QUARTERLY ENERGY MONITOR (JUL-SEP 2021)

IGCEP 2021 AND THE REVISED VRE TARGETS

RDPi
Rural Development Policy Institute
پالیسی ادارہ برائے دیہی ترقی

Table of Contents

Introduction

Indicative Generation Capacity Expansion Plan (IGCEP) 2021-30 presents the results of the latest expansion planning studies conducted by National Transmission and Dispatch Company (NTDC). This generation planning study is composed of two key processes: 1) Load forecast; and 2) Generation capacity expansion and dispatch optimization. Alongside other revisions, the 30% non-hydro renewable energy by 2030 target as outlined in the national Alternative Renewable Energy Policy-2019) (AREP-2019) and last version of IGCEP has been revised down to 16%. This is a big reversal. And while IGCEP claims that Pakistan has promising solar and wind potential, which has also become cheapest sources of energy procurement—associated intermittency challenges and need for additional reserve requirements backup generation required to provide for reserve requirements have been cited as the major reason for the stated downward revisions in targets.

This argument of *'additional reserve requirements*' is not only marred by misconceptions and misinformation but also contradicts the findings of *Variable Renewable Energy (VRE) Integration and Planning Study conducted by* World Bank study (2020), which otherwise claimed that achieving least cost electricity mix in Pakistan would require a rapid expansion of VRE**.** Importantly, since these claims distract the focus on VRE uptake which otherwise have promising potential in Pakistan, there is a strong need for system-wide approach while analyzing VRE and its integration related aspects. VRE has become currently the fastest-growing sources of electricity globally best captured by innovative and cost-efficient integration strategies. Pakistan already has some ideal pro-VRE features which could maximize its net benefits. In "dynamic" power systems with growing electricity demand such as is the case of Pakistan, wind power and solar PV are ideal to meet incremental demand. In the case of solar, the output profile coincides with electricity demand, making the power sector naturally flexible for its integration.

Pakistan is also moving toward a competitive electricity market. This market will ensure additionally ancillary service, supporting its course toward energy transition. A systemic approach is therefore the appropriate answer to system integration which dramatically reduces the need for additional reserve requirements. Renewables have come a long way in terms of breaking through the cost barriers and becoming more efficient than fossil fuels, and so any delay in its uptake will only be a lose-lose situation for the country.

A vision with sustainability at its core, could have helped in achieving a more RE centric planning by the NTDC, currently lacking in the IGCEP. Since its approval by the Council of Common Interests (CCI) on September 6th, 2021, the IGCEP has been in the limelight for its optimistic reliance on hydro as well as extensive reliance on coal—at a critical timing when the rest of the global world is phasing it out. With this context, our current quarterly energy monitor aims to bring attention to the identified gaps in the IGCEP, and the impacts of this long-term planning on Pakistan's power sector in the absence of any further review of the IGCEP.

IGCEP 2021-30: An Overview

Long-term generation plans are a fundamental activity for guiding a national power system strategy and policy. IGCEP was also rolled out with the primary objective to determine a minimum cost strategy for long-range expansion of the power sector and improve decision-making under different long-term uncertainties while assuring a robust generation expansion plan with least cost and minimum risk.

The total installed generation capacity of NTDC system reached to 34,776 MW by the end of September 2021. The source wise installed capacity mix is shown in Fig.1 where 34% of installed capacity comprises of RE including hydro, solar, wind and bagasse-based technologies; and 66% thermal plants comprises of natural gas, local coal, imported coal, RFO, RLNG and nuclear based technologies.

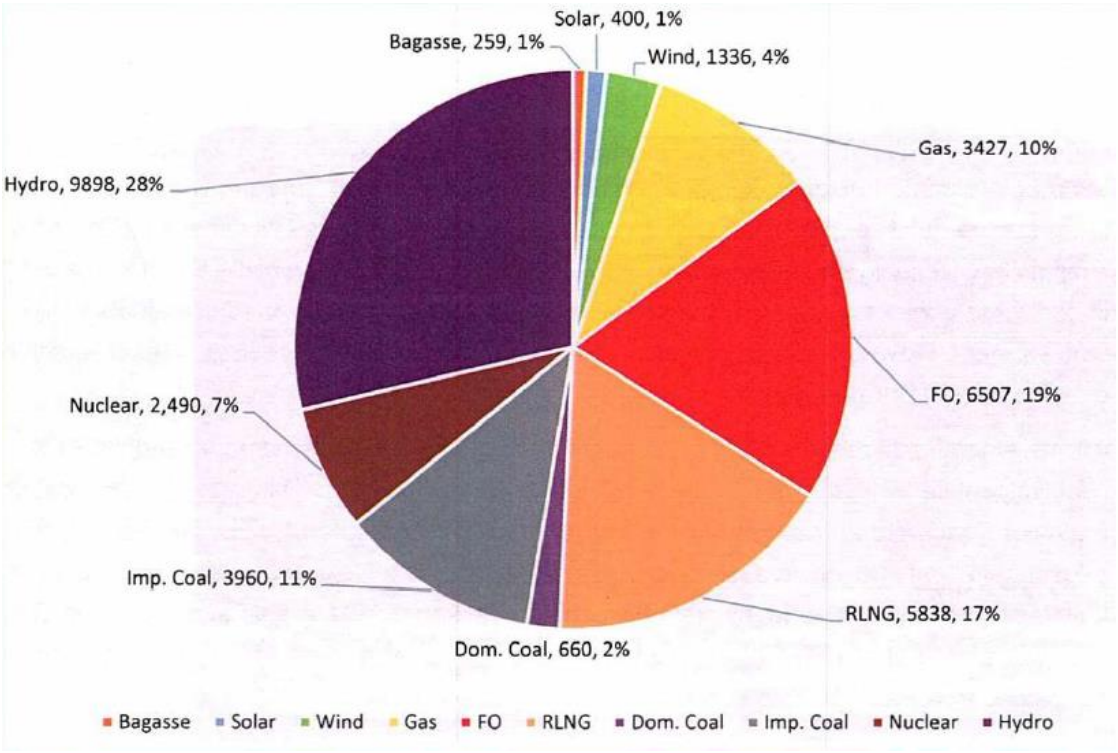

Figure 1: Installed Capacity (MW) as of September 2021, Source: IGCEP 2021-30.

The overall generation capacity as outlined in IGCEP 2021-30 increases from 34,776 MW in 2021 to 61,112 MW by 2030. The plan aims to gradually reduce reliance on largely imported thermal fuels i.e., imported coal, Re-gasified Liquid Natural Gas (RLNG) and Residual Furnace Oil (RFO), while increasing the share of indigenous resources in the energy mix. Based on this premise, gradual phase-out in the capacity is observed in the Gas, RFO and RLNG. The contribution of gas fired power plants in the generation mix (GWh) will decrease from present 15% to mere 6%. The RLNG based plants, though installed and available are envisaged to have a decreasing share in the energy mix from 2021 to 2030 i.e., from 18% to 2% in 2025 and then eventually falling nearly to 0% in 2030. Further, the share of solar and wind in the overall energy mix increases from about 3% in 2021 to 16% in 2030. Whereas major increase is envisaged in the hydropower capacity with its share increasing to 38% of the energy mix by 2030.

Although the skewed focus on indigenization of power sector expansion is quite noteworthy, nonetheless, there remains questions over the reduced share of solar and wind, ambitious hydro-build out and continued reliance on coal. As a first step, the plan is not interfaced with the AREP. The stated differences in mandates, goals and targets have created widespread confusion and skepticism toward a uniform decarbonization strategy and roadmap. Further, the outlined hydro-build out is simply too ambitious and not realistic. Whereas no 'risk accounting' or 'alternative-case scenario' has been built to accommodate for any gaps/delays in case of unfulfillment of these optimistic assumptions. However, as decentralized on-grid solution such as Distributed Generation (DG) which offers a major opportunity to devolve capacity payment to end-users and reduce the financial liability of RE expansion —continues to be overlooked in the plan.

The fact that engaging in fossil fuel-based, take-or-pay power generation along with other reasons[1] has also caused a financial turmoil in the power sector. Pakistan's circular debt stand today over PKR 2.3 trillion, and Chinese companies under China Pakistan Economic Corridor (CPEC) are now showing their agitation over non-payment issues. In the IGCEP, we again see a proliferation of coal and large hydro power projects, which are committed[2]. In Fig. 2 below, we can see that hydropower projects have taken 60% share in the committed power projects, followed by 13% share by the local coal-based power projects, and 4% share by the imported coal-based power projects. Unless, the structural issues[3] in the power sector supply chain are addressed, the power sector expansion through capital intensive committed projects will only enhance the financial woes of the sector. Against these challenges, IGCEP needs to be very realistic about implementation periods or doing at least additional scenarios to account for the stated risks.

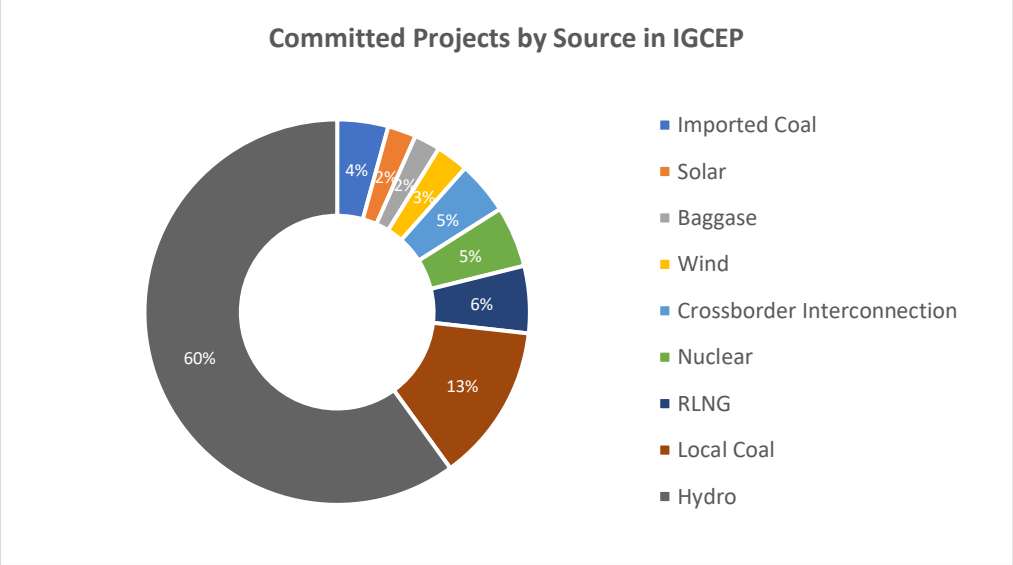

Figure 2: Share of committed Projects by Source in IGCEP

[1] Structural issues in the power sector supply chain

[2] Projects which have received LOS from NEPRA, their PC-1 have been approved and financing has been secured, or the projects is listed under Federal government's international commitments and their financing agreement has been signed, or RE plants listed in Category II & III of Cabinet Committee on Energy (CCoE)

[3] Structural issues include: poor management and administration at the level of distribution companies, less than 100% recoveries against the electricity bills, power thefts, high technical and line losses at the transmission level, accumulating payments to the power generation companies for keeping their plants available (capacity payments) and compounding interest on the late payments.

The Need for Reorienting Focus Toward System-Wide Approach

According to the IGCEP (*vide section 3.6.5*), *although ARE Policy 2019 aims to include at least 30% of renewable energy generation capacity mix by the year 2030, yet because the renewable energy resources such as wind and solar require appropriate amount of backup generation to provide for reserve requirements of the system, their targets have been revised down to 10%.* This argument of *'additional reserve requirements*'—is marred by misconceptions and misinformation. VRE have become currently the fastest-growing sources of electricity globally best captured by innovative and cost-efficient integration strategies. Several factors could contribute to its least cost deployment. This includes system friendly VRE deployment, improved system and market operation, flexible operational resources, tariff design, balanced induction over a well-distributed time span etc. So, costs depend on how well different components of the system fit together. For instance, an assessment of revised IEA Flexibility Assessment Tool (FAST2) showed that "annual VRE shares of 25% to 40% can be achieved from a technical perspective, assuming current levels of system flexibility."

The greater cost for VRE uptake is incurred by those countries who have stagnant power demand as they simultaneously have to manage the costs associated with scaling down the old system. But for a country like Pakistan characterized by a "dynamic" power system with growing electricity demand and enormous potential of solar and wind resources, it can facilitate system transformation without any economic stress on incumbents. From Fig. 3 below we can see the ratcheting up power demand in different sectors. In past one year alone, the peak demand has rose by 7% from 121,867 GWh in fiscal year 2020 to 130,223 GWh in fiscal year 2021.[i] This year, July 2021, also witnessed the highest demand and supply of power in history of Pakistan achieved at 24,284 MW.[ii]

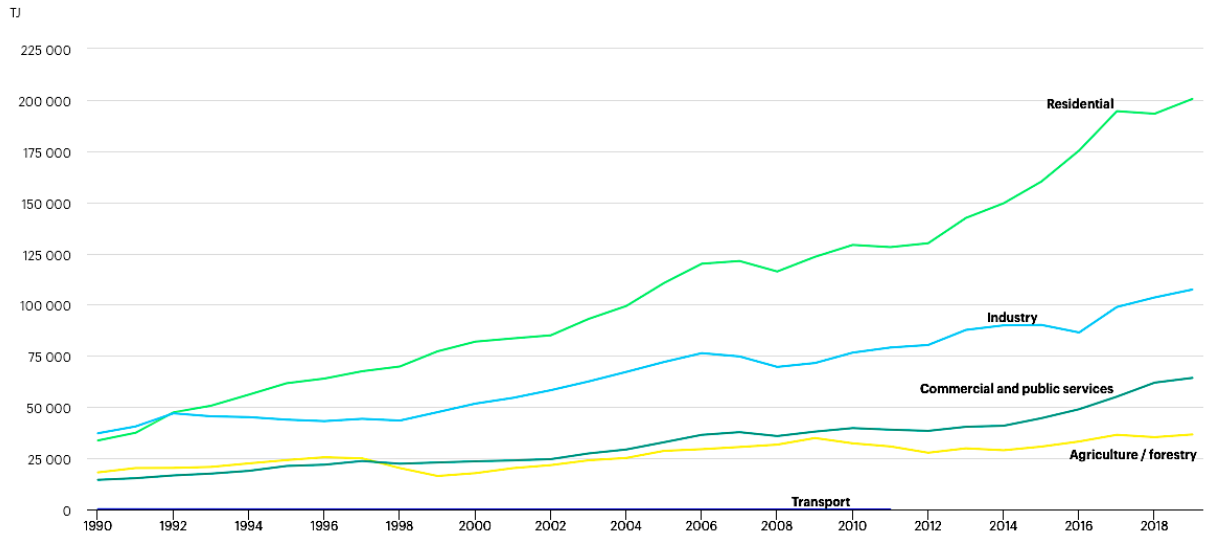

Figure 3: Electricity consumption by sector, 1990 – 2021
Source: IEA, all rights reserved (https://www.iea.org/countries/pakistan)

Moreover, VRE offers several other advantages to the power sector. For instance, the country has unique natural flexibility for solar PV. The sunny periods in the country coincide with high electricity demand load profiles, and so solar PV generation could be both conveniently integrated and displace fuel-based

thermal plants production—contributing to enormous variable cost savings. Based on a thorough assessment of flexibility options carried out in the World Bank commissioned study *VRE Integration and planning Study* (2020), it visualizes how VRE generation could cover for essential parts of the peak load supply both during summers and winters. The same study also assumes the argument on reserve costs, outlining the case of deployment of VRE in combination with hydropower, which could result in decreasing overall costs by more than $5 billion. However, to materialize this outcome, the study states that several system adaptations are required such as high accuracy central forecasting system; changes to operational procedures and revisions in contractually agreed ramp rates of existing and committed plants; optimal planning of VRE expansion; and competitive electricity market which allow for enhanced flexibility in the system. Therefore, it is the interaction of VRE and other system components that determine the additional costs for its deployment. If solar and wind uptake are planned optimally from the very start, a flexible system can be built, and the cost of transforming the system could be reduced substantially.

In a nutshell, Pakistan could have sufficient flexible generation to balance adequately higher shares of VRE without building additional reserves. The new paradigm for power sectors therefore is to prudently plan VRE expansion, and system-wide transformation to harness *flexibility*. All that is needed is a coordinated transformation of the system as a whole. Also based on the unique pro VRE characteristics that Pakistan enjoys, the net economic benefits for the country could be substantially higher than other regions. Finally, new alternative solutions are emerging such as green hydrogen and cost-effective storages, which overtime will enable 100% RE transition. We need to steer the power sector in the right direction from now, so as to reap maximum benefits of these ongoing developments.

Distributed Generation Unaccounted

Distributed Generation (DG) solar in Pakistan has promising potential in terms of solar radiation, architectural landscape, suitable demographic and socio-economic conditions in terms of a large population in need of power grid back-up on a daily basis. With major technological breakthroughs, today it has also broken through the cost barrier—currently emerging as the most economically efficient resource of power procurement in the country. It is very important to understand here that for Pakistan, net-metering offers a major opportunity to devolve capacity payment to end-users and reduce the financial liability of RE expansion —a much overlooked discourse and important dimension in the wake of the country's ballooning capacity payment, which have increased over 53%[iii] since 2018.

Figure 4: Increasing power sector capacity payments
Source: Figures from the Express Tribune (https://tribune.com.pk/story/2296006/power-consumers-to-pay-rs11tr)

Further, it particularly provides three key major advantages: encouraging renewable energy uptake, reducing distribution losses and finally providing uninterrupted supply to end-users.[iv] In terms of reducing losses, the general principle directs that the losses increase with increment of distance between the generation facility and the load centers.[v] A well-chosen distributed generation facility can contribute to the decrement of about 10-15% of the technical losses.[vi] In parallel, distributed generation is also a useful

tool for the liberalization of energy markets. With the liberalization of power and energy markets, the reliability in energy supply and cost-benefit analysis is assured).[vii] So, loss minimization, reliability, sustainable energy provision, and clean and cheap energy mechanism—all could be aligned with the solar photovoltaic based distributed generation in regions with high losses, interruption of power supply and high consumption tariff.[viii,ix]

Decentralized energy has therefore instilled renewed hope for a more sustainable trajectory of power accessibility in Pakistan. A solar prosumerism[4] revolution (if it happens) would help not in meeting the ambitious renewable energy target as set under the recently introduced AREP-2019 but would simultaneously help in addressing the longstanding challenges in the power sector. It could prove a package for the ailing power sector — including devolution of the capacity payment charges to end-users, gradual phase out of subsidies, less distribution losses (due to consumption near generation point), and reliance on indigenous clean resources with almost negligible variable cost of generation. Against the background, there is an unprecedented potential for solar energy advancement in Pakistan wherein it offers a long-term reliable source of power for consumers—contributing to the versatility of energy sources, emission abatement and energy security.

A quick glance at its growth trendline shows that recently it is picking growth speedily— overall crossing 160 MW in March 2020 and registering more than 40 MW of growth in the past three months alone. IGCEP (vide section 7.3) also acknowledges that "a major share of future power generation will come from small, distributed and dispersed technologies. The plan needs to account for DG both in their load forecast analysis, and generation capacity expansion.

Ambitious Hydro-build Out: Risk Assessment

Total committed hydropower included in the planning of power sector expansion sums to 13.161 GW, which accounts for 59% of the total committed power projects. For most of these projects, PC-1[5] has been approved and financing has been secured, and for the remaining, Letter of Support (LOS) has been issued. The largest hydro project in the committed projects has a capacity of 4.5GW, and is expected to be commissioned in 2029. Fig. 5, below shows yearly hydropower additions that will come online during 2021 to 2030.

[4] Generating electricity from renewable energy resource, consuming as much as you need and selling the rest to the utility, i.e. to both produce and consume energy. (https://www.energy.gov/eere/articles/4-fast-facts-about-solar-prosumers)

[5] PC-1 is known as a planning tool for the development and execution of any projects in the Government Departments. Source (https://www.iucn.org/content/3-day-training-workshop-pc-1-formulation-and-project-proposal-development-quetta)

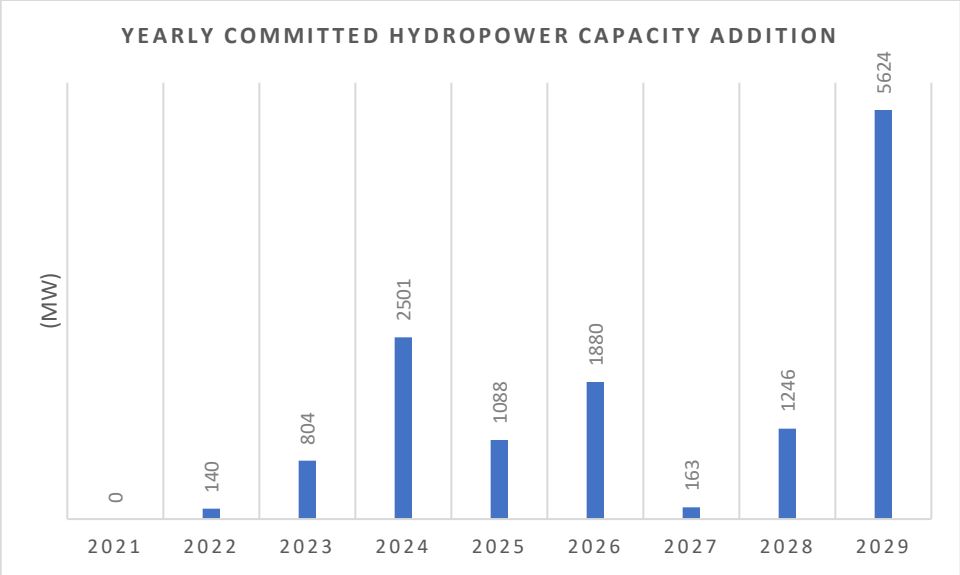

Figure 5: Yearly additions of committed hydropower projects

Hydropower has been the most prevalent non-fossil-fuels-based power generation source around the globe. Fig. 6 below depicts that hydropower has held a significant share globally after fossil-fuels-based electricity production, and share of renewable energy sources such as wind, and solar have been on a rising trend since the past two decade.

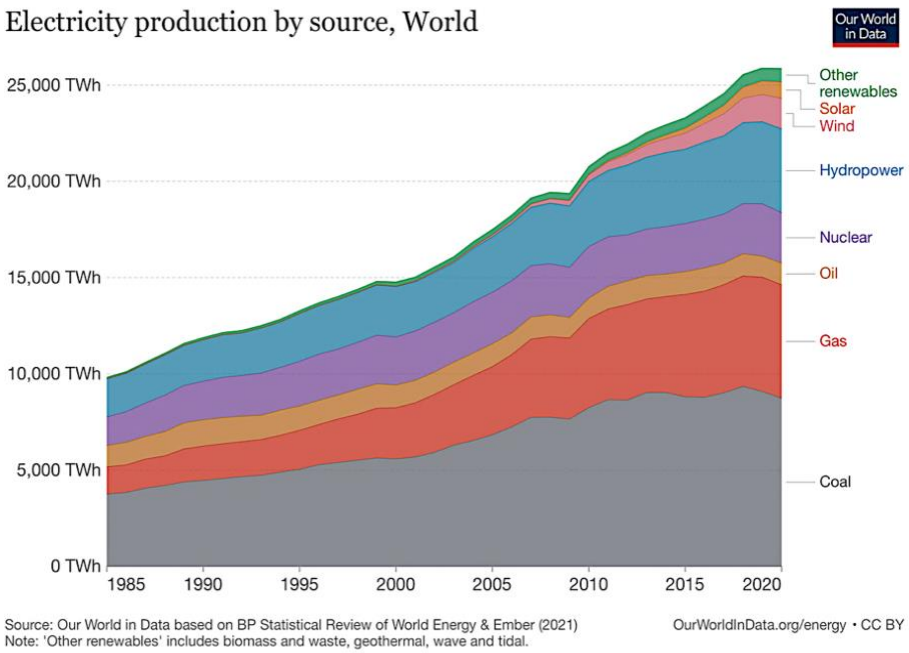

Figure 6: Global electricity production by source

In the developed countries, the periods of industrialization have also been met by hydropower besides coal. In the US alone there are over 82,000 large dams, and over 2 million small low-head dams.[x] However, many of these large dams are being decommissioned every year in the US and Europe, due to their economic infeasibility and environmental concerns. Hydropower projects reached their peak in the US

and Europe around 1960s' and now more hydropower plants are being dismantled than installed — in the US now it only supplies 6% of the electricity.[xi]

Hydropower provides cheap electricity, but adding their social and environmental costs would challenge their feasibility. They are associated with issues such as disruption of river ecology, substantial deforestation, loss of aquatic and terrestrial biodiversity, substantial greenhouse gases, and displacement of thousands of people.[xii] For countries with agricultural landscape, the hydropower projects also affect water availability for the farming communities down and along the water channels. Thus, Pakistan, having agriculture rich terrain, has to think about energy sector expansion in nexus with water availability and food security. The implications of negligence in this regard are already evident from the alarming statistics. Pakistan ranks 88th out of 107 countries on 2020 Global Hunger Index[xiii] and a national nutrition survey conducted in 2018 shows that 36.9% of the population faces food insecurity.[xiv] In an assessment[6] conducted by World Food Program in 2020 in the merged districts and tribal sub-divisions of Khyber Pakhtunkhwa, water scarcity has been identified by the local communities as one of the limiting factors in farming, enhancing food insecurity in the area.

The current iteration of IGCEP does not take into account interactions of power sector with other key sectors of Pakistan's economy. In the scenarios built out in the current iteration of IGCEP, with extensive expansion coming from hydropower, water related conflicts are also bound to arise — both within the water intensive sectors such as agriculture and power, and also over water rights among the provinces. The geopolitics around water issues with our neighboring countries, is another critical factor, which if not accounted for, can mislead the planning outputs. Thus, we see a skewed reliance on some of our indigenous resources such as water and coal, and not enough projects to tap the excessive solar and wind energy resources.

Moreover, another lurking concern, that arises from heavy reliance on hydropower, is the untimely completion of the hydropower projects. In the IGCEP, we see that hydropower projects take 59% share of the committed projects. Any delays in these projects will not only significantly impact the overall objective of the IGCEP, i.e. provision of low cost and reliable energy, but will also prove costly. The gravity of such impacts can be deciphered from the recent developments on Dasu hydropower project and Mohmand hydropower project. The delays have not only deferred the timeline, but have also inflated the project costs. The Chinese company Gezhouba Group Corporation, responsible for the project activities on Dasu hydropower project, have suspended their work on the project site since the last two months, and are not resuming the work, despite the security being provided by the Pakistan Army.[xv] The one-day delay in such projects, translates into deferment of 21 more days in restarting the project activities, resulting in hefty cost overruns.[xvi]

The large hydropower projects are also capital extensive requiring billions of dollars of investment. On top of it, the cost overruns and underestimation in costs, make them even more expensive. From a research study done on 245 dams built in the last century, it has been found that most budgets are underestimated 99% of the time.[xvii] Moreover, if inflation, debt servicing, and environmental externalities priced in, a dam could end up requiring twice its initial financial commitment with little chance of a return on investment.[xviii] The chairman of Water and Power Development Authority (WAPDA) also shared his concerns about higher project development costs, especially because of engagement of foreign

[6] Comprehensive Food Security and Livelihood Assessment (CFSLA) 2020 (Source: https://docs.wfp.org/api/documents/WFP-0000118584/download/?_ga=2.183694886.1495786651.1633581897-1659173499.1633581897)

consultants on the projects.[xix] In his opinion, the local engineering capacity in the country is deteriorating, and there is lack of focus on building capacity of hydro sector since last 30-40 years .[xx]

Considering all the discussed factors, the hydropower extensive direction of our power sector, will only lead us to conclusions that developed countries have already drawn, and the reversal from that point would be more expensive for our struggling economy. We have learned, that to date, 4,980 dams have been removed in countries including France, Sweden, Finland, Spain, England, Scotland, Denmark, and Germany, [xxi] and hundreds of dams have been removed in the United States and Europe at an enormous financial cost.[xxii] In the absence of feasible environment to harness solar and wind energy, hydropower would have been a better alternative, but given the plethora of solar and wind energy available, our aim should be to exploit these resources.

Continuous Reliance on Coal

Followed by hydropower, the plan extensively relies on committed local and imported coal power projects for power sector expansion. The coal power projects account for 17% share in the total committed projects. The projects categorized as 'candidate projects' in the power expansion plan, also comprise significantly of local and imported coal power plants. For the existing thermal power projects, the plan assumes continuation of their operations as per the terms of their respective signed Power Purchase Agreements (PPAs), and power will be procured from RLNG and imported coal projects on the basis of minimum obligated dispatch. In aggregation, the plan enlists over 8.5 GW of coal power projects either committed or candidates. Addition of this quantum of power from coal, that also during the era of climate change emergency, does not reflect responsible planning. Understanding the fact that Pakistan has huge reserves of coal, and energy security is a concern, but propagating a dirty fuel at the cost of environmental degradation, public health, and disruption of local livelihoods is not just. Moreover, as compared to VRE, it's also not inexpensive.

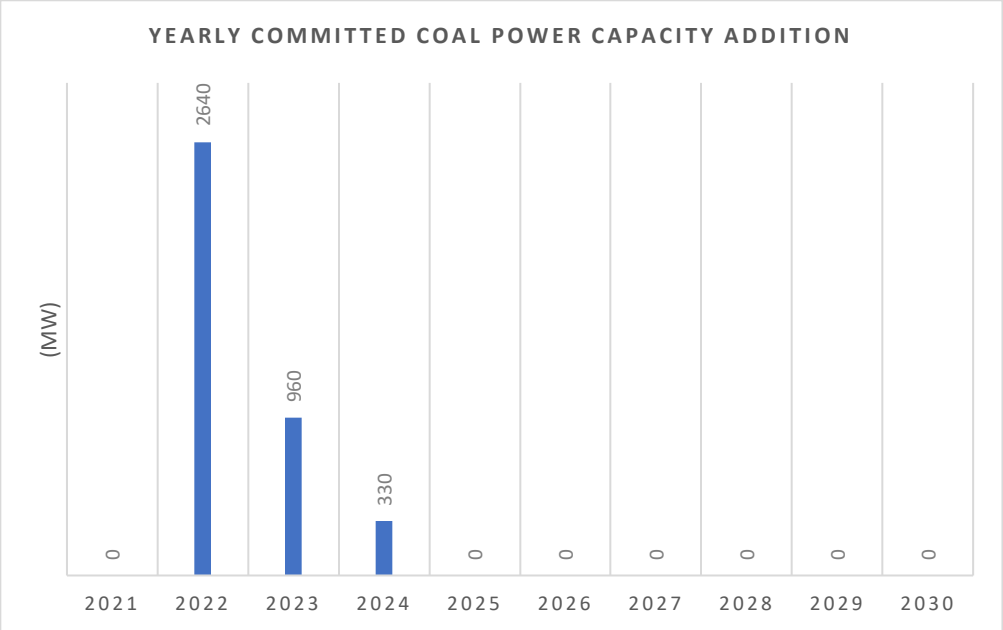

Figure 7: Yearly committed coal power additions

The country's premier announced in December 2020 coal moratorium, a commitment not to have coal-based power generation, but to put coal to use through conversions to gas and liquid.[xxiii] The inclusion of coal projects in the expansion planning thus appears to be a reversal from that stance. China also recently has announced to end its support for coal-based generation abroad and promote renewable energy instead.[xxiv] With China being a key player in Pakistan's development projects, and especially power projects, the implications of this announcement are not yet envisaged and the future of their involvement in coal projects in Pakistan is not clear. Nonetheless, such announcements 'in action' are needed for a greener energy transition. A study conducted by IRENA shows that global coal consumption would have to decline by 41% by 2030, and 87% by 2050 from 2016 levels to achieve energy transformation.[xxv]

Getting past coal is not only necessary for a green future, but also indispensable for the retention of the ecosystems where coal reserves are found. In Pakistan, since the exploitation of the coal reserves in Thar have begun, life for Tharis[7] is not familiar anymore. They have been displaced, lands through which they made their living have been taken away, the livestock they used to graze are now sold, the paths they used to cross are now restricted spaces for them, they are being discriminated in their own land by the foreign managements, their health and their lives are no more secured. The water is contaminated from coal mining disposal, the air has coal ash particles suspended, and the air quality has degraded from the emissions of the coal-fired power plant. The development also does not help the locals economically. Tharis, known for their abysmally low literacy rates — below 17%[xxvi] — have not been offered any management tier jobs in the companies that occupied Thar for coal mining and power production. They have been hired as truck drivers and similar jobs, that also without any protections in place. The capacity building of the local people has also been a distant promise made under corporate social responsibility agreements by the operating companies. This has been the 'development' for Tharis since past few years. If more coal-fired power projects are to come online in this upcoming decade, in the name of energy security, and indigenization of fuels for power generation, the future of Tharis is extinction. Therefore, the exclusion of such dynamics from the power sector planning, and acceptance of results as generated using a software, depicts a very constricted approach.

Even economically, the coal fired power generation, is no longer the cheapest energy option. According to a report[8] issued by IRENA in 2019, the projects costs for onshore wind and utility-scale PV in 2021 will fall to USD 0.043/kWh, and USD 0.039/kWh respectively — cheaper than the marginal operating costs of existing coal-fired power plants.[xxvii] Whereas, the coal-fired power generation cost around USD 0.177/kWh, estimating from new coal power generation units in China.[xxviii] An analysis of Levelized Cost of Energy conducted by LAZARD, also illustrates falling costs of renewable energy sources over the last decade, currently stand considerably lower than fossil fuel generation technologies. Therefore, considering the economic, environmental and social feasibility of coal-fired power projects, the emphasis on coal in the IGCEP will take us further away from meeting the climate goals.

[7] People of Thar

[8] Renewable Power Generation Costs in 2019, IRENA

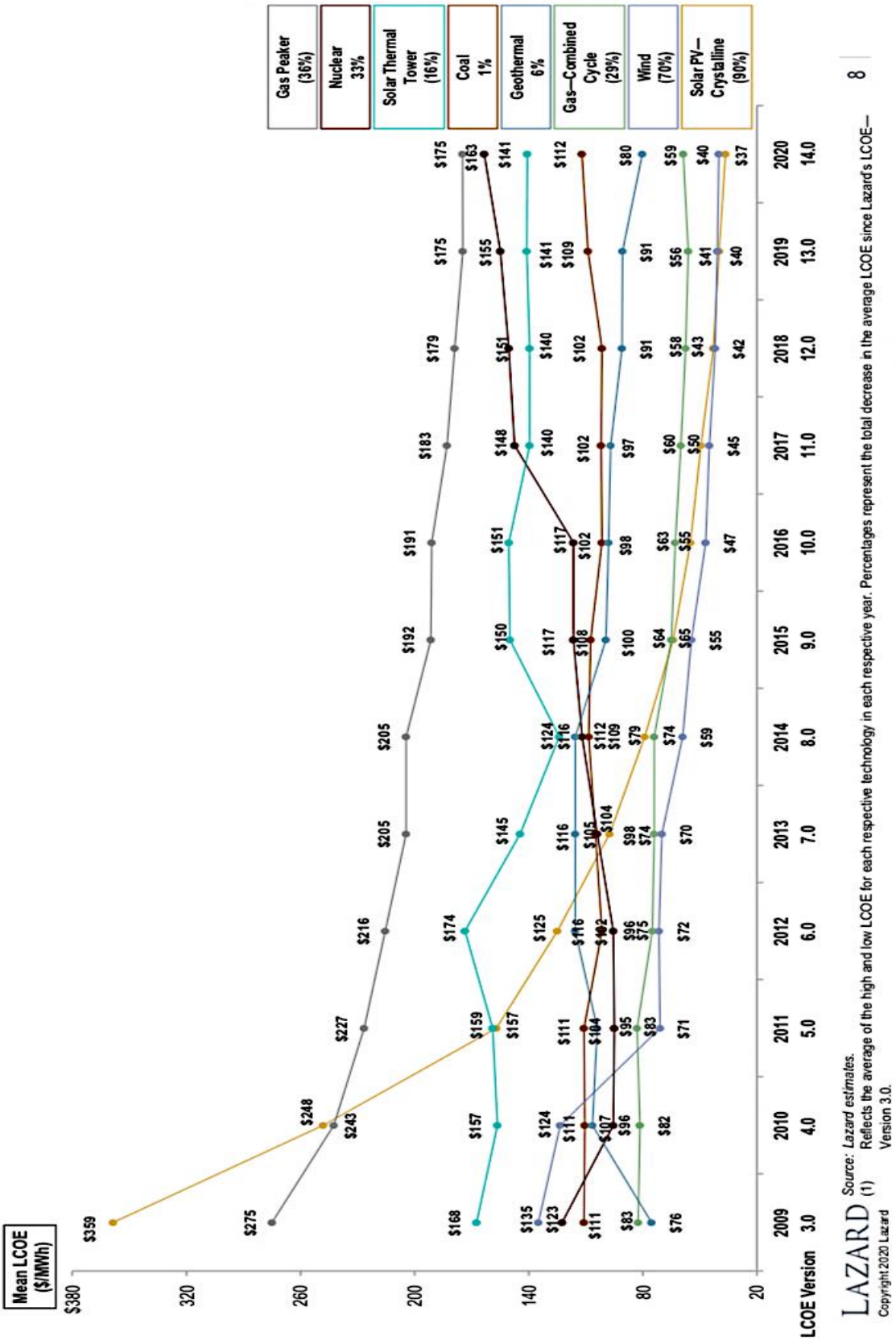

Figure 8: Mean LCOE comparison by technology

Discussion

There are certain gaps in the plan that need to be addressed. Where on one hand the assumptions on hydropower build-out are quite optimistic, IGCEP does not hint on any potential delays/risks of committed plants. The plan needs to be very realistic about implementation periods or doing at least additional scenarios to account for the stated risks. This again could be done through increasing ambition for VRE. Further, Distributed Generation (DG) is not accounted in the plan. Based on its growth trend, DG crossed 160 MW of installed capacity in March 2020 and is speedily increasing. IGCEP should consider this growth trend line in their analysis i.e., load forecast, and generation capacity expansion.

Importantly, in the run-up to carbon neutrality, the international community is setting extensive set of guidelines designed to accelerate decarbonization efforts across the countries. Since coal-fired power generation is a major source of direct CO_2 emissions, stranding these assets would constitute a key decarbonization initiative. Regions with ongoing coal build out will face greater financial risks. IGCEP also envisage addition of around 8 GW of local and imported coal-based additions by 2030. Based on the scale of these additions, this continued coal build out of power plants in Pakistan will have a large impact where under business as usual, the coal-fired capacity would need to be stranded after 2030 to meet decarbonization targets. Delayed policy action and overlooking these aspects while planning power sector expansion will only entail wide-scale negative economic impacts.

As IGCEP observes “Pakistan is at a crossroads at the moment and in fact faces a defining moment in its history”. The country has a clear opportunity to set the tone for adopting RE by following up on its ARE Policy 2019 pledge and committing to an ambitious 60% of power mix by 2030 which targets an end to the fuel’s use for power generation as early as possible. With the economics pointing towards this being feasible before the end of this decade, we should seriously consider embracing this chance to move to the forefront of global action in tackling the climate crisis. An urgent realignment of Pakistan’s power system with greater VRE penetration is the need of hour.

References

Ahmed, Syed Haris. 2020. "A realistic view of Pakistan's energy mix." *The Express Tribune.* March 23. https://tribune.com.pk/story/2181838/realistic-view-energy-mix.

Ansar, Atif, Bent Flyvbjerg, Alexander Budzier, and Daniel Lunn. 2013. "Should we build more large dams? The actual costs of hydropower megaproject development." *Energy Policy* 43-56.

Bhutta, Zafar. 2021. "Power consumers to pay Rs 1.1tr." *The Express Tribune.* April 22. https://tribune.com.pk/story/2296006/power-consumers-to-pay-rs11tr.

Essallah, Sirine, Adel Khedher, and Adel Bouallegue. 2019. "Integration of Distributed Generation in Electrical Grid: Optimal Placement and Sizing under Different Load Conditions." *Computers and Electrical Engineering* 79: 106461. https://doi.org/10.1016/j.compeleceng.2019.106461.

n.d. *Dam Removal Europe.* Accessed October 2020. https://damremoval.eu.

Dawn.com. 2020. "60pc of Pakistan's energy will be 'clean' by 2030: PM Imran." *Dawn News.* December 12. https://www.dawn.com/news/1595373.

Farooqui, Usmaan. 2021. "The Cost of Pakistan's Dam Obsession." *The Diplomat.* March 04. https://thediplomat.com/2021/03/the-cost-of-pakistans-dam-obsession/.

IRENA . 2020. *Renewable Power Generation Costs in 2019.* Abu Dhabi: International Renewable Energy Agency.

IRENA. 2020. *Global Renewables Outlook: Energy Transformations 2050.* Abu Dhabi: International Renewable Energy Agency.

LAZARD. 2020. *LAZARD'S Levelized Cost of Energy Analysis—Version 14.0.* Analysis, LAZARD.

Lopes, J. A.Peças, N. Hatziargyriou, J. Mutale, P. Djapic, and N. Jenkins. 2007. "Integrating Distributed Generation into Electric Power Systems: A Review of Drivers, Challenges and Opportunities." Electric Power Systems Research 77 (9): 1189–1203. https://doi.org/10.1016/j.epsr.2006.08.016.

Lueken, Colleen, Pedro M.S. Carvalho, and Jay Apt. 2012. "Distribution Grid Reconfiguration Reduces Power Losses and Helps Integrate Renewables." *Energy Policy* 48: 260–73. https://doi.org/10.1016/j.enpol.2012.05.023.

Ma, Chenjie, Jan Hendrik Menke, Johannes Dasenbrock, Martin Braun, Matthias Haslbeck, and Karl Heinz Schmid. 2019. "Evaluation of Energy Losses in Low Voltage Distribution Grids with High Penetration of Distributed Generation." Applied Energy 256 (September): 113907. https://doi.org/10.1016/j.apenergy.2019.113907.

Malik, Sadia, Maha Qasim, and Hasan Saeed. "Green finance in Pakistan: Barriers and solutions." *Handbook of Green Finance: Energy Security and Sustainable Development* (2019): 1-17.

McGrath, Matt. 2018. "Large hydropower dams 'not sustainable' in the developing world." *BBC News.* November 05. https://www.bbc.com/news/science-environment-46098118.

Mirjat, Nayyar Hussain, Mohammad Aslam Uqaili, Khanji Harijan, Gordhan Das Valasai, Faheemullah Shaikh, and M Waris. 2017. "A Review of Energy and Power Planning and Policies of Pakistan." *Renewable and Sustainable Energy Reviews* 79 (March): 110–27. https://doi.org/10.1016/j.rser.2017.05.040.

NTDC. 2021. Revised Indicative Generation Capacity Expansion Plan 2021-2030. Power System Planning, Islamabad: National Transmission and Dispatch Co. Ltd.

Pepermans, Guido, J. Driesen, D. Haeseldonckx, R. Belmans, and W. D'haeseleer. 2005. "Distributed Generation: Definition, Benefits and Issues." *Energy Policy* 33 (6): 787–98. https://doi.org/10.1016/j.enpol.2003.10.004.

Purchala, K, R Belmans, K U Leuven, L Exarchakos, and a D Hawkes. 2006. "Distributed Generation and the Grid Integration Issues." *Imperial College London*, 9.

Siddiqui, Salman. 2021. "Power generation hits all-time high." *The Express Tribune.* August 13. https://tribune.com.pk/story/2315305/power-generation-hits-all-time-high.

Samejo, Deedar Hussain. 2016. " A nightmare in Thar Desert." *The Daily Times .* March 15. https://dailytimes.com.pk/92935/a-nightmare-in-thar-desert/.

Sengupta, Somini, and Rick Gladstone. 2021. "China Pledges to Stop Building Coal-Burning Power Plants Abroad." *The NY Times.* September 21. https://www.nytimes.com/2021/09/21/climate/china-power-plants-coal.html.

World Bank. 2020. *Variable Renewable Energy Integration and Planning Study.* Pakistan Sustainable Energy Series, Washington DC: World Bank .

n.d. *World Food Program.* Accessed October 2021. https://www.wfp.org/countries/pakistan.

END NOTES

[i] Siddiqui, Salman. 2021. "Power generation hits all-time high." The Express Tribune. August 13. https://tribune.com.pk/story/2315305/power-generation-hits-all-time-high.

[ii] Ibid

[iii] Bhutta, Zafar. 2021. "Power consumers to pay Rs 1.1tr." The Express Tribune. April 22. https://tribune.com.pk/story/2296006/power-consumers-to-pay-rs11tr.

[iv] Mirjat, Nayyar Hussain, Mohammad Aslam Uqaili, Khanji Harijan, Gordhan Das Valasai, Faheemullah Shaikh, and M Waris. 2017. "A Review of Energy and Power Planning and Policies of Pakistan." Renewable and Sustainable Energy Reviews 79 (March): 110–27. https://doi.org/10.1016/j.rser.2017.05.040.

[v] Lopes, J. A.Peças, N. Hatziargyriou, J. Mutale, P. Djapic, and N. Jenkins. 2007. "Integrating Distributed Generation into Electric Power Systems: A Review of Drivers, Challenges and Opportunities." Electric Power Systems Research 77 (9): 1189–1203. https://doi.org/10.1016/j.epsr.2006.08.016.

[vi] Pepermans, Guido, J. Driesen, D. Haeseldonckx, R. Belmans, and W. D'haeseleer. 2005. "Distributed Generation: Definition, Benefits and Issues." Energy Policy 33 (6): 787–98. https://doi.org/10.1016/j.enpol.2003.10.004.

[vii] Purchala, K, R Belmans, K U Leuven, L Exarchakos, and a D Hawkes. 2006. "Distributed Generation and the Grid Integration Issues." Imperial College London, 9.

[viii] Ma, Chenjie, Jan Hendrik Menke, Johannes Dasenbrock, Martin Braun, Matthias Haslbeck, and Karl Heinz Schmid. 2019. "Evaluation of Energy Losses in Low Voltage Distribution Grids with High Penetration of Distributed Generation." Applied Energy 256 (September): 113907. https://doi.org/10.1016/j.apenergy.2019.113907.

[ix] Essallah, Sirine, Adel Khedher, and Adel Bouallegue. 2019. "Integration of Distributed Generation in Electrical Grid: Optimal Placement and Sizing under Different Load Conditions." Computers and Electrical Engineering 79: 106461. https://doi.org/10.1016/j.compeleceng.2019.106461.

[x] Emilio F. Moran, Lopezb, Maria Claudia, Nathan Moore, Nobert Muller, and David W. Hyndman. 2018. "Sustainable hydropower in the 21st century." PNAS 8.

[xi] McGrath, Matt. 2018. "Large hydropower dams 'not sustainable' in the developing world." BBC News. November 05. https://www.bbc.com/news/science-environment-46098118.

[xii] Ibid

[xiii] Farooqui, Usmaan. 2021. "The Cost of Pakistan's Dam Obsession." The Diplomat. March 04. https://thediplomat.com/2021/03/the-cost-of-pakistans-dam-obsession/.

[xiv] .d. *World Food Program.* Accessed October 2021. https://www.wfp.org/countries/pakistan.

[xv] Mustafa, Khalid. 2021. "After Pak Army's security cover: Suspension of work at Dasu project worries Wapda." The News International. September 11. https://www.thenews.com.pk/print/890974-after-pak-army-s-security-cover-suspension-of-work-at-dasu-project-worries-wapda.

[xvi] Ibid

[xvii] Ansar, Atif, Bent Flyvbjerg, Alexander Budzier, and Daniel Lunn. 2013. "Should we build more large dams? The actual costs of hydropower megaproject development." Energy Policy 43-56

[xviii] Ibid

[xix] Mustafa, Khalid. 2021. "After Pak Army's security cover: Suspension of work at Dasu project worries Wapda." The News International. September 11. https://www.thenews.com.pk/print/890974-after-pak-army-s-security-cover-suspension-of-work-at-dasu-project-worries-wapda.

[xx] Ibid

[xxi] n.d. Dam Removal Europe. Accessed October 2020. https://damremoval.eu.

[xxii] Emilio F. Moran, Lopezb, Maria Claudia, Nathan Moore, Nobert Muller, and David W. Hyndman. 2018. "Sustainable hydropower in the 21st century." PNAS 8.

[xxiii] Dawn.com. 2020. "60pc of Pakistan's energy will be 'clean' by 2030: PM Imran." Dawn News. December 12. https://www.dawn.com/news/1595373.

[xxiv] Sengupta, Somini, and Rick Gladstone. 2021. "China Pledges to Stop Building Coal-Burning Power Plants Abroad." *The NY Times.* September 21

[xxv] IRENA. 2020. Global Renewables Outlook: Energy Transformations 2050. Abu Dhabi: IRENA.

[xxvi] Samejo, Deedar Hussain. 2016. " A nightmare in Thar Desert." The Daily Times. March 15. https://dailytimes.com.pk/92935/a-nightmare-in-thar-desert/.

[xxvii] IRENA (2020), Renewable Power Generation Costs in 2019, International Renewable Energy Agency, Abu Dhabi

[xxviii] Ibid