficit)	Actual Primary Reserve and De-rating	Computed Required Capacity	Cumulative Capacity Surplus/ (Deficit) Addition	cumulative Investment Surplus/ (Deficit)
	MW	MW	MW	MW	MW	MW	MW	MW	Million US$
2000	14,444	10,104	9,556	9,609	495	43%	13,933	511	511
2001	15,534	9,957	10,033	9,988	(31)	56%	14,483	1,051	1,051
2002	15,819	10,660	10,368	10,389	271	48%	15,064	755	755
2003	15,819	10,958	11,000	11,044	(86)	44%	16,014	(195)	(195)
2004	17,367	11,834	11,527	11,598	236	47%	16,817	550	550
2005	17,395	12,792	12,385	12,595	197	36%	18,263	(868)	(868)
2006	17,395	12,600	13,066	13,847	(1,247)	38%	20,078	(2,683)	(2,683)
2007	17,526	13,292	13,645	15,838	(2,546)	32%	22,965	(5,439)	(5,439)
2008	17,827	12,442	14,151	17,398	(4,956)	43%	25,227	(7,400)	(7,400)
2009	18,022	13,637	14,055	17,852	(4,215)	32%	25,885	(7,863)	(7,863)
2010	18,892	13,445	14,309	18,467	(5,022)	41%	26,777	(7,885)	(7,885)
2011	20,986	13,193	14,468	18,521	(5,328)	59%	26,855	(5,869)	(5,869)
2012	20,499	13,193	15,062	18,940	(5,747)	55%	27,463	(6,964)	(6,964)
2013	20,850	13,193	14,756	18,827	(5,634)	58%	27,299	(6,449)	(6,449)

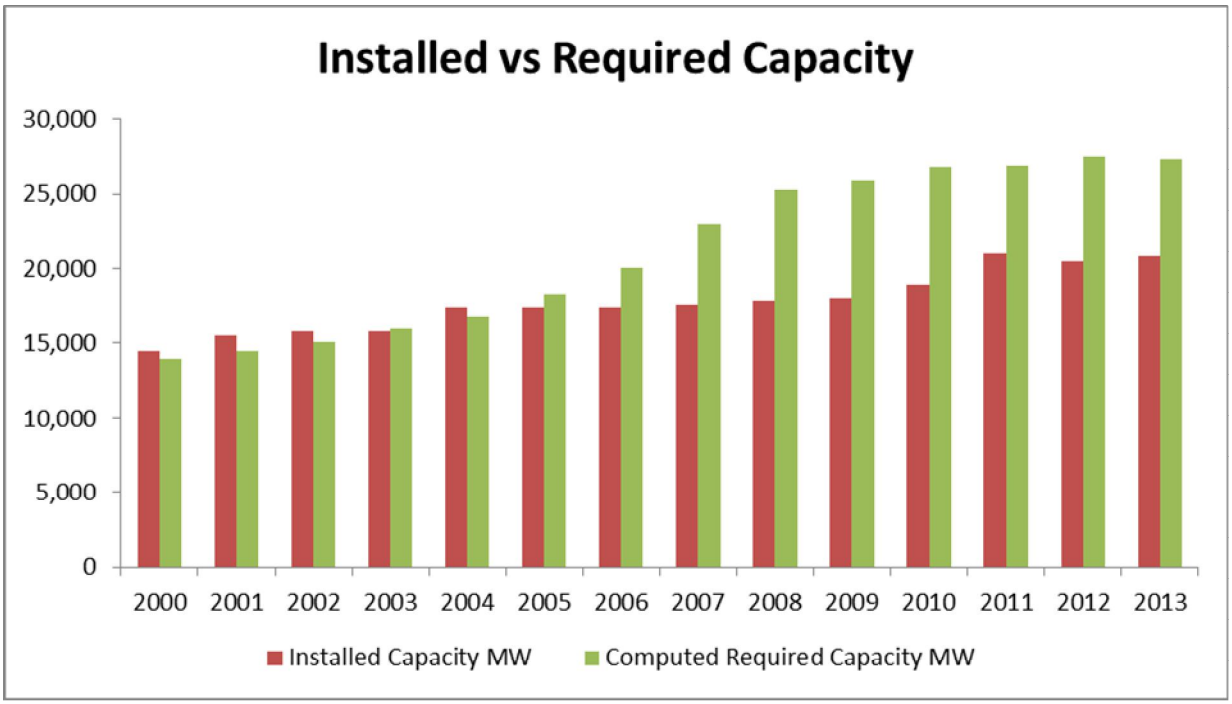

Figure 3. Comparison of installed vs. required capacity during the post-reform period (2000–2013).

4.2 Generation Mix

During the pre-reform period the hydel ratio was 70%, but this had declined by 2001,down to 30%, due to the additional capacity based on fossil fuels that was developed as a result of the 1994 private power generation policy. However, during subsequent years, the government tried through a number of policies [6–11] to restore the ratio of clean energy, but real success is yet to be achieved. Therefore,in2013, the thermal ratio was still 66%, which is an increase from its lowest level of 60% in 2004(**Figure 4**).

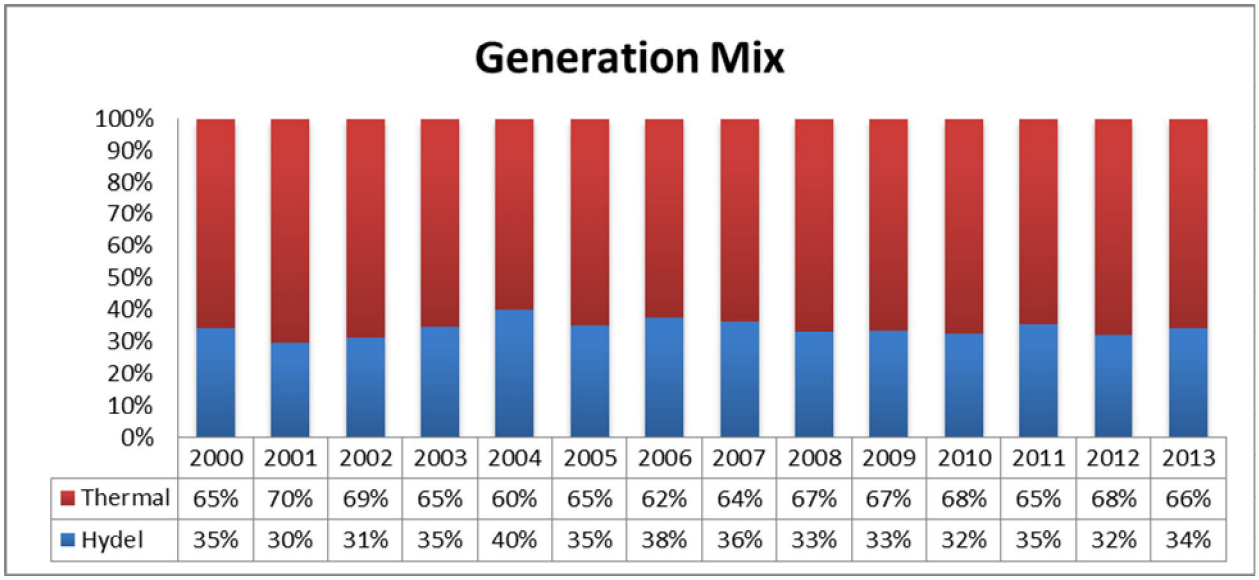

Figure 4.The changing thermal–hydel generation mix over the post-reform period (2000–2013), highlighting the dominance of thermal generation over hydel.

4.3 Efficiency

Operating performance in terms of efficiency was only considered for public sector thermal projects. The efficiency and specific fuel consumption followed a sinusoidal trend and did not exhibit any significant gain during the post-reform period [**Table 2, Figure 5**]. However, compared with the significant post-reform efficiency gains in the Abu Dhabi power sector[23], and efficiency gains in public sector conventional power generation in Europe [24], the operating performance of Pakistan's public sector did not respond positively to the post-reform regulatory framework.

Table2. Post-reform specific fuel consumption and efficiency.

	Output Power generation		Actual Fuel Consumption	Efficiency	Specific Heat Rate
Year	**Gwh**	**MBtu**	**MBtu**	**η_e**	**Btu/kWh**
2000	19,157	65,363,684	202,877,722	32%	10,590
2001	16,858	57,519,496	187,615,519	31%	11,129
2002	18,684	63,749,808	205,809,552	31%	11,015
2003	19,646	67,032,152	212,815,204	31%	10,832
2004	21,054	71,836,248	230,418,556	31%	10,944
2005	22,212	75,787,344	242,307,774	31%	10,909
2006	22,519	76,834,828	249,619,847	31%	11,085
2007	21,617	73,757,204	239,748,541	31%	11,091
2008	20,509	69,976,708	228,162,307	31%	11,125
2009	19,569	66,769,428	223,554,360	30%	11,424
2010	19,632	66,984,384	224,851,758	30%	11,453

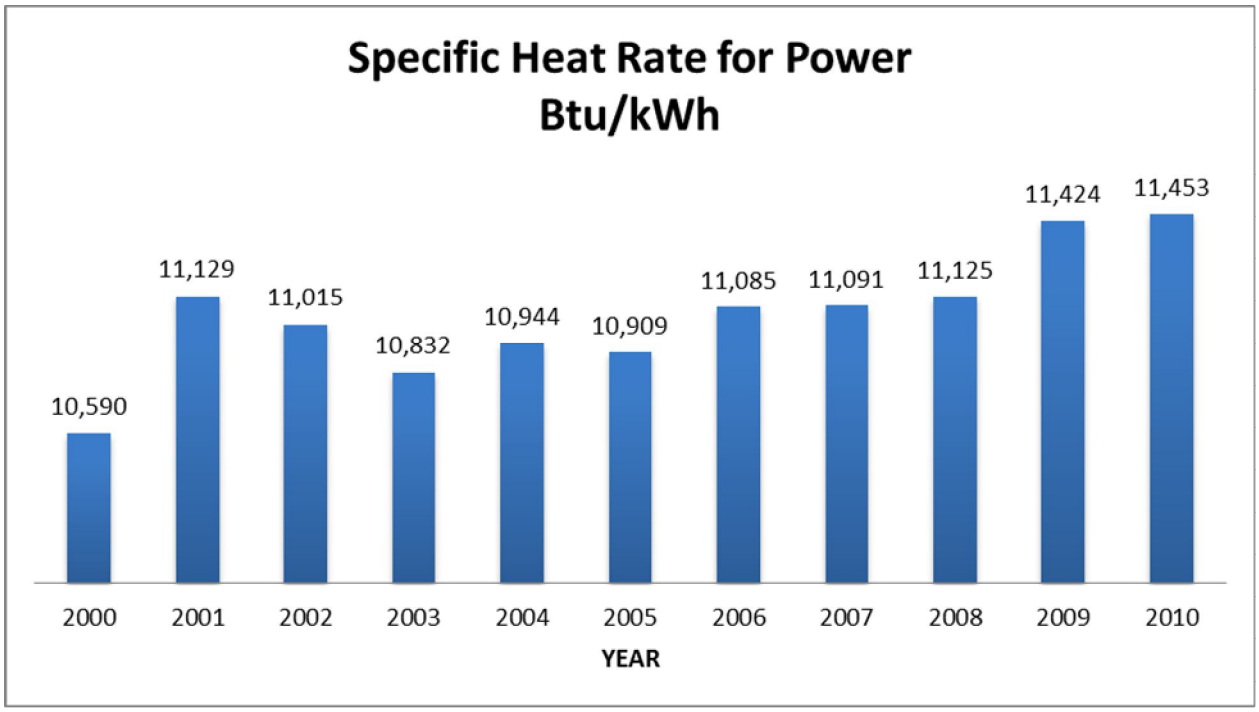

Figure 5. Comparison of specific heat rates of power generation (2000–2010).

4.4 Emissions

Carbon emissions were calculated using the IPCC default emission factors (**Table3**), and historical fuel consumption and energy production data. The results from the specific fuel consumption calculations indicated reduction in emissions, but the actual emissions data showed an increasing trend, which was due to the increased use of fuel oil in the fuel mix. While, the current emissions of 535 grams/kWh [**Table 4**] are still lower than the world average of 565grams/kWh [25], with the current level of development in Pakistan, these levels are still relatively high.

Table 3. IPCC Tier 1 default emission factors.

Fuel Type	CO_2 Emission Factor (tCO_2/TJ)
Gas	56.1
Diesel Oil	74.1
Furnace Oil	77.4
Coal	94.6

Table4. Yearly carbon emissions. Thevalues in tons (or kg) are CO_2 equivalent from water and electricity use.

	GROSS OUTPUT			CO2 EMISSIONS		
	Hydel	Thermal	Total			
Year	Gwh	Gwh	Gwh	Ton	grams/kWh	kg/Person
2000	19,288	36,585	55,873	25,798,605	462	199
2001	17,259	41,196	58,455	30,364,083	519	230
2002	19,056	41,804	60,860	30,929,132	508	230
2003	22,350	41,690	64,040	30,316,316	473	221
2004	27,477	41,617	69,094	29,203,040	423	209
2005	25,671	47,849	73,520	33,843,600	460	238
2006	30,675	51,370	82,045	37,209,780	454	257
2007	31,942	55,895	87,837	41,863,688	477	278
2008	28,667	57,602	86,269	43,603,199	505	284
2009	27,763	56,614	84,377	43,863,412	520	280
2010	28,492	60,745	89,237	47,719,788	535	299

4. Conclusions

The post-reform period for Pakistan's power sector did not provide similar success in terms of capacity adequacy, efficiency gains, and emission reductions as were brought by similar reforms in Abu Dhabi. The success of the reforms

in Abu Dhabi suggests that there were no problems with the structure and architecture of the reform model in Pakistan, but that it was the market environment that made the difference in Abu Dhabi. Therefore, Pakistan requires an effective regulatory framework that will create a market environment that encourages the private sector. The regulatory body in Abu Dhabi is a group of seasoned professionals, whereas NEPRA's technical and economic management positions are filled by bureaucrats who lack the professional capabilities required for an effective and efficient regulatory body. This suggests the need for further research into the market environment associated with the power sector in Pakistan to identify the key indicators and actions required to match other successful developing countries and so achieve the desired objectives.

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