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Hydropower and Solar Alternatives in Khyber Pakhtunkhwa

A POLICY REVIEW



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Hydropower and Solar Alternatives in Khyber Pakhtunkhwa

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The Centre for Regional Policy & Dialogue (CRPD) is an Islamabad-based, non-governmental research and policy institution, dedicated to policy analysis, governance reform, democratization, and civil society. CRPD leads research and policy advocacy on Pakistan's energy transition, particularly in Khyber Pakhtunkhwa, advancing renewable energy, solar power, decentralization and a just, low-carbon transition. CRPD strengthens cross-border civic networks, advances inclusive governance, and promotes sustainable peace in the borderlands, focusing on the Pakistan–Afghanistan borderlands.

Executive Summary

Khyber Pakhtunkhwa sits on the largest concentration of hydropower resources in Pakistan. Of the country's roughly 60,000 MW of technically exploitable hydel potential, Khyber Pakhtunkhwa alone accounts for an estimated 30,000 MW, of which only about a fifth has been developed.[1,5] The province already hosts more than half of Pakistan's installed hydroelectric capacity; approximately 5,800 MW of Pakistan's total of 10,852 MW as of the 2022 Private Power and Infrastructure Board reporting[2]; anchored by the Tarbela complex (4,888 MW), the CPEC-financed 884 MW Suki Kinari plant commissioned in September 2024, and a growing provincial fleet operated by the Pakhtunkhwa Energy Development Organization (PEDO), which reached 10 completed stations totaling 224 MW by January 2026.[3,7]

A further approximately 5,200 MW is under construction across ten major projects, dominated by Dasu Stage-I (2,160 MW), the Tarbela 5th Extension (1,530 MW), Mohmand Dam (800 MW), and PEDO's World Bank- and ADB-backed portfolio in Swat, Mansehra and Chitral.[3,4,12] The money behind these dams is overwhelmingly foreign: Chinese policy-bank debt of roughly US\$1.5 billion for Suki Kinari; over US\$2.3 billion in World Bank commitments across Dasu, Tarbela and the KHRE program; US\$550 million from AIIB; and US\$300 million from ADB for Balakot.[7,9,12,13]

The word 'disruption' in this brief cuts both ways, and the document treats both edges. Floods have wrecked hydropower: the 2022 super-floods; which killed 1,735 people across Pakistan, approximately 18% of them in Khyber Pakhtunkhwa, wiped out dozens of mini and micro hydel units in Kohistan, knocked the 17 MW Ranolia station out of service for years, flooded the Dasu tunnels, and repeatedly forced the 108 MW Golen Gol plant offline.[14,15,21] And hydropower has wrecked: run-of-river schemes dewater long river reaches (roughly 35 km of the Kunhar below Suki Kinari's intake), fragment trout fisheries, and displace communities; over 2,200 people face resettlement at Balakot alone, with documented compensation delays and blasting damage to homes.[11,18]

Against this backdrop, solar photovoltaics has become the fastest-moving force in Pakistan's power sector. The country imported 17 GW of panels in 2024, the largest volume of any country in the world, and net-metered capacity passed 5.3 GW by April 2025.[22,25] Khyber Pakhtunkhwa's own government has pivoted part of its energy budget toward solar: Rs 55 billion for solarizing 13,000 public buildings and 130,000 households, plus a Rs 13 billion scheme for 120,000 homes in the merged districts.[22,23,24] Distributed solar delivers energy at an estimated 2.6–4.9 US cents/kWh in under a year, against Suki Kinari's contracted 8.84 cents/kWh over 30 years and a 5–8 year hydropower build cycle.[5,7,26] The evidence suggests that Khyber Pakhtunkhwa's comparative advantage lies in accelerating the deployment of low-cost solar energy, Battery Energy Storage Systems (BESS), and decentralized electricity systems, rather than continuing to invest in large-scale hydropower projects that face long construction timelines, significant social and environmental costs, and increasing climate-related risks.

1. Khyber Pakhtunkhwa's Hydropower Endowment and the Installed Base

Pakistan's identified hydropower potential is around 60,000 MW; roughly 6,600 MW had been tapped by the time PEDO's mandate documents were drafted, and nearly half of that installed base sits inside Khyber Pakhtunkhwa. The province's own share of Pakistan's total potential is estimated at close to 30,000 MW.[1] The World Bank's 2020 appraisal of the Khyber Pakhtunkhwa Hydropower and Renewable Energy (KHRE) program puts the realized share of Khyber Pakhtunkhwa's potential at about 20% and notes a structural paradox: the province with the richest hydel endowment has the lowest per-capita electricity consumption in Pakistan.[5]

The installed base divides into three ownership classes. Federal WAPDA plants: Tarbela (4,888 MW including the 4th Extension), Warsak (243 MW), the Khan Khwar / Allai Khwar / Duber Khwar trio (~323 MW combined), Golen Gol (108 MW) and Gomal Zam (17.4 MW): deliver into the central grid and pay Khyber Pakhtunkhwa a Net Hydel Profit under Article 161 of the Constitution. Private/CPEC capacity is dominated by the 884 MW Suki Kinari plant on the Kunhar, commissioned on 13 September 2024.[7] And the provincial fleet under PEDO reached ten completed stations totaling 224 MW by January 2026, expected

to earn about Rs 13 billion annually for the provincial exchequer; the Energy Department projects the fleet approaching 1,000 MW and Rs 55 billion in annual earnings within two years as pipeline projects land.[3] The most recent provincial completions were Koto (40.8 MW, Lower Dir), Karora (11.8 MW, Shangla) and Jabori (10.2 MW, Mansehra), all finished in 2025 from Khyber Pakhtunkhwa's own resources.[4]

Table 1 — Major operational hydropower stations located in Khyber Pakhtunkhwa (2026)

Station	River / District	MW	Owner	Status
Tarbela (Units 1–17, incl. 4th Ext.)	Indus / Swabi–Haripur	4,888	WAPDA	Operational
Suki Kinari	Kunhar / Mansehra	884	IPP (CPEC)	COD Sep 2024
Warsak	Kabul / Peshawar	243	WAPDA	Operational (rehab.)
Duber Khwar	Indus trib. / Kohistan	130	WAPDA	Operational
Allai Khwar	Indus trib. / Battagram	121	WAPDA	Operational
Golen Gol	Mastuj trib. / Chitral	108	WAPDA	Flood-interrupted
Malakand-III	Swat canal / Malakand	81	PEDO	Operational
Khan Khwar	Indus trib. / Shangla	72	WAPDA	Operational
Koto	Panjhora / Lower Dir	40.8	PEDO	COD 2025
Daral Khwar	Swat trib. / Bahrain	36.6	PEDO	Operational
Pehur	Pehur canal / Swabi	18	PEDO	Operational
Ranolia	Indus trib. / Kohistan	17	PEDO	Flood-destroyed 2022; under restoration
Karora / Jabori / Machai etc.	Various	~25	PEDO	COD 2024–25

Sources: PEDO, WAPDA, Khyber Pakhtunkhwa Energy & Power Department briefings [1][3][4][15]. PEDO fleet total: 10 stations, 224 MW (Jan 2026).

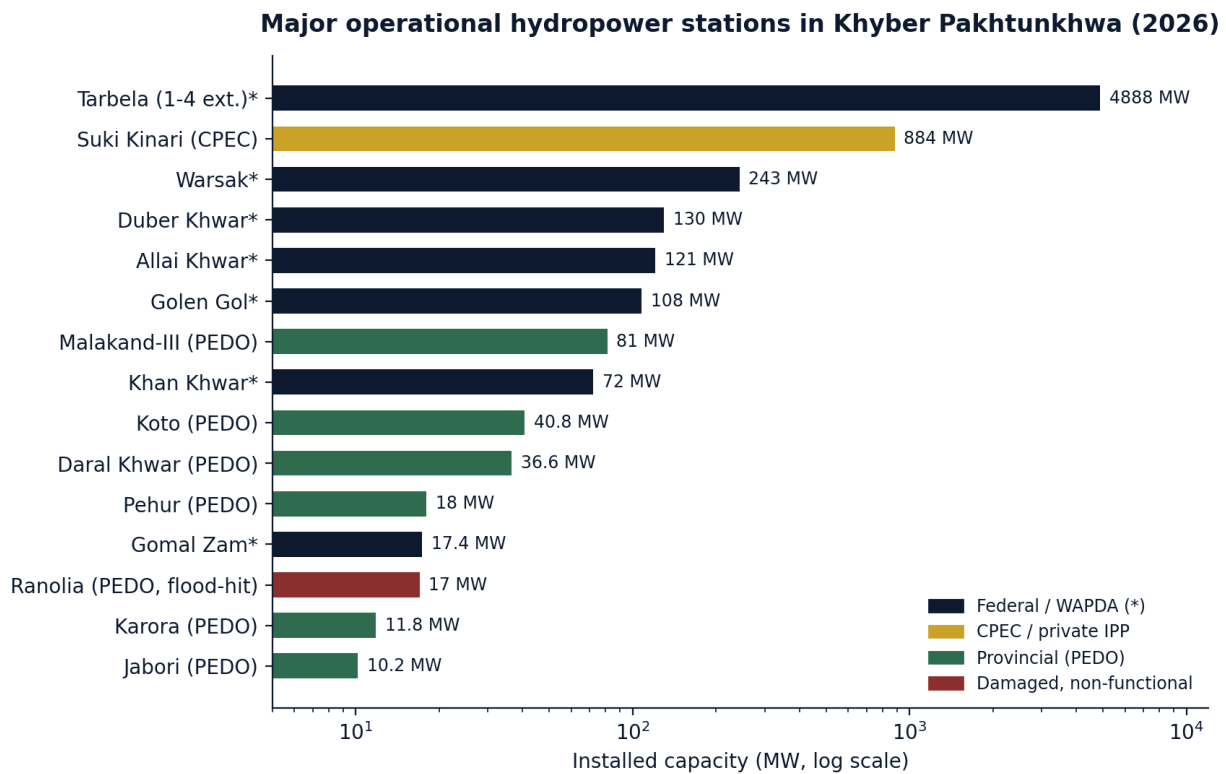


Figure 1 — Operational stations by capacity (log scale). Tarbela alone is larger than the rest of the province's fleet combined.

2. What Is Under Construction and in the Pipeline

Roughly 5,200 MW is physically under construction in the province across ten major projects. The federal tier carries the bulk: Dasu Stage-I (2,160 MW of an ultimate 4,320 MW) on the Indus in Kohistan, the 1,530 MW Tarbela 5th Extension (commissioning now expected July 2027), and the 800 MW Mohmand Dam on the Swat River.[2,13] Notably, Tarbela-5 civil works stood at 53% completion in November 2025 against a planned 76.6%; a reminder that megaproject schedules in Pakistan routinely slip, with cost overruns following.[12]

The provincial tier is PEDO's seven-project pipeline of just over 700 MW: Balakot (300 MW, Kunhar), Madyan (157 MW, Swat), Gabral-Kalam (88 MW, Gabral), Matiltan (84 MW, Ushu/Swat), Lawi (69 MW, Chitral) and the 6.95 MW Mujahidin project in Torghar, with the three Swat flagships (~330–387 MW combined) under explicit ministerial pressure to deliver within two years.[3,4] The Energy Department has also accelerated a 40 km Swat-corridor transmission line intended to sell low-cost PEDO power directly to industry; an institutional innovation, since where NTDC/PESCO grid integration fails, PEDO now seeks distribution licenses under a direct-supply model.[3,8]

Table 2 — Hydropower under construction in Khyber Pakhtunkhwa (2026)

Project	MW	Lead financier(s)	Notes
Dasu Stage-I	2,160	World Bank (IDA + AF)	Indus, Kohistan; 2022 floods flooded tunnels; Stage-I target ~2027
Tarbela 5th Ext.	1,530	World Bank \$390m+\$300m; AIIB \$300m	COD expected Jul 2027; works behind schedule
Mohmand Dam	800	Federal PSDP / WAPDA	Multipurpose storage on Swat River
Balakot HPP	300	ADB \$300m; AIIB \$250m; Govt Pakhtunkhwa \$175m	Kunhar; ~2,200 people face resettlement
Madyan HPP	157	World Bank (KHRE \$450m)	Swat River; PEDO's 2nd-largest project

Gabral-Kalam HPP	88	World Bank (KHRE)	US\$182m; 339 GWh/yr
Matiltan HPP	84	Govt Pakhtunkhwa / PEDO	Ushu River, Kalam
Lawi HPP	69	Govt Pakhtunkhwa / PEDO	Chitral
Kurram Tangi St-I	18	Federal (earlier USAID support)	North Waziristan
Mujahidin HPP	6.95	Govt Pakhtunkhwa / PEDO	Barandoo River, Torghar; bid stage

Sources: World Bank, ADB, AIIB project documents; Khyber Pakhtunkhwa Energy & Power Department [3][4][6][9][12][13].

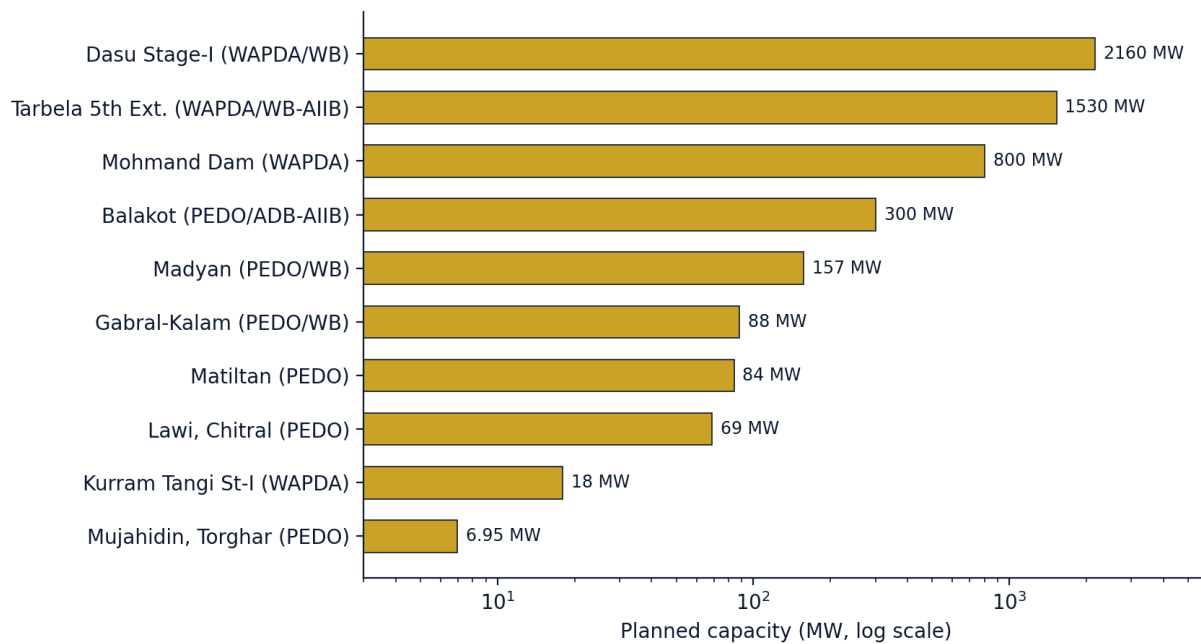


Figure 2 — The under-construction pipeline. Two federal megaprojects dwarf the entire provincial program.

3. Who Funds Khyber Pakhtunkhwa's Dams and Why

Foreign capital dominates. Four distinct financing channels are visible in the data, each with its own logic:

(i) Chinese commercial/policy-bank debt under CPEC. Suki Kinari (US\$1.8–1.96 billion total cost) was financed 75% by debt from the Export-Import Bank of China and the Industrial and Commercial Bank of China, sponsored by Gezhouba Group / China Energy Engineering Corporation on a Build-Own-Operate-Transfer basis, with NEPRA guaranteeing a 30-year levelized tariff of 8.8415 US cents/kWh on a cost-plus basis.[7] The motivation is straightforwardly commercial and geostrategic: a sovereign-backed, dollar-indexed return stream for Chinese lenders, a flagship deliverable for the Belt and Road Initiative, and export markets for Chinese turbines and EPC contractors. The tariff structure, not the turbines, is where the long-term cost to Pakistani consumers is locked in.

(ii) Multilateral development banks. The World Bank approved US\$450 million in September 2020 for the KHRE program (Madyan, Gabral-Kalam, cascade planning and associated solar PV), framing it as reducing reliance on imported fossil fuels and lowering generation costs.[5,9] It has separately committed well over US\$1.2 billion to Dasu Stage-I and US\$690 million to the Tarbela extensions, the latest US\$300 million approved in June 2026 to cover Tarbela-5 cost overruns.[13] ADB lent US\$300 million for Balakot in 2021, with AIIB co-financing US\$250 million and the provincial government injecting US\$175 million of a US\$755 million total.[9,10,11] MDB motivations blend development mandate (Khyber Pakhtunkhwa's low electrification, cheap firm energy) with portfolio logic: hydropower is one of the few asset classes large enough to move billions in a single loan. Earlier European involvement; a German-supported, EIB-linked contract for the 128 MW Keyal Khwar project; collapsed in 2017 and is being retendered.[2]

(iii) Federal budget (PSDP/WAPDA). Mohmand Dam, Kurram Tangi and the equity portions of Dasu and Tarbela ride on the federal development budget, historically supplemented by donors (USAID supported Gomal Zam’s completion and Kurram Tangi’s early phases).

(iv) Khyber Pakhtunkhwa’s own resources. The province self-financed Koto, Karora and Jabori (63 MW combined, ~Rs 4.4 billion expected annual revenue) and treats PEDO stations as revenue-generating provincial assets; the clearest fiscal argument for why the Khyber Pakhtunkhwa government keeps building: hydel royalties, Net Hydel Profit claims against the centre, and direct sales revenue.[4]

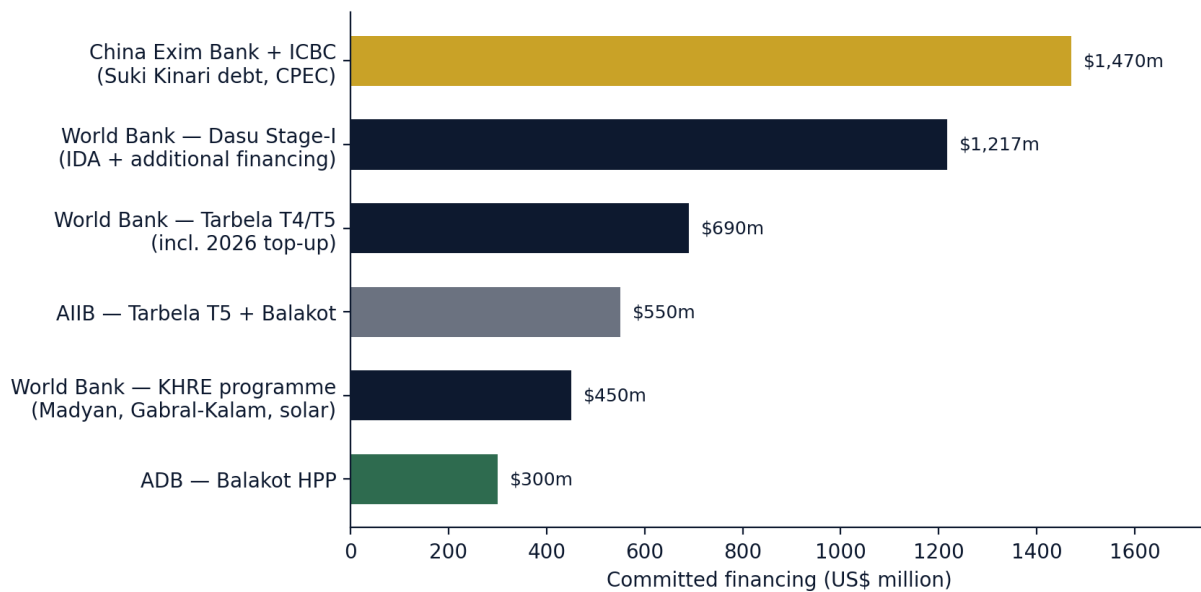


Figure 3 — Selected foreign financing commitments. Chinese policy-bank debt for a single plant rivals the World Bank’s entire KHRE program threefold.

Counting ‘foreign investments involved’ therefore depends on the boundary drawn. On a narrow definition; foreign-financed projects currently operating or under construction in Khyber Pakhtunkhwa; at least seven are live: Suki Kinari (China), Dasu (World Bank), Tarbela-5 (World Bank + AIIB), Balakot (ADB + AIIB), Madyan and Gabral-Kalam (World Bank/KHRE), and the retendering Keyal Khwar (European finance, lapsed). Combined foreign commitments to Khyber Pakhtunkhwa hydropower comfortably exceed US\$4.5 billion, and the ADB estimates the full 2020–2035 provincial hydel program (4,903 MW of additions) would need about US\$11 billion.[8]

4. The Disruption Ledger

‘Disruption’ in the Khyber Pakhtunkhwa hydropower story runs in two directions, and any honest assessment has to keep both books open: what floods and climate do to the dams, and what the dams do to rivers and communities.

4.1 Disruption of hydropower: floods, glaciers, and a warming basin

The 2022 super-floods killed 1,735 people across Pakistan and caused about US\$40 billion in damage; approximately 18% of the deaths and 24% of the damaged bridges were in Khyber Pakhtunkhwa.[21] For the power sector the toll was direct: in Lower Kohistan the floods wiped out numerous small hydel units and severely damaged the 17 MW Ranolia station, which remained non-functional years later and is only now under a PEDO rehabilitation-and-restoration contract.[14] At Dasu, the floods inundated tunnels and halted construction on Pakistan’s largest hydropower project.[2] The pattern is not a one-off. The PEDO-run 4.5 MW Reshun powerhouse in Chitral was washed away by flash floods, leaving over 15,000 households in Upper Chitral without electricity for years while PEDO and PESCO argued over tariff and wheeling mechanics for Golen Gol’s power; a dispute that turned a completed 108 MW plant into stranded capacity for a whole district.[16] As of mid-2026 Upper Chitral still lacked reliable supply and a replacement project was

only being launched under the Access to Clean Energy Program.[17] In July 2024 flooding again shut Golen Gol entirely, blacking out both Chitral districts, and destroyed Mahandri bazaar in the Kaghan valley, for the second time since 2022.[15]

The underlying driver is structural. Khyber Pakhtunkhwa's hydropower depends on glacier- and snow-fed rivers whose regimes climate change is destabilizing: basin studies of the Kunhar project temperature rises of 2.0–4.4°C and precipitation shifts by the 2080s, with streamflow variability that simultaneously threatens flood damage and dry-season generation shortfalls.[18] Every run-of-river plant in Swat, Kunhar and Chitral is a fixed asset bolted to an increasingly violent hydrological system. Journalistic accounts of Golen Gol note that flood risk was inadequately reflected in the plant's design.[2]

4.2 Disruption by hydropower: dewatered rivers, displaced people

Run-of-river designs are marketed as low-impact, but their mechanics divert most of a river's flow into tunnels. Suki Kinari routes the Kunhar through a 21.4 km headrace tunnel, reducing natural flows along roughly 35 km of river, with consequences for trout habitat, fish migration, river morphology and the rafting-and-angling tourism economy of the Kaghan valley; monitoring during construction found elevated trace metals (iron, lead, zinc, copper, manganese) in river water and fish.[18] The World Bank's own cumulative Environmental and Social Impact Assessment for the Swat basin catalogues stacked impacts of the planned cascade; Madyan, Gabral-Kalam, Matiltan, Asrit-Kedam; on river flows, irrigation releases and aquatic ecology, because several projects will draw down the same river in sequence.[20] Independent of the dams, unregulated sand and gravel mining is already degrading the Swat River's bed and banks, compounding flood deadliness.[19]

The social ledger is equally concrete. At Balakot, over 2,200 people face resettlement, with civil-society monitoring documenting delayed or denied compensation payments, reportedly falling hardest on women and on residents who spoke up, and tunnel-blasting damage to homes for which no compensation channel exists.[11] PEDO's own notifications of land-rate disputes at Gabral-Kalam, Muza Kanai and Utror point to the same friction on the provincial pipeline.[1] Tarbela's legacy is the cautionary tale: resettlement cases from the 1970s dam and the 1990s Ghazi Barotha project were still being processed by a Resettlement Commission financed under the Tarbela-4 loan half a century later.[12]

4.3 The circular risk

These two ledgers interact. Deforested, mined and dam-fragmented river basins flood more destructively; more damaging floods destroy generation assets and the roads and transmission lines that serve them; reconstruction then absorbs the budgets that were meant to build resilience. Khyber Pakhtunkhwa's hydropower strategy is, in effect, a long position on hydrological stability at precisely the moment that stability is eroding. That does not only make hydropower wrong; it makes single-technology concentration risky.

5. Solar versus Hydropower in Khyber Pakhtunkhwa

Pakistan's solar boom is the fastest structural change in the country's energy history. Pakistan imported 17 GW of solar panels in 2024, double the 2023 volume and the largest of any country in the world, and net-metered rooftop capacity reached 5.3 GW by April 2025, with NEPRA recording over 302,000 net-metering connections totaling 4,492 MW.[22,25] The economics explain the speed: distributed solar's levelized cost is estimated at 2.6–4.9 US cents/kWh, payback on a typical rooftop system runs 2–4 years, and installation takes weeks.[26] Hydropower, by contrast, must be planned and financed 5–8 years before commissioning, as the World Bank's own KHRE appraisal states[5], and Khyber Pakhtunkhwa's record (Tarbela-5 slippage, Dasu's flood halt, decade-long PEDO gestations) suggests 5–8 years is the optimistic bound. Suki Kinari's power is contractually priced at 8.84 cents/kWh for 30 years.[7]

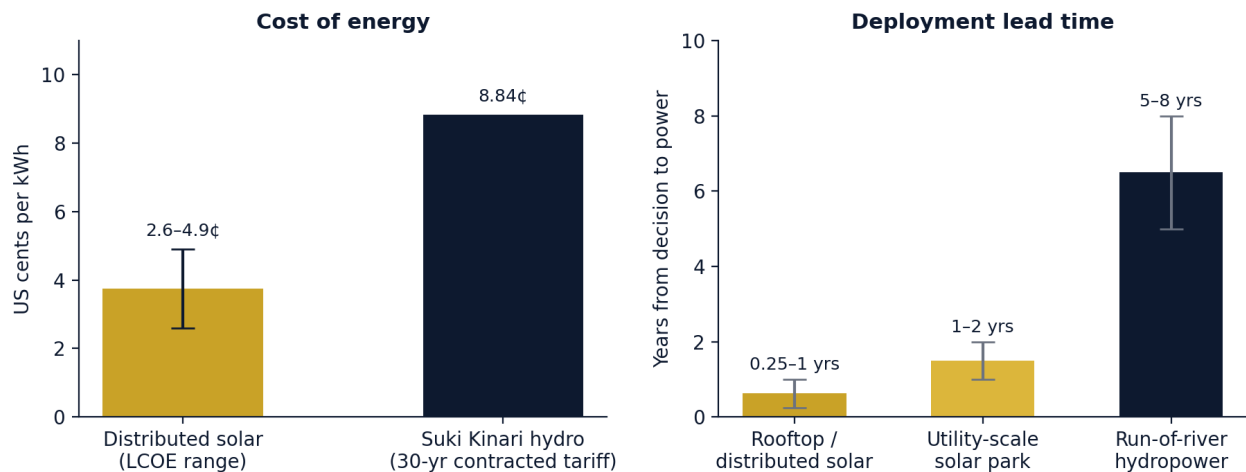


Figure 4 — Cost and lead-time comparison. Sources: NEPRA tariff determination for Suki Kinari; industry LCOE estimates; World Bank KHRE PAD [5][7][26].

Table 3 — Solar vs hydropower in Khyber Pakhtunkhwa: a structured comparison

Attribute	Solar PV	Hydropower
Cost of energy	≈2.6–4.9 ¢/kWh distributed; utility-scale similar or lower	8.84 ¢/kWh (Suki Kinari, 30-yr); PEDO plants cheaper but site-specific
Lead time	Weeks (rooftop) to 1–2 yrs (utility)	5–8 yrs minimum; frequent slippage
Capital intensity	Low, modular, private household capital mobilizable	US\$2–6m per MW; sovereign debt required
Flood / GLOF exposure	Minimal (distributed assets)	Severe: Ranolia, Reshun, Golen Gol, Dasu all flood-hit
Firmness	Daytime only; needs storage or grid backup	Dispatchable; seasonal (summer-peaking with melt)
Winter output	Reduced but non-zero; strong in southern Khyber Pakhtunkhwa	Low (river flows drop sharply)
Displacement / ecology	Land use for utility parks; negligible for rooftop	Dewatered reaches, fisheries loss, resettlement (2,200+ at Balakot)
Revenue to province	Savings-based; little direct PEDO revenue	Rs 13bn/yr now; Rs 55bn/yr projected at ~1,000 MW
Transmission need	None (rooftop) — bypasses PESCO's weak grid	Dedicated lines (e.g., 75 km SK line; Swat corridor)

Compiled from [3][5][7][11][14][22][25][26].

5.1 Khyber Pakhtunkhwa's own solar pivot

The provincial government has effectively acknowledged the arithmetic. Two mega-programs worth Rs 55 billion are underway: solarization of 13,000 public buildings (hospitals, schools, police stations) and free or half-subsidized solar systems for 130,000 low-income households (65,000 fully free, 65,000 at 50% cost on instalments), financed through Bank of Khyber–PEDO arrangements and allocated by population-proportional balloting.[22,23] A parallel Rs 13 billion scheme under the Accelerated Implementation Program provides 2 kW kits to 120,000 households in the merged districts; Bajaur, Khyber, Kurram, Orakzai, Mohmand and the Waziristans; where grid extension is hardest.[24] Notably, these programs are run by PEDO itself: the province's hydropower agency is now also its solar delivery vehicle, alongside mosque-, court- and street-light solarization tenders.[1]

5.2 What solar cannot do: the necessary caveats

A fair comparison must also state solar's limits. First, firmness: Khyber Pakhtunkhwa's evening and winter demand cannot be met by PV without storage, and battery costs, while falling, are not yet embedded in any provincial program at scale. Second, the grid-finance problem: federal policy has already cut the net-metering buyback rate from about Rs 27 to Rs 10 per unit precisely because prosumer defection strips revenue from a grid still carrying CPEC-era capacity payments; an estimated Rs 159 billion in costs shifted onto non-solar consumers.[25] A province that pushes mass solarization while its provincial utility ambitions depend on selling hydel power to that same grid is, to some degree, competing with itself. The real question isn't which technology wins, but how we design the portfolio.

6. Prospects and Opportunities

Hybrid hydel-solar at existing sites. Reservoirs and forebays are natural hosts for floating or adjacent PV using existing interconnection; the World Bank's Tarbela-5 financing already includes a floating solar pilot.[13] PEDO's 10 operational stations and their transmission assets are ready-made anchor points for the same model at provincial scale.

Direct supply to industry. PEDO's Request for Information on supplying low-cost electricity from its own plants to industrial estates, and the Swat-corridor transmission line, open a business-to-business market that bypasses PESCO's losses; the single strongest commercial argument for finishing the Swat flagships. [1,3]

Financing discipline. Suki Kinari's 30-year cost-plus tariff and Tarbela-5's overrun top-ups illustrate the risk profile of debt-financed megaprojects. The ADB's US\$11 billion estimate for Khyber Pakhtunkhwa's 2020–2035 hydel program[8] should be read against solar's ability to mobilize private household capital at zero fiscal cost; 17 GW of panels entered Pakistan in one year without a single sovereign guarantee. Future hydel commitments deserve screening for climate-adjusted hydrology, cumulative basin impacts, and honest resettlement budgets, not just EIRR arithmetic.

7. Conclusion

Khyber Pakhtunkhwa holds roughly 30,000 MW of hydel potential, hosts more than half of Pakistan's installed hydroelectric capacity, and has approximately 5,200 MW under construction financed largely by Chinese, World Bank, ADB and AIIB money whose motives range from Belt and Road geopolitics to development-bank portfolio logic. But the disruption ledger is real on both sides: floods have repeatedly wrecked the province's plants, and the plants have dewatered rivers and displaced communities. Solar has broken the cost and speed frontier and Khyber Pakhtunkhwa's government is already reallocating billions of rupees toward it. The defensible strategy for the province is neither dam-maximalism nor solar romanticism, but a deliberately hybrid portfolio anchored by BESS.

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