Haneea Isaad, Energy Finance Analyst
September 2022

Institute for Energy Economics and Financial Analysis
IEEFA.org

To Build or Not to Build: Keeping Pakistan's Hydropower Reliance in Check

Unmet Project Targets Could Jeopardize Energy Security and Increase Fossil Fuel Reliance

Executive Summary

Hydropower has commanded a significant share of Pakistan's power consumption needs over the years by serving almost 30% of the power generated in the country. Its vast network of rivers, fed by summer monsoons and glacier and snow melt, has provided a favorable environment for adding more hydropower capacity to the grid so far.

As these natural elements fall prey to a changing climate and the economic challenges faces become more pronounced, Pakistan's planned reliance on hydropower may not materialize to provide readily available dispatchable power source and serve its renewable energy goals.

According to the country's long-term energy plan, the Indicative Generation Capacity Expansion Plan (IGCEP 2021), almost 14 GW of both large and small hydropower capacity is projected to come online by 2030.

IEEFA's analysis suggests that only 51% of this pipeline capacity has achieved financial closure and only 39% has begun construction, while the rest is riddled with implementation risks and cost overruns. Based on these factors, only 15% of the hydropower pipeline is estimated to come online in time, while the rest may face delays, further exacerbating Pakistan's energy security issues.

Only 15% of the hydropower pipeline is estimated to come online in time by 2030.

Almost 81% of the planned hydropower capacity comprises of large dams, which have historically proven to be extremely difficult to finance. They often require credit support from multi-lateral banks such as the World Bank (WB) and Asian Development Bank (ADB), or matching guarantees and financing from the government itself.

The planned hydropower capacity follows a similar pattern and is receiving widespread support from MDBs along with a hefty amount of investment (USD 7.7 billion) under the China Pakistan Economic Corridor.

Yet, with the problematic past of mega hydro projects like the Neelum Jhelum Hydropower Project and the Diamer Bhasha Dam in mind, there are various factors to be considered before the country can rely on these projects to meet its projected future energy demand.

IEEFA categorizes three key risks which could delay the realization of this capacity by 2030:

- Cost and schedule overruns are a normal occurrence for large dams leading to a huge economic burden on the national exchequer, higher costs of debt financing and non-provision of project benefits. Delays in pipeline realization will likely lead to a supply-demand mismatch in the country prompting a switch back to fossil fuel-based power to bridge the gap

- Pakistan and the government's hydropower development wing Water and Power Development Authority (WAPDA) were recently downgraded by all three prominent credit rating agencies: Moody's, Fitch and S&P. As Pakistan's economic outlook is predicted to remain weak for the next few years, this hinders the governments' ability to raise capital for these projects, which could further delay project implementation cycles

- The hydropower pipeline is becoming increasingly vulnerable to extreme weather events and climate change. Should there be an early onset of summers or droughts in the country, water availability in hydropower reservoirs for power generation could be severely limited. Competing water usages for irrigation and agricultural demand would precede hydropower generation leading to power outages and widespread load shedding within the country

The country's economic outlook faces further stress, as recent floods shift the government's focus towards disaster recovery. Capital for development projects such as mega dams may be even harder to come by further jeopardizing the realization of large hydropower projects.

While the country's burgeoning power demand cannot be denied, it is important to shift the focus from 'generation-driven' planning towards more holistic solutions which combine smaller, quick to build more agile technologies such as floating or rooftop solar with grid upgradation and modernization.

Otherwise, there is a high chance that system vulnerabilities within the power sector could lead to an un-sustainable power generation system and high power prices for consumers.

Table of Contents

Table of Figures

Country Context

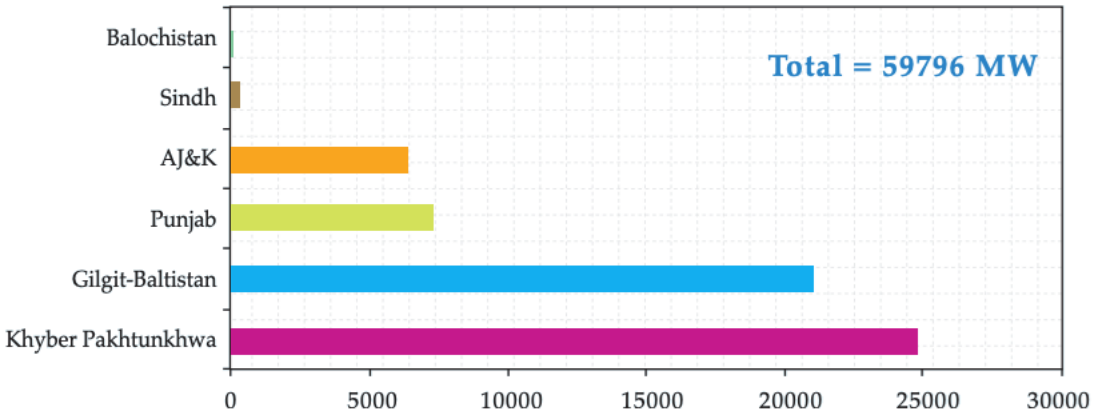
Historic Rise of Hydropower in Pakistan

Pakistan has consistently depended on hydropower for meeting its power consumption needs throughout the years. The country has sought to take advantage of its vast network of rivers, aided by glacier and snowmelt in the Himalayan region and summer monsoons.

The first hydropower project in Pakistan was initiated in 1925 when construction began on the 1 MW Renala Khurd in Punjab for purposes of lifting water for irrigation. Over the years, this capacity has increased manifolds with the addition of mega dams like the 1,150 MW Mangla and 3,500 MW Tarbela dams, which have provided services such as water security, electricity generation and irrigation.

Most of the hydropower potential of the country lies in the northern region; concentrated within the Khyber Pakhtunkhwa province, the Gilgit Baltistan autonomous territory, as well as the Azad Jammu and Kashmir districts, which constitute a significant portion of the country's hydropower pipeline.

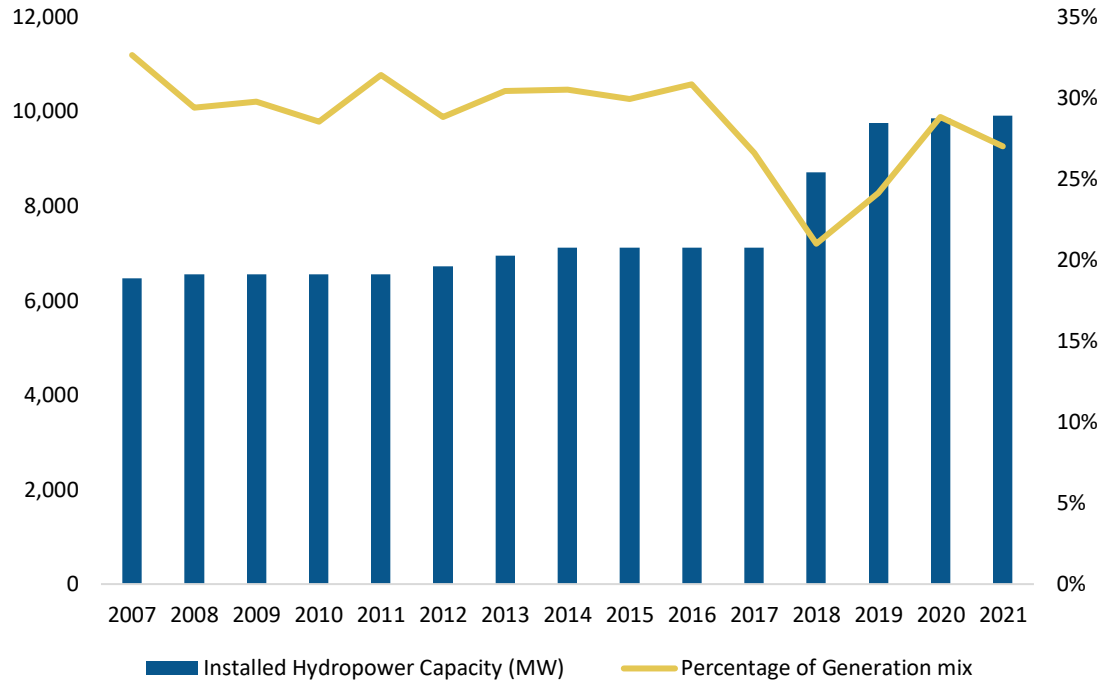
Figure 1: Hydropower Potential in Pakistan



Source: Private Power and Infrastructure Board (PPIB), Pakistan

Hydropower generation has been a cornerstone for Pakistan's electricity mix, in past decades, serving as a majority of dispatchable generation during times of availability. The country's installed hydropower capacity has grown from just 60 MW at the time of partition in 1947 to 9.9 GW as of 2022.

Figure 2: Installed Hydropower Capacity and Hydropower Generation in Pakistan (2007-2021)

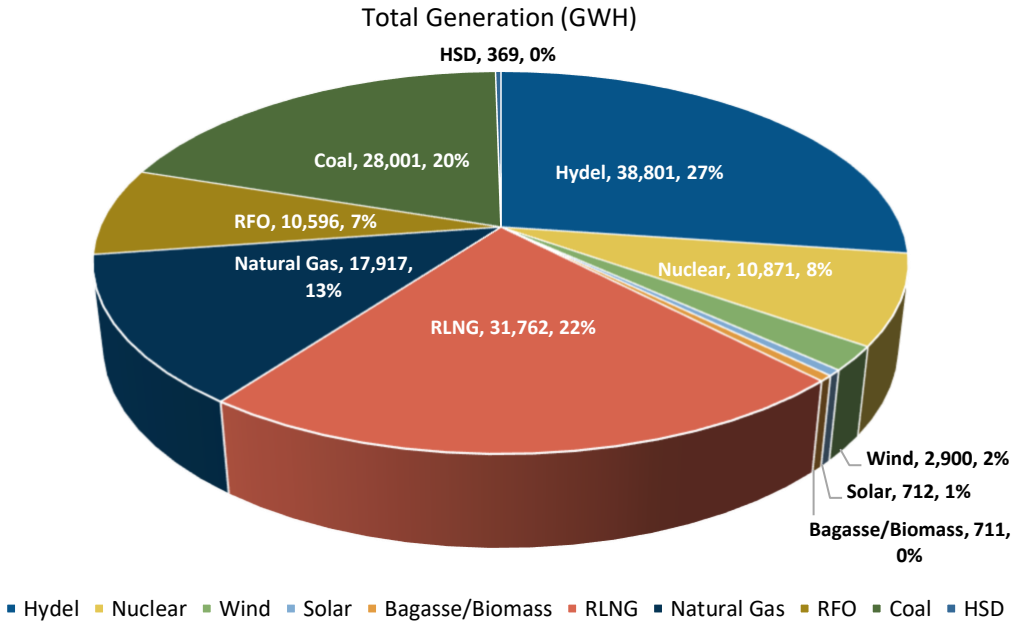


Source: National Electric Power Regulatory Authority (NEPRA), State of the Industry Reports (2007-2021)

Figures above demonstrate how hydropower has historically contributed around 30% of the country's power generation. In FY 2020-2021 alone, around 27% (38.8 TWh) of the country's electricity generation came through hydropower, making it the largest source of power generation.[1]

[1] National Electric Power Regulatory Authority. State of the Industry Report, 2021.

Figure 3: Share of Hydropower in Pakistan's Energy Mix (2020-2021)



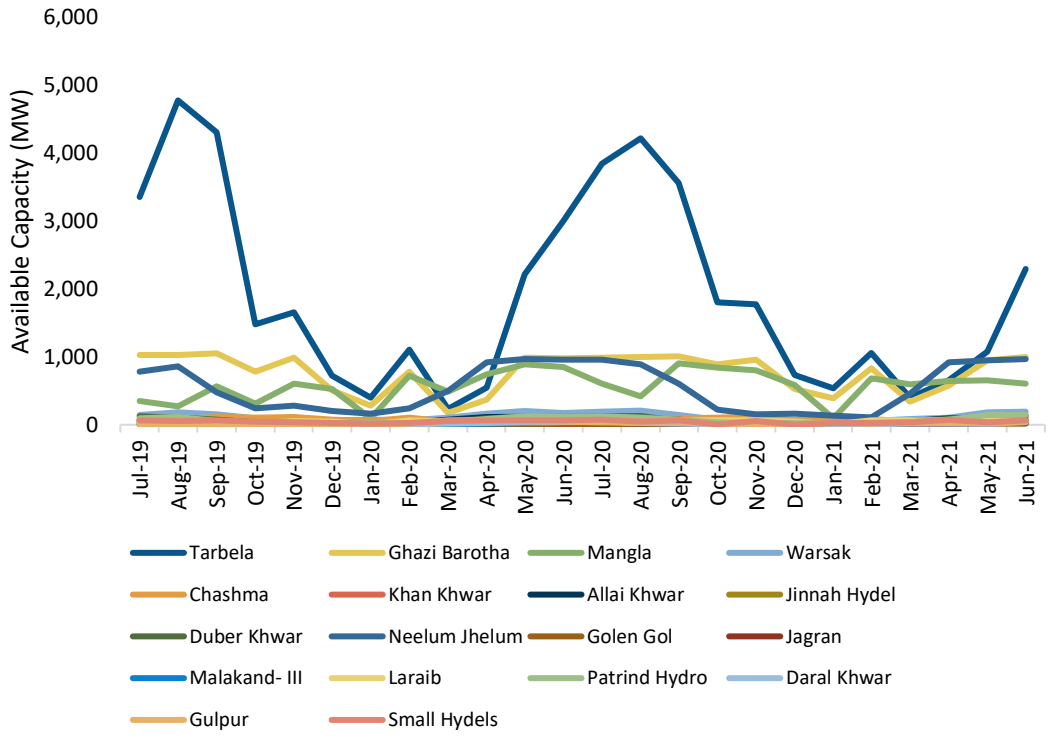
Source: National Electric Power Regulatory Authority (NEPRA), State of the Industry Report 2021.

Despite holding such a significant share of the country's power mix, water stored within hydro power reservoirs and dams isn't solely meant for power generation. Agricultural productivity and irrigation compete with power generation when it comes to water usage. For example, Pakistan's two largest dams. Mangla and Tarbela, are known as seasonal regulators. They depend upon the monsoon season for replenishment, mostly available for power generation during the summer months and drained during the winters for crop production.[2]

The rest of the hydropower capacity follows the same pattern as well, as demonstrated by the chart below. Summer monsoons in Pakistan begin from June every year, lasting till September, coinciding with peak hydropower production in the country.

[2] The Diplomat. The Cost of Pakistan's Dam Obsession. March 04, 2021

Figure 4: Variability in Hydropower Production Levels for Existing Hydropower Plants in the Country

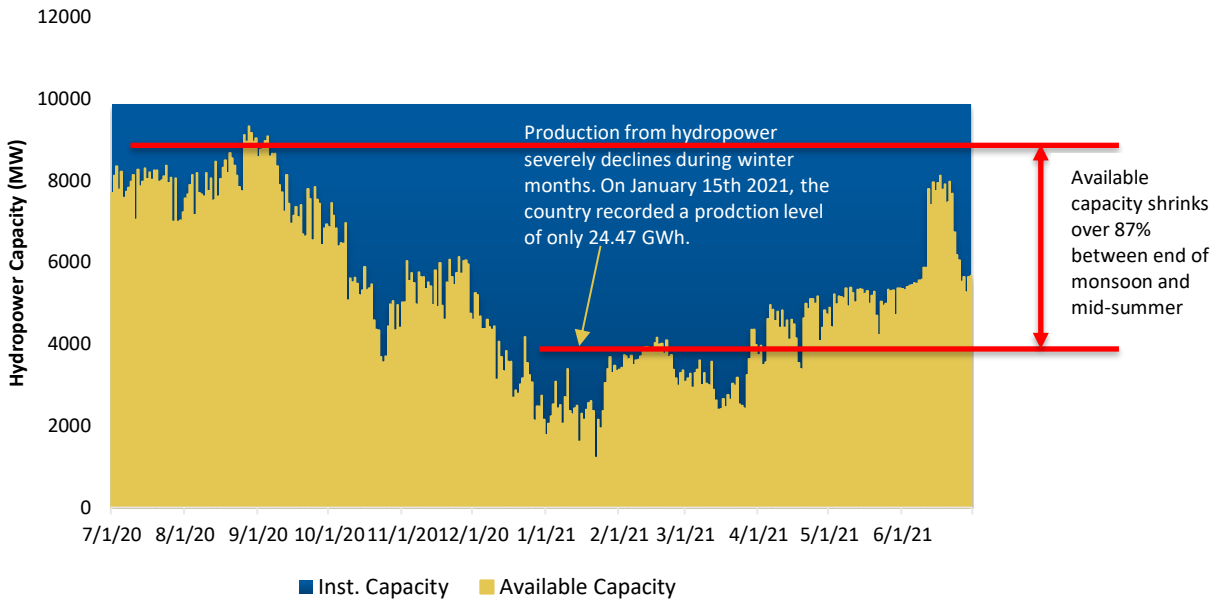


Source: National Electric Power Regulatory Authority (NEPRA), State of the Industry Report 2021

On a collective level, generation levels are also affected by hydropower availability. Hydropower availability for power generation is high during the summer months, then declines rapidly during the winter season until it is only a fraction of the total installed capacity.

In FY21, for instance, Pakistan's hydropower availability declined from a peak of 9325 MW in August 2020, to a mere 13% of 1227 MW in January 2021.

Figure 5: Variation in Total Hydropower Capacity Availability for Power Generation (2020-2021)



Source: National Electric Power Regulatory Authority (NEPRA), State of the Industry Report 2021.

Planned Hydropower Capacity

Hydropower in Pakistan is often considered a symbol of nationalist pride and a fundamental resource for water security. Tarbela dam located within the Swabi district is the World's largest earth filled dam and, at 11.62 Million Acre Feet (MAF), has the second largest reservoir capacity over the globe.

Diamer Bhasha Dam, a behemoth 4500 MW multipurpose dam and hydropower project under construction is said to be the highest roller compacted dam in the world with a reservoir height of 272 metres.[3]

These large, once-in-a-generation dams are considered fundamental to socio-economic development in the country through the provision of water storage capacity and agricultural sustenance.

Several large dams and run-of-the-river projects have thus been in the pipeline for a while. In 2021, the government announced the 'Decade of Dams' program under which more than 10 dams would be built, adding 11.7 MAF of water storage and 9000 MW of power generation to Pakistan's capacity.[4]

Long-term energy planning and new policies on renewable energy have also favored hydropower. The National Electric Power Regulator (NEPRA) for instance has time and again called for the inclusion of hydropower into the official definition of

[3] Dawn. Rs442bn accord for construction of Diamer-Bhasha dam signed. May 14, 2020.
[4] The Express Tribune. 10 projects under 'Decade of Dams' plan announced. October 28, 2021.

Renewable energy (RE) via an amendment to the country's Alternate Renewable Energy Policy (ARE) 2019, which at present doesn't classify the resource as such.[5]

The regulator argues that hydropower is an attractive source of renewable energy due to its low greenhouse gas emissions, its provision of supposedly low-cost electricity and its ancillary services to the grid.[6]

The draft National Energy Plan, available for comment earlier this year, envisages a renewable energy share of 40% (including hydro) by FY2025, increasing to a 60% share in the generation mix by FY 2030. This would be an upward revision of existing targets of 20% and 30% by 2025 and 2030, set by the ARE 2019 policy. Through this policy, the increased capacity targets were to be met mainly through variable renewable energy sources such as solar and wind.

In line with this, the latest iteration of the annual long-term plan, Indicative Generation Capacity Expansion Plan (IGCEP 2021), diversifies the planned energy mix by a revision of renewable energy targets to a 60% share of RE in the generation mix including hydropower. The target is to be met primarily through hydropower contributing 46% of the total power generation in 2030, which will necessitate an addition of almost 14 GW of hydropower capacity.

Table 1: IGCEP 2021- Baseline Scenario for 2030

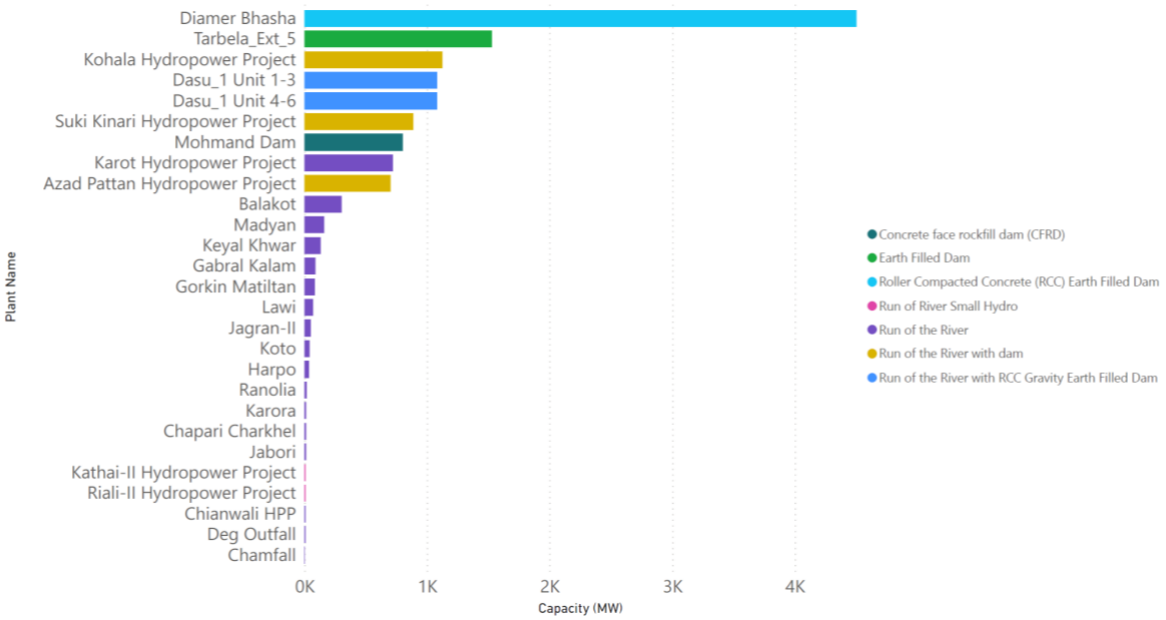
Fuel Type	Current Installed Capacity (MW)	Installed Capacity (MW)-2030	Power Generation (GWh)-2030	Utilization Rate-2030
Bagasse	259	749	3,380	51.5
Cross Border	Non-firm capacity	1,000	3,436	39.2
Gas	3,427	2,582	5,623	21.1
Hydro	9,898	23,653	94,649	49.7
Imp.Coal	3,960	4,920	18,448	35.1
Local Coal	1,320	3,630	23,145	72.9
Nuclear	2,490	3,635	24,910	75.7
Furnace Oil	6,507	1,220	0	0.0
RLNG	5,838	6,786	686	0.5
Solar	400	7,932	15,916	20.9
Wind	1,336	5,005	17,225	35.4
Total	**35,436**	**61,112**	**207,418**	
VRE share %	5%	22%	18%	
Hydropower share %	28%	39%	46%	

Source: Various media outlets, ADB, WB, Power Technology and IEEFA Analysis

[5] Dawn. Nepra orders inclusion of hydropower in renewable energy category. September 6, 2021.
[6] *ibid.*

According to IEEFA analysis, almost 81% of this planned capacity will comprise of large hydropower projects with a capacity over 700 MW. These include dam types such as roller compacted concrete (RCC), concrete face rockfill dam (CFRD) or even run-of-the-river projects with a dam component. Ownership of 9.1 GW (68%) of the pipeline capacity lies with the government while the remainder have been planned in Independent Power Producer (IPP) model.

Figure 6: Type and Capacity of Hydropower Projects in the Pipeline

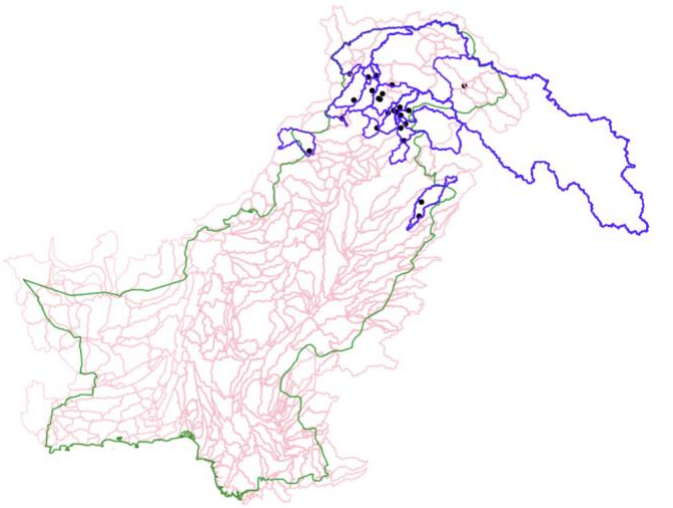


Source: Water and Power Development Authority, Private Power and Infrastructure Board (PPIB), Various media outlets

Apart from a few small or run-of-the-canal hydropower projects, almost the entire proposed hydropower pipeline is located in the northern belt of the country in the Khyberpakhtunkhwa province, or the administrative regions of Azad Jammu and Kashmir (AJ&K) and Gilgit Baltistan.

Although these regions are well connected to the national grid, the remote project locations and specific geographical conditions will necessitate the construction of interconnection facilities and transmission lines.

Figure 7: Location of Proposed/Under Construction Hydropower Projects in Pakistan



Source: Various media outlets, ADB, WB, Power Technology and IEEFA Analysis

Hydropower projects especially large/multi-purpose dams have been difficult to fund historically in Pakistan. Multilateral banks such as the WB and ADB have often had to step in with loans or credit enhancement support for the realization of such plans.

The 3478 MW Tarbela Dam completed in 1978, for instance, was supported by the WB through a loan and two IDA credits amounting to a total of USD 67 million[7]. The WB also acted as an administrator of the Tarbela Development Fund (TDF), bringing in investments and contributions from Australia, Germany, Italy, United Kingdom and the United States.[8]

While the total cost of the project has exceeded slightly over $1.47 billion and a majority of the funds has been contributed by Pakistan itself and international donors, subsequent extensions to the hydroelectric power plant (Tarbela 4th extension and Tarbela 5th extension) are being financed mainly by the WB.[9]

Gazi Barotha, another large dam in Pakistan providing 1450 MW of capacity had funding support from both the WB and ADB. The ADB provided a 25-year loan of USD 300 million and the WB provided a 20 year loan of $350 million.

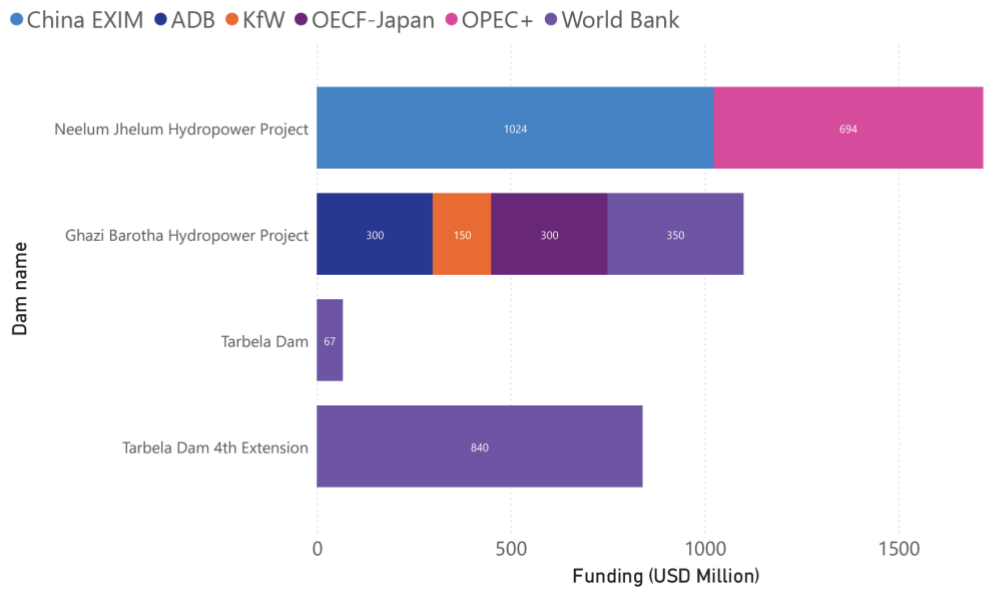
The rest of the foreign financing was covered by development aid through Japan's Overseas Economic Co-operation Fund ($350 million) and Germany's Kreditanstalt

[7] The World Bank. Pakistan-Tarbela Dam Projects. September 15, 1986.
[8] Ibid.
[9] Water Technology. Tarbela Dam.

für Wiederaufbau (KfW) ($150 million). WAPDA also contributed a large share of the funding equalling $1 billion (44.4%) of the total $2.25 billion.[10]

The 969 MW Neelum Jhelum power plant proved extremely difficult to finance as well, with a lack of financing delaying the project for several years until Chinese creditors came to the project's rescue in 2013. Two separate loans were provided by the China Exim bank, including a $448 million China Eximbank buyer's credit loan in 2013, followed by a $576 million preferential buyer's credit loan in 2016.[11]

Figure 8: Sources of Funding for Existing Large Dams in Pakistan



Source: Various media outlets, ADB, WB, Power Technology and IEEFA Analysis

Several projects included in the current pipeline had also been facing financing hurdles until foreign support through development funds or bilateral support from friendly countries breathed new life into them.

Azad Pattan, Karot, Kohala and the Suki Kinari hydropower project are all being financed through the China-Pakistan Economic Corridor (CPEC), with a cumulative funding of USD 7.7 billion. The Suki Kinari Hydropower project and the Karot power project both achieved financial close in 2017, while the Kohala and Azad Pattan projects are yet to achieve financial closure.[12] The Karot hydropower plant recently achieved commercial operations in June 2022.[13]

The first phase of the 4320 MW Dasu Hydropower Project, which includes the construction of the main dam and its hydraulic structures, a 2160 MW hydropower

[10] Power Technology. Ghazi Barotha Run-of-River Hydroelectric Project.
[11] China Aiddata. China Eximbank provides $448 buyer's credit loan for the 969 MW Neelum-Jhelum Hydroelectric Project (Linked to project #54087) (non-CPEC, IPP).
[12] CPEC Authority. CPEC Energy Projects.
[13] SMEC. Karot Hydro Power Project commences commercial operation. July 11, 2022.

generation facility and a 500 KV transmission line from Dasu to Islamabad is being supported by the World Bank. The total cost of the project exceeds USD 4.7 billion, of which almost 50% (USD 2.46 billion) will be covered through the WB in the form of several International Bank for Reconstruction and Development (IBRD) and International Development Assistance (IDA) commitments.[14]

Table 2 below sheds more light on the financing arrangement for current hydropower projects in the pipeline. A 5.2 GW (37%) out of the 14 GW will be financed through MDB support. Most of the projects with support from MDBs will require matching funds from the Government of Pakistan (GoP), which could mean additional economic burden for the country and allocation through public funds. Almost 9.9 GW (70%) of the pipeline requires partial or complete funding by either WAPDA or provincial government bodies in KP, AJ&K and Gilgit Baltistan. The total hydropower pipeline is valued at USD 31.2 billion at present.

Despite such widespread support from the government and multi-lateral financial agencies, IEEFA estimates that only 51% of the pipeline capacity has achieved financial closure and only 39% has begun physical construction. This could hamper the pipeline's ability to come online in time. If power demand continues to rise at predicted rates, the country may experience a serious electricity shortfall in the short to medium term.

[14] The World Bank. Dasu Hydropower Stage I Project.

Table 2: Financial Arrangements for the Hydropower Pipeline in Pakistan

Committed Hydropower Projects according to PPIB/IGCEP

KEY

Financial Closure

✗ Not yet achieved ✓ Achieved GF Government Financing (Partial or Full) CN Chinese Financing MDB MDB Financing G+MDB Government and MDB financing

Plant Name	Capacity (MW)	Agency	Capital Costs (USD mn) - present	Financing Source	Sponsor	Financial Closure	Current Status
Riali-II Hydropower Project	7.08	PPIB	20.05	Unable to arrange financing to due to non-availability of security documents		✗	LOS issued Under FC / under Construction
Suki Kinari Hydropower Project	884.00	PPIB	2000	Exim and ICBC.	SK Hydro Goup and China's Ghezouba group (holds a majority 98% share in SK Hydro).Al-Jomaih Holding, China Gezhouba Group, and Haseeb Khan are sponsoring the project.	✓	FC Achieved. Under Construction
Kathai-II Hydropower Project	8.00	PPIB	22.352	Not yet achieved		✗	LOS issued FC in Progress"
Azad Pattan Hydropower Project	700.70	PPIB	1600	Not yet achieved	Laraib Energy / China Gezhouba Group Company	✗	LOS issued FC in progress"
Kohala Hydropower Project	1,124.00	PPIB	2400	Not yet achieved Foreign banks led by the consortium of China Development Bank are expected to provide 85% of the debt financing, while local banks, led by the syndicate of Habib Bank, are expected to provide the remaining 15% debt.	CTG/CWEI (China Three Gorges) / (CWE Investment Crop)	✗	LOS issued FC in progress
Chianwali HPP	5.38	PPDB	26.6	ADB Loan	ADB	✓	Reportedly in the testing and commissioning phase. Construction Complete
Jabori	10.20	PEDO	21.8	PEDO Funding--70% Loan, 30% Equity	PEDO- Hydel Dvelopment Fund/ Annual Development Fund	✓	Final Stage of Construction
Koto	40.80	PEDO	87.5	PEDO Funding--80% Loan, 20% Equity	PEDO- Hydel Dvelopment Fund/ Annual Development Fund	✓	Final Stage of Construction
Ranolia	17.00	PEDO	36.27	PEDO- ADB Loan-- 80% Loan, 20% Equity (PHYDO)	PEDO- Hydel Dvelopment Fund/ Annual Development Fund	✓	Construction Complete, COD Achieved
Karora	11.80	PEDO	48.5	PEDO Funding--80% Loan, 20% Equity (Local loans)	The project is sponsored by the government of Khyber Pakhtunkhwa through 10% provincial ADP and 90% through Hydel Development Fund/ Foreign Investment.	✓	Final Stage of Construction
Chamfall	3.20	AJK	4.4	Annual Development Budget Allocations AJK	Government AJK	✓	Projet Under Construction According to AJK GoF/ 49% work completed in June 2020
Jagran-II	48.00	AJK	31	Annual Development Budget Allocations AJK	Power Development Organization AJK	✓	Significant progress acheieved on the civil works
Deg Outfall	4.04	PPDB	22	ADB Loan	ADB	✓	Energy Purchase Agreement being signed
Karot Hydropower Project"	720.00	PPIB	1740	Total Equity: 340 mn USD China Three Gorges Corporation: 316.2 (93%) Others: 23.8 (7%) Debt: 1360 mn USD China Development Bank (CDB), EX-IM Bank of China, IFC (100 mn), Other Silk Road Fund	China Three Gorges Corporation (CTG)	✓	Fully operational in June 2022
Gorkin Matiltan	84.00	PEDO	294	Financing by Government of KP- 20%of the costfrom Annual Development Program (ADP) and 80%from Hydel Development Fund (HDF). Debt to Equity: 80:20	PEDO	✓	Under Construction
Chapari Charkhel	10.56	PEDO	21.2			✗	Initial Phase
Lawi	69.00	PEDO	119.17	PEDO: Project financing structure is based on 80:20 debt-equity ratio, though the Project has been entirely funded from PEDO's resources. 80% of the project capital cost is considered to be arranged through sponsor loan and 20% is considered as equity. The proposed reference tariff is based on the following assumptions. A	PEDO	✓	Under Construction
Tarbela_Ext_5	1,530.00	WAPDA	807	WB and AIIB Co-financing: The World Bank is providing US$390 million and the Asian Infrastructure Investment Bank (AIIB) US$300 million. The remaining was supposed to be financed by GoP (Approx. USD 133.5 mn)	WB (IBRD), WAPDA, AIIB	✓	Under Construction
Dasu_1 Unit 1-3	1,080.00	WAPDA	1956.35	IBRD Commitment: USD700 million, IDA : USD 588.40 million plus PCG of USD 460 million. A consortium of local banks led by HBL bank extended financing of Rs144bn ($1.03bn), the first tranche of which was released in May 2017. Credit Issue Bank agreed to offer $350m, of which the first tranche of $188m was released in June 2017. A commercial loan of $2bn is proposed to be obtained from local and foreign banks by utilising the World Bank's PCG. The remaining funds will be provided by WAPDA and the Government of Pakistan.	WB, WAPDA	✓	Under Construction. Significant progress has been made on transmission infrastructure, but civil works and land acquisition are in initial stages of development. Power plant is only 15% complete
Mohmand Dam	800.00	WAPDA	2200	Islamic Development agreed to provide USD 180 milion. Total project cost is US$2.2 billion, and will be co-financed with the Islamic Development Bank, the Kuwait Fund for Arab Economic Development, and the Saudi Fund for Development. OPEC Fund to provide USD 72 million. Pakistan's government is contributing around US$1 billion, through its own resources and from the proceeds of a green eurobond issued last year.	WAPDA, OPEC	✓	Under Construction
Dasu_1 Unit 4-6	1,080.00	WAPDA	1956.35	IBRD Commitment: USD700 million, IDA : USD 588.40 million plus PCG of USD 460 million . A consortium of local banks led by HBL bank extended financing of Rs144bn ($1.03bn), the first tranche of which was released in May 2017. Credit Issue Bank agreed to offer $350m, of which the first tranche of $188m was released in June 2017. A commercial loan of $2bn is proposed to be obtained from local and foreign banks by utilising the World Bank's PCG. The remaining funds will be provided by WAPDA and the Government of Pakistan.	WB, WAPDA	✓	Under Construction. Significant progress has been made on transmission infrastructure, but civil works and land acquisition are in initial stages of development. Power plant is only 15% complete
Keyal Khwar	128.00	WAPDA#	242.6	100 million EIB	KfW Germany, European Investment Bank (EIB), to be financed with a loan from Germany's Kreditanstalt fur Wiederaufbau (KfW), with co-financing from the Agence Française de Développement.	✗	Stalled
Harpo	34.50	WAPDA	94.3	M/s KfW Germany and AFD France signed Loan Agreement with EAD (GoP) for € 20 million & € 50 million on 20.12.2013 & 02.04.2014 respectively.		✓	
Gabral Kalam	88.00	PEDO	230.15	100% Loan financing :WB	Khyber Pakhtunkhwa Hydropower and Renewable Energy Development sponsored by the WB	✓	Construction Expected to start in 2025
Madyan	157.00	PEDO	438.4	WB		✗	Permitting Stage
Balakot	300.00	PEDO	750	ADB Loan : USD 300 million AIIB Loan: USD 250 million The government will invest $175 million in the project	ADB and AIIB	✓	
Diamer Bhasha	4,500.00	WAPDA	14000	The government will provide 30% funding, while the rest will be arranged by the Wapda, WAPDA to invest Rs. 100 billion (500 million USD approx.)	WAPDA	✗	The contractor has commenced the works w.e.f 07.08.2020. Main Dam works are in progress.

Sources: WAPDA, PEDO, AK&K Power Development Organizations, Several media outlets, IEEFA Analysis

Increased Focus on Hydro Problematic for a Myriad of Reasons

Large dam projects have a well-documented track record of major cost overruns and significant delays due to implementation risks that have been confirmed time and again through research. IEEFA speculates that an over-reliance on hydropower to meet 46% of the country's power generation needs by 2030 could be a risky move from an energy security perspective.

The realization of these targets essentially relies on mobilization of project capacity which has already faced significant delays. IEEFA categorizes three risks which could make the realization of this capacity hard to achieve by 2030:

Cost and schedule overruns are a normal occurrence for large dams leading to a huge economic burden on the national exchequer, higher costs of debt financing and non-provision of project benefits. Delays in pipeline realization will most likely lead to power outages and load shedding in the country, and prompt a switch back to fossil fuel based power to bridge the gap

Pakistan and the government's hydropower development wing Water and Power Development Authority (WAPDA) were recently downgraded by all three prominent credit rating agencies: Moody's, Fitch and S&P. This hinders the governments' ability to raise capital for these projects, which could further delay project implementation cycles

The hydropower pipeline is becoming increasingly vulnerable to extreme weather events and climate change. An early onset of summers and droughts could limit water availability in large dams for power generation.

Realized Risks in Hydropower Implementation Undermine Hydro Reliability in Pakistan

Cost and Schedule Overruns Could Constrain Power and Water Availability to the Public

Cost and schedule overruns are a common phenomenon associated with large and multipurpose dams in Pakistan. Geopolitical conflict, lack of financing, natural disasters and local opposition to large dams are just a handful of reasons behind cost overruns and schedule delays in hydropower projects in Pakistan.

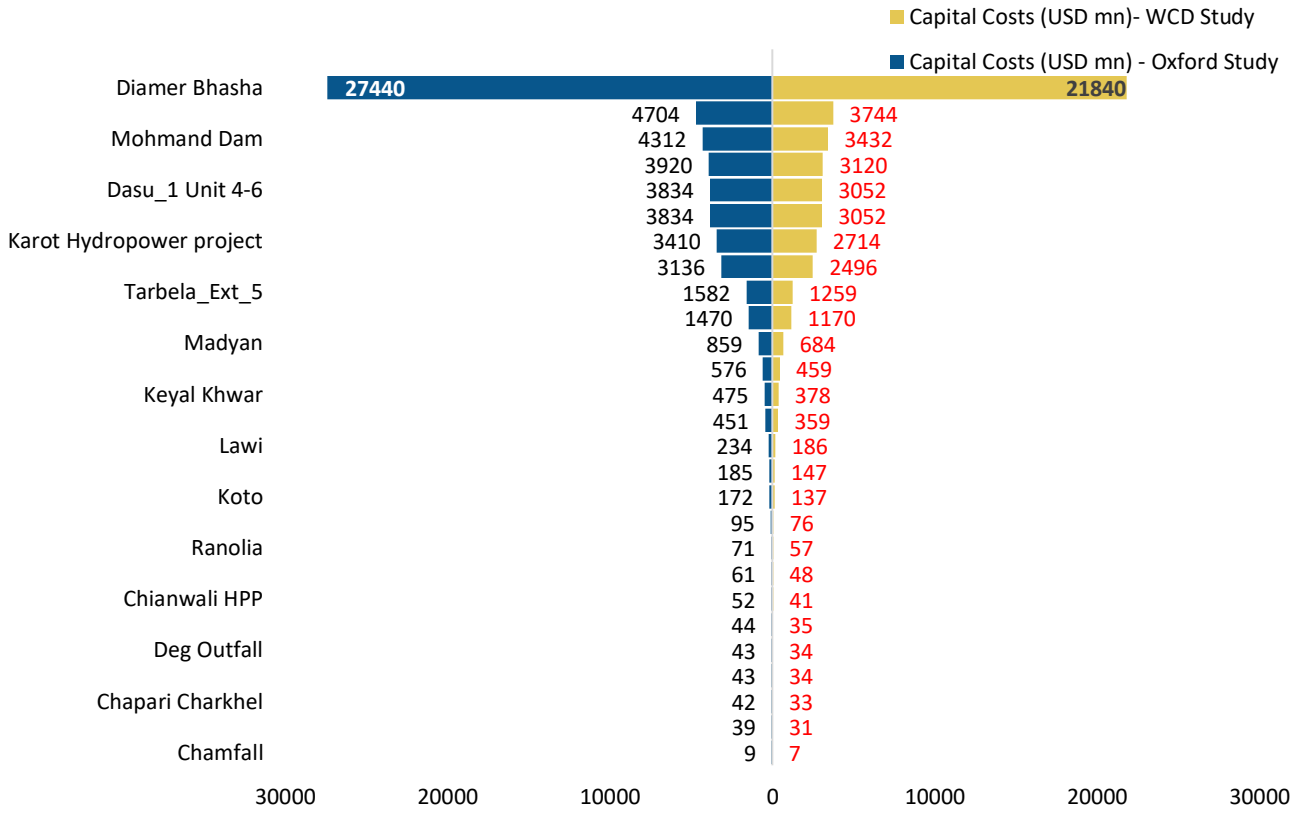
The 2000 World Commission on Dams report was the first attempt to quantify these overruns on a global scale by assessing projects in terms of the variability they faced in achieving their technical, financial and economic targets. The report revealed an average cost overrun of 56% for large dams and 63% for multi-purpose dams. Half

of the dams surveyed failed to meet their implementation timelines as well, with schedule delays ranging from 2 to 10 years.[15]

Evidence does not suggest that these implementation delays improve over time. Another global study carried out by the University of Oxford with a wider sample size of 245 dams reported large dams to suffer from average cost overruns of 96% and schedule delays of 44%.[16]

Based on average cost overrun factors from both studies, IEEFA estimates that the cost of pipeline could go up from USD 31 billion to USD 49-61 billion.

Figure 9: Estimates of Cost Overruns for the 14 GW Hydropower Pipeline in Pakistan Based on Factors Cited by the University of Oxford and the World Commission on Dams



Sources: University of Oxford, the World Commission on Dams and IEEFA Analysis

Factors Impacting Cost and Schedule Overruns

Cost escalation for large dams is usually due to a combination of insufficient site investigation prior to design, unforeseen circumstances during construction, and

[15] The World Commission on Dams. Dams and development; a new framework the report of the world commission on dams. November 2000.
[16] International Rivers. Large Dams Are Uneconomic, Scientific Study Finds. May 3, 2014.

overall poor management of these variables during implementation. Insufficient investigation and design during the feasibility assessment stage lead to poor forecasting of actual costs. Poor performance by contractors and supervisors during construction lead to delays, rework, and additional costs.

Changes in external conditions, both economic and regulatory, which are difficult to predict accurately, can lead to increases in initial project cost forecasts as well. In particular, hydro projects are particularly susceptible to changes in inflation and exchange rates, as they impact the cost of materials, equipment and labor. Any delays in construction compound these cost overruns.

Hydro projects are particularly susceptible to changes in inflation and exchange rates, as they impact the cost of materials, equipment and labor.

Construction costs can also exceed their original forecasts when contractors are faced with actual geotechnical conditions on ground. The rock quality for the foundations of the dam structure and tunnels, as well as the quality of construction materials, cannot be precisely assessed until construction is underway. Unfavorable site conditions may lead to the need for revised engineering and designs, changes of construction technique and materials, culminating in timeline delays and cost escalation.

Delays in commissioning in turn can further escalate the cost of projects by postponing revenue creation and raising costs of debt servicing through an increase in interest accrued on the amount borrowed. Commissioning delays also impact the delivery of benefits to the public by non-provision of power and water supply.[17]

Other factors that could cause delays in project commissioning include labor unrest and opposition by project affected personnel.

As mentioned earlier, only 39% of the hydropower pipeline has actually begun construction, many of which are smaller hydropower projects nearing completion (more details in Table 3 below). A distinct pattern of schedule delays can be observed around these planned power plants; almost 78% of the projects have already exceeded their initial implementation deadlines.

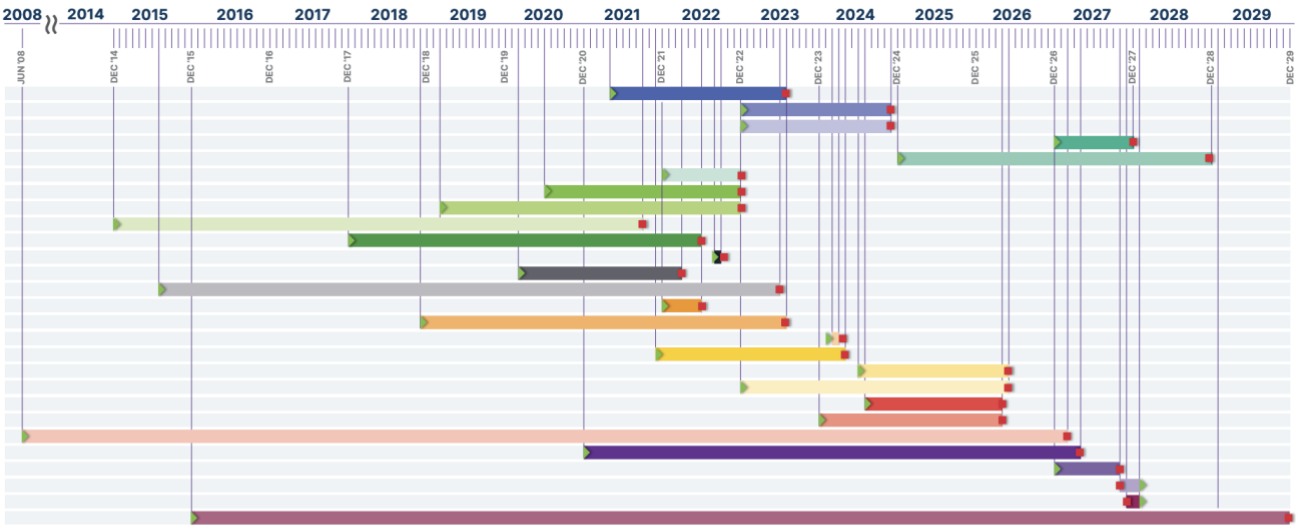
Based on the status of the delays, the percentage of physical progress made on the civil works and construction of powerhouse and the status of financing, IEEFA estimates that only 15% of this planned capacity is likely to come online on time, while the rest maybe delayed well beyond the end of the decade, leading Pakistan to

[17] The World Commission on Dams. Dams and development; a new framework the report of the world commission on dams. November 2000.

miss its target of achieving 60% of the power mix through renewables and hydropower by 2030.

Implementation delays would also create a supply demand mismatch for the country's projected power generation in the future prompting a switch back to thermal fuels such as furnace oil or coal; the very situation it intends to avoid.

Table 3: Project Realization Analysis for Pakistan's Hydropower Pipeline



Plant Name	Financial Closure	Year Proposed	Initial COD	Expected COD
Riali-II Hydropower Project	Not yet achieved	2004	Apr-21	Jul-23
Suki Kinari Hydropower Project	Achieved	2005	Dec-22	Nov-24
Kathai-II Hydropower Project	Not yet achieved	2018	Dec-22	Dec-24
Azad Pattan Hydropower Project	Not yet achieved	2007	2027	Sep-27
Kohala Hydropower Project	Not yet achieved	2009	2025	Dec-28
Chianwali HPP	Achieved	2005	Dec-21	Dec-22
Jabori	Achieved	2011	Jun-20	Dec-22
Koto	Achieved	2008	Feb-19	Dec-22
Ranolia	Achieved	2006	Dec-14	Sep-21
Karora	Achieved	2013	Dec-17	Jun-22
Chamfall	Achieved		Aug-22	Sep-22
Jagran-II	Achieved	2010	Feb-20	Mar-22
Deg Outfall	Achieved	2005	Jul-15	Jun-23
"Karot Hydropower Project"	Achieved	2007	Dec-21	Jun-22

Plant Name	Financial Closure	Year Proposed	Initial COD	Expected COD
Gorkin Matiltan	Achieved	1996	Nov-18	Jul-23
Chapari Charkhel	Not yet achieved	2019	Mar-24	Mar-24
Lawi	Achieved	2016	Nov-21	Apr-24
Tarbela_Ext_5	Achieved	2016	Jun-24	May-26
Dasu_1 Unit 1-3	Achieved	2009	2023	May-26
Mohmand Dam	Achieved	2000	Jul-24	Apr-26
Dasu_1 Unit 4-6	Achieved	2009	2024	Apr-26
Keyal Khwar	Not yet achieved	2004	Jun-08	Feb-27
Harpo	Achieved	2002	2021	Apr-27
Gabral Kalam	Achieved	2016	2027	Oct-27
Madyan	Not yet achieved	2016	Jan-28	Oct-27
Balakot	Achieved	2016	2028	Nov-27
Diamer Bhasha	Not yet achieved	2006	2016	Dec-29

Initial COD Expected COD

Sources: WAPDA, PEDO, AK&K Power Development Organizations, Several media outlets, IEEFA Analysis

Case Studies: Current Hydro Projects Facing Implementation Delays and Cost Overruns in Pakistan

Neelum Jhelum hydropower project. The 969 MW Neelum Jhelum hydropower project (NJHP) is a classic demonstration of how all these factors can combine to unprecedented cost escalation and schedule delays. The project was initially proposed in 1987 with a PC-I[18] cost of Rs. 15.25 billion, an implementation schedule of 90 months and a capacity of 500 MW. Non-availability of funds however

[18] PC-I means the Planning Commission's form for the planning and budgeting of public development projects.

prevented the project from getting initiated. The project design was then revised in 1997 where the project capacity was increased to the 969 MW.

Based on the new project design a revised project cost of Rs. 84 billion was approved in 2002, however project activities could not begin on time. In 2005 the project site was struck by an earthquake, which further delayed progress on the project till 2008, when the project design was reviewed again post-earthquake. At this point, the project didn't have any funding, nor was there any land availability or access to electricity for the construction activities to commence. The project design was revisited once again in 2010, and two Tunnel Boring machines were added instead of the conventional drill and blast (D&B) methodology to speed things along. The project cost also subsequently readjusted to Rs. 272 billion in 2013, but financial close couldn't be achieved.

At this point the project had a scheduled completion date of November 2016, yet project milestones couldn't be met and the project cost had to be revised upwards to Rs. 404 billion. The project was finally completed in 2018 with a cost of Rs. 507 billion ($4.1 billion)-600% higher than its initial estimate and a schedule delay of 21 years.[19] The NJHP also wasn't able to achieve financial close until it reached commercial operations.[20]

In addition to the extra cost the project incurred on behalf of lack of financing and revisions to project design, the project continues to be problematic even after its operations. In July 2022, the project was shut down as cracks developed within its tail race tunnels. Though experts speculate that the fault may be due to geo-technical reasons, the exact cause hasn't been identified yet. The plant will remain shut down for six months as contractors aim to identify and repair the fault.[21]

This plant closure couldn't have occurred at a more unfortunate time, as the country faces extreme heat and peak summer demand. The plant shutdown has thus led to an almost immediate removal of 969 MW of dispatchable generation from the national grid, further exacerbating the energy shortage the country has been experiencing since the heatwaves of March.

It is reported that the closure of the power station took the country's generation shortfall to 7.3 GW, which is 21% of the country's current installed capacity. This has resulted in in widespread load shedding across the country, which goes up to 16 hours in rural regions.[22] The country will also have to rely on imported fossil fuels such as furnace oil, coal and LNG to replace the gap left by the NJHP, resulting in more expensive power generation and higher electricity bills for the consumers.

Diamer Bhasha dam. The controversial dam project was first envisioned in 1980 but wasn't officially approved until 2006, when the then president Gen. Parvez

[19] Auditor General of Pakistan. Performance audit report on neelum jhelum hydropower project muzaffarabad audit year 2016-17. July 2018.
[20] Profit. Delays caused Neelum-Jhelum project cost to balloon to Rs500 billion. May 3, 2018.
[21] The News. Closure of 969 MW Neelum-Jehlum hydropower project: Chinese contractor mobilised at the site. August 01, 2022.
[22] Geo News. No power generation from Neelum-Jhelum plant for six months. Jul 19, 2022.

Musharraf green lit the project at an initial cost of USD 6.5 billion and a completion period of 10 years.[23] The mega-dam project had been a subject of contention between the downstream province Sindh and the federal government on the premise that it would reduce downstream flows of the River Indus to the region.[24] In addition to political opposition, the Dam has also sparked debate due to its location in Gilgit Baltistan, which experts fear is a zone of high seismic activity.

In 2014, the project site led to internal conflict between KP and Gilgit Baltistan over boundary issues, claiming the lives of many. These boundary disputes were only resolved in January 2022 when victims of the conflict were compensated monetarily for the losses they had incurred.[25]

The project site has also been disputed by India, which has voiced its concerns at various international forums which have prevented Multilateral development banks such as the WB and ADB from showing financial interest in the project. In 2017, the government considered making the Diamer Bhasha Dam a part of the CPEC, but later withdrew its decision due to tight monetary policies by the Chinese. The government then tried to raise public funds for the project by running a donation campaign within the country in 2018 but was only able to raise Rs.10 billion by 2019.[26]

Work on the project was finally able to begin in 2020 when the government awarded the construction contract of the dam portion to a joint consortium between China Power and Frontier Works Organisation (FWO). The contract is worth Rs.442 billion or approximately USD 2 billion[27], while the entire project is currently valued at USD 14 billion.[28] The project is slated for completion by 2029[29], which is highly unlikely given that funding is only available for the dam site right now and construction is yet to begin on the powerhouse and a major portion of the land acquisition in KP is yet to take place. Overall physical progress on the dam is only 7% right now.[30]

WAPDA had been able to raise funds for the project through a Eurobond it issued in 2021[31], but the USD 500 million that was raised had to be received in PKR in Pakistan, due to Pakistan's banking regulations.[32] The amount isn't worth the same anymore, due to the rupee losing 31% of its value only this year. It has also been reported that the Rs.442 billion construction contract awarded for the dam is only

[23] Dawn. All reservoirs will be built: Musharraf: Diamer-Bhasha dam project launched. April 27, 2006.
[24] The Daily times. Diamer Bhasha Dam: Many a slip between the cup & the lip. August 16, 2020.
[25] The Express Tribune. Border dispute over Diamer-Bhasha dam resolved. January 12, 2022.
[26] The Express Tribune. PAC summons ex-CJP Nisar over dam fund. August 24, 2022.
[27] Dawn. Rs442bn accord for construction of Diamer-Bhasha dam signed. May 14, 2020.
[28] Dawn. Opinion: The Diamer-Bhasha dam is neither green nor cheap. November 10, 2021.
[29] The News International. Hydropower Potential.
[30] WAPDA. Diamer Bhasha Dam.
[31] Dawn. Wapda floats first green Eurobond for $500m. May 28, 2021.
[32] Business Recorder. Weak PKR exacts a toll on Wapda's Eurobond as well. August 5, 2022.

worth Rs.336 billion at present which will necessitate a revision of PC-I costs for the dam.[33]

Keyal Khwar hydropower project. Keyal Khwar hydropower project, a 128 MW hydropower generation facility has also been pending since 2004 and is now projected to be completed by 2027. The project was initially approved in 2004 with a PC-I cost of Rs.7.1 billion, which was then revised twice: first in 2014 to Rs. 27.8 billion and then a slightly downward revision to Rs. 26.1 billion in 2016.

A detailed engineering design for the project was completed in 2011, but actual progress on the scheme still remains in the initial stages. In 2017, the civil works contract for the project was terminated on accounts of non-performance of the contractor. To date, the retendering for the contractor is still in place.

Due to these delays, the cost of the project has ballooned up and new PC-I cost amounting to Rs. 49.7 was submitted for the project in July 2021, a jump of almost 700% from its initially proposed cost in 2004.[34]

The COVID-19 pandemic and insufficient land acquisition are leading to delays in project progress.

Dasu hydropower project. More recently, the World Bank-funded Dasu hydropower project also became the subject of national news as the project got delayed by three to four years. The 4320 MW project is supposed to be constructed in two phases of 2160 MW each, with the first phase coming online by 2023-2024.

However, the COVID-19 pandemic and insufficient land acquisition are leading to delays in project progress. A bus carrying Chinese officials to the project site was attacked by terrorists resulting in the loss of life of nine Chinese officials and four Pakistanis.[35] Security concerns for other workers halted construction work at the project site for almost six months until project activities were resumed in January 2022. Victims of the attack were offered compensation packages ranging from USD 4.6 to USD 20.3 million, while the project contractor China Gezhouba Group Company also refused to resume work at the site unless paid a compensation of USD 37 million.[36]

[33] The Express Tribune. Rupee's fall increased Diamer-Bhasha dam's cost, NA panel told.
[34] WAPDA. Keyal Khwar Hydropower Project.
[35] BBC. Chinese engineers killed in Pakistan bus blast. 14 July 2021.
[36] The Express Tribune. China resumes work on Dasu Hydropower Project. January 20, 2022.

Together these delays have led to cost overruns of almost Rs. 100 billion (USD 450 million).[37] The project was initially approved in 2014 with a total cost of USD 3.9 billion,[38] but now faces an overrun of almost 12%.

High project costs not only necessitate additional funding by project investors but are also likely to result in an economic burden for both the government and end-consumers. Hydropower projects financed by multilateral development banks (MDBs) or the government usually come with very long debt servicing periods in order to rationalize tariffs and keep them low. Cost recovery, especially for government owned projects, becomes an uphill task. This could also lead to a higher cost of electricity for end-users, as project costs are passed on to consumers especially for IPPs.

High project costs not only necessitate additional funding by project investors but are also likely to result in an economic burden for both the government and end-consumers.

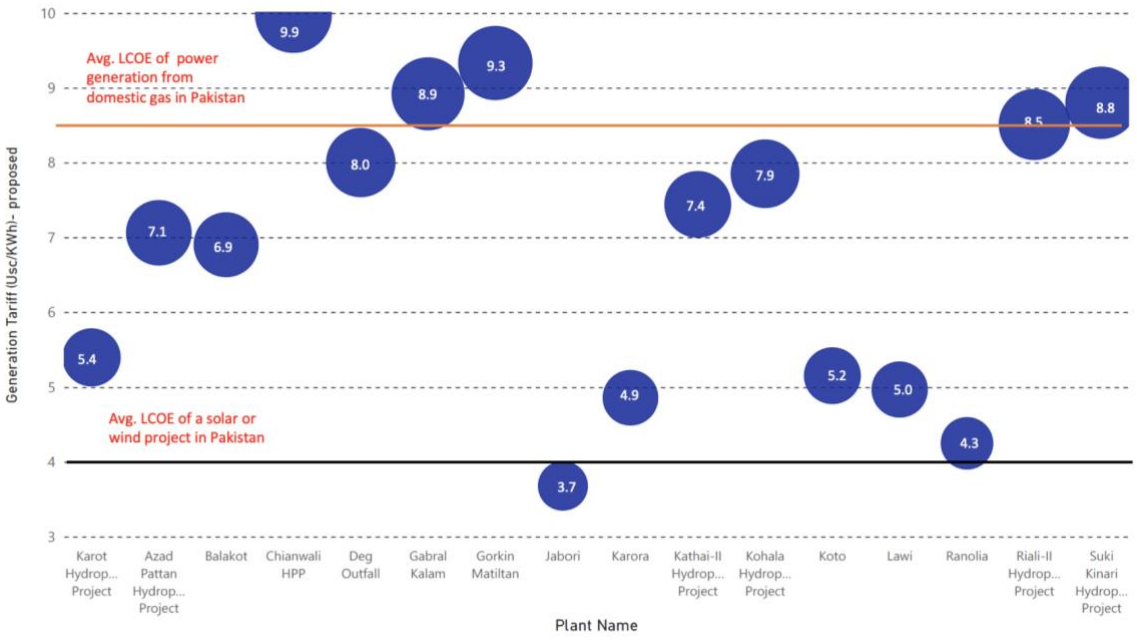
The Neelum Jhelum Hydropower Project for instance has a 28 year debt servicing period, yet still serves as the most expensive hydropower project in Pakistan with a tariff of Rs.9.1/KWh[39], almost 3.3 times higher than its original tariff of Rs.2.77/KWh.[40]

Moreover, proponents of hydropower generation can often be seen pushing for the technology, on the premise that it produces 'cheap' electricity. While this may be true for older plants and nationalized assets, which have written off their debt, it certainly doesn't hold for newer plants which will be coming online.

IEEFA's analysis of proposed tariffs for hydropower plants currently in the pipeline reveal that the average cost of generation will range between 4-10 usc/KWh (These are pre-COD tariffs, actual cost of generation may be much higher). This is on parity with the cost of generation on domestic gas (8.5 usc/KWh on average), but much higher than power generation cost from variable renewable energy sources such as solar and wind (4 usc/KWh on average).

[37] The News International. Rs100bn cost overrun likely to hit Dasu hydropower project. August 09, 2022.
[38] The World Bank. Dasu Hydropower Project Stage-I.
[39] The Express Tribune. Neelum-Jhelum project to sell power at Rs9.1 per unit. August 03, 2021.
[40] Dawn. Neelum-Jhelum project: delays and cost over-runs. December 26, 2011.

Figure 10: Cost Comparison for Power Generation in Pakistan (Proposed Hydropower Plants, Domestic Gas and Renewables)



Sources: NEPRA, WAPDA, PEDO, AJ& K Power Development Organization, State of the Industry Report 2021

Pakistan's Ability to Raise Capital Hampered by Recent Credit Downgrades

Pakistan's ability to raise capital from external sources took a massive blow earlier this year as the country was downgraded by all three prominent credit rating agencies including Moody's, Fitch and Standard and Poor's (S&P).

Moody's was the first one to act, downgrading the country's outlook from stable to negative (B3) citing Pakistan's "heightened external vulnerability risk and uncertainty around its ability to secure additional external financing to meet its needs" in June.[41]

Pakistan's poor economic performance can be attributed to global uncertainty after the COVID-19 pandemic and the impact of Russia's invasion of Ukraine on the price of imported commodities and fuel. Internal political turmoil and conflict amongst the country's own political parties has also been a major reason behind its external vulnerability risk.

The Pakistani rupee has lost 30% of its value so far in 2022 alone and the country's foreign exchange reserve dipped dangerously below $10 billion, enough to cover only two months of imports. According to Moody's, the country's weak institutions and poor governance adds uncertainty around the future direction of

[41] Bloomberg. Moody's Lowers Pakistan Outlook to Negative Over IMF Delay. June 2, 2022.

macroeconomic policy, including whether the country will complete the current International Monetary fund (IMF) program; a $6 billion bailout package that has been hanging in the balance for months now.[42]

Inflation has also been at record high in Pakistan, as consumer prices rose 27.26% in August 2022, in comparison to 2021. This puts inflation in Pakistan at a 47 year high since 1975. Pakistan's high level of imported fuels and commodities had already been creating an upward pressure on food, fuel and electricity prices within the country amidst political uncertainty however, the current inflation mainly arises out of the devastating floods the country has been experiencing since June 2022.

Pakistan's high level of imported fuels and commodities had already been creating an upward pressure on food, fuel and electricity prices.

The country's north and south have been badly affected by recent floods due to record monsoon rainfall, leading to loss of infrastructure, lives and agricultural activity in more than 50% of the country. As floods continue to wreak havoc on the country's food supplies, agricultural produce will likely have to be imported from neighboring countries such as Afghanistan and Iran in order to avert a food crisis.[43]

Shortly after the Government of Pakistan's downgrade, the government's hydropower development wing, Water and Power Development Authority (WAPDA), was also downgraded by Moody's owing to the agency's close linkages with the government. WAPDA was assigned a B3 corporate family rating (CFR) and a B3 Baseline Credit Assessment (BCA). Moody's official statement reads that the downgrade reflects the close linkage of the entity's credit quality with that of the GoP because of the government's full ownership and direct supervision of the organization.

Due to these close ties, WAPDA is more than likely to receive support from the government in its time of need, however this support is offset by the risks arising from the Pakistani government's low policy predictability and consistency.

WAPDA's financial performance stemming from the organization's inability to collect revenue itself along with the sizable hydropower capacity expansion plan it

[42] Bloomberg. Pakistan's Outlook Cut to Negative by S&P on Rupee's Free Fall. July 28, 2022.
[43] Bloomberg. Pakistan Inflation Hits 47-Year High Before Full Impact of Flood. September 1, 2022.

has, the long receivables cycle and delayed tariff decisions were also listed as a reason for concern by the credit rating agency.

While the company's weak financial performance is driven primarily by the Central Power Purchasing Authority's (CPPA) ability to pay back the hydropower producer due to the significant cash shortfall it experiences in the form of circular debt, tariff delays and the long receivables cycles are due to bureaucratic hurdles and the regulatory structure of power purchase agreements in Pakistan.

Moody's also predicted WAPDA's 'funds from operations (FFO)' to debt ratio to remain weak over the next two years due to the company's plans to spend sizable capital in order to expand its hydropower production capacity coupled with the continued inability to collect revenue in time. Liquidity will also be an issue as Moody's considers the company's cash balance of PKR 158 billion as of 31 December, 2021, insufficient to cover its capital spending and maturing debt in 2022.

From an Environmental, Social and Governance (ESG) perspective, Moody's considers WAPDA exposed to increasing climate risks in the form of extreme weather patterns. WAPDA's inability to get its tariffs adjusted timely as well as the high cost of power generation from costly hydropower plants could also trigger affordability concerns from a social angle.[44]

WAPDA's inability to get its tariffs adjusted timely as well as the high cost of power generation from costly hydropower plants, could also trigger affordability concerns from a social angle.

Following Moody's Fitch's and S&P also downgraded Pakistan's credit outlook from stable to negative in July, listing the same concerns as Moody's. By this time, the country's economic performance had worsened, with the rupee depreciating even further, the fiscal deficit worsening to 7.5% of the GDP (from 6.1% in FY21) and an IMF support deal still not secured. Soaring oil prices and a rising consumption of non-oil imports had also led to an increase in the Current Account Deficit (CAD) which now stood at USD 17 billion.[45] [46] Consistent with its Government of

[44] Moody's investor service. Rating Action: Moody's revises Pakistan Water and Power's outlook to negative; B3 rating affirmed. 03 Jun 2022.
[45] Dawn. S&P downgrades outlook on Pakistan's long-term ratings to 'negative'. July 29, 2022.
[46] Fitch Ratings. Rating Action Commentary Fitch Revises Pakistan's Outlook To Negative; Affirms At 'B-'. 18 Jul, 2022.

Pakistan sovereign credit rating, Fitch also revised WAPDA's outlook to negative from stable to match.[47]

These credit downgrades could highly impact the government's ability to provide financing for the considerable hydropower capacity it intends to fund. Projects supported by the government are financed through the Public Sector Development Programme fund or through commercial financing raised through local or foreign banks.

WAPDA mainly acts as the conduit for channeling these funds towards the projects, but is known to provide financing itself to some projects too. For instance, in the case of the Mohmand and the Diamer Bhasha Dam, WAPDA issued its first Eurobond to secure USD 500 million for the construction of these projects. The company had plans to raise additional funds through subsequent green bonds issuances, but this may not be practical given the firm's negative credit rating will force it to pay a higher interest rate on the bond principal, raising the costs of these hydropower projects further.

Pakistan's dollar denominated bonds currently show a mixed performance already, with those due in 2030 quoted below 60 cents on the dollar.[48] IEEFA predicts that demand from investors for Pakistani bonds is likely to stay weak amidst the bleaker outlook on upcoming bond financing. WAPDA's credit downgrade to negative could deter bond subscription or future financing.

If the country is unable to raise sufficient debt in time to fund these projects, the 6.6 GW of capacity that is yet to achieve financial closure may face significant financing hurdles leading to even more cost overruns and implementation delays. In instances where the government is supposed to match MDB funding, this could even lead to the MDB's withdrawing from the project. The 1450 MW Ghazi Barotha Hydropower project was stalled in 1997, due to the government's inability to match funding by the donor agencies. The government had been undertaking some deficit cutting measures prompted by the IMF due to which it could not support the hydropower project in time. As a result, many of the planned infrastructure for the hydropower project [including bridges and culverts] could not materialize.[49]

As credit downgrades emerged one after the other for both Pakistan and WAPDA, there was high speculation in the market that the country would default. Pakistan desperately needed forex reserves to provide stability to its economy in the immediate term as a mitigating factor. Fortunately, almost $5 billion in deposits or loans rolled over by friendly countries: a $2.3 billion loan rollover by the Chinese[50] and a $3 billion deposit rollover by Saudi Arabia,[51] which stabilized the country's rapidly depleting foreign exchange reserves to a degree. The IMF programme was also revived and a $1.1 billion tranche was received by the State Bank of Pakistan at

[47] Fitch Ratings. Fitch Revises Outlook on WAPDA to Negative on Sovereign Rating Action. 25 Jul, 2022.
[48] The Nation. Crucial IMF Meeting For Revival Of Bailout Package Today. Aug 29, 2022.
[49] Power Technology. Ghazi Barotha Run-of-River Hydroelectric Project.
[50] Dawn. $2.3bn Chinese loan expected 'within couple of days', says Miftah. June 23, 2022.
[51] The Express Tribune. Stocks surge as Riyadh rolls over $3b deposits. August 15, 2022.

the end of August but comes with a heavy tag of increased taxation and energy prices.

These achievements worked in favor of the country's economy but only temporarily. The rupee now continues to depreciate against the dollar, as the greenback strengthens globally[52] and inflation continues to rise due to elevated energy prices. The IMF predicts that Pakistan's inflation would be sustained at 20% in the near future, while its GDP growth would decline to 3.5% in FY 23.

Spillovers from the Russia-Ukraine war would continue to exert an upward pressure on food and duel prices, while political uncertainty and policy reversals undermine the country's external stability.[53] It would thus be crucial for Pakistan to curb spending, in order to maintain liquidity which could very well mean a lack of financing for the 14 GW hydropower pipeline the country hopes to build by 2030.

Increased Vulnerability to Extreme Weather Patterns and Climate Change

Hydropower generation projects can also be made riskier by the effects of climate change, which could prevent them from delivering the very benefits that formed the premise for their construction. Designs for many new dams and planned dams have been created without using up-to date climate models or precipitation data.

As a result, these projects could be relying on data that over-estimates rainfall or underestimates the climate risk to project sites, putting the financial viability of these projects into question or raising risk for communities and workers.

As weather patterns become more unpredictable and extreme with the on-set of every year, the risk of hydropower generation becoming an unreliable source of power generation in the case of extreme weather events such as droughts or excessive rainfall becomes even more real.[54]

History has countless examples of how extreme weather patterns have affected hydropower availability for over-reliant countries, but we won't need to go any further than this year to demonstrate how unprecedented levels of heat and drought can affect a country's hydropower production levels.

China

A record-breaking drought hit Southwest China in July, causing many rivers including the mighty Yangtze to dry up. Sichuan province which relies 80% on hydropower for its energy needs was hit the hardest, as water levels to reservoirs located within the region dropped by half.

---

[52] Global Village Space. Rupee continues to depreciate despite the revival of IMF loan programme. 7 September 2022.
[53] Dawn. Inflation, global conditions will continue to weigh on Pakistan's economy: IMF. September 2, 2022.
[54] Bloomberg. The dangerous future of hydroelectric power. March 15, 2022.

The situation was compounded further as the extreme heat caused electric demand to soar by 25%. Unable to meet the rising demand, Sichuan had to suspend or limit power supply to thousands of factories and rationed power usage for residential consumers. Reduction in water flows on the Yangtze also disrupted major shipping routes.[55]

As hydropower reservoirs supply water for competing usages such as drinking purposes and agricultural activity, the government had to arrange for alternate means of water provision resulting in economic losses worth 2.73bn yuan (£340m), affecting 5.5 million people in July alone.[56]

Europe

Droughts have also rattled parts of Europe throughout the first half of FY 22, severely impacting hydrological flows in major European rivers such as the Rhine and the Loire and dampening hydropower generation prospects.

Sustained high temperatures and low rainfall saw hydropower production levels drop significantly in France, Italy and Spain during the first half of year 2022. In France, a rainfall deficit of about 84% in the month of July caused lakes and river stocks dropped to a 20-year low. In the Rhone Valley, the Alps and the Cote d'Azur region, responsible for more than 70% of France's hydropower capacity, hydroelectric power capacity fell by 60% since the beginning of this year.

In Italy, River Po, the main source of Italy's hydroelectric power saw a 50% decline in its levels, leading to a 40% reduction in hydroelectric power supply in the country since January. Spain's major dams are facing a 27 year low in their reservoir levels, while hydropower capacity only stands at 36.9%.[57] [58] [59]

In Norway, where 90% of the power comes from hydropower, reservoir levels are below 50% which will not only affect availability of power within the country but will also hamper exports to UK, which is already reeling from a power crisis brought on by high gas prices in the wake of the Russia-Ukraine conflict.[60] [61]

[55] The Guardian. China drought causes Yangtze to dry up, sparking shortage of hydropower. 22 August 2022.
[56] The Guardian. China drought causes Yangtze to dry up, sparking shortage of hydropower. 22 August 2022.
[57] Business Standard. Energy crisis deepens in Europe as high temp, drought hits power supply. August 23, 2022.
[58] Bloomberg. Spanish Dams at 27-Year Low as European Energy Crisis Widens. August 23, 2022.
[59] S&P Global. Droughts rattle Europe's hydropower market, intensifying energy crisis. 05 Aug 2022.
[60] Reuters. Norway scrambles to avoid empty hydropower reservoirs this winter. July 7, 2022.
[61] Islamabadpost. Water crisis: Panic spreads as Tarbela dam hits dead level. May 23, 2022.

Pakistan

Pakistan too experienced an early onset of summers this year, leading to a record-breaking heat wave with temperatures exceeding 40 degrees for over two months. Due to the high temperatures and no rainfall, water capacity levels fell for all major reservoirs, Tarbela, Mangla and Chashma in Pakistan. Tarbela in fact reached dead pool level leading to a massive reduction in hydropower output. This was a repeat of last year when hydropower production levels at Tarbela decreased by 62%, as 13 out of 17 units at the plant went offline due to low reservoir levels, intensifying the power crisis in the country.[62]

Evidence suggests that these extreme weather events are becoming more frequent. This does not bode well if Pakistan continues to rely on hydropower to serve 46% of its future consumption needs by 2030 as planned in the IGCEP. A significant portion of the pipeline hydropower capacity has also been planned as run-of the river projects to reduce their environmental impact. Run-of-the-river projects are heavily dependent on seasonal rainfall for replenishment, which in Pakistan would translate to the monsoons.

As monsoons become more erratic and unpredictable, the power generation capacity of these hydropower projects and hence the revenue they could generate becomes equally uncertain.

In addition, it is highly likely that insufficient hydropower production could prompt a shift back to fossil fuels, this would not only defeat the purpose of building more hydropower, but also undermine the country's struggle to move away from expensive imported fuels.

Recommendations

Hydropower's role as a dispatchable source of power generation cannot be denied. However, large hydropower projects, especially those that involve the construction of massive dams, are proving to be not only difficult to finance, but may also carry a significant environmental footprint.

IEEFA recommends that a clear criterion be set for projects within the pipeline in times of such economic distress.

Projects that are yet to achieve their financial closure or begin construction should be put on hold, while the existing hydropower capacity should be complemented with a portfolio of solutions which are smaller, quicker to build and easier to finance.

The goal is to meet its power generation targets on time and avoid exacerbating the power crisis by focusing on projects which are likely to succumb to implementation delays.

---

[62] Billinfo.pk. Production from Tarbela Dam fell by 62%, power crisis feared to intensify. Lower water level affects hydropower generation in Tarbela, WAPDA. June 28, 2021

1. Install Floating Solar on Existing Hydropower Reservoirs and Canals

The cost-competitiveness of utility-scale wind and solar assets in Pakistan is a known fact, however regulatory hurdles and policy inconsistency have prevented their widespread penetration into Pakistan's national grid.

At present, only 1200 MW of wind and 430 MW of solar powered capacity has been added to the system, while almost 8.4 GW of solar and wind capacity remains in the pipeline waiting for regulatory hurdles to be removed or competitive bidding to occur.[63]

While this capacity remains in the pipeline, another modular approach can be adopted which would not only complement the existing and planned hydropower projects soon to be realized, but would also add to their economic competitiveness.

The addition of floating solar photovoltaic (FPV) to hydropower assets can open up new opportunities for scaling up solar power, especially in countries like Pakistan with high population densities and competitive usages for available land. Installing FPVs on existing hydropower reservoirs could offer benefits such as the ability to utilize existing transmission networks, a close proximity to load centers, as well as improved energy yields due to the cooling effect produced by the presence of solar PV on reservoirs.[64]

Suitable areas for installation of solar PVs on hydropower projects can be along river banks, access roads and floating surfaces behind weir tunnels and other suitable project infrastructure. FPV addition to large hydropower capacity can be of particular interest in Pakistan owing to the ability of hydropower sites to be operated flexibly. The solar capacity can even help to manage periods of low water availability by allowing these assets to operate in 'peaking' mode during the beginning of the summer months, before monsoons arrive.

In return, hydropower can smooth the variability of solar output by operating in a 'load-following' mode during the day. FPV can also be installed on run-of-the-river hydropower projects or the vast canal network that supplies irrigation water across the country.

The WB has already been pushing for such projects and recently negotiated a loan of $341.5 million with WAPDA for the installation of a 300 MW floating solar PV setup on the Tarbela-Gazi Barotha complex.[65] The WB also intends to support FPV on smaller hydropower projects through the Khyber Pakhtunkhwa Hydropower and Renewable Energy Development Programme for which the bank is providing a USD 450 million loan.

---

[63] NEPRA. State of the Industry Report, 2021.
[64] The World Bank Group. Where Sun Meets Water, Floating Solar Market Report.
[65] Business Recorder. Floating solar project: World Bank invites Pakistan to hold talks on $341.5m loan. May 7, 2022.

The bank has set aside USD 12 million for the installation of about 10-15 MW of solar PV on smaller hydropower assets being developed by the Pakhtunkhwa Energy Development Organization (PEDO). The bank asserts that generation capacity of hydropower plants can be enhanced by 5-10% with the induction of solar. FPV on hydropower assets can also enhance the economic performance of such plants, for instance the addition of a 5 MW FPV set up on the 88 MW Gabral Kalam Hydropower project can enhance its returns by up to 19%.[66]

2. Incentivize Private Rooftop Solar Solutions

Enhancing distributed solar generation capacity through the addition of more rooftop solar systems across the residential, industrial or commercial sector might be another way of adding more flexible generation capacity to the grid within a short period of time. However, the government's approach to amplifying rooftop solar generation capacity through feed-in tariff and net metering has had limited success so far, due to a lack of affordable and accessible capital.

The government also recently announced its intention to launch solar power projects worth 14 GW to rid the country of its dependence on imported fuels by the next year.[67] 9 GW of this planned capacity will be kicked-off on priority, which could include 6 GW of large scale projects, 2 GW of residential solar on 11 KV feeders and 1 GW of solar projects for the conversion of government buildings and diesel tubewells to solar power.[68]

For residential consumers, the initiative would include the setting up of 1-3 KW solar PV systems in residential feeders through a model where installation costs would be recovered from the consumers through monthly power bills. Government buildings, along with seven existing thermal power generation sites, would also be converted to solar power in a separate phase.[69]

This is certainly a step in the right direction and if pursued with determination could yield its intended results in a short period of time. The proposed model of incentivizing rooftop installations in the residential sector through the provision of capital however could be a risky move given the low recovery rates of some of the power distribution companies.

The government of Pakistan seems to be leaning towards bi-lateral financing from friendly countries for the installation of a major chunk of this capacity[70] while providing lucrative incentives such as payment guarantees, tax breaks, off-take guarantees and attractive tariffs.[71] IEEFA instead recommends the

[66] World Bank Documents. Project Appraisal Document; Khyber Pakhtunkhwa Hydropower And Renewable Energy Development (KHRE). August 31, 2020.
[67] The Express Tribune. Govt plans 14,000MW solar power through incentives. August 10, 2022.
[68] The Express Tribune. 9,000MW solar energy planned. August 30, 2022.
[69] Dawn. Govt to explore solar options amid high energy costs, zero LNG. July 8, 2022.
[70]Business Recorder, Qatar to invest $3bn in Pakistan's airports, fuel terminals, LNG plants, solar parks: Miftah Ismail. August 26, 2022.
[71] The Express Tribune. 9,000MW solar energy planned. August 30, 2022.

mobilization of private capital for this purpose, given the sector's higher propensity for risk and availability of capital. The private sector would also be more amenable towards competitive bidding leading to true price discovery and cheaper electricity production.

3. Upgrade and Modernize Grid Infrastructure

In Pakistan, the governments and power planning agencies' focus has mainly been on adding generation capacity to the grid to meet future demand but very little thought seems to have been given to the transmission and distribution aspect of these schemes.

For instance, despite being a must-run technology, wind power plants in the Jhimpir corridor have faced regular curtailment due to in-adequate transmission capacity. The national grid will require significant strengthening and modernization for the widespread addition of variable renewable energy, be it utility scale solar and wind, or distributed generation in the form of rooftop/floating solar PV.

This would include the introduction of flexibility into the grid through smart grid technologies which could include two-way metering systems allowing electricity to flow from the center to consumers and back to the grid, intelligent and responsive demand management systems monitoring demand in real time and reducing peak-load by managing variability across the grid, improving grid connections in regions where there is a high concentration of renewable energy and complementing a high share of variable renewable energy with energy storage capabilities.[72]

Due to the 'low-return' nature of these investments, we have seen very little interest in grid enabling technologies, other than from the government itself or multi-lateral banks. While that may not change, these grid upgrades can be packaged into the planned projects themselves by adding a transmission component, as has been the practice with some MDB-aided projects. Diverting public funds from projects which are at a high risk of not being realized such as mega-dams and large hydropower towards investments in the grid could also ensure some financial stability for transmission projects.

Conclusion

Power planning in Pakistan had mostly been done with a 'generation-driven' lens, instead of factoring in system inconsistencies and realities which may hamper the achievement of these objectives. This report demonstrates that without taking into account the realities and risks during implementation, an over-reliance on hydropower could lead to a vulnerable energy system.

History has numerous examples to support the increasing unpredictability that comes with a power system with a high share of hydropower. Even now, as parts of

[72] International Renewable Energy Agency (IRENA). Renewable Energy Integration in Power Grids. April 2015.

the world face a severe drought and water reservoir levels shrink to a fraction of what they used to be, entire power supply chains have been disrupted, leading to power outages and losses to the economy.

Economic challenges are quite significant as well, especially as Pakistan battles an intense wave of monsoon flooding which has left a third of the country submerged. Coupled with record inflation, rising commodity prices, a weak credit outlook for at least another two years, and a strict economic reforms program guided by the IMF, the country faces a tough road to recovery ahead.

While most efforts now focus on building back the infrastructure damaged by the recent flooding, raising financing for a vast fleet of hydropower projects, which are susceptible to economic, geographical and climate risks of their own, will be an uphill task.

There needs to be a balance between a focus on "generational projects" – those that people may only see realized once in their lifetime – and on more immediate and incremental demands for diversified and reliable supply. For example, a risk-adjusted investment effectiveness metric can be applied to capital allocations for power infrastructure. If all public treasure is sunk into projects that are almost certain to be late and over budget, that money is not well spent and not economically contributive in a reasonable timeframe.

Pakistan's focus instead should be building agile and modular sources of power generation, such as solar and wind power, or even small hydro. They require only quick construction, provide distributed generation to wide portions of demand and add flexibility to the grid.

About IEEFA

The Institute for Energy Economics and Financial Analysis (IEEFA) examines issues related to energy markets, trends and policies. The Institute's mission is to accelerate the transition to a diverse, sustainable and profitable energy economy. www.ieefa.org

About the Author

Haneea Isaad is an energy finance analyst at IEEFA. Based in Pakistan, she covers Asian energy markets with a focus on Southeast Asia and Pakistan.
hisaad@ieefa.org