Pakistan's Power Future

Renewable Energy Provides a More Diverse, Secure and Cost-Effective Alternative

Institute for Energy Economics and Financial Analysis
IEEFA.org

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Table of Contents

Executive Summary

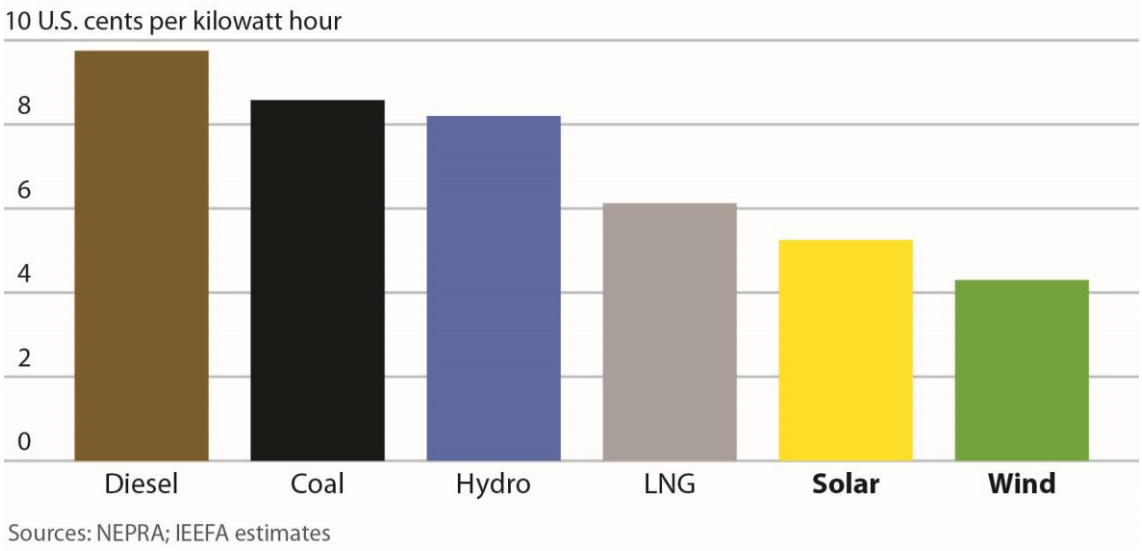
Renewable energy including wind and solar is now the cheapest form of new electricity generation in Pakistan.

With over half the rural population unable to access electricity, Pakistan is rightfully undertaking a major build-out of electricity generation capacity to meet demand growth into the future. Further adoption of ever-cheaper and accessible renewable energy can make a greater contribution towards meeting Pakistan's growing electricity demands. Instead, Pakistan is currently on an energy pathway towards over-reliance on imported fossil fuels, out-dated coal technology, and expensive, seasonal and delayed hydro power.

Polluting power plants relying on fossil fuel imports are being planned in the context of Pakistan's weakening currency, growing current account deficit, declining foreign exchange reserves and escalating circular debt, reducing Pakistan's energy security. This is not necessary now that tariffs for wind and solar are below all other generation sources.

Wind and solar are now the cheapest sources of energy in Pakistan

Average levelised tariffs, detemined by NEPRA for recent projects in the country, show the renewables' advantage over fossil fuels, with costs expected to continue to decline.



Sources: NEPRA; IEEFA estimates

Increasing reliance on cheaper renewables means pragmatic decisions can be made to reduce reliance on hydro and thermal power projects which are planned but have not yet begun construction. These expensive projects will not be necessary.

In addition to outcompeting other power technologies on price, renewables also have much faster construction times (18 to 24 months). Evidenced by current project delays in Pakistan, large hydro power projects are notorious for running over schedule and over budget, which only adds to their already very large costs. Nuclear power projects increasingly suffer large cost and time over-runs around the world. Pakistan is building more nuclear power units at a time when nuclear power globally is in decline, and its outlook is clouded.

Without the need for fuel, renewable energy has clear advantages over polluting, expensive thermal coal power. Many of Pakistan's proposed coal-fired power plants will

be fuelled by imported coal which has become increasingly expensive as the rupee has weakened. Coal- and LNG-fired plants will increase the nation's reliance on expensive fossil fuel imports, placing Pakistan's current account deficit under increasing pressure, reducing energy security, and further contributing to the nation's import burden. Fossil fuel imports will also put upward pressure on inflation and interest rates, creating a permanent headwind to economic growth.

With renewable technology set to get cheaper into the future, a build-out of coal-fired power risks locking Pakistan into decades of out-dated technology. Renewable energy options will inevitably increase and eventually impact the utilisation rate of any coal-fired power plants built, impacting their viability and increasing the risk of stranded assets.

The Institute for Energy Economics and Financial Analysis (IEEFA) has modelled a high-level, alternative future for Pakistan's electricity system that addresses cost burdens and energy security. Our model assumes increased utilisation of Pakistan's abundant wind and solar resources, while limiting the nation's exposure to an over-build of hydro power, out-dated coal-fired power and an excessive reliance on increasingly expensive fossil fuel imports. The resulting power mix makes better use of ever-cheaper and cleaner renewable energy technology to lock in a deflationary energy platform.

In IEEFA's model, we project renewables supplying 28% of Pakistan's increasing electricity requirements by 2030. Generation costs would be reduced and energy security increased through a diversity of generation technologies roughly split 30:30:30:10 between renewable energy, thermal power, hydro power, and nuclear power.

By increasing reliance on renewable energy to generate almost 30% of electricity by 2030, Pakistan can accrue the following benefits:

- **Improved energy security** through the diversification of Pakistan's electricity generation sources, including limiting unnecessary thermal, nuclear and hydro projects.
- **Improved energy security** through a reduction in expensive fossil fuel imports.
- **Reduced economic pressure** via a reduced need to import coal and LNG, thereby improving Pakistan's current account balance and relieving pressure on foreign currency reserves.
  Reduced cost of electricity generation thereby reducing the cost of tariffs currently putting additional pressure on consumers and businesses, while resolving the cost-tariff deficit in the electricity system's to address circular debt.
- **Further reductions in the cost of renewables** through committed and ambitious energy policy settings driving down the cost of wind and solar as the domestic renewables industry scales up.
- **Diversification of investment in energy sources** including investment from China, a global renewable energy leader and a major investor in Pakistan's electricity system, and from other domestic and foreign investors, aided by ambitious clean energy policies and a plan to embrace new power technology. Renewable energy is far more likely to attract new international investors to Pakistan than coal-fired and hydro power.

IEEFA's electricity model to 2030 builds a more diversified, lower cost electricity system for Pakistan that is more likely to provide a stronger foundation for sustainable economic growth into the future than the current energy path being taken.

Introduction

Pakistan needs a significant build-out of electricity generation capacity to meet current and future demand growth. Recognising this, a major new capacity build program has begun. Much of this new build is based on hydro power, an often controversial source of power generation with projects frequently taking many years to complete, and usually well behind schedule. A significant coal-fired power build out is also planned, as is an increased dependence on imported liquefied natural gas (LNG).

By following this path, Pakistan is cementing an increased reliance on out-dated coal technology, locked in for several decades, while much of the rest of the world moves away from coal power. Furthermore LNG, and coal-fired plants based on imported coal, will increase the nation's reliance on expensive fossil fuel imports, reducing energy security. Finally, fuel imports will place Pakistan's current account deficit under increasing pressure, and creating a permanent headwind to economic growth.

In this report, we review the current status of the electricity system of Pakistan. We then model an alternative future for the system that limits the nation's exposure to an over-build of hydro power, out-dated coal-fired power and an excessive reliance on fossil fuel imports. Our model assumes increased utilisation of Pakistan's excellent domestic wind and solar resources, thereby improving energy security through greater diversification into domestic natural resources. The resulting power mix makes better use of ever-cheaper renewable energy technology to lock in a deflationary energy platform.

This alternative approach is a far more appropriate one for a developing nation seeking to not only meet expanding electricity demand but also find solutions to a current account deficit and declining foreign exchange reserves.

The Economic Status of Pakistan

The Asian Development Bank's (ADB) 2018 Outlook Update noted Pakistan's Gross Domestic Product (GDP) growth at 5.8% for 2017/18. Growth was driven by higher agricultural output, increased industrial activity and continuing expansion in the services sector.

In recent years, investment in the Pakistan economy has been significantly supported by the China-Pakistan Economic Corridor (CPEC), a key element of China's Belt and Road Initiative (BRI). The CPEC proposes US$50bn of investment into Pakistan infrastructure projects including energy, roads, rail and ports.[1] Electricity generation makes up a major proportion of that investment, mostly in hydro and coal power and, to a lesser extent, renewables.

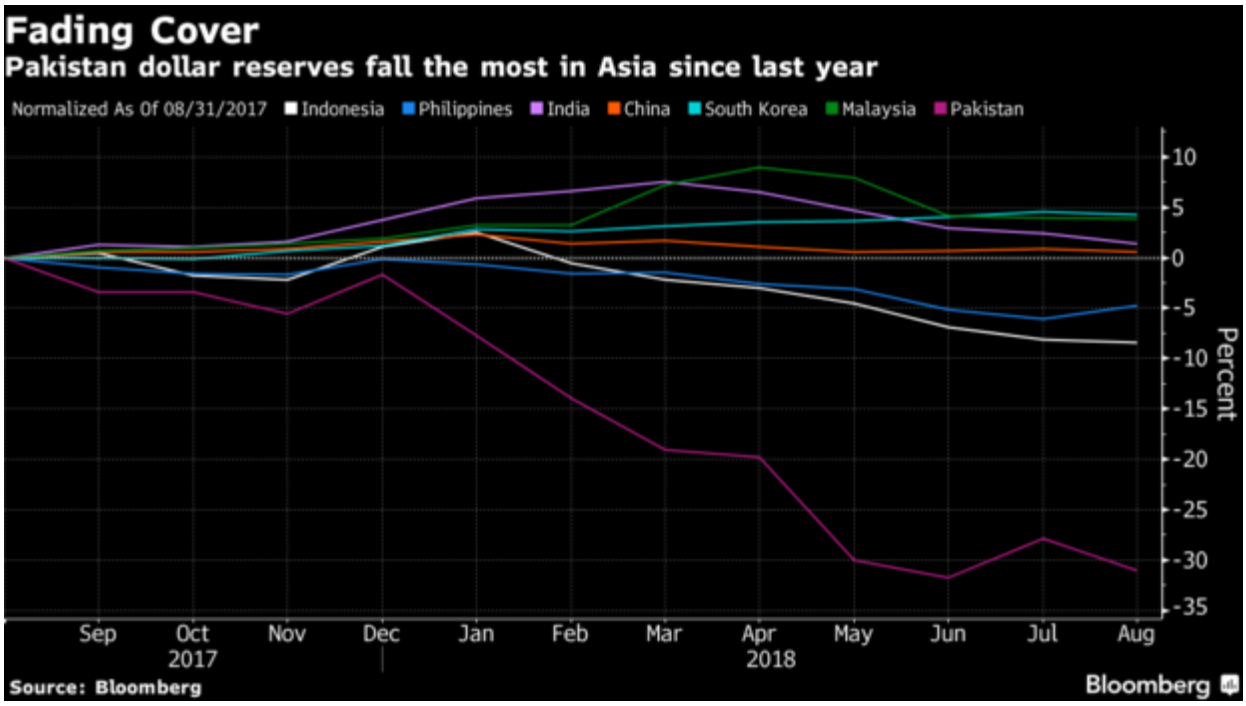
More recently however, Pakistan's strong GDP growth has been clouded by falling foreign exchange reserves reflecting deteriorating current account and budget deficits. As a result, the Asian Development Bank downgraded its GDP growth forecast for 2019 to 4.8%.[2] In September 2018, the State Bank of Pakistan also downgraded its growth forecast to 5.0%, down from the 5.5% it forecast in July 2018, and even further away from the government target of 6.2%.[3] In October 2018, the IMF forecast real GDP growth of just

[1] Pakistan Board of Investment, China Pakistan Economic Corridor.
[2] Asian Development Bank, Outlook 2018 Update.
[3] Dawn, "Interest rate hiked amid warnings of inflation, deficits", 30 September 2018.

4.0% for 2019 and 3.0% for the following year in response to the rising currency and funding risks.[4]

To date in 2018, the Pakistan rupee has depreciated significantly against the U.S. dollar, down 20% since December 2017, making imports of commodities traded in U.S. dollars (such as fossil fuels) increasingly expensive. By the end of financial year (FY) on 30 June 2018, Pakistan's foreign exchange reserves were down to US$9.9bn, representing only two months of import cover. By the end of September 2018, that figure was US$8.4bn – reduced to around one-and-a-half months of import cover. By mid-October 2018, the figure was only US$8.1bn.[5]

Figure 1: Decline in Pakistan's U.S. Dollar Reserves



Pakistan is reported to be targeting 12 million tonnes (Mt) of coal imports in 2018/19, double the imports of just a few years earlier.[6] This growing reliance on more expensive fossil fuel imports has contributed to increased core inflation during 2018 from 6.5% to 7.5% which in turn gave rise to interest rate hikes which are likely to provide a further drag on economic growth.

In the fiscal year 2018, Pakistan's current account deficit increased significantly to US$18bn or 5.8% of GDP, up from 4.1% in the previous fiscal year, as imports increased 14.7% to US$56bn.[7] Pakistan's finance minister recently stated the current account deficit may widen to as much as US$21bn by the end of the current fiscal year. Furthermore, the nation's budget deficit may widen from 6.6% to 7.2% over the same period.[8]

The scale of Pakistan's economic problems and the mounting payments crisis led to a decision by the Pakistan government to approach the IMF for an emergency loan. In deliberations, the IMF were initially of the opinion that the Pakistan rupee should be

[4] IMF, World Economic Outlook October 2018.
[5] Express Tribune, "Foreign Exchange: SBP's reserves fall $219m, stand at $8.1bn", 18 October 2018.
[6] Dawn, "Sharp rise in handling charges pushes up price of imported coal", 4 October 2018.
[7] Asian Development Bank, Outlook 2018 Update.
[8] Bloomberg, "Pakistan Budget Deficit May Widen as Fiscal Crisis Deepens", 18 September 2018.

allowed to weaken further, a move that would make fossil fuel imports even more expensive.[9] Following the official announcement of the government's approach to the IMF, the rupee depreciated an additional 7.5%.

Pakistan's government and industry regularly references instability of electricity supply and the energy crisis as a key constraint on industrial growth.[10] In October 2018 the Islamabad Chamber of Commerce and Industry called upon the government to focus more on renewable energy due to the benefits of lower cost and reliable energy supply, while signalling the investment, jobs and exports this focus would bring to the national economy.[11]

Issues in Emerging Markets

Pakistan is not the only emerging economy to experience a recent currency devaluation. Other growing economies with similar trends have taken steps to reduce imports, including fossil fuel imports which are a key economic drain, while lessening their current account burdens.

The latest bout of weakness concerning emerging economies was led by Turkey where the weakening lira has significant implications for its electricity system as coal imports become even more expensive.[12]

Indonesia's increasing current account deficit and weakening currency has led it to delay power projects (mostly fossil fuel-based) totalling almost 9 gigawatts (GW) in an effort to reduce imports.[13] There are also plans to curb imports on some consumer goods.

Indonesian state-owned utility Perusahaan Listrik Negara (PLN) had an over-aggressive capacity build-out program involving expensive, foreign-financed independent power producer (IPP) deals for coal-fired power plants. The utility is now saddled with burdensome IPP guaranteed payments and increasing foreign exchange-exposed financing costs which are straining central government finances. PLN has had to cut back on power capacity expansion, with the 10% reduction in the value of the Indonesian rupiah so far this year further exposing its deteriorating financial position.[14]

India has also taken steps to curb imports and address its widening current account deficit.[15] The rupee recently slumped to record levels against the U.S. dollar on the back of expanding U.S. dollar costs of fossil fuel imports (oil, diesel, LNG, coking and thermal coal).

While India is a major importer of thermal coal, it remains government policy to reduce imports, a stance hampered by India's coal power build out. Supply has exceeded demand with plants using outdated technology often built a long way from domestic coal sources. This has led to coal transport logistical issues that have made the troubled Indian coal-fired power sector even more vulnerable to deflationary renewable energy.

[9] Express Tribune, "IMF suggest higher interest rate, rupee depreciation", 4 October 2018.
[10] The Nation, "Govt focusing on wind, solar energy: Minister", 31 October 2018.
[11] PV-Tech, "Major industrial body urges Pakistan government to focus on wind and solar", 16 October 2018.
[12] Fitch Solutions, "Turkey Currency Crisis to Cement Focus on Renewables and Coal Power", 31 August 2018.
[13] Asian Power, "A riddle wrapped in an enigma – Why can't Indonesia get the power sector right?", 14 November 2018.
[14] IEEFA, "Indonesia hits the reset button on PLN's expansion plans", 18 September 2018.
[15] BloombergQuint, "Import Curbs to Bring Rupee to 68-79 Level, Economic Affairs Secretary Says", 23 September 2018.

Responding to economic conditions, India's policy commitment to renewable energy has led to an increase in installations and greatly reduced renewable energy prices. Indian wind and solar tariffs are now significantly lower than new coal-fired power generated using either imported or domestic coal.

Pakistan's Electricity Sector

Pakistan's electricity system has historically been characterised by insufficient generation capacity to meet demand, high technical and commercial losses that contribute to "circular debt" (see below), and an over-reliance on fossil fuel imports and hydro power. In addition, more than half of Pakistan's population live in rural areas, and only half of those people have access to electricity.

According to the National Electric Power Regulatory Authority's (NEPRA) 2017 State of the Industry report, Pakistan's objectives for the power generation sector include reduced dependence on imported fossil fuels, increased use of renewable energy, diversification of fuel resources, and security of fuel supply.[16]

Over the last four years, total generation capacity – the maximum power output across all energy sources in the country - has started to rise significantly as the nation makes an effort to meet growing electricity demand.

In addition to gas, Pakistan has been historically reliant on expensive imported oil to fuel its thermal power plants. It is now striving to reduce oil use in the electricity sector to reduce both costs and the pressure that oil imports impose on the nation's current account balance.

More recently, Pakistan has seen a reduction in imported oil-fired power generation and an increase in coal and LNG based generation. This has reduced generation costs, however one form of fossil fuel imports is simply being replaced by others. The overall cost of fuel in power generation has actually increased this year with costs at August 2018 nearly 24% higher than the same month in the prior year.[17]

Although power generation based on imported LNG is cheaper than oil and diesel, Pakistan is still subject to fluctuating fossil fuel prices if it replaces oil-based generation with LNG and coal.

Institutional Structure

An overview of the key institutions involved in Pakistan's power sector can be found in Annexure I.

The Power Division of the Federal Ministry of Energy has oversight over all issues regarding power generation, transmission, distribution and pricing in Pakistan. The provincial governments also have their own energy departments that can and do implement power projects within their province.

Pakistan's electricity sector is regulated by NEPRA whose independent mandate oversees generation, transmission and distribution. Power generation is provided by state-owned

[16] NEPRA, State of the Industry Report 2017.
[17] Express Tribune, "Power generation hits all-time high at 14,017GWh", 25 September 2018.

generation companies (GENCOs) for thermal power, the Water and Power Development Authority (WAPDA) for hydropower, and independent power producers (IPPs).

The national electricity transmission system is run by state-owned National Transmission and Despatch Company (NTDC) which transmits power between generators and the state-owned distribution companies (DISCOs) which serve consumers. Power is purchased from generators on behalf of the DISCOs by the Central Power Purchasing Agency (CPPA) which acts as Pakistan's power market operator.

The exception is K-Electric; a vertically integrated, private company that provides power generation, transmission and distribution to the Karachi metropolitan area. In 2016, a deal was struck between Pakistan's Abraaj Group and Shanghai Electric Power Company of China for the latter to acquire a majority stake in K-Electric for US$1.8bn – a deal that is yet to be confirmed by the Pakistan government.

Finally, the Alternative Energy Development Board (AEDB) is an autonomous body under the Ministry of Energy whose role is to promote and implement renewable energy projects in Pakistan, a critically important role given the need to leverage domestic natural resources to curtail fossil fuel imports.

Transmission and Distribution Losses and Circular Debt

A major issue within Pakistan's electricity system is "circular debt" which has accumulated over the years to reach Rs1.55 trillion (US$11.7bn) as at June 2018.[18] Pakistan's Economic Coordination Committee has defined circular debt as "the amount of cash shortfall within the Central Power Purchasing Agency (CPPA), which it cannot pay to power supply companies".[19] The CPPA is often unable to recover full amounts from the power distribution companies (DISCOs) in order to pass those amounts onto power generators.

A difference between the high cost of generation and lower tariffs for some consumers creates a deficit. Government payments to cover the difference are often delayed.

A further contributor to circular debt is that DISCOs cannot recover all billable amounts; for FY2016-17 the recovery rate was 92% against a target of 100%.[20]

Another major contributing factor to circular debt is the large transmission and distribution (T&D) losses that afflict the Pakistan electricity system. The target for T&D losses for FY2016-17 was 15.3% whilst the actual loss was almost 18%. However, the total difference between electricity generated and electricity sold by DISCOs amounted to 21.6% of generation in FY2016-17. All of this leads to cash flow problems, often leaving DISCOs unable to make timely payments to power producers.

In its 2017 State of the Industry Report, NEPRA notes with concern that the DISCOs have made little progress in addressing T&D losses, and have requested higher allowable losses than previously proposed. It further identifies Pakistan's high T&D losses as a major impediment to the power sector's financial sustainability, undermining the bankability of PPAs, and identifying the need for government to assign a high priority to the issue.

[18] Dawn, "Senate panel wants Rs400bn injected into power sector", 8 October 2018.
[19] Pakistan Observer, "Pakistan's power sector: How to eliminate circular debt", 22 March 2017.
[20] NEPRA, State of the Industry Report 2017.

Theft of electricity is also a major issue that contributes to losses. According to a recent report on circular debt to a Senate Committee, the estimated cost of power theft for FY2017-18 was over Rs53bn (US$430m), with the rate of theft from the grid at 3.9%.[21]

The Senate Committee noted that unrecovered bills and T&D losses have left an annual funding gap of Rs295bn (US$2.2bn), part of which will be recovered through consumers bills and part of which (around US$900m) remains a burden on government, thereby becoming circular debt.

Amongst the report's recommendations to tackle the circular debt issue is an immediate injection of Rs400bn (US$3bn) to prevent power plant closures, reduced reliance on imported fossil fuels, and increased emphasis on renewable energy.

Power Tariffs Increasing

With fossil fuel costs increasing, NEPRA allowed increased power tariffs to compensate for higher imported fuel costs for all distribution companies except K-Electric. Consequently, from October 2018 tariffs were higher by Rs1.16/kWh.[22]

NEPRA's tariff determination revealed the fuel cost of LNG-fired generation to be Rs10.37/kWh, below that of oil-fired generation (Rs14.47/kWh) and diesel (Rs17.50/kWh). This is significantly higher than the fuel cost of domestic gas (Rs4.99/kWh), while coal's fuel cost for August 2018 was Rs6.42/kWh.[23]

In October 2018, NEPRA allowed a further increase in tariffs for distribution companies of Rs0.20/kWh from November 2018 to compensate for further imported fuel cost rises.[24]

On top of NEPRA increases for higher fuel costs, a further tariff increase has been under consideration to address circular debt within the electricity system. The current average tariff of Rs11.70/kWh is below the determined power supply cost for 2018-19 of Rs15.53/kWh.

In October 2018, the cabinet's Economic Coordination Committee (ECC) decided to increase average electricity prices by Rs1.20 to Rs12.91, a 10% increase.[25] Domestic consumers with low-electricity use, small and medium commercial users, and schools and hospitals will be exempted from the increase. Large commercial users will have an increase of around 20%, and high-use domestic consumers around a 33% increase.

Meanwhile, a long term energy policy is reportedly under development that will seek to promote improved efficiency while reducing dependence on fuel imports and making better use of indigenous resources to keep electricity costs down.

[21] Dawn, "Power theft reached over Rs53bn in 2017-18", 3 October 2018.
[22] Express Tribune, "NEPRA increases power tariff by Rs1.16 per unit", 26 September 2018..
[23] NEPRA, Fuel Charges Adjustment August 2018, 3 October 2018
[24] Express Tribune, "NEPRA raises power tariff by 20 paisa per unit", 24 October 2018..
[25] Express Tribune, "ECC approves 33% hike in power tariff", 25 October 2018.

Current Electricity Capacity and Generation

With oil/diesel-fired generation being replaced with newer LNG- and coal-fired power, Pakistan is still largely dependent on thermal power, currently contributing almost two-thirds of capacity and 70% of power generation, with much of the fuel imported. Almost all of the rest of Pakistan's power generation is made up with hydro and, to a lesser extent, nuclear power (Figure 2).

Renewables make up just 5.1% of installed capacity (2.8% of generation in 2017/18).

While there has been some exploitation of Pakistan's excessive wind and solar radiation resources, wind and solar power installations remain low. The renewables sector is yet to experience the highly significant, fast-paced build out seen across other parts of Asia, which is driving renewable energy costs lower.

Pakistan's previous, interim Minister for Energy highlighted identified the need for an increased role for renewable energy in the nation, in preference to reliance on LNG and coal imports.[26]

Figure 2: Pakistan Electricity Market Composition 2017/18

Source	Electricity market Composition 2017/18				
	Capacity		Generation		Capacity Utilisation
	GW	% of Total	TWh	% of Total	
Oil, Gas, LNG	18.6	57.2%	82.4	61.0%	48%
Coal	2.7	8.4%	11.9	8.8%	59%
Nuclear	1.3	4.0%	8.7	6.5%	79%
Hydro	8.2	25.4%	28.2	20.9%	44%
Solar	0.4	1.2%	0.7	0.5%	22%
Wind	0.9	2.9%	2.1	1.5%	29%
Bagasse	0.3	1.0%	1.1	0.8%	40%
Total	**32.5**	**100.0%**	**135.1**	**100.0%**	
Import from Iran	-	-	0.5	-	-

Source: NEPRA, IEEFA estimates.

Capacity Addition Plans

IEEFA notes that Pakistan needs to significantly and sustainably expand its power generation capacity in order to adequately serve current and future demand growth.

The most recent State of the Industry Report from NEPRA includes a summary of planned generation capacity additions out to 2025 (Figure 3).

In the period to 2025, Pakistan is planning to more than double its generation capacity from 26 GW to 62 GW. Under this plan, which dates from when the previous Pakistan government was in power, no additional oil-fired generation capacity is planned to be added and no gas/LNG-fired generation will be added after 2021. This avoids the further

[26] Pakistan Today, "Energy minister presents guidelines for improving power sector", 18 August 2018.

expense burden of these fuels and the pressure they place on Pakistan's current account balance.

Instead, most of the planned capacity additions will come from coal-fired and hydro power. In addition, two nuclear power plants totalling 2.2 GW of capacity are under construction with another 1.1 GW planned.

Figure 3: Planned Capacity Additions as Per NEPRA's State of the Industry 2017 Report

Technology	As at Jun-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23	2023-24	2024-25
Oil	6,785	-	-	-	-	-	-	-	-
Coal	810	1,980	1,320	823	3,300	2,610	1,320	-	-
Gas/LNG	8,868	2,508	830	420	-	-	-	-	-
Wind	785	149	299	-	1,224	-	-	-	-
Solar	400	12	600	600	-	-	-	-	-
Bagasse	280	77	583	144	-	-	-	-	-
Hydro*	7,116	2,709	41	201	177	824	3,080	4,325	2,203
Nuclear	1,142	340	-	-	1,100	1,100	-	-	1,100
Yearly addition	**-**	**7,775**	**3,673**	**2,188**	**5,801**	**4,534**	**4,400**	**4,325**	**3,303**
Total Capacity	**26,186**	**33,961**	**37,634**	**39,822**	**45,623**	**50,157**	**54,557**	**58,882**	**62,185**

**NEPRA concedes that delays in hydro projects may occur which would prevent the meeting of the 2025 target*

Source: NEPRA, NTDC.

IEEFA notes a significant proportion of planned coal-fired power additions are based on imported coal (see Figure 6). In its 2017 State of the Industry report, NEPRA concedes that with rising coal imports and up to 12 GW of thermal power plants running on LNG by 2021, consumers will not get any reprieve from currency and price uncertainties that come with fossil fuel imports.[27]

Most strangely, according to the plan, no further renewable energy capacity is to be added after 2021. This makes little sense as globally, renewables are continually getting cheaper at a rapid rate. With renewables in Pakistan still in their relative infancy and set to get much cheaper going forward, the nation will be missing out on a very cheap, domestic energy source if it does not add significant renewable energy capacity by the second half of the next decade.

On hydro, NEPRA concedes there is the possibility of hydro project delays which could see the timetable for hydro additions slip.[28] Similar to most international experiences, this is not surprising given the scale, complexity and often-controversial nature of large hydro power projects.

Status of Hydro Generation

Hydro power makes a significant contribution to electricity generation in Pakistan, representing around 25% of capacity and 21% of generation. In 2017-18, hydro power capacity had a utilisation rate of 44% although this ranges widely during the year due to the seasonal nature of Pakistan's water resources.

The nation's hydro capacity has remained fairly constant over the last five years but is currently in focus as Pakistan makes major efforts to increase capacity.

The NEPRA 2017 State of the Industry Report notes there is 13.6 GW of hydro capacity additions planned out to 2025. However, Pakistan's hydro plans extend much further than this. WAPDA's current hydro development pipeline lists 6.3 GW of projects under

[27] NEPRA, State of the Industry Report 2017, p.23.
[28] NEPRA, State of the Industry Report 2017, p.7.

construction, 13.6 GW ready for construction, and a further 6.8 GW identified as projects 'for the future'. In addition, there are 6.1 GW of IPP hydro projects on the Private Power and Infrastructure Board's (PPIB) development list.[29]

IEEFA notes Pakistan is in danger of becoming over-reliant on hydro. Not only is hydro power seasonal, there may be increasing competition for water used in power generation. A November 2018 'Regional Risks for Doing Business' report by the World Economic Forum found that "water crises" was identified as the number one business risk in Pakistan.[30]

NEPRA noted in its 2017 State of the Industry Report that hydro generation decreased in 2016-17 due to water availability issues, including the release of significant quantities of water from reservoirs for agricultural irrigation.[31] October 2018 saw hydro power output drop 44% compared to the prior month due to seasonal and water management issues.[32]

As the globe experiences further extremes in weather and with hydrological patterns expected to be less easy to predict going forward, competition for water use may well escalate. Currently, it appears that more dams are often perceived as the answer to increasing water scarcity. However, this ignores more cost-effective solutions such as addressing crippling distribution losses, reducing water intensive crops, and de-silting existing dams.[33] Such solutions make more sense given Pakistan's current economic situation.

Large hydro power projects are often complex, expensive and lengthy undertakings that are prone to delay, as noted by NEPRA, at a time when wind and solar power construction can be started and finished within 18 to 24 months.

A good example of the delay and expense of dam building in Pakistan is provided by the Daimer-Bhasha proposal. This huge proposal for a dam has recently been re-approved and will have a capacity of 4,500 MW at a total cost of US$14bn if built. This huge figure is likely to prove highly conservative given the tendency for dam project costs globally to escalate almost without exception.[34] The expected construction time of 5 years seems highly optimistic given the project has already been in development for 17 years.

Finance for this proposal, located in the earthquake zone, has been hard to come by. The World Bank, Asian Development Bank, and potential Chinese financiers and dam builders do not appear to want to be involved. The seismic risk has led some to believe the dam is not technically feasible.[35] In the latest development, the government has sought funding contributions from the public and including from Pakistanis living overseas, in an effort to finance the dam.

The Diamer-Bhasha proposal is part of a series of planned dams along the Indus river often known as the "Indus Cascade".[36] Other Indus projects include the 4.3 GW Dasu project, the 7.1 GW Bunji proposal and the 2.4 GW Patan proposal.

The Dasu Dam project is also facing significant delays despite being described as "under

[29] PPIB, Upcoming IPPs, August 2018.
[30] World Economic Forum, Regional Risks for Doing Business 2018.
[31] NEPRA, State of the Industry Report 2017, p.12.
[32] Express Tribune, "Power production drops significantly as winter begins", 11 November 2018.
[33] Dawn, "Seismic costs", 7 October 2018.
[34] Daily Times, "Folly, thy name is Diamer-Bhasha", 10 September 2018.
[35] Daily Times, "Folly, thy name is Diamer-Bhasha", 10 September 2018.
[36] The Quint, "Pakistan's Indus Cascade a China-Sponsored 'Himalayan Blunder'", 22 May 2017.

construction" on WAPDA's website. The World Bank, which approved a US$3.8bn loan for the project in 2014, has warned that the loan agreement may lapse if construction does not begin soon. The project was supposed to be completed by June 2021 but to date only 7% of 12,000 acres of land required has been secured.[37] The government is determined to progress the Dasu project as a matter of priority, but the proposal is already at least two years behind schedule and given the pattern of delay for major dam projects around the world, a completion date of 2023 is likely to prove highly optimistic.

The size and social impact of the Indus Cascade power projects virtually guarantees additional cost and significant delays at a time when Pakistan is in need of new generation capacity as soon as possible to meet rising demand.

Status of Coal-Fired Generation

Historically, coal-fired power has played little role in Pakistan's power system but more recently that has started to change.

A fleet of coal-fired power plants is planned, or under construction, as part of the CPEC investments by China which includes US$35bn of Chinese loans for power generation.[38] Some of these developments will be fuelled by domestic lignite (brown coal) from the Thar coalfield in Pakistan while others will be fuelled by imported coal.

The plan to develop more coal-fired energy generation is in stark contrast to what is happening in much of the world where coal-fired power is declining in developed countries. Even in developing countries such as India, the roll-out of new coal fired power plants is slowing dramatically, in part a reflection of a nearly insurmountable US$100bn of non-performing loans from failed, stranded thermal power plants in the Indian financial system.

The global pivot away from coal is gaining pace; as recently as September 2018, Marubeni Corporation, one of the most significant builders of coal-fired power plants around Asia and Africa, committed to cease building further coal plants, and divest from 50% of its coal power plants by 2030 whilst doubling the ratio of electricity it generates from renewables by 2023.[39] Mitsui & Co of Japan has made a similar commitment.[40]

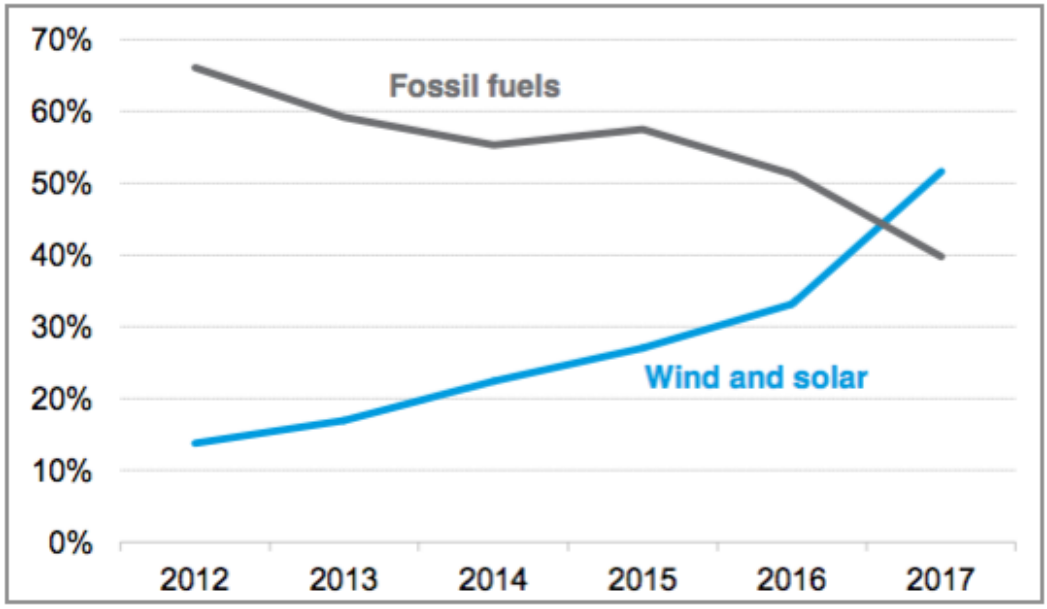
The build out of coal-fired power has dropped sharply in developing countries. From a peak of 97 GW in 2015, additions in developing nations slipped to 48 GW in 2017. Most of the reduction in fossil fuel capacity additions can be attributed to China and India. These countries are also responsible for much of the increase in clean energy additions. However, clean energy additions are not confined to these countries and are becoming more and more widespread whilst fossil fuel additions are largely confined to countries were such technology already exists.[41]

The year 2017 was a landmark one for developing countries; for the first time renewable energy accounted for the majority of all new power capacity additions added. A total of 186 GW of capacity was added with wind and solar alone accounting for 94 GW (just over half – see Figure 4). Whereas wealthier nations dominated clean energy additions in

[37] Express Tribune, "$3.78bn Dasu dam loan may get lapsed, warns World Bank", 22 October 2018.
[38] Financial Times, "Pakistan's pivot to coal to boost energy gets critics fired up", 31 July 2018.
[39] Marubeni, Notification Regarding Business Policies Pertaining to Sustainability, 18 September 2018.
[40] Reuters, Japan's Mitsui may sell stake in Australia thermal coal mine, 31 October 2018.
[41] Bloomberg New Energy Finance/Climatescope, Emerging Markets Outlook 2018.

the past, in 2017 the great majority of clean energy additions were built in developing nations.[42]

Figure 4: Share of Annual Capacity Additions by Technology in Emerging Markets



Source: Bloomberg New Energy Finance/Climatescope.

As at June 2018, two of Pakistan's planned new coal plants are up and running; the 1,320 megawatt (MW) Sahiwal coal power station located in the province of Punjab, and the 1,320 MW Port Qasim EPC power station in Sindh province. Both plants are fuelled by imported coal.

China Huaneng's Sahiwal power station was awarded a levelised tariff of Rs.8.12/kilowatt hour (kWh) (U.S. cents 8.36/kWh), however this does not include the coal rail transportation costs estimated by NEPRA at Rs.1.07/kWh.[43] The Port Qasim plant, located close to the coast and owned by a subsidiary of PowerChina and Al-Mirqab Capital of Qatar, also receives a levelised tariff of Rs.8.12/kWh (U.S. cents 8.36/kWh).[44] In both cases, domestic coal from the Thar coalfield was deemed to be too high in both sulphur and lime content, i.e. too poor quality for the projects.

Another Chinese-built 1,320 MW import coal power plant is now in the commissioning phase with grid operations set to begin in December 2018.[45] This plant will also be fuelled by imported coal, worsening the current account deficit and hence currency pressures.

NEPRA and the Pakistan government have demonstrated concern about over-reliance on imported coal. The Federal government has placed a cap on power generation plants based on imports. In its 2017 State of the Industry Report, NEPRA noted that every one rupee the currency weakens against the U.S. dollar results in an approximate Rs.4bn (US$30m) annual increase in the fossil fuel import bill for the planned thermal power plants.[46]

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[42] Bloomberg New Energy Finance/Climatescope, Emerging Markets Outlook 2018.
[43] NEPRA, Generation Licence Determination for Huaneng Shandong Ruyi (Pakistan) Energy (Pvt.) Ltd, 10 June 2015.
[44] NEPRA, Port Qasim Tariff Determination, 13 February 2015.
[45] Dawn, "1,320 MW coal-power plant energised", 2 October 2018.
[46] NEPRA, State of the Industry Report 2017, p.9.

Using this approximation, the significant weakening of the rupee against the U.S. dollar over the last year would have resulted in an increased fossil fuel import fuel bill of around US$800m per year over the existing cost.

Figure 5: Pakistan Rupee vs U.S. Dollar Over 12 Months to 31 October 2018

Source: Thompson Reuters.

A recent Supreme Court order has further pushed up the expense of importing coal. Port handling charges for coal shipments have reportedly risen 40% after the Supreme Court banned the unloading of coal at Karachi Port Trust berths located in Karachi, Pakistan, on pollution grounds. Coal may now only be unloaded at Pakistan International Bulk Terminal which is a purpose-built 'dirty cargo' terminal within Port Qasim.[47]

Pakistan's Coal Plant Pipeline

According to the PPIB, Pakistan has 3.1 GW of coal-fired power plants under construction and another 3.6 GW in the pipeline at various stages of development.

IEEFA notes however that Pakistan has seen almost 22 GW of coal-fired power proposals cancelled or shelved since 2010, accoding to Global Coal Plant Tracker data,[48] with more at risk given Pakistan's increasing currency and financing pressures.

The 3.1 GW of coal-fired capacity under construction includes the 1,320 MW plant being built in Balochistan which is due online in December 2018. The project proponent is ultimately 74% owned by State Power Investment Corporation – a Chinese state-owned enterprise and financed by a consortium of Chinese banks led by China Development Bank. The plant will be fuelled by imported coal and will use outdated supercritical technology rather than the most modern ultra-supercritical equipment.

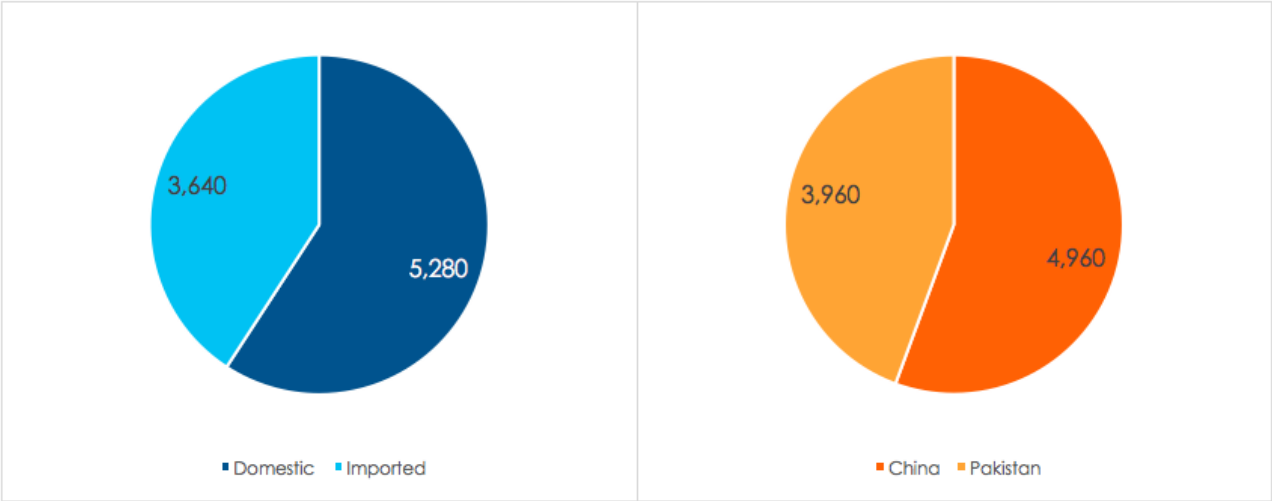
The Thar Engro Coal Power Project (Thar-II) in Tharparkar District, Sindh, Pakistan is also under construction. This 660 MW plant will be fuelled by lignite from the Thar coal fields and is expected to also use inefficient and out-dated subcritical technology. The proponent is owned mostly by Pakistani companies and will be engineered by China Machinery Engineering Corporation (CMEC). Finance was obtained from a consortium of

[47] Dawn, "Sharp rise in handling charges pushes up price of imported coal", 4 October 2018.
[48] Global Coal Plant Tracker, July 2018 data.

Chinese and Pakistani banks. A third unit of 330 MW at the Thar Block II is also under construction by a separate proponent (Thar Energy Ltd) which is majority-owned by Pakistani corporations and will also be constructed by CMEC supported by Chinese finance.

Chinese proponents and engineering firms also dominate the pipeline of coal-fired projects yet to begin construction (Figure 6), a significant number of which will use imported coal. Figure 7 breaks down the coal plant pipeline by development status.

Figure 6: Pakistan's Coal-Fired Power Pipeline by Coal Source and Proponent Domicile



Source: Global Coal Plant Tracker.

The 2.3 GW of proposals that have been granted development permission but are yet to begin construction are all based on domestic coal. The significant amount of imported coal-based proposals that are in earlier stages of development and are yet to be granted permission to proceed.

Figure 7: Pakistan's Coal-Fired Power Development Pipeline

Status	Coal Source	Capacity (MW)
Announced	Domestic	1,320
	Imported	-
Pre-permit	Domestic	1,650
	Imported	3,640
Permitted	Domestic	2,310
	Imported	-
Total		**8,920**

Source: Global Coal Plant Tracker.

Concerns over the cost of imported fossil fuels as Pakistan's currency weakens have led to calls for imported coal-based projects to be de-prioritised. The 1,320 MW Rahim Yar Khan coal-fired power proposal that was to be fuelled by imported coal has reportedly been put on hold.[49]

However, power plants fuelled by domestic coal also have their risks. Turning towards domestic coal-fired power risks dependence on an increasingly out-dated power

[49] Express Tribune, "Pakistan eyes $8b investment from China, Saudi Arabia", 18 September 2018.

technology which is fast being out-classed by newer technology on all measures.

Growing water stress is another key financial risk for an excessive reliance on thermal power generation. Thermal power is extremely water use intensive. Particularly when there are agricultural water shortages, having the added burden of thermal power plants requiring water highlights the critical need for Pakistan to address the water-food-energy nexus.[50] Water risk is also a factor for domestic coal mining in the Thar desert, which is by definition an arid zone.

Status of Other Thermal Generation

Pakistan is already planning to phase out highly expensive furnace oil-and diesel-fuelled power generation as alternatives become available. These alternatives include LNG imports which, while cheaper than furnace oil and diesel, will still place a high fiscal burden on Pakistan along with other fossil fuel imports.

To supplement domestic gas, Pakistan has turned to LNG imports. Three new LNG-fuelled power plants totalling 3.6 GW have been constructed, however, these have been prevented from coming online due to a series of technical issues. In the latest update, they are reportedly set to secure clearance to begin commercial operations during December 2018 and January 2019.[51] The plants, which have all been granted levelised tariffs above U.S. cents 6/kWh, are Chinese-built with turbines supplied by GE.

The construction of Pakistan's LNG-fuelled plants comes at a time of significant downturn in gas-fired power plant orders with consequent erosion of profitability for the companies at the heart of the sector. GE itself recently took a US$23bn write-down on the value of its gas-fired power business.[52] GE acquired the gas-fired power business of Alstom in 2015 after which demand for gas-fired turbines collapsed in the face of increasingly cheap renewable energy.

With renewable technology set to get cheaper into the future, power utilities around the world are unwilling to commit to expensive coal and gas-based generation. The value destruction of the gas turbine downturn has been highly significant for GE – the company was a 19th-century founding member of the Dow Jones index but its' value has declined so much that it has been now removed from the index.

Other gas turbine companies have suffered too. Siemens, a key competitor to GE, has also seen renewable energy materially reduce demand for its thermal power turbines. Siemens is reportedly considering the strategic options for its power and gas unit, which could include a sale or a combination with a rival. In November 2017, Siemens announced 6,900 job cuts within its power and gas division as well as factory closures.[53] The company has lowered its forecast for power turbine sales in 2018. Mitsubishi Heavy Industries has also seen declining profitability in its power systems division, which contributes the majority of the company's operating income, with orders for power system equipment dropping significantly.

Pakistan agreed to a deal with Qatar in 2016 to import LNG from the Middle East nation for 15 years. The agreement has been criticised for being too expensive and the Pakistan

[50] The Herald Dawn, "The high price of producing electricity with coal", 26 September 2018.
[51] Express Tribune, "Delayed gas-power plants set for final checks", 22 October 2018.
[52] Bloomberg, "GE's $23 Billion Writedown Stems From a Bad Bet on Fossil Fuels", 23 October 2018.
[53] https://www.bloomberg.com/news/articles/2018-06-13/siemens-said-to-consider-sale-of-flagship-gas-turbine-business

government is now seeking to re-negotiate the deal.[54] LNG prices have been 40% higher in 2018 than the previous year, driven by increased demand in China as they explore alternatives to coal in order to address serious air pollution problems. China has become the world's second largest importer of LNG after Japan with imports this year expected by Wood Mackenzie to be 37% higher than 2017, after 2017 imports were 46% higher than 2016.[55] Meanwhile, the fact that Pakistan has no gas storage capacity means there is no mitigation of the negative effect on energy security caused by LNG imports.[56]

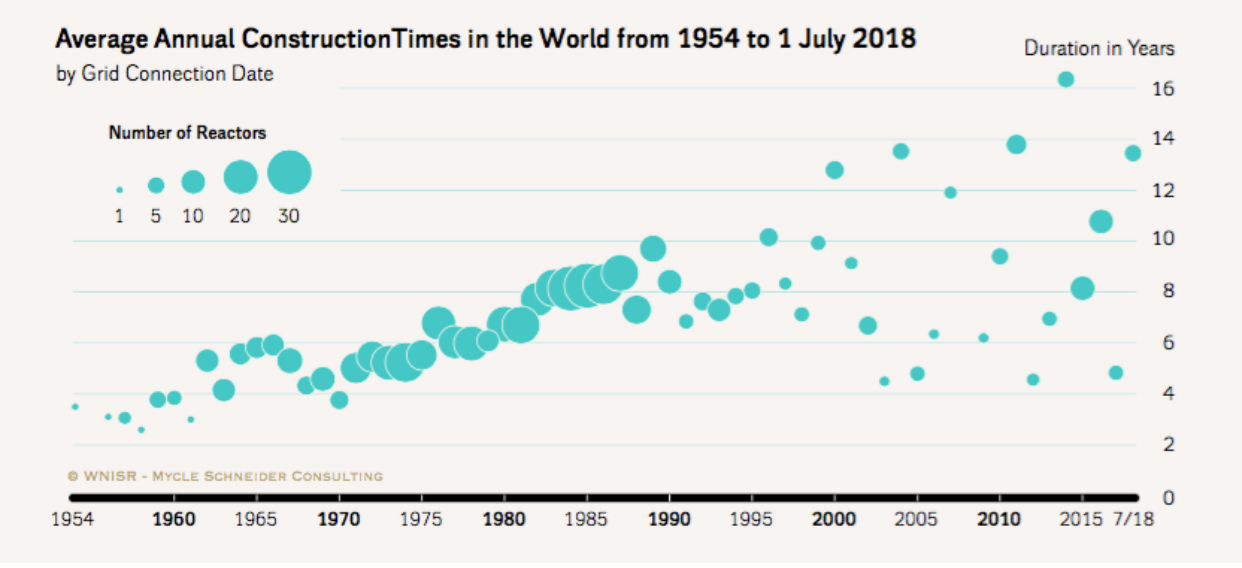
Status of Nuclear Generation

Pakistan has five small operating nuclear reactor units with a total capacity of 1.3 GW. Two more are under construction totalling 2.2 GW and expected to be on line in 2020 and 2021 if completed on time. The construction time of Pakistan nuclear power units has tended to range between 5.2 and 5.6 years. However, IEEFA has long documented the extremely long delays accompanying most large scale nuclear plant builds globally.[57]

A cooperation agreement between the Pakistan Atomic Energy Commission (PAEC) and China National Nuclear Corporation (CNNC) was signed in November 2017 for the latter to build a further unit - the third HPR1000 Hualong One-type reactor in Pakistan. The unit will be the seventh Chinese-built reactor in the country.[58] Pakistan's atomic energy commission also has further development plans, with the intention of achieving almost 9 GW of operating nuclear capacity by 2030.[59]

Pakistan is building more nuclear power units at a time when nuclear power globally is in decline. Outside of China, global nuclear power generation declined for the third year in a row. Only four new reactors came online in 2017, three of which were in China and the fourth was a Chinese-built reactor in Pakistan. No new construction of any commercial reactors in China has begun since 2016.

Figure 8: Global Average Nuclear Reactor Construction Time 1954-2018



Source: World Nuclear Industry Status Report 2018.

[54] The Nation, "Qatari FM discusses LNG deal with Imran", 20 October 2018.
[55] Financial Times, "LNG prices leap on strong Chinese demand", 2 October 2018.
[56] The News, "Govt plans for building underground gas storages" 21 October 2018.
[57] IEEFA, The U.S. Nuclear Project Cancellation Announcement Heard 'Round the World, 1 August 2017.
[58] World Nuclear News, "Pakistan, China agree to build Chasma 5", 23 November 2017.
[59] ET Energyworld, "Pakistan plans new nuclear reactors, 9,000 MW of energy by 2030", 2 November 2018.

The number of nuclear reactors under construction globally has declined for the fifth year in a row, down to 50. At least 33 of these projects are behind schedule, most of them by several years.[60]

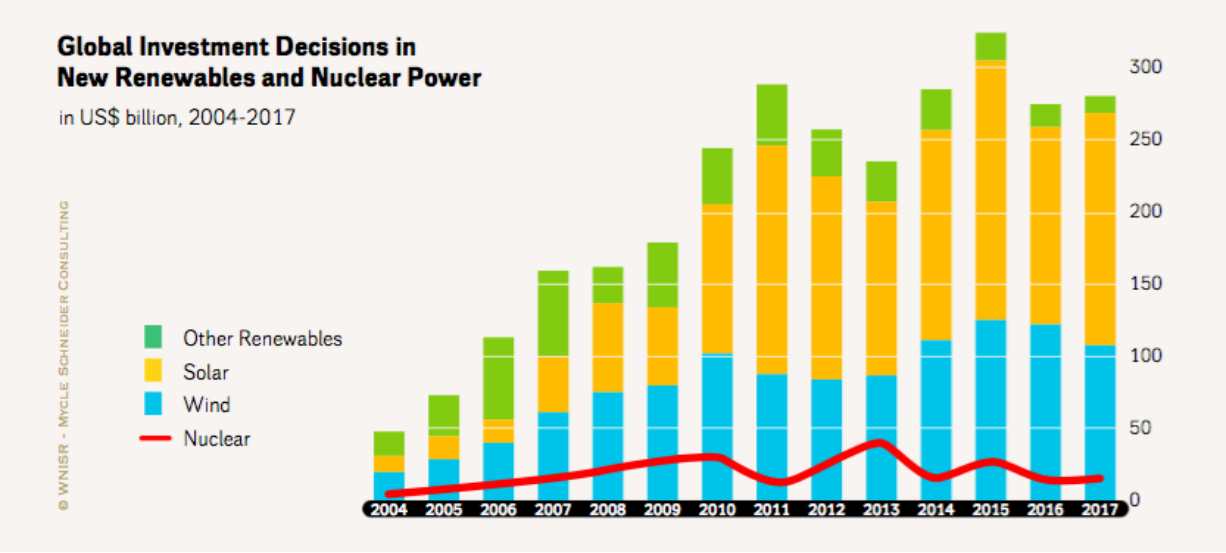
In its latest Energy, Electricity and Nuclear Power Estimates report, the International Atomic Energy Agency (IAEA) cites cheap domestic gas and the impact of renewable energy technology on electricity prices as reasons why the outlook for nuclear power going forward is clouded.[61]

After years of steadily increasing construction times, the period required to complete construction of nuclear reactors has become highly erratic, with durations above 10 years in some cases (Figure 8). The IAEA attributes the increase in construction times to higher safety standards and difficulties in rolling out new nuclear technology.[62]

Examples in Europe demonstrate the difficulty of completing new-technology nuclear power projects in the 21st century. The Flamanville-3 project in France is at least seven-and-a-half years late and more than €7 billion over budget, while the Olkiluoto project in Finland is ten years behind schedule and is coming in at three times over budget. Hinkley Point, the first nuclear plant to be built in the UK since 1995, will be the most expensive power plant in the world. Despite the fact that construction has not officially started, Hinkley developer EDF has already admitted the project is up to £2.2 billion over budget and running 15 months late.[63] November 2018 saw Toshiba of Japan withdraw from the long proposed Moorside, U.K. nuclear power plant.[64]

While nuclear power stagnates, renewable energy is making significant progress globally (Figure 9). Non-hydro renewables produce 3,000 terawatt hours (TWh) more power around the world than a decade ago, while nuclear is producing less.

Figure 9: Global Investment Decisions in Renewables and Nuclear Power 2004-2017



Source: World Nuclear Industry Status Report 2018, FS-UNEP/BNEF 2018.

[60] World Nuclear Industry Status Report 2018..
[61] International Atomic Energy Agency: Energy, Electricity and Nuclear Power Estimates for the Period up to 2050, 2018 Edition
[62] International Atomic Energy Agency: Energy, Electricity and Nuclear Power Estimates for the Period up to 2050, 2018 Edition.
[63] The Guardian, "Hinkley Point C is £1.5bn over budget and a year behind schedule, EDF admits", 3 July 2017.
[64] The BBC, "Toshiba's UK withdrawal puts Cumbria nuclear plant in doubt", 8 November 2018.

Construction began on only five nuclear reactor projects globally in 2017 with a total investment of US$16bn. Meanwhile, according to data from the United Nations Environment Program (UNEP) and Bloomberg new Energy Finance (BNEF), global investment in renewables (excluding large hydro) in 2017 totalled nearly US$280bn.[65]

Status of Renewable Energy

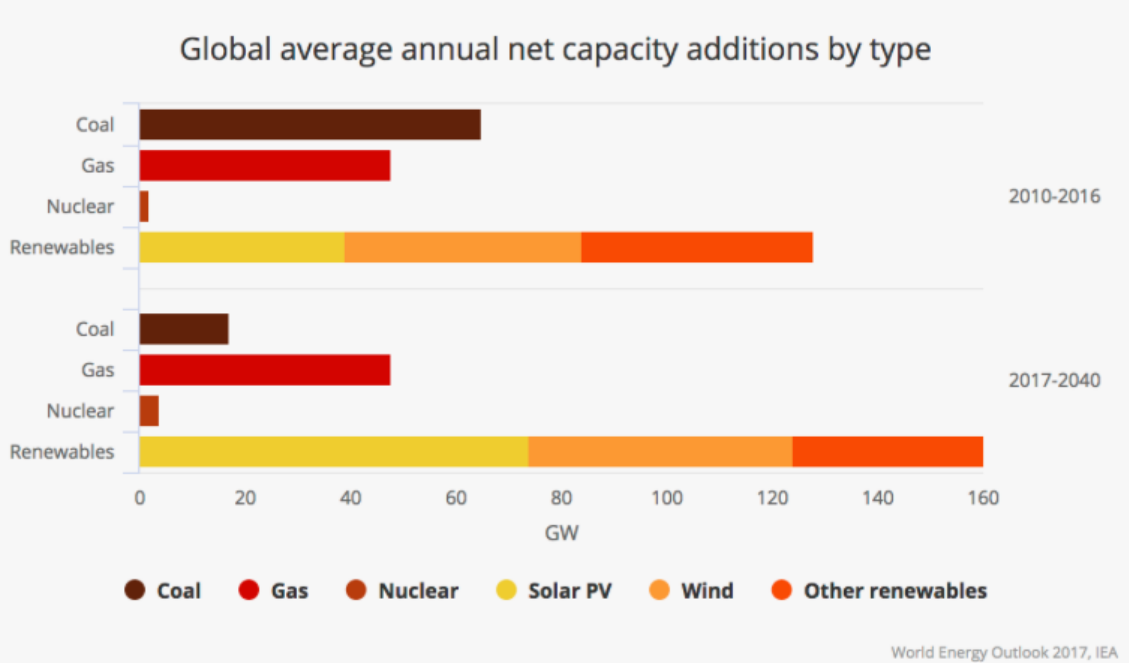
In recent years, solar and wind power technology has made stunning progress in improving efficiency and reducing costs. Rapid renewable energy tariff declines have been seen around the world.

India for instance has seen a major decline in renewable energy tariffs down to INR 2.44/kWh (US$0.034/kWh), after instituting an ambitious 275 GW, 2027 renewable energy target and reverse auctions to generate competition and drive down prices for wind and solar projects. Further, a large Abu Dhabi solar project has seen the tariff below US$0.03/kWh.[66]

In its 2017 State of the Industry Report, NEPRA noted that: "The prices of solar and wind based technology have fallen over past three years, and now their resulting tariffs are quite attractive in comparison with other technologies."[67] Prices have fallen even further since that 2017 report.

The decline in cost has resulted in booming renewable energy installations globally. The year 2017 saw a new record of 178 GW of renewables installed, including 98 GW of solar (up 29% on the prior year) and 52 GW of wind power.[68]

Figure 10: Renewable Energy Will Dominate Power Capacity Additions Going Forward



Source: International Energy Agency, World Energy Outlook 2017.

[65] World Nuclear Industry Status Report 2018.
[66] Reneweconomy, "Japan's Marubeni deals 'body blow' to coal, in pivot to renewables", 17 September 2018.
[67] NEPRA, State of the Industry Report 2017, p. 23.
[68] Reuters, "Record amount of renewable energy installed in 2017 – research", 4 June 2018.

Given the massive deflationary trend, renewable energy is now ready to break out in Pakistan. Amjad Ali, Chief Exectuive Officer of the Alternative Energy Development Board (AEDB), stated in a recent interview that Pakistan's transition towards renewable energy was "irreversible".[69]

Pakistan has begun to install renewable energy but has lagged behind many nations, despite having excellent solar and wind resources.[70] [71] An estimated 1.3 GW of wind and solar was installed in Pakistan by June 2018, with another 300 MW of bagasse-fuelled generation also online.

To date, all of Pakistan's wind power development has been in the Gharo-Keti Bandar corridor in the south of the country which has a theoretical potential of around 50 GW of wind energy.[72] This corridor combines good wind resources with relative proximity to load centres and national grid connectivity.

Pakistan also has good solar radiation resources, particularly in the south and southwestern parts of the country. Areas of high solar radiation include the Thar desert in Pakistan, parts of which have been allocated for coal mining to supply fuel to some of the proposed coal-fired power plants.[73]

In southeast Pakistan, Sindh Province has initiated its' Sindh Solar Energy program (SSEP) that will see utility-scale, distributed and residential solar installed, including up to 400 MW of capacity in solar parks.[74] The World Bank has committed US$100m to the program.

Pakistan is also moving into hybrid wind and solar installations which help to smooth out variability in wind and sunshine. According to the AEDB, 13 letters of intent have been issued to project sponsors for hybrid systems.[75]

Renewable Energy is Now The Cheapest Form of Electricity Generation in Pakistan

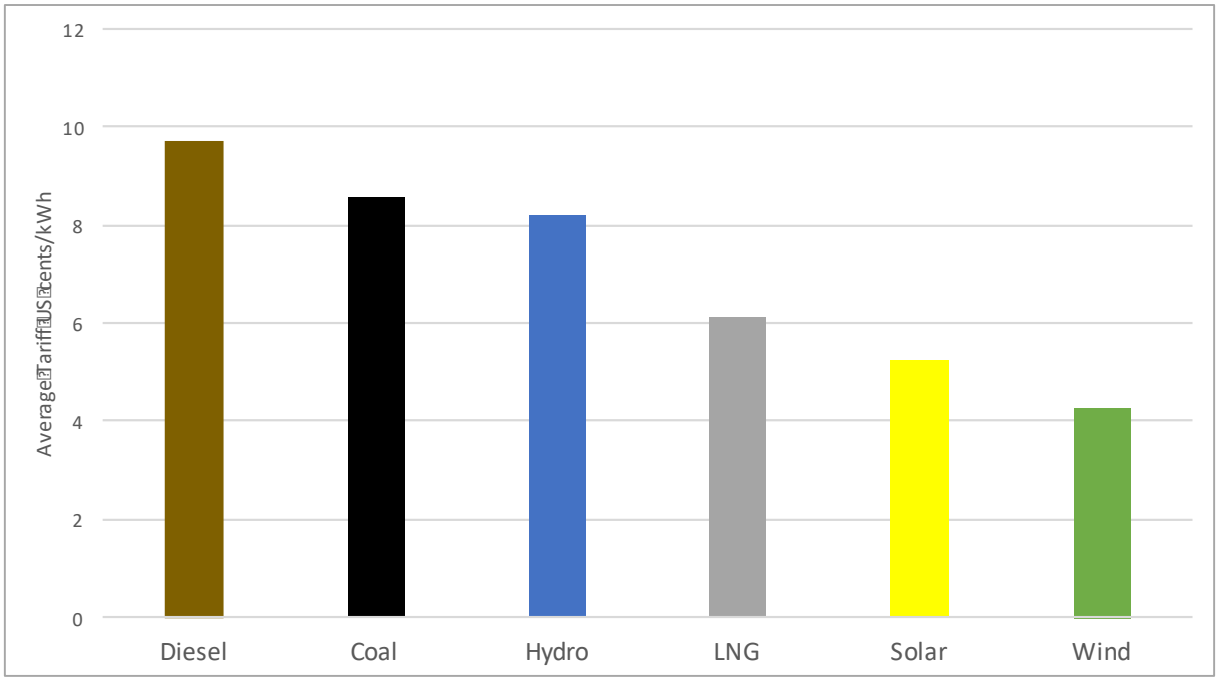
Wind and solar are now the cheapest sources of new electricity generation in Pakistan. This fact will assist the nation increase the uptake of renewable energy.

Figure 11 shows the average levelised tariff determined by NEPRA for recent projects from a variety of sources. Coal and hydro projects have recently had levelised tariffs in excess of eight U.S. cents/kWh, while the three LNG projects due to come online have levelised tariffs in excess of six U.S. cents/kWh.

In comparison, solar levelised tariffs determined in 2018 have averaged U.S. cents 5.25/kWh and recent wind projects are even lower, averaging U.S. cents 4.3/kWh.

[69] Bloomberg New Energy Finance, "Only Power Demand Could Constrain Pakistan Renewables: Q&A", 20 August 2018.
[70] Bloomberg New Energy Finance, "Only Power Demand Could Constrain Pakistan Renewables: Q&A", 20 August 2018.
[71] Reuters, "Is Pakistan's solar power poised to take off amid energy crisis?", 8 May 2017.
[72] IRENA, Renewables Readiness Assessment: Pakistan, April 2018.
[73] Dawn, "Pakistan's coal trap", 4 February 2018.
[74] PV-Tech, "Pakistan's Sindh details 400MW solar parks and 250,000 solar homes plan", 29 March 2018.
[75] Bloomberg New Energy Finance, "Only Power Demand Could Constrain Pakistan Renewables: Q&A", 20 August 2018.

Figure 11: Recent Average Determined Levelised Tariffs in Pakistan by Power Source



Source: NEPRA, IEEFA estimates.

Firming up renewable energy with energy storage to ensure a consistent power supply would make renewables slightly more expensive. Initially however, only a low proportion of renewable capacity would need to be backed up in this way. Crucially, Pakistan is unlikely to need to back up wind and solar with energy storage until renewable energy becomes a much more significant proportion of Pakistan's electricity generation. By this time, storage systems such as batteries will have become significantly cheaper. Pumped hydro storage, demand response management and increased regional grid connectivity are additional solutions to variable renewable energy.

There are also significant opportunities for solar energy in the Commercial and Industrial (C&I) sector. C&I renewable energy tariffs are now being referenced at half the price of industrial tariffs offered by Pakistani power distribution companies, which are high due to the cost of fossil fuel imports.[76]

IEEFA forecasts a decline in solar tariffs of 10% annually for the coming decade, in tandem with the rest of the world and as Pakistan's renewable installation capacity increases and improves efficiency. While solar cost deflation has received the largest headlines, wind cost deflation continues to trend down some 5% annually on the back of continuous technology improvements. For example, India's average new wind farm installations are today reporting capacity utilisation rates of some 35% relative to the 20-23% achieved using older technologies just one decade earlier. Higher wind towers and longer blades are dramatically improving access to more sustained wind flows, reducing intermittency and improving competitiveness of wind farms.

Significantly for Pakistan, renewable energy tariffs will only decrease going forward.

[76] PV-Tech, "ACT Group plans 1GW of solar module assembly in Pakistan", 7 November 2018.

Manufacturing Potential

An added economic boost in establishing a long-term renewable energy development pathway is the significant potential to develop manufacturing and assembly operations in Pakistan. A consistent pipeline of 1 GW each of wind and solar installs annually could encourage global technology leaders to reduce supply line transportation costs, particularly if a medium-term local content target was set. This would further help reduce imports into Pakistan.

In November 2018, the Pakistan-based conglomerate ACT Group announced plans to set up 1 GW of solar PV module assembly capacity in Pakistan by the summer of 2021, starting with a 250 MW first phase by July 2019.[77]

Even without solar module or wind turbine manufacturing facilities, there are many components supply opportunities across tracking, solar frames, smart meters, inverters and tower frames, plus ongoing engineering, procurement and construction (EPC) requirements to boost local content, investment and employment opportunities.

Distributed Renewable Energy

While Pakistan's central grid extension will continue to play a role in accelerating people's access to electricity (95% of new connections since 2000 have been from the grid[78]), there is rising momentum in the number of distributed renewable energy options to meet energy access goals.

Globally, distributed renewable energy (DRE) systems have experienced a three-fold increase from under 2 GW in 2008 to over 6.5 GW in 2017[79]. According to the International Energy Agency's (IEA) World Energy Outlook 2018, 65% of additional demand due to access will be met through renewables, with a further strong shift under the New Policies Scenario towards decentralised technologies in rural areas. On account of technology innovations and declining cost reductions in photovoltaics (PV), battery storage and the introduction of new business models, distributed renewable energy options are becoming increasingly affordable.

DRE is a cost-effective option to rapidly increase rural electrification. In addition, DRE systems offer positive environmental and social impacts in terms of reduced emissions, increased productivity, and income generation opportunities. A number of decentralised solutions such as mini grids, where small groups of energy users are connected together to generate, store and share energy, and stand-alone solar home systems for remote off-grid households are becoming increasingly popular and considered a more affordable option than grid extension for communities living far from the electricity grid. While the upfront cost of such systems can be a challenge, innovative business models and availability of low-cost financing would be instrumental in increasing access.

Mini Grids. Mini grids powered by solar power or biomass gasification (where biomass, such as agricultural waste, is converted into a clean gaseous fuel) can be a key solution to achieve energy access, particularly when integrated into rural electrification plans, including tariff mechanisms and subsidy schemes. The most successful and financially sustainable use of the mini grid is the "ABC" strategy, where an anchor load is identified (such as in agro-processing in Africa, or via telecom towers in India etc.), which is then

[77] PV-Tech, "ACT Group plans 1GW of solar module assembly in Pakistan", 7 November 2018.
[78] IEA, World Energy Outlook, 2018..
[79] IRENA 2018.

shared to simultaneously meet the energy requirements of small local businesses or domestic consumers. Increasingly, mini grid developers are focussing on the productive use of energy to increase demand and generate revenue. Smart metering, remote asset monitoring, and pay-as-you-go technology platforms have led to improvements in mini grid operational efficiency.[80]

Solar Appliances for Lighting. Solar lanterns are basic, relatively affordable applications which can be used to meet the basic lighting needs of rural consumers. In India, lanterns retail from US$7 for a simple lantern to US$34 for a high-end five-watt lantern providing 160 lumens and nine hours of lighting per night, as well as phone-charging capabilities. Solar home systems (SHS) are higher-grade products with multiple installed ceiling lights and switches, and they retail from US$60 for a 10-watt system to US$320 for a 100-watt system[81]. In providing these solutions, there are a wide range of business models adapted to different contexts. Some companies provide financing through microfinance institutions, some partner with established retailers, and others have worked with social enterprises for distribution and after-sales service.

Solar Appliances for Irrigation. Solar water pumps and cold storage (for both large agricultural units and small commercial units) are appliances with the highest demand among off-grid consumers. They also have the highest perceived impact. Due to the increased demand for sustainable irrigation, governments globally have been promoting deployment of solar irrigation pumps, however uptake has been slow. As per an IEEFA report on the potential of solar-powered irrigation in India[82], a significant up-scaling of solar irrigation pumps would provide multiple benefits in terms of:

- providing distributed / end of grid generation;
- reducing the need for heavily subsidised electricity to the agricultural sector, helping to alleviate the financial distress of electricity distribution companies;
- positively aligning solar generation with water irrigation time of use;
- replacing subsidised, imported diesel, thereby reducing the drain on associated foreign exchange and current accounts;
- being significantly more environmentally friendly; and
- expanding and diversifying farmer incomes.

Rooftop Solar. Rooftop solar PV systems are gaining popularity in developed and developing markets as they provide both off-grid and on-grid flexibility. The systems can be conveniently installed at various locations, such as on household and commercial building rooftops and above parking spaces, using a balance of systems including inverters, transformers, wiring, and monitoring equipment. The majority of power generated is used for self consumption by consumers, however excess power can be traded if net metering is an option. Bangladesh has been a global pioneer in the roll-out of simple solar home systems to off-grid rural areas. Currently more than 5 million such systems are in place providing electricity to almost 12% of the nation's population.[83]

Given the huge renewable energy potential in Pakistan, and also given the country already has net metering regulations in place, IEEFA notes there is a huge opportunity for distributed power generators. A comprehensive distribution power plan and enabling

[80] PowerforAll, Research Summary, The bankability of mini-grid business models is improving but regulation remains the biggest challenge, September 2018.
[81] IISD, Building a Market for Off-Grid Solar Lighting, August 2017.
[82] IEEFA, India: Vast Potential in Solar-Powered Irrigation, August 2018.
[83] Reuters, "With solar farms and roof panels, Bangladesh inches towards green power goal", 16 October 2018.

framework should be put in place to meet electricity requirements of potential consumers currently without access to energy.

IEEFA Pakistan Electricity Model

We begin our modelling of the Pakistan electricity system out to 2029-30 with demand and supply projections (refer to Annexure II) involving some key assumptions.

Assumptions

GDP Growth and Electricity Multiplier

As previously noted in this report, Pakistan's GDP growth reached 5.8% in 2017-18 but since then the economic outlook for the nation has dimmed. In its September 2018 Outlook update, the Asian Development Bank reduced its GDP growth forecast for Pakistan to 4.8%, down from 5.1% in its previous forecast.[84] In October 2018, the IMF forecast 2019 GDP growth of 4.0% for Pakistan in its World Economic Outlook.[85]

IEEFA conservatively assumes GDP growth of 4.5% through to 2030. This allows our model to account for economic and electricity demand growth at the higher end of expectations. This means we can model a planned energy transition for Pakistan even at high demand growth.

The ratio of electricity consumption to GDP growth (electricity multiplier) grew in the last five years as Pakistan began efforts to significantly expand power generation capacity and hence power availability. The ratio averaged 1.25x over the period 2012-13 to 2016-17.

In our model, we assume a gross electricity multiplier (before energy efficiency gains are taken into account) of 1.2x. With GDP assumed to grow at 4.5%, this results in an average 5.4% per annum growth rate in gross electricity demand.

Energy Efficiency

The latest Energy Efficiency market report from the IEA finds that the right energy efficiency policy settings can lead to significant economic, social and environmental benefits for a country. The report also noted that, at a global level, current energy efficiency policies are *not* sufficient to realise the full potential of these gains.[86]

While Pakistan is lagging behind much of the rest of the world on energy efficiency progress, the the nation will have many efficiency savings ahead.

In our model, we have conservatively assumed a 1% per annum energy efficiency gain that lowers electricity demand growth. With the right policy settings, Pakistan would have the potential to exceed this 1% per annum gain.

Taking the 1% energy efficiency gain into account lowers the net electricity demand growth we model out to 2030 to 4.4% per annum.

[84] Asian Development Bank, Outlook 2018: Update, September 2018.
[85] IMF, World Economic Outlook, October 2018.
[86] IEA, Energy Efficiency 2018.

Transmission and Distribution Losses

Excessive transmission and distribution (T&D) losses are a key cause of Pakistan's significant circular debt problem, with additional attention recently drawn to the issue by a Senate Committee review. There is significant potential to reduce T&D losses in Pakistan[87] and this is likely to involve significant investment in equipment upgrades and smart meters, among other expenditures. Countering the upside potential for T&D gains is the fact that current high losses have remained unresolved for many years, as noted by NEPRA.[88]

In our model, we conservatively assume a 0.2% reduction in T&D losses per year out to 2030.

Utilisation Rates

In our model, we use power plant utilisation rates for different technology types. These rates are based on recent power output and capacity for each technology: coal-fired power – 59%, wind – 29%, solar – 22%, baggase – 40%, hydro – 44%, nuclear – 79%, and other thermal power – 48%.

Meeting Increased Electricity Demand

The demand/supply model in Annexure II forecasts net electricity demand to increase from 106 TWh in 2017-18 to 178 TWh by 2029-30, an increase of 72 TWh. Despite modelling a reducing rate of T&D losses of 0.2% per annum, total T&D losses will be higher by 2030 due to the increased generation capacity required to meet this demand. As such, an additional 85 TWh of electricity generation will be required in order to allow for T&D losses while matching net demand growth of 72 TWh.

Figure 12: Summary of Electricity Demand Forecast and Generation Required by 2029-30

Pakistan's Waterfall Chart				
Net Electricity consumed in Pakistan in 2017/18 (TWh)			106	
Real GDP Growth	4.5%	pa		
Electricity to GDP multiplier	1.20	times		
Gross Electricity Demand Growth	5.4%	pa	93	
Energy Efficiency	-1.0%	pa	-22	
Net Electricity consumed in Pakistan in 2029/30 (TWh)			178	
Net expansion in electricity demand 2029/30 (TWh)			**72**	
Growth: gross production losses			18	
Reduced grid AT&C losses	-0.20%	pa grid efficiency gain	-5	
Net expansion in electricity production required (TWh)			**85**	

Source: IEEFA estimates.

In IEEFA's model, much of the increase from the additional 85 TWh of generation produced from expansions in capacity (as set out in Figure 13) comes from the completion of coal, hydro and nuclear power plants that are currently under

[87] Express Tribune, "T&D losses can be cut by half", 1 October 2018.
[88] NEPRA, State of the Industry Report 2017.

construction. In addition, we model a significant increase in the capacity of wind and solar energy. The increased production from these sources allows for a large reduction in power required from expensive non-coal thermal power sources such as oil, diesel and LNG.

Figure 13: Meeting the Increase in Required Electricity Generation

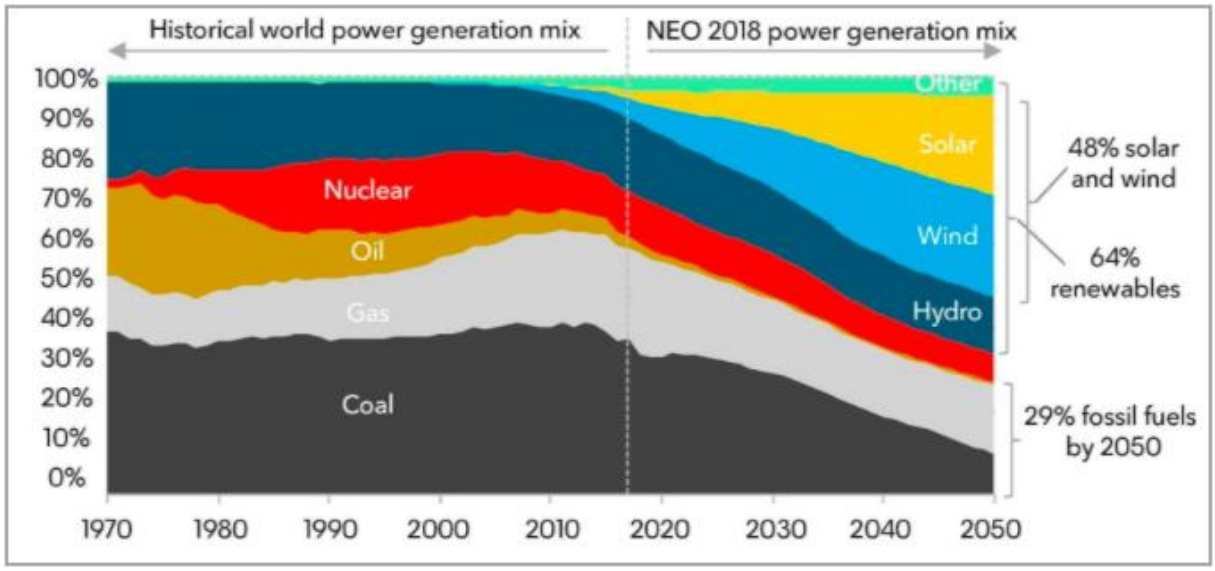
The Increase in Electricity Production is met by (TWh)	TWh	Uplift	Capacity 2016/17 (GW)	Capacity 2029/30 (GW)
Solar expansion	23	27%	0.4	12.4
Onshore wind expansion	31	36%	0.9	12.9
Increase in biomass generation	4	4%	0.3	1.3
Increase in hydro electricity	35	41%	8.2	16.2
Increase in nuclear generation	15	18%	1.3	3.5
Increase in coal-fired electricity	18	22%	2.7	5.8
Change in other thermal generation (oil, gas, LNG)	-41	-48%	18.6	22.2
Net expansion in Electricity Production by 2029/30 (TWh)	**85**	**100%**	**32.5**	**74.4**

Source: IEEFA estimates.

Renewable Energy

IEEFA's alternative electricity system build-out for Pakistan is reliant on a significant increase in focus on renewable energy. With the price of renewables in constant decline, countries around the world are increasingly turning towards renewable energy construction to power their electricity systems. Bloomberg New Energy Finance foresees cheap renewable energy and battery storage technology as transforming the world's electricity system from a system based two-thirds on fossil fuels in 2017, to a system that is two-thirds renewable energy-based by 2050.[89]

Figure 14: Forecast Change in Global Power Generation Mix to 2050



Source: Bloomberg New Energy Finance: New Energy Outlook 2018.

[89] BNEF, "New Energy Outlook 2018".

In our model, we have Pakistan installing 1 GW of solar and 1 GW of wind power per year out to 2030. Importantly, this is an average over the 12 years. The build out can start at a smaller level, perhaps several hundred megawatts a year, which can then be ramped up as wind and solar get even cheaper, installation capability improves, and costs fall even further. This level of per annum installation is highly achievable with many nations already building out renewables at a similar scale.

For instance, Egypt's latest target calls for renewables to reach 20% of the electricity mix by 2022 and 42% by 2035, with 10 GW of wind and solar is to be installed by 2022.[90] Saudi Arabia may tender 4 GW of renewable energy projects in 2018.[91] Vietnam's renewable energy sector has taken off recently with a reported 20 GW of large-scale solar projects in the pipeline at various development stages.[92] And in India, renewable energy is now cheaper than new coal-fired power based on either imported or domestic coal. India is now installing up to 10 GW of renewable energy each year.

In our model, Pakistan reaches almost 27 GW of renewable energy by 2029-30 which represents 36% of total capacity, while supplying around 28% of the nation's electricity.

Renewable energy tariffs in Pakistan are already below coal-fired power tariffs and hydro power tariffs, and well below other thermal power tariffs. Other nations have seen a series of record low prices achieved via competitive reverse auctions.

We note that NEPRA has been considering moving to a competitive bidding process for renewable energy. IEEFA encourages this move to help significantly drive down the cost of renewable energy as the country utilises its significant renewable energy resources.[93]

We note the seasonality of some of Pakistan's energy resources. Wind energy achieved an overall utilisation rate of 29% in the year 2017-18 but this varied widely throughout the year. To some extent, the peaks and troughs of wind energy production fluctuate in line with that of hydro energy, which may limit wind power development to some extent. This can be overcome, at least in part, through the construction of hybrid wind and solar installations which can help smooth out the variability of energy generation. The AEDB has noted that such hybrid installations are now under development in Pakistan.[94]

There is potential for further bagasse fuelled generation with the International Renewable Energy Agency (IRENA) noting potential for almost 2 GW of generation potential. In our model we assume only 1 GW is added out to 2030.

As well as allowing for reduced reliance on fossil fuel imports and the expense that entails, increased renewable energy reliance can improve energy security by diversifying Pakistan's electricity sources away from expensive thermal power and seasonal hydro power dominance. Renewable energy is also better placed to increase the rate of rural electrification by providing distributed energy solutions that cannot be fulfilled via large, expensive, centralised power stations.

[90] IRENA, Renewable Energy Outlook: Egypt, October 2018
[91] The National, "Saudi leads renewable energy developments with $7bn in new tenders", 23 June 2018.
[92] Rystad Energy, "Vietnam's large-scale solar pipeline at 20GW", September 2018.
[93] IRENA, Renewables Readiness Assessment: Pakistan, April 2018.
[94] Bloomberg New Energy Finance, "Only Power Demand Could Constrain Pakistan Renewables/ Q&A", 20 August 2018.

Requirements for Increased Renewables Focus

An increased rate of renewable energy installation in Pakistan is only possible with the right policy settings. As we have previously noted, a move towards competitive bidding for renewable energy projects is currently being considered, and this will be key to the development of renewable energy in Pakistan. Grid enhancements to allow the electricity system to handle increased variability of generation will also be necessary.

Pakistan's provinces have their own renewable energy ambitions and overall central government policy should allow for provincial ambitions to flourish. Sindh and Punjab provinces are examples of provincial governments that have significant wind and solar energy plans.

The acceleration of renewable energy roll-out can be assisted by enabling new project proponents to invest in Pakistan renewables beyond the domestic and Chinese proponents that are currently typical of recent renewable installations. Pakistan and China have recently agreed to allow third-country investors to be part of the CPEC scheme.[95]

Other necessary policy measures include the creation of an integrated long-term renewable energy plan, the setting of targets, the creation of renewable energy zones, and encouraging distributed power, which have all been identified by IRENA in its 2018 Pakistan Renewables Readiness Assessment.[96] All of this will build momentum to encourage financial institutions and corporates to accelerated renewable energy investments in Pakistan.

China's Renewable Energy Leadership

Third party nations are reportedly allowed to join the CPEC scheme and may have an interest in exporting their renewables technology to Pakistan. However, as China is positioning itself as a global renewable energy leader[97] it is fully capable of driving increased renewable energy investment and construction in Pakistan.

The Chinese company TBEA was the EPC contractor for the first 100 MW of the 1,000 MW Quaid-e-Azam Solar Park in Pakistan. In May 2017, China's SANY signed a memorandum of understanding with the Punjab Power Development Board to install 1 GW of wind energy projects over five years.

There are also a number of renewable energy projects on the CPEC energy project priority list.[98] This includes wind projects from China Three Gorges, a Chinese company diversifying away from hydro power and into new renewable energy technology. In addition to wind projects, further extensions to the Quaid-e-Azam solar plant are planned within CPEC as the project scales up towards 1,000 MW.

A curtailment to Pakistan's hydro and coal-based energy projects need not be an end to Chinese energy development in Pakistan. Increased renewable energy ambition will create many opportunities for Chinese companies already present in Pakistan and fits well with Chinese ambitions to be a major world player in clean energy.

[95] Dawn, "Pakistan, China agree to broaden CPEC base", 10 September 2018.
[96] IRENA, Renewables Readiness Assessment: Pakistan, April 2018.
[97] IEEFA, "China in 2017 Continued to Position Itself for Global Clean Energy Dominance", 9 January 2018.
[98] CPEC, Energy Priority Projects.

Other Renewable Technologies

In our model, we have only considered current renewable energy technologies that are proven and in operation in Pakistan, including wind and solar PV technology and to a lesser extent bagasse. Beyond 2030, various other technologies will be viable in Pakistan which can take renewable energy penetration to the next level in the nation's post-2030 energy system.

Offshore wind was pioneered in Northern Europe and is now set to make significant inroads into Asian power markets. The IEA expects global offshore wind installations to more than triple to over 60 GW by 2025[99] while Asian nations have the potential to build a combined 100 GW of offshore wind by 2030. China has a target of 10 GW by 2020 and Wood Mackenzie Power & Renewables suggests China could reach 30 GW by 2030. India has an initial target of 5 GW by 2022 and 30 GW by 2030. South Korea has an 18 GW target by 2030 while Japan and Taiwan have targets of 10 GW and 5.5 GW, respectively.

We have not included offshore wind in our modelling of Pakistan's power system out to 2030. Pakistan would be better off allowing other Asian nations to drive offshore wind development around the continent, to push down the cost. Pakistan can then consider offshore wind development once the cost has declined sufficiently.

Concentrated solar power (CSP) has not taken off globally to the same extent as solar PV technology, however commercial projects are operating or under development in the U.S., Europe, Australia and South Africa, among others. CSP has the advantage of complementing solar PV with its' ability to store energy, which can then be consumed in the evening when solar PV is no longer generating. Pakistan has high 'direct normal irradiance', a term referring to the amount of solar radiation received on a surface that is always held perpendicular to the sun's rays at its current position in the sky. This is a useful measure for CSP. Pakistan's dry plateaux and rock deserts have values as high as some of the top locations around the world.[100] As with offshore wind, Pakistan would be better off developing CSP in future years after other countries have driven the cost down further.

Our model does not account for energy storage such as that provided by batteries or pumped hydro systems. Both of these technologies will be important globally as variable renewable energy penetration increases in order to smooth the wind and solar energy, and to provide energy after dark once solar PV installations are no longer generating. Battery technology in particular is quickly declining in cost.

Our model sees renewable energy reaching 28% of electricity generation in Pakistan by 2030, with the nation having gas-fired and hydro power plants that could potentially be used to balance the variability of wind and solar. Consequently, Pakistan can hold off on significant large scale battery deployment until cost reductions make it more affordable.

Nuclear Power

Pakistan currently has 2.2 GW of nuclear power units under construction and our model factors in the completion of these units. However, with nuclear power increasingly beset with very large cost and schedule over-runs around the world, our model does not factor in the proposed third HPR1000 Hualong One-type reactor. We deem this project unnecessary thanks to the increase in ever-cheaper and more efficient wind and solar

[99] IEEFA, "IEA: Offshore wind capacity could top 200GW by 2040", 26th September 2018..
[100] IRENA, Renewables Readiness Assessment: Pakistan, April 2018.

technology that can be used to exploit Pakistan's excellent renewable resources. Nuclear power around the world is increasingly being outcompeted on all levels by renewables, and the nuclear industry is stagnating.

As a result, in our model Pakistan's nuclear power capacity levels out at 3.5 GW by 2030 and ceases to grow. This results in nuclear power contributing 11% of Pakistan's electricity generation in 2029-30 which is enough to add diversity to the nation's electricity mix and enhance energy security.

Hydro Power

The IEEFA model assumes that all hydro projects marked as 'under construction' by WAPDA, and including those which are on the PPIB's IPP development list of hydro power IPPs, will be built to completion. Our model includes 8 GW of new hydro generation consisting of 6.3 GW of WAPDA projects and 1.7 GW of IPP projects, including the Karot project and the Suki Kanari project. As a result, Pakistan would have 16.2 GW of hydro power installed by 2030, contributing almost 29% of the nation's electricity generation.

The 6.3 GW of WAPDA projects includes the 4.3 GW Dasu Dam project which, although considered 'under construction' by WAPDA, is still in the process of acquiring land needed for the project to proceed. IEEFA notes that the Pakistan government considers this project a high priority, despite being at least two years behind schedule.

Given the inevitable delays faced by major hydro projects, and the need for a fast build-out of new electricity capacity to meet Pakistan's growing demand, our model assumes that any further hydro projects currently in the development pipeline but not under construction, do not proceed. Large hydro projects are notorious for their high expense and are almost guaranteed to run well over budget and over schedule. Pakistan is not in a position to afford such over-runs.

Wind and solar power can be built much faster than hydro projects, and with renewables now the cheapest electricity source in Pakistan, a limit on the amount of hydro power built makes increasing sense for Pakistan. By switching emphasis from hydro to renewables, Pakistan can create a more diverse and secure electricity system that is not overly reliant on seasonal hydro power.

Coal-Fired Power

Our model assumes that all coal-fired power plants currently classified as 'under construction' on the PPIB's IPP development list will continue to completion. This amounts to 3.1 GW of new coal-fired power that will be added to the electricity system in the coming years.

As a result, in our model Pakistan would have 5.8 GW of coal-fired power by 2029-30, contributing almost 14% of the nation's electricity.

Beyond this, our model assumes no further coal-fired power development. The remaining coal-fired power projects are yet to reach financial close according to the PPIB's development list, so there is an opportunity for Pakistan to halt these projects and replace this generation capacity with cheaper renewable energy.

A large proportion of the coal-fired power projects in the development phase will rely on imported coal. By limiting the coal power build-out and increasing focus on renewable energy, Pakistan can improve energy security while lowering generation costs.

Other Thermal Power

Adding significant amounts of renewables, coal-fired and hydro power to the electricity system means there would be less reliance on expensive oil- and diesel-fired generation, and a reduced need for imported LNG. Our model includes the addition of 3.6 GW of LNG-fired power projects that are due to come online in the coming months, but assumes no other, non-coal thermal power plants are added.

The effect of ceasing other thermal power capacity additions while renewables, hydro and coal-fired power is added, is that the utilisation of other thermal power declines. In 2017-18 we estimate a 48% utilisation rate for other thermal power in Pakistan. In our model this declines to 21% by 2029-30. The 22 GW of other thermal power capacity in place at 2029-30 would contribute just 19% to Pakistan's electricity generation, being a high cost source best suited for peaking power supply.

This low utilisation of oil, diesel, gas and LNG-based generation will help reduce the cost of generation and also provide flexibility to the energy system. Utilisation of other thermal power could be increased to cover seasonality and variability of hydro and renewable energy in Pakistan.

Potential 2030 Electricity Mix

According to our model, Pakistan's electricity mix has reached a more sustainable balance by 2029-30, with energy security enhanced through a diversity of generation technologies, as laid out in Figure 15.

In our model, Pakistan's electricity generation is roughly split in the ratio 30:30:30:10 between thermal power, hydro power, renewable energy and nuclear power all providing the nation with a more diverse and therefore secure electricity system. The increased reliance on renewable energy also means less generation is required from expensive imported oil, diesel and LNG-fired power stations, which further enhances energy security while reducing cost.

Figure 15: Pakistan Electricity Market Composition 2029-30 As Per IEEFA's Model

Source	Electricity market Composition 2029/30				
	Capacity		Generation		Capacity Utilisation
	GW	% of Total	TWh	% of Total	
Oil, Gas, LNG	22.2	29.8%	41.7	19.0%	21%
Coal	5.8	7.8%	30.3	13.8%	59%
Nuclear	3.5	4.7%	24.1	11.0%	79%
Hydro	16.2	21.8%	63.0	28.6%	44%
Solar	12.4	16.7%	23.6	10.7%	22%
Wind	12.9	17.4%	32.7	14.9%	29%
Bagasse	1.3	1.8%	4.6	2.1%	40%
Total	**74.4**	**100.0%**	**220.0**	**100.0%**	

Source: IEEFA estimates.

Under this model, Pakistan progressively transitions from the current reliance on both expensive fossil fuel imports and seasonal hydro power, towards wind and solar technology that will only get cheaper over the years to 2030. The capacity mix proposed in our model has a far better chance of reducing the cost-tariff deficit[101] than will occur under Pakistan's current development plan, which instead focusses on highly expensive and lengthy hydro power construction, and an increased reliance on coal and LNG based on out-dated technology which will increase expensive fossil fuel imports.

Reducing the cost-tariff deficit will be key to resolving the electricity system's circular debt issue. By utilising ever cheaper renewable energy, the deficit can be approached by reducing the cost of generation, rather than by increasing tariffs which put additional pressure on consumers and businesses.

Conclusions

Pakistan needs to increase the supply of electricity to meet growing demand while also tackling its circular debt issue. At the same time, the weakening rupee is making fossil fuel imports even more expensive, putting further pressure on Pakistan's current account deficit.

With wind and solar now the cheapest form of new electricity generation in Pakistan, renewable energy provides a solution to both of these issues.

Domestic power sources, such as coal-fired power fuelled by domestic coal and hydro power, avoid the pressures placed on the Pakistan economy by importing fossil fuels, but they present other drawbacks.

Large hydro power projects are highly complicated, inordinately expensive, have a very long construction time, and are notorious for running severely over-budget and over-schedule. This is equally true of large nuclear power projects globally.

Domestic coal-fuelled power also has a long construction time compared to renewable energy. Such projects lock nations into decades of out-dated power technology at a time when newer, clean technology is increasingly outclassing it on cost, build time and pollution emissions.

With Pakistan needing to expand generation quickly, renewable energy is much better placed to meet growing demand than hydro, coal or nuclear, as wind and solar projects can be built within an 18-24-month timeframe.

Wind and solar power are already cheaper than new thermal and hydro power in Pakistan and, importantly, they will only get cheaper going forward. An increased emphasis on renewables can help reduce the cost of generation and address the cost-tariff deficit, without the need for tariff increases that would impact consumers and businesses.

An increased reliance on renewable energy also means lower dependence on fossil fuels, which not only lowers costs and improves the nation's current account, but also improves Pakistan's energy security while avoiding a technological lock-in of out-of-date coal technology.

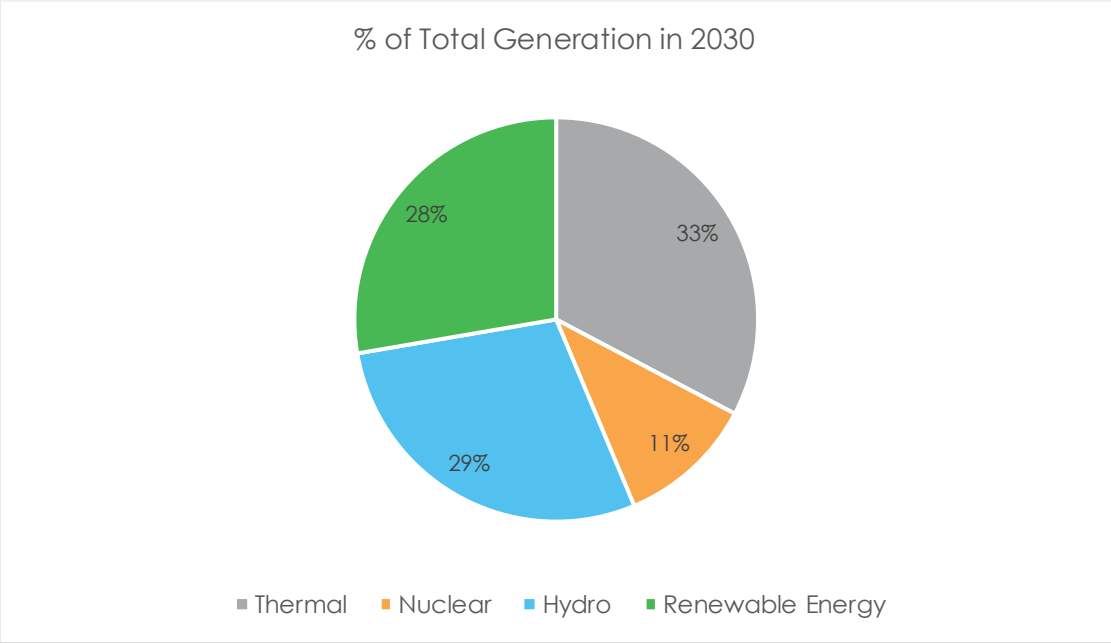
[101] Express Tribune, "Circular debt-solution lies in removing the cost-tariff deficit", 29 October 2018.

The role of energy efficiency should be promoted. Adopting new technologies across the grid, smart meters, and mandating installation of high-rated equipment, will lower the rate of energy growth and help the expanding electricity system meet demand.

IEEFA's electricity model for Pakistan out to 2029-30 takes a pragmatic view of the current power development pipeline and assumes steps can be taken to reduce the over-reliance on thermal and hydro power and increase the reliance on renewables.

The resulting electricity mix produced provides a more diversified electricity generation system for Pakistan, roughly split in a ratio of 30:30:30:10 between renewables, thermal, hydro, and nuclear power (Figure 16). This alternative path would give a more secure and cost-effective electricity system that is better placed to serve Pakistan's power needs into the future.

Figure 16: Pakistan Electricity Generation Composition 2029-30 As Per IEEFA's Model



Source: IEEFA estimates.

Annexure I

Key Power Sector Institutions

Organistion	Type	Roles and Responsibilities
Power Division, Federal Ministry of Energy	Federal Ministry division	The executive arm of the Government of Pakistan for all issues pertaining to power generation, transmission, distribution, pricing, regulation and consumption. Co-ordinates and plans the nation's electricity sector; formulates policy and specific incentives. Liaises with provincial governments and has oversight for all line agencies and autonomous bodies.
NEPRA	Regulator	Independent regulator with a mandate to ensure transparent, competitive and commercially oriented power market operations including generation, transmission and distribution. Issues generation, transmission and distribution licences, and determines tariffs for the power sector.
PPIB	Agency	A "one-window" facilitator on behalf of the federal government to promote private-sector participation in the power sector for large hydropower and non-renewable technologies.
AEDB	Agency	Autonomous body under the Ministry of Energy with the mandate to promote and facilitate exploitation of renewable energy resources. Develops national strategies, drafts policies and plans for utilisation and promotion of renewable energy. Co-ordinates and facilitates commercial application of renewable energy technologies as well as facilitating private investors. Forum for evaluation, monitoring and certification of renewable energy projects and products.
NTDC	State-owned public limited company	Responsible for all properties, rights, assets, obligations and liabilities of the 220 kV and 500 kV grid stations and transmission lines and networks.
CPPA (Guarantee)	State-owned limited guarantee	Responsible for power procurement from generation companies, hydropower and IPPs on behalf of DISCOs for delivery through 500 kV, 220 kV and 132 kV networks. Performs power market clearing function.
Power utilities (DISCOs)	State-owned companies	Ten separate electricity retail companies responsible for administering the O&M, supply, distribution, construction and expansion of the 132 kV and 11 kV grid network within their respective areas of jurisdiction.
K-Electric	Private power utility company	Responsible for generation, transmission and distribution of electric power for the city of Karachi.
Provincial energy departments	Provincial government departments	Four provincial energy departments (Punjab, Sindh, Khyber Pakhtunkhwa and Baluchistan) and the AJK Power Development Organization support energy project implementation within their respective regions. Responsibilities include liaising with the federal government to implement policies and measures to incentivise energy project development.
WAPDA	Agency	Responsible for large-scale hydropower project development and water sector projects.
Generation companies (GENCOs)	State-owned companies	Government-owned but independently operated companies responsible for O&M of public-sector thermal power plants.
PEPCO	State-owned company	Established in 2007 to manage the transition of government entities from a bureaucratic structure to a corporate, commercially viable entity. It is responsible for the management of all the affairs of the corporatised nine DISCOs, four generation companies (GENCOs) and NTDC, all of whom are working under an independent Board of Directors

Source: IRENA, Pakistan Renewables Readiness Assessment, 2018

Annexure II

Pakistan Electricity Supply/Demand Model to 2030

GDP Growth (%)	4.5%
Electricity to GDP multiplier pre-EE	1.20
Electricity Demand Growth (%)	5.4%
Energy Efficiency (%)	-1.0%
Electricity to GDP multiplier	0.98
Reduced grid T&D losses	-0.2%

Year ended June	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24	2024/25	2025/26	2026/27	2027/28	2028/29	2029/30
Gross Production (TWh)	120.6	135.7	141.3	147.1	153.2	159.5	166.1	173.0	180.1	187.6	195.3	203.4	211.8	220.6
Gross Production Growth (%)		12.5%	4.1%	4.1%	4.1%	4.1%	4.1%	4.1%	4.1%	4.1%	4.1%	4.1%	4.1%	4.1%
AT&C Losses (TWh)	26.1	29.3	30.3	31.2	32.2	33.2	34.3	35.3	36.4	37.6	38.7	39.9	41.2	42.4
AT&C Losses (%)	21.6%	21.6%	21.4%	21.2%	21.0%	20.8%	20.6%	20.4%	20.2%	20.0%	19.8%	19.6%	19.4%	19.2%
Reduced Grid losses		0.0%	-0.2%	-0.2%	-0.2%	-0.2%	-0.2%	-0.2%	-0.2%	-0.2%	-0.2%	-0.2%	-0.2%	-0.2%
Real GDP Growth (%)	5.4%	5.8%	4.5%	4.5%	4.5%	4.5%	4.5%	4.5%	4.5%	4.5%	4.5%	4.5%	4.5%	4.5%
Electricity Multiplier (x)			1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
Electricity Growth (%)			5.4%	5.4%	5.4%	5.4%	5.4%	5.4%	5.4%	5.4%	5.4%	5.4%	5.4%	5.4%
Energy Efficiency			-1.0%	-1.0%	-1.0%	-1.0%	-1.0%	-1.0%	-1.0%	-1.0%	-1.0%	-1.0%	-1.0%	-1.0%
Net Demand Growth (TWh)	94.5	106.3	111.0	115.9	121.0	126.3	131.8	137.6	143.7	150.0	156.6	163.5	170.7	178.2
Net Demand Growth (%)		12.5%	4.4%	4.4%	4.4%	4.4%	4.4%	4.4%	4.4%	4.4%	4.4%	4.4%	4.4%	4.4%

Institute for Energy Economics and Financial Analysis

The Institute for Energy Economics and Financial Analysis (IEEFA) conducts research and analyses on financial and economic issues related to energy and the environment. The Institute's mission is to accelerate the transition to a diverse, sustainable and profitable energy economy. More can be found at www.ieefa.org.

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Tim Buckley

Tim Buckley, IEEFA's director of energy finance research, South Asia / Australia, has 30 years of financial market experience covering the Australian, Asian and global equity markets from both a buy and sell side perspective. Tim was a top-rated Equity Research Analyst and has covered most sectors of the Australian economy. Tim was a Managing Director, Head of Equity Research at Citigroup for many years, as well as co-Managing Director of Arkx Investment Management P/L, a global listed clean energy investment company that was jointly owned by management and Westpac Banking Group.

Important Information