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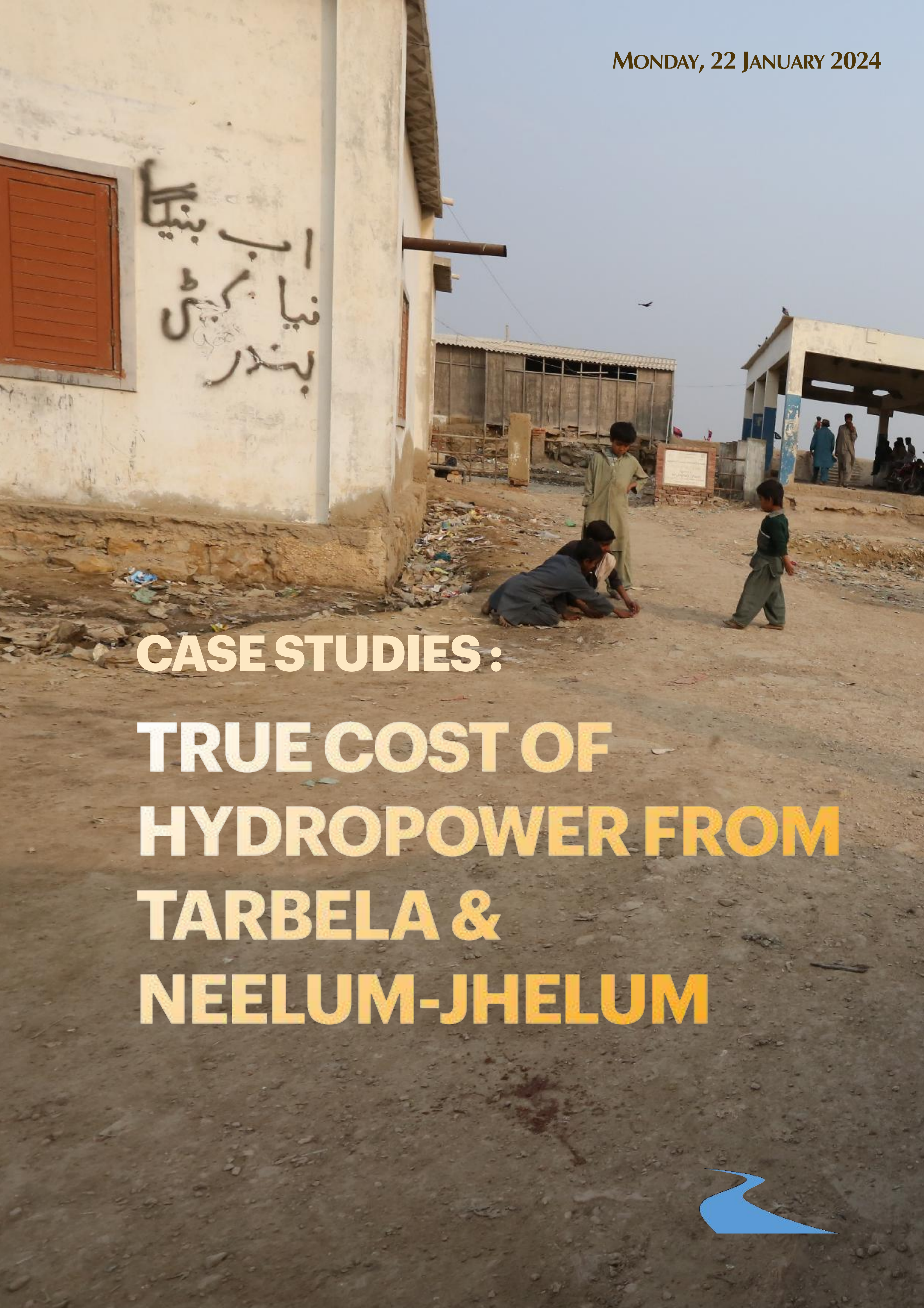

CASE STUDIES :

TRUE COST OF HYDROPOWER FROM TARBELA & NEELUM-JHELUM

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Tara Climate Limited

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Deliverable 02

True Cost of Hydropower in Pakistan:

Case Studies
Cost of Hydropower from Tarbela and Neelum-Jhelum Hydropower

By

*Hassan Abbas**

This report feeds into the broader perspective of Energy Transition in South Asia. Collaboration partners in developing this report include: Alliance for Climate Justice and Clean Energy (ACJCE), Policy Research Institute for Equitable Development (PRIED) and Alternative Law Collective (ALC). This Hydro-costing methodology was prepared as a precursor to the project specific case studies of two large hydropower facilities in the Indus Basin of Pakistan - one, hydropower with water storage, and two, hydropower as run-of-the-river.

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Cover Photo: Barefooted children play in dirt besides an open sewerage channel and a graffiti on the building reads 'now a new town of Keti Bandar will be built'. Keti Bandar - once a thriving port city on Indus Delta drifted into poverty due to sea water intrusion after large dams and diversions on the Indus River choked the silt supply to Indus Delta, vital to keep seawater intrusion in check. Photo © Abbas

Document Control Sheet

Key Persons:	**Other Info:**
Dr Mushtaq Gaadi (Tara Climate Limited)	**Project Code:** C-2212-00168
Dr Hassan Abbas (Consultant PI) Ph.D. Hydrology & Water Resources (MSU, USA) M.Sc. Groundwater Management (UTS, Australia) B.Sc. Civil Engineering (MCE/NUST, PK) *Forte: Integrated Water Resources Management*	**Parties:** • Tara Climate Limited • Consultants **This Document:** True Cost of Hydropower in Pakistan: Case Studies - Tarbela & NJHP
Asghar Hussain (Consultant) MS Computer Science (ICT, GWLC, UK) BS Computer Science (CICS, CA, USA) River Basin Information Management System (Jena, Germany) Certified Remote Sensing & GIS Professional (ITC, Netherlands) Certified GPS Professional (IGN, France) *Forte: Hydroinformatics*	**Corresponding Nodes** • Consultants: Dr Hassan Abbas abbashas@msu.edu • Tara Climate: Dr Mushtaq Gaadi mushtaq.gaadi@taraclimate.org

Title:	**True Cost of Hydropower from Tarbela**
Author(s):	Abbas, H., & Hussain, A.
Reviewed by:	
Synopsis:	In tariff determination of electric power, the cost of hydropower is reckoned as one of the lowest in Pakistan. However, the cost of social, environmental and economic externalities - such as its impact on Indus delta and displacement of population, both in the near and far proximities of the project are not accounted for in the tariff calculations. This report, makes an endeavour to take a comprehensive account of true cost of hydropower from Tarbela and

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Executive Summary

The estimated cost of producing electricity from hydropower dams exceeds Rs 50 per unit when we take into account the externalities. We found that it costs Rs 53.61 to produce a unit of electricity at Tarbela and Rs. 50.55 at Neelum-Jhelum.

In this report, an effort has been made to account for the true cost of hydropower in Pakistan, using two case studies as examples. The first case study is for Tarbela hydropower. Tarbela was built as multipurpose dam, while the second study is on Neelum-Jhelum Hydropower built as the run-of-the-river hydropower facility.

In case of Tarbela, the major cost is accrued from one, carbon footprint of the reservoir lake and lost ecological services responsible for carbon sequestration; and two, from its share of silt trapping which results in erosion of the Indus Delta. Other costs are shown Table E1 below.

Table E1 - Tarbela Costs

Item	Section of this report	Costs (billion USD)
Total direct cost	4.1	15.961
Cost of financing	4.2	19.792
Feasibility exaggeration and lost water	**4.3**	**194.567**
Lost Income	4.4.2	0.646
Land Lost in Indus Delta	4.4.2	50.000
Trauma	4.4.3	0.019
Secutiry	4.5	0.120
O&M	4.6	2.146
CO_2e	4.7	58.660
Risk/insurance	4.8	5.000
Decomissioning	4.9	4.000
Other externalities	4.10	1.000
Total Cost		**351.911**

The prime function of Tarbela Dam was water storage and supply for irrigation and its supplementary function was power generation. It was envisaged in Lieftink Report that 75% benefits of the dam will accrue from water supply and 25% from power generation. The case study on Tarbela, however, revealed that the facility has done more harm to water resources than good. The losses due to water are highlighted in blue in the Table above, and have not been added to the cost of electricity. One can see, however, that the loss due to water is more than all other costs combined.

In case of Neelum-Jhelum Hydropower, time/cost overruns, cost of financing and social costs are the biggest factors in raising the generation cost. Seismicity is the biggest risk and people are neither aware not informed about its dangers. The dam has already been designed to breach under certain conditions in way that major infrastructure will remain safe and the deluge of water will pass down the valley. But for the valley and it's residents, their is neither insurance cover nor any emergency plan know to the public.

Table E2 Neelum-Jhelum Costs

Item	Section of this report	Costs (billion USD)
Total direct cost	8.1	5.100
Time/cost orverruns	8.2	5.470
Financing cost	8.3	6.259
O&M	8.4	4.570
Legal battle	8.5	0.010
Social cost	8.6	7.420
Environ. Impacts	8.7	2.000
Seismic risk	8.8	1.000
Decomissioning	8.9	0.500
Total Cost		**32.329**

The aim of the study had not been to evaluate dollar values with precision, but to highlight the ballpark costs involved in producing hydropower in Pakistan. The cost estimates given in this study, therefore, are for general reference and can be improved with detailed study of each aspect covered here.

Moreover, the aspects covered in these estimates are not comprehensive. There could be more externalities which have not be touched upon. Further studies can help fine-tune the process as well as the estimates made here.

Acronyms and Abbreviations

Abbreviation	Explanation
ADB	Asian Development Bank
AIIB	Asian Infrastructure Investment Bank
BCM	Billion Cubic Meter
CO_2e	Carbon-dioxide equivalent of green house gasses
DISCO	Distribution Company
GHG	Green house gasses
GW	Gigawatt
IBDF	Indus Basin Development Fund
IBP	Indus Basin Project
IBRD	International Bank for Reconstruction and Development
IRSA	Indus River System Authority
IWT	Indus Waters Treaty
kW	Kilowatt
kWh	Kilowatt-hour
MAF	Million Acre Feet
MoWR	Ministry of Water Resources (Pakistan)
MW	Megawatt
MWh	Megawatt-hour
NEPRA	National Electric Power Regulatory Authority
NJHP	Neelum-Jhelum Hydropower
NJHPC	Neelum-Jhelum Hydropower Company (Private) Limited
NTDC	National Transmission and Despatch Company
O&M	Operations and maintenance
SCC	Social cost of carbon
T4	Tarbela 4th Extension
T5	Tarbela 5th Extension

Abbreviation	Explanation
TAMS	Tippets-Abbett-McCarthy-Stratton (Consulting firm)
TDF	Tarbela Dam Fund
TDP	Tarbela Dam Project
TWh	Terawatt-hour
UN	United Nations
WAPDA	Water and Power Authority
WB	The World Bank

Table of Contents

List of Figures

True Cost of Hydropower in Pakistan

CASE STUDY 01

TRUE COST OF TARBELA HYDROPOWER

1. CONTEXT

Hydropower from Tarbela Dam is touted as one of the cheapest in Pakistan and clean (carbon free) energy too. National Electric Power Regulatory Authority (NEPRA) has set power generation tariff for Tarbela's power generation at Rs. 4.57 per kilowatt hour (kWh) in September 2023. However, this tariff does not seem to include the social, environmental and economic externalities associated with large hydropower generation.

Tarbela Dam was primarily built as part of '*replacement works*' to offset the impact of shutting down the flow of Ravi, Beas and Sutlej Rivers by India across the border of Pakistan. International Bank for Reconstruction and Development (IBRD), now called The World Bank (WB), brokered a deal between India and Pakistan - now called the Indus Waters Treaty (IWT), which allowed India to cut, shut, dam and divert these rivers. Pakistan, in turn, was promised loans by IBRD to build replacement works.

The prime purpose of Tarbela Dam was, thus, to hold summer flows (reckoned as surplus) and release it to supplement for winter cropping or *Rabi*, in the irrigated areas of Pakistan. The dam, however, was built as a multi-purpose dam and power generation was part of its original design. The dam has no provision of flood control in its original design. Any flood control provided by the dam is 'incidental', according to a 1994 report published by Water & Power Development Authority (WAPDA).

The dam, hence, serves two purposes, i.e., supplement irrigation water supplies and generate hydropower. The lifecycle cost/benefit of the dam is, therefore, divided between its functions of water supply for irrigation and power generation.

The aim of this study is to estimate the per unit cost of power generation over the lifecycle of Tarbela Dam. This implies that costs incurred on water supply and power generation should be separated from each other.

This study first looks at the total benefits of irrigation water supply and energy generation from the dam. It then looks at the lifecycle cost of building and operating the dam. Finally it distributes the total costs proportional over the multipurpose benefits of the dam i.e., irrigation water supply and energy generation.

2. HISTORICAL BACKGROUND

Soon after partition of Sub-Continent in 1947, a water sharing dispute broke out between India and Pakistan in April 1948 when India, being the upper riparian, shut the irrigation canals leading into Pakistan across the international boarder. India showed her intentions to take 100 % waters of the Ravi, Beas, and Sutlej (the Eastern Rivers) plus 7% from Indus, Jhelum and Chenab (the Western Rivers). Pakistan, however, maintained that historical use of water from the Eastern Rivers should continue into Pakistan and that the Western Rivers should remain 100% in Pakistan's use.

IBRD brokered the deal between the two countries such that India could get her desired share of Water (100% Eastern Rivers and 7% Western Rivers) while Pakistan gets and infrastructure c of the 'replacement works' to divert water into the Eastern Rivers from the Western Rivers to maintain historical flows in the Eastern Rivers, along with some new projects. However, India would pay a fixed amount of £62 million (USD 1.86 billion current value) towards the construction of the replacement works.

An Indus Basin Project (IBP) was conceived for Pakistan at an estimated cost of USD 895 million (USD 9.577 billion current value) for the required plumbing in the river system. An Indus Basin Development Fund (IBDF) of was created to finance the IBP with contributions from the WB and other donors which included Australia, Canada, Germany, New Zealand, the United Kingdom and the United State.

An agreement[1] (later known as Indus Waters Treaty or IWT) was signed between India, Pakistan and IBRD and annexed to Indus Basin Development Fund Agreement to ensure India's contribution to IBDF . The Treaty was, however, opposed by those who maintained that IBP would only include (ever-depleting) large storage facilities, replacing water that Pakistan would be losing, by surrendering to India the perennial flow waters of the three eastern rivers (Asianics 2000).

However, it soon became apparent the funds committed would be insufficient for the works conceived. The Bank, the contributing governments and Pakistan, reached a compromised on a for a reduced system of works in which Mangla Dam, the barrages and the link canals would be given priority and the tube wells and drainage works would be omitted; leftover funds from IBDF would be made available to Pakistan for financing the Tarbela Dam Project (TDP).

A new financing plan involving an additional USD 315 million (USD 2.867 billion current value) in foreign exchange from the contributors was arranged by 1968 and signed by all parties. Besides provision of replacement flows for the rivers ceded to India, the TDP was conceived to integrate/regulate Indus Basin Irrigation System (IBIS), with following objectives in view:

(1) to provide 9.3 MAF of storage to almost doubling the dry season - *Rabi* ;

(2) to provide additional supplies to facilitate further development of new and ongoing irrigation projects ;

(3) to achieve self sufficiency, especially in wheat; and,

(4) to generate up to 2100 MW hydropower in staged phases.

The first of the three objectives relate to water storage function of the dam. The last one relates to energy generation.

The useful life of the dam is now considered to be 85 years (Asianics 2000, Lorrai and Pasche 2007). It is predicted, however, that by 2035, the dam will be more like a run-of-the-river power

[1] This agreement is also called Indus Waters Treaty. It was entered in the UN Register (United Nations - Treaty Series) as a formal international treaty (with annexes) No.6032 on 16 January 1962 on India's request

generation facility with useful storage almost gone (Munir et al., 2022).

3. BENEFITS OF TARBELA DAM

It must be borne in mind that the main purpose of building Tarbela Dam was to store and provide water for irrigation. The energy generation function was to be a supplementary benefit only.

3.1. Water Storage

During the negotiations of IWT, on February 5, 1954, IBRD submitted its proposal to both India and Pakistan according to which the entire flow of Indus, Jhelum and Chenab (Western Rivers) would be available for exclusive use of Pakistan while Ravi, Beas and Sutlej (Eastern Rivers) would be available for exclusive use of India.

The IBRD (1954) proposal also stated that:

> *"... no reservoir storage will be required [in Pakistan] to supplement flow water in continuing the historic withdrawals. The interconnected system which the link canals would provide could be so operated as to meet the existing requirements... Even without further storage construction, Pakistan could supply her historic withdrawals... [and] could also meet the requirements of [new] projects on the Indus."*

The statement implied that, according the assessment of IBRD's engineers, on the basis of data collected and of their field inspections of sites and works, Pakistan did not need storage reservoirs to meet historic and/or upcoming irrigation needs. Essentially, irrigation system of Pakistan was 'run-of-the-river' and could continue as such with link canals without having to build dams. The Bank's engineers felt that they could guarantee the historic uses to pre-partition levels, as well as for the upcoming Kotri and Thal projects.

3.1.1. Political Failure

It is interesting to note that India had readily accepted IBRD's proposal of 1954 and completely withdrew from her 7% claim on Western Rivers. Pakistani engineers and decision makers, however, did not accept the 1954 plan and kept on insisting for the provision storage reservoirs as part of replacement works. This delayed the signing of the treaty until 1960, but in the meantime, India successfully asserted her demand for 7% of water from the Western Rivers as was her original position in 1953 on the distribution of Indus Waters. On the one hand, when the treaty was finally signed in 1960, Pakistani engineers had convinced the Bank for two large dams on Jhelum and Indus (Mangla and Tarbela respectively) with a combined storage of 8.95 MAF[2] (4.75 MAF for Mangla and 4.2 MAF for Tarbela at the time the Treaty was signed), but on the other hand, had lost 7 MAF from Western Rivers to India. Net gain was only 2 MAF or so, for which Tarbela's net share for irrigation comes to just 1 MAF. The cost of building the dams hardly justifies this bargain.

3.1.2. Technical Failure

How valid is the assertion today, that Tarbela and Mangla are the backbone of Pakistan's irrigation system? And how sound was the assessment of Pakistani engineers, for the need of storage dams for irrigation? Or, were the IBRD engineers right that Pakistan's irrigation system does not need dams? We delve into the data since the construction of dams to scrutinise these questions. Our prime focus will remain on Tarbela for the context of this study.

Nazir and Chaudhry (1988) reported Post-Tarbela[3] additional supply for Rabi cropping for 1976-78 average as follows:

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[2] At the time of signing the treaty, the storage volumes conceived for Jhelum Dam (Mangla) and Indus Dam (Tarbela) was conceived to be of 4.75 MAF and 4.2 MAF respectively. However, when the dams were actually built, the live storage of Mangla and Tarbela was 4.75 MAF and 9.3 MAF respectively (Ahmad and Chaudhry 1988).

[3] Additional contribution at Guddu, Sukkur and Kotri from Mangla has been proportionately deducted compared to the figures reported by Ahmad and Chaudhry (1988) to focus on Tarbela's contribution only.

Table 01: Post Tarbela additional water supplies (1976-78)

Canal Headworks	Additional Rabi Supply (MAF)
Pehur	0.04
Thal	0.38
Taunsa	1.19
Guddu	0.52
Sukkur	0.73
Kotri	0.66
Total	**3.52**

With 9.3 MAF of live storage, the reservoir could only supplement 3.52 MAF at canal heads because of the conveyance efficiency of the river system. This implies the river's conveyance efficiency from the dam to the canal heads is only 38%. And given only 70% conveyance efficiency of canals and also 70% that of the water courses, the contribution of Tarbela at the farm gate is only 1.77 MAF.

Reservoir Sedimentation

One of the technical reasons for not building dams on the Indus prior to Tarbela was because the river was highly silted and any reservoir build on its main channel would have short life due to sedimentation (Michel 1967).

Before the construction of Tarbela Dam, TAMS - the consultants of Tarbela Dam Project (TDP) analysed river sediment data from Irrigation Research Institute (IRI) and WAPDA and estimated 430 million tons of annual sediment load at Darband which would be fully trapped in Tarbela reservoir. They estimated annual depletion rate of reservoir storage at 0.16 MAF, with estimated useful life of the reservoir to be about 50 years (Nazir and Chaudhry 1988).

Roca (2012) estimated an average annual accumulation of approximately 200 million tonnes.

The reservoir capacity of Tarbela Dam has depleted at the annual rate of 0.11 MAF. It has depleted by 40% since its construction and now the live storage capacity of the reservoir stands at 6.17 MAF. By 2035, the gross storage capacity will be only 2.33 MAF and live storage will on just 0.97 MAF. It will become a run-of-the-river reservoir (Munir et al., 2022).

Holding Back Early Summer Flows

It is obvious that Tarbela will not be able to serve irrigation needs after 2035 - losing its prime function of storage to supplant irrigation. But has it paid any dividends to irrigation (agriculture) sector during its hey days?

The data from Tarbela's inflows and outflows from 1976 to 2010 were analysed to estimate the net irrigation benefits during early period of its life.

The data suggests that between 1976 and 2010, the reservoir has stored an average of 6.9 MAF of in summers and released 6.8 MAF in winters. The difference may be reservoir losses due to evaporation and deep drainage etc.

Taking into account 38% conveyance efficiency from the dam to the canal heads, the irrigation supplement to canals in Rabi season is 2.55 MAF. The subsequent contribution after canal/water course losses at farm gate though Tarbela Dam is only 1.27 MAF in Rabi season.

But for Kharif season, the impact of Tarbela had been negative, especially for early summer sowing in southern parts of the basin where summers set earlier (Abbas and Hussain 2022).

The data shows that the filling of reservoir begins as soon as summer flows from snow melt and glacial melts begin in early summers. Tarbela Reservoir holds back an average of 1.9 MAF of pre-monsoon early summer flows between March and June. This is time of very low rainfall and early summer sowing, especially in Sindh, is critically dependent on early summer flows from snow and glaciers in the river system. However, 1.9 MAF held back behind Tarbela Dam not only deprives irrigation needs in early Kharif but also causes disputes among the federating units of Punjab and Sindh (upper and lower riparian) on water allocations during the summer.

Economically speaking, summer crops fetch more economic value than the winter ones. Tarbela's overall contribution of 1.27 MAF in Rabi is more than offset by creating 1.9 MAF of shortages in Kharif.

Reduction in Winter Flows

Apparently after construction of Tarbela Dam, summer flows in the river have decreased while those of winters should have increased. However, it may sound counter intuitive, but due to uncontrolled modifications in the riverine hydrology after the dam, winter flows have actually reduced in the Indus.

Kharal and Ali (2007), assessed the losses and gains in the Indus river system before and after the construction of Tarbela reservoir, in the context of historical data from 1940 to 2003. It was found that post-Tarbela losses in the Indus, between Tarbela and Kotri, increased from 10.86 MAF to 18.22 MAF, a net additional loss of 7.36 MAF — which is already higher than the 6.8 MAF of water that Tarbela releases in the Rabi season. In other words, 7.36 MAF more water would reach Kotri every year if there was no Tarbela Dam. The same study has also reported that during pre-Tarbela winters, the river would gain about 2.5 MAF of additional water between Tarbela and Kotri, primarily due to groundwater seepage. However, in the post-Tarbela era, the river loses about 2.3 MAF of water between the same reach — or about 4.8 MAF net loss in water in the winter months at Kotri after Tarbela. In other words, the river running in its natural state was bringing 4.8 MAF more water in winters compared to 1.27 now supplied by the dam - net loss of winter flows by 3.53 MAF.

This loss alone more than nullifies the 1.27 MAF of contribution of the Indus in the Rabi season.

3.1.3. Net Benefits for Irrigation

Pakistan's irrigation system consumes 104 MAF of water in a year. Tarbela supplements 1.27 MAF at farm gates in Rabi only - or a little over 1% of total irrigation. However, the dam deprives 1.90 MAF of river flow water in the critical period of Kharif sowing. And finally, there is a net decrease of 4.8MAF in winter flows of the river due to structural modifications upstream. But on top of all these losses, we forfeited 3.5 MAF on account of Tarbela (total water forfeited to India from western rivers was 7 MAF) from to get the loans for two dams.

In summary, we lost 3.53 MAF of winter flows (Rabi), 1.9 MAF of summer (Kharif) flows and 3.5 MAF of water was forfeited to India. The total river flows due to Tarbela is a staggering **8.93 MAF of loss.**

Given 34% of flow efficiency of the river, we lost 3.4 MAF of irrigation supply in the canals.

This analysis shows that IBRD's engineers were right that Indus is a run-of-the-river system for irrigation supplies and additional reservoirs were not required in Pakistan to supplement irrigation needs. Storage for irrigation from Tarbela is a net loss to the system.

3.2. Energy Generation

The primary function of Tarbela Dam was irrigation, with power as a secondary objective (Asianics 2000), however, since its construction, the energy gains have outweighed the irrigation benefits (Tate and Farquharson 2000).

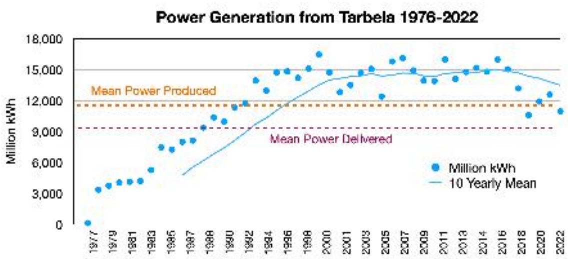

Figure 01: Energy produced at Tarbela since 1976 (Source Data: WAPDA http://archive.wapda.gov.pk/index.php/projects/hydro-power/o-m/tarbela-dam/item/665-statistical-data-2022 accessed on 03 January 2024)

Year wise energy generation from Tarbela hydropower is shown in Figure 01 from 1976 to 2022. Total energy produced at Tarbela, as reported by WAPDA is between this time is 534 TWh. Mean annual energy produced at Tarbela is 11.61 TWh, and after reported losses of 18.1% (NTDC 2023), 9,651 million KWh annually was delivered to the consumers. Total current installed capacity is 4,888 MW as follows:

Tunnel 1 - 700 MW (completed 1977)
Tunnel 2 - 1,050 MW (completed 1985)
Tunnel 3 - 1,728 MW (completed 1993)
Tunnel 4 - 1,410 MW (completed 2018)
Tunnel 5 - 1,530 MW (under construction)

4. LIFECYCLE COSTS OF TARBELA DAM

In order to assess the true cost of hydropower from Tarbela, we need to assess the true cost of Tarbela borne by the society and the environment, taking into account externalities which are often ignored/omitted from the cost calculations.

This section assess the costs incurred on TDP as part of IBP. The aim is not to arrive at the most accurate cost estimate but to get to a ballpark figure for the unit cost of electricity generation through Tarbela, as received at the consumer end after line losses have been accounted for.

When the project was designed, its life was known to be limited due to reservoir silting, given substantial silt load in the river upstream. Various studies have estimated the life of the dam. Most recent ones predict that the live storage capacity would be almost completely lost and the dam will only be a run-of-the-river power generation facility by 2035, generating limited power - and highly susceptible to season variations in the river flow. Installed capacity of Tarbela after the 5th Extension will be 6418 MW.

4.1. Direct Costs

The exact figures of the total direct cost spent over the lifetime of Tarbela are not known. Instead, we take only the costs which have been documented and reported through sources such as IBRD, WAPDA, published literature and Ministry of Water Resources (MoWR) etc.

Inflation in currency values are catered for. The cost reported in each year have been converted o current USD value for consistency.

4.1.1. The Dam and Power House

The financing of TDP came through Tarbela Development Fund (TDF) created in 1968 out of the remaining balance from the IBDF and additional loans and grants from friendly countries. Pakistan agreed to fund the local currency (PKR) component of the project.

- USD 324million from IBDF
- USD 498million from WB and friendly countries
- Equivalent PKR component USD 675million
- Total Cost amounted to USD 1.497billion (USD 13.6billion current value)

Tarbela was completed two years behind schedule. The delays were caused by technical issues. The above cost does not cater for the delays and additional costs incurred in solving the major technical problems.

4.1.2. Tarbela 4th Extension

Tarbela 4th Extension or T4 will add 1,410 MW of installed power at Tarbela. The annual energy generation from T4 project will be 3,840 GWh (MoWR)[4].

USD 914million in 2012 (USD 1.261billion Current value) provided by the WB[5]

4.1.3. Tarbela 5th Extension

Tarbela 5th Extension or T5 will add 1,530 MW of installed power at Tarbela. The annual energy generation from T5 project will be 1,347 GWh (MoWR)[6].

- Asian Infrastructure Investment Bank (AIIB) - USD 300million
- WB provided USD 390million
- WAPDA's contribution of 14% equivalent USD 114million

[4] https://mowr.gov.pk/Detail/ZmM5YzU5NjgtOWRlMS00YWE4LTg3ODUtMzM4YzUzN2IyMjIw

[5] https://projects.worldbank.org/en/projects-operations/project-detail/P115893

[6] https://mowr.gov.pk/Detail/Y2VkZWQ3Y2ItNTBiNy00ZWEyLWJmMGQtNjI1YTk3ZjVlYjI5

- NTDC's contribution of 1% equivalent USD 8 million

Total financing was USD 826.1million (USD 1.09 billion current value) as reported in Express Tribune in 2016[7].

4.1.4. Total Direct Costs

Current value of direct costs, added up, is **USD 15.961 billion**. This is a conservative estimate of direct costs as it does not include cost overruns and other such supplements - just the costs as recored at the time of project finance approvals.

4.2. Costs of Financing

The WB has been awarding loans to Pakistan at different interest rates on lending. Their data[8] from 2004 to 2022 ranges between 7 to 14 percent and their map puts Pakistan in the range of 6.02% to 9.62%. Exact figures for interest rates on foreign loans were not available, therefore we assumed a conservative lending interest rate of 7.5% for a repayment period of 25 years to estimate cost of financing on all foreign loans. It may be different from the actual interests paid, but this simplification helps get an idea of the cost of financing within a ballpark estimate. For example, Asian Development Bank's loan for Ghazi Barotha Project was at around14% interest to be paid in 25 years (ADB 2005). Our assumptions are very conservative.

As a rule of thumb, the cost of financing for USD 1 billion at an interest rate of 7.5%, compounded annually, for a term of 25 years will be around USD 1.24 billion. In other words, we can safely assume the cost of financing equal to 124% of the principal amount.

By using the current value of all the loans taken, and applying the interest for a period of 25 years, currency devaluation is also catered for in ballpark terms.The cost of financing, taken as 124% of the estimated principal among of 15.961billion is thus **USD 19.792billion** (current value).

4.3. Feasibility and Outlook

Lieftinck Report found TDP as 'technically feasible and economically justified' for agriculture and power benefits (Naqvi 2013).The report emphasised the need for 'undertaking the project… as soon as possible' because of *possible* shortages of water and power in 1970's.

On top of it, in 1985, the WB estimated that Pakistan was earning an economic return of 12.5% on the investment in Tarbela for USD 1.497billion (Naqvi 2013), or USD 187 million (approximately USD 1.7Billion current value).

Exaggeration in benefits in the feasibility study has an on going cost to the society and national economy.

Optimism, exaggeration and scare mongering was part of the feasibility. Environmental impacts were not adequately considered. The report estimated 75% benefits from water supply and 25% from power generation. However, as we concluded in Section 3.1.3, the irrigation part of Tarbela, is actually a net loss of 3.4 MAF per year, due to disrupted natural rhythms of the river, poor political vision and other technical factors.

The economic value of irrigated water in Pakistan has been reported by Young et al,. (2019) for the 12.2 million and 2.5 million hectare in Punjab and Sindh respectively as USD 0.08 and USD 0.06 per cubic meter respectively (against 1980 USD value). Based on this criteria, if estimated loss in irrigation supplies is 3.4 MAF due to Tarbela Dam , it is USD 1.235 billion (against USD current value) annually to Pakistan's economy.

The estimated life of Tarbela is 85 years until 2060 (Lorrai and Pasche 2007). However, to be conservative, assuming the life of Tarbela Reservoir as 60 year until it becomes only a run-of-the-river project in 2035, the cost of lost water for irrigation over this period comes to **USD 194.567billion** in current dollar value.

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[7] https://tribune.com.pk/story/1186099/infrastructure-world-bank-approves-390m-loan-tarbela-fifth-extension

[8] https://data.worldbank.org/indicator/FX.OWN.TOTL.60.ZS.end=2021&locations=PK&start=2004&view=chart

4.4. Land Acquisition and Re-settlement

4.4.1. Proximity Issues

96,000 persons were displaced and 135 villages drowned in Tarbela Reservoir (Asianics 2000). It was part of the resettlement policy that places on the periphery of the lake will be developed so that local displaced communities from the drowned villages could settle as close as possible to their ancestral lands. However, the lake peripheries are drowned in poverty. 90% of resettled people surveyed have expressed dissatisfaction on their resettlement (Azhar 2016). The second generation of settlers, however, does not feel that way as they haven't felt the loss first hand - which also points to the loss of cultural values and heritage and caused intergenerational injustice as well.

According to Rizvi (2018):

> *The de facto law enforced in Pakistan for land acquisition for infrastructure development is a colonial law: Land Acquisition Act, 1894. The law entrusts the Pakistani state with the power of eminent domain to appropriate land for 'any public purpose', upon provision of a 'just' compensation.However, the law does not provide for a resettlement and a rehabilitation plan.*
>
> *This law has a particularly harsh impact on those who are non-titleholders of land because it does not recognise them as the intended beneficiaries of compensation due to forced displacement.*
>
> *Instead, the colonial law restricts the definition of an 'affected person' to only those who hold legal title to land.*

Gross injustice have been reported in literature about resettlement plans for the forced migrants of Tarbela. Besides economic and social issues, people had been subjected to emotional trauma for leaving their ancestral lands, memories of childhood and drowning of ancestral graves.

Poverty still surrounds the lake where migrants are still living in mud houses and tents. The lake creates pools of stagnant water, breeding mosquitos and putting. Living conditions, which were promised to improve, have actually deteriorated. The pictures in Figure 2 tell many stories.

Figure 02: From makeshift ports to cess pools, the periphery of Tarbela Lake is a picture of misery [Photos: © Abbas].

4.4.2. Remote Issues

96,000 is a figure which, at the very least, recognises these individuals as affected people of the dam. However, the is yet another group of forced migrants due to Tarbela Dam,1200 kilometres away in distance, and 40 years away in time. These communities belong to Indus Delta, which is being encroached by the sea because its life giving *silt supply* is being choked in the reservoir behind Tarbela Dam. Along with Tarbela, other dams on Indus also came up on Sutlej, Ravi, Beas and Jhelum, but out of these, Indus is not just the biggest river, but also carried the most silt load per unit volume of water.

Richter et al. (201) have also highlighted that most studies and schemes have ignored the severe impacts of dams caused to the downstream communities due to alterations in river regime, resulting in degradation ecosystems - the life bread of downstream communities.

Hadi, A. (2019) concluded that:

> *The deltaic communities of Indus River, who have historical and traditional rights on the Indus River, paid the huge price of dams in terms of irreparable damages to their livelihood along with other impacts, including physical, cultural, and spiritual well-being.*

Five large dams built, as a consequence IWT, are choking the silt supply to the Indus Delta. The impact of Tarbela on the delta, however, is the most significant. Delta erosion is incessantly causing migration of people whose lands, houses, villages and towns have been engulfed by the sea. Their agriculture lands, once capable of growing rice and taking 3 to 4 crops in a year have come under tidal action or altogether lost to the sea. An estimate from satellite imagery shows that the Indus Delta is losing land at the rate of 96 acres per day since 1984. Property losses aside, there are other elements of forced migration such as, trauma, loss of livelihoods, lost farming and fisheries, forced migrations to areas where migrants are not welcomed… the list goes on. Pictures in Figure 03 illustrate some issues.

Walling (2008) reported loss of sediment load downstream of Kotri, Figure 04, between 1935 and 2000. The change in annual sediment loads relate to specific anthropogenic impacts - dam construction being the most prominent of all.

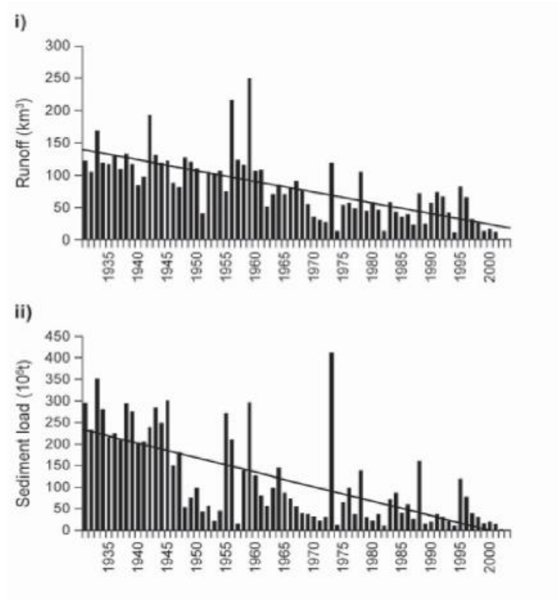

Figure 03: Plots reproduced from Walling (2008) showing how sediment loads have diminished reaching the Indus Delta.

Memon (2005) estimated that as a result of resource degradation, 90,000 individuals have been displaced and about 120 villages have been depopulated. These figures rival those of Tarbela, however, the migration from the Delta is continuous and the number is increasing for both, the land lost and the people forced to migrate.

Income Lost

Lowest level of poverty is an income of one dollar a day. However, Indus Delta and Indus Valley in Tarbela was a fertile land and people were generally well off. By migrations, they lost their incomes. According to CIEC data, average income of a family in Pakistan is PKR. 45,545[9] per month or USD 162 per month. Taking the family size of 7 as per census data of 2018, and assuming that migrant families lost at least half of their incomes, over a time period of 25 years (the dam is 50 years old) the cost comes to be **USD 646million**.

[9] https://www.ceicdata.com/en/pakistan/household-integrated-economic-survey-average-monthly-income-household/average-monthly-income-household

Land Lost

Finally, there are many concerns about the Indus Delta being lost to the sea because of choking silt supply in dams and diversion canals (Ibrahim 2020). Syvitski et al., (2013) estimated that in its pristine conditions, Indus Delta was served with at least 270+ million tons of sediment per annum, which is now reduced to only to ~13 million tons. The reduction in silt load is more than 250+ million tons per annum. In terms of land lost, the satellite images show that the Delta is losing 96 acres per day sine 1984, and has lost about 1.3 million acres since.

Sediments trapped by Tarbela Dam between 1975 and 2020 are estimated at 198 million tons per annum (Munir et al., 2022). This sediment load is significant. Even if 70% of this reaches Indus Delta, it makes more than half the silt load reaching the Indus Delta.

These numbers in view, at least half the land lost since 1984 in the Indus Delta can be attributed to the silt trapping behind Tarbela Dam.

The land lost to seawater intrusion in the Delta, as mentioned earlier, was of very high quality capable of growing rice and taking 3 to 4 crops in a year. Such land, in todays market, is at least PKR 10 million an acre.

If out of 1.3 million acres lost in Delta, we attribute 0.7 million (about half) to silt trapping in Tarbela Dam, the cost of the land lost comes to be USD 25billion USD thus far, and increasing.

But it is just the land that was lost. Historically, Indus Delta had more than 20 ports, along with roads and related urban infrastructure. Many of these ports were facilitating international trade. There were industries and thriving towns. All of this was gradually lost with land.

We may put the cost of potential of each port lost at USD 1 billion (total USD 20 billion for all port locations) and that of industrial and other infrastructure loss at a lump-sum of USD 5 billion.

This puts accumulative loss in delta of land lost to the sea, port locations lost, industrial units lost, and urban infrastructure lost at **USD 50 billion** in current value.

Figure 04: An old map of areas now under the sea;; seawater intrusion is getting into town of Keti Bandar ; boat people struggle when no water reaches the delta; remnants of a rice mill visible in low tide [Photos: © Abbas]

4.4.3. Trauma and Human Relations

It is difficult to put a price tag on human suffering. But an effort is made to put some kind of price tag in order to get to the true cost paid by society for 'cheap electricity' provided by Tarbela.

We make a wild estimate for human trauma and sufferings first for a population of 96,000 from Tarbela and 90,000 from the Indus Delta (this number by 2024 is much higher, but we keep it as such to make a conservative number). A traumatised person needs medical therapy. If the medical bill for each person is only USD 100 for life, then the bill for the population is **USD 18.6million**

4.5. Security

Large dams of Pakistan are considered national assets and are highly guarded with active troops. Exact expenditure on security is not known, but we make a ballpark estimate based on the knowledge that both facilities have small garrisons of 5,000 regular troops (retired with pension and benefits after 15 years of service)- drawing salaries, post retirement benefits, training and equipment etc.

Without catering for the higher rank structure, we make broad assumptions on salaries, training, equipment and service benefits for 5.6 terms of 5000 troops over 85 years life of the dam (without expounding on details in this study). The ball park expense is **USD 120million** over the lifetime of 85 years.

4.6. O&M Costs

WAPDA, in their Tariff Petition to NEPRA in 2023, has estimated their O&M and depreciation costs for hydroelectric in the approximate range of PKR 35 billion against annual hydropower generation of 31 GWh.

Given the above numbers, we can assume that for each GWh of energy produced, the O&M plus depreciation costs are PKR 113billion in the current value, or USD 4.02million per GWh of energy supply.

For the total generation of 534,000 GWh thus far from Tarbela, the O&M and depreciation costs are **USD 2.146billion**.

4.7. Carbon Footprint

GHG Emissions from the Reservoir

Scherer and Pfister (2016) has estimated the hydropower's biogenic carbon footprint, after studying 1,473 dams world wide. Tarbela Dam is part of the study sample. For Tarbela Dam, 1 MWh of energy produced generates 265.68 kg of carbon dioxide equivalent (CO_2e).

For 534 TWh of electricity generation by Tarbela thus far, Tarbela has added 142 million tons of CO_2e.

Damage to Natural Carbon Sequestration Systems

Mangroves are the richest carbon sinks and their importance cannot be overemphasised in the current era of global warming. At an average, mangrove forest sequesters 937 tons carbon per hectare. If mangrove carbon stocks are disturbed, resultant gas emissions may be very high (Alongi 2012).

Mangrove forests in the Indus Delta have reduced from 380,000 hectare in 1950 to 86,767 hectare in 2005. A total loss of 293,233 hectare (Ahmad and Shaukat 2015). Since silt load blocked by Tarbela is about is about 70% of historical silt load of the Delta, we may conservatively assume that Tarbela's contribution to this destruction is at least 50%. This implies that due to Tarbela Dam, we have lost almost 150,000 hectare of carbon sequestering mangrove forests - which translates into 140 million tons of CO_2e.

This estimate remains conservative as it does not take into account the other natural systems, such a forests and wetlands drowned in the lake or degraded downstream.

Social Cost of Carbon

US EPA[10] has put the social cost of carbon (SCC) at USD 204 for 2023. SCC will increase to USD 308 by 2050.

[10] https://www.instituteforenergyresearch.org/regulation/epa-ups-estimates-for-the-social-cost-of-carbon/#:~:text=The%20working%20group%20has%20not,2030%20and%20%24308%20in%202050 .

Although over the lifetime of dam this cost will keep adding, but for a conservative estimate, the SCC of Tarbela Dam thus far is **USD 58.66billion**.

4.8. Risks without Insurance

Tarbela Dam is exposed to following major risks which are not covered by insurance or any other mechanism. In other words, the cost of these risks is externalised to other public and private entities, with no liability on the makers of the structures.

There has to be a *duty of care* by the project builders when the consequences of a risk are serious - likely deaths, no matter how remote the probability.

4.8.1. Major Risks

Seismic

One of the major geological phenomenon responsible for the earthquakes in the upper Indus Basin, the plate tectonics, was not yet fully established when Tarbela Dam was conceived and designed. This knowledge gap may have serious consequences as a studies have shown that none of the dams built in second half of 20th century in the Hindukusch-Karakoram-Himalayan (HKH) are safe for magnitude 8.0 or higher earthquake.

Geologically speaking, the upper Indus Basin sits in the Main Himalayan Thrust Zone. Bilham (2019) quantified along the arc of the thrust zone, along with the historical rupture zones of past earthquakes to assess the slip potential at fifteen locations. It was found that ten of these segments are sufficiently mature to cause a great earthquake of magnitude 8.0 or higher.

This puts the dam in a high probability of earthquake risk - from dam failure to overtopping of water over the dam due to mega tsunamis which can occur in dam lakes, as happened in case of Vajont Dam in Italy.

Silt Liquéfaction

An unexpected aspect of the sediment deposition, however, is the advancement of the sediment delta, which is now located 14km from the dam. There are concerns that under earthquake loading, the sediment may liquefy and block all low-level outlets, including power intakes.

Upcoming Upstream Cascade

When Tarbela was constructed, there was no dam upstream on Indus. Now Dasu Dam and Diamer Bhasha Dams are already under construction while more are planned for the Indus Cascade. This puts yet another layer of risk. If one dam collapses in a cascade, there is a domino effect of collapse for the down stream dam. In 1975, a casdace of Shimantan and Banqiao Dams[11] collapsed in Henan Province, China, killing 171,000 people - worst death toll of a dam failure in the world. In case of Tarbela, this new risk is emerging (Abbas 2017). There is no demarkation of 'flood hazard zones' along the Indus in case of dam collapse and people are living in the hazard zones in complete ignorance of the risk.

Since owners and operators of TDP (primarily WAPDA) have allowed the cascade of dams without any objection, Tarbela must cover the cost of insurance if any of the dams upstream fails, or releases a deluge which may threaten the public and private lives and properties down stream of Tarbela. With each additional dam in the cascade, the risk for Tarbela increases in magnitude of the disaster and probability of occurrence.

Climate Change

Climate change puts another layer of risk to the structure of dam because the hydrology on which the parameters such as probable maximum flood (PMF) etc., were estimated do not hold any more with changing global climatic patterns. Banqiao Dam in China, for example, had the reputation of 'Iron Dam' for its strength and stood for 20 years. It was designed on PMF of 20.9 inches rainfall over three days. However, this exceeded when a typhoon hit the region and the dam collapsed.

4.8.2. Design Shortcomings, Negligence and Duty of Care

There is likelihood of design shortcomings because when the Tarbela was constructed, one, the climate change was not factored in, two, environmental issues were not adequately identified

[11] https://damfailures.org/case-study/banqiao-dam-china-1975/

and addressed, and, three, plate tectonics were not fully understood at the time. The designers had worked with deficient knowledge base. However, now that we know of the limitations of earlier planners and designers, it is part of the duty of care that a reassessment of dam safety is undertaken and a complete risk management plan be made and communicated to the public. Not doing so amounts to externalising the costs and consequences of these shortcomings to public and private entities.

Professor Denis Binder wrote comprehensive article about Legal Liabilities for Dam Failure (Binder 2002). Here are some excerpts for the article which highlight the importance of the duty of care that dam owners/builders/management must exercise as a legal requirement:

In terms of dam safety, following questions must be considered:

a) How likely is a dam to fail?
b) What are the potential consequences should it fail?
c) What safety precautions are available?

Because of the potential risk involved with a dam failure, the standard of care frequently imposed by courts is that one must use care commensurate with the undertaking; i.e., the duty of reasonable care is measured by the magnitude of the project.

The owner is bound to exercise in construction and maintenance of the dam a degree of care proportionate to the injuries likely to result to others if it proves insufficient.

The degree of care required to prevent the escape of water is commensurate with the damage or injury that will probably result if the water does escape.

Because of the potential risk involved with a dam failure, the standard of care frequently imposed by courts is that one must use care commensurate with the undertaking; i.e., the duty of reasonable care is measured by the magnitude of the project.

Care must be taken by dam owners/managers in proportion to the danger involved. In other words, ordinary care depends on the circumstances of each particular case. Where the risk is great a person must be especially cautious.

The degree of care required to prevent the escape of water is commensurate with the damage or injury that will probably result if the water does escape.

The degree of care increases in proportion to the hazards to be anticipated; and that because of the dangers inherent in the management of flowing waters, the concept of ordinary care and prudence under the particular circumstances requires that its management not to left to novices

If a recognised professional standard of care is established, then that standard will generally provide the minimal legal duty.

"...if the risk is appreciable one, and the possible consequences are serious, the question is not of mathematical probability alone".

4.8.3. Downstream Infrastructure and Public Safety

Downstream Infrastructure at Risk

In case of dam failure, or a sudden release of water from spillways to prevent dam failure, there are many structures of national importance at risk. Table 02 gives a partial list with and the estimated costs, and the insurance premium at the rate of 15% over the lifetime of Tarbela Dam.

The estimates in Table 02 are conservative because further downstream of Chashma, there are more bridges and barrages all the way to Sajawal Bridge in Sindh, which could be impacted.

The rate of insurance premium at 15% is selected for estimation because this was the insurance rate provided for loss and damage during construction of Tarbela Dam (WB 1985).

Other than the national infrastructure, lives, livelihoods, businesses, and properties of a significant population will also be at risk. In the event of a catastrophic release of water from Tarbela Dam, no one will be safe in the zone of catastrophic flooding. It remains the duty of Tarbela Dam owners and operators to demarcate the hazard zone and provide insurance cover to the population at risk. As a ball park figure, we assume that almost as much insurance cost is externalised to the public as is for the infrastructure mentioned above.

Table 02 Major infrastructure, downstream of Tarbela up to Chashma Barrage, its estimated cost and expected insurance premium

Infrastructure piece	AdditionEs-timated Current Value (Million USD)	Insurance Premium during the life of Tarbela (Million USD)
Motorway bridges	200	30
Gas pipeline crossing at Attock	20	3
Grand Trunk Road bridges	300	45
Railway bridge at Attock	250	37.5
Road bridge at Khushhal Garh	150	22.5
Railway bridge at Khushhal Grah	300	45
Road Bridge at Kalabagh	200	30
Railway bridge at Kalabagh	300	45
Jinnah Barrage	4,000	600
Chashma Barrage	8,000	1,200
Total	**13,720**	**2,058**

We can, therefore, assume that around USD 3billion is the insurance cost against the dam disaster that has been externalised to the resident population, commercial enterprises, utilities and other entities in the harms-way.

Indus Cascade Increases the Risk

When Tarbela was constructed, there was no dam upstream on Indus. Now Dasu Dam and Diamer Bhasha Dams are already under construction while That, Patan and Bunji are planned for the Indus Cascade (Abbas 2017). This puts yet another layer of risk. If one dam collapses in a cascade, there is a domino effect of collapse for the down stream dam(s). In 1975, a cascade of Shimantan and Banquia Dams collapsed in HenanProvince, China, killing 171,000 people - the worst death toll of a dam failure in the world. In case of Tarbela, this new risk is emerging and the probability of a dam disaster downstream of Tarbela is increasing.

There is no demarkation of 'flood zones' along the Indus in case of dam collapse and people are living in the danger zones in complete ignorance of the risk.

We assume that a conservative estimate of insurance bill for every thing in the risk zone of Tarbela disaster is in the ballpark of **USD 5billion**.

4.8.4. Insurance Cost of the Dam

If Tarbela is not insured against the risks discussed in Sections 4.8.1 and 4.8.2, this cost has been externalised to the tax payers.

The direct cost of the dam was estimated at USD 13.6billion. Applying a 15% insurance premium, the required insurance for the dam against realise of catastrophic flow, it may cost around **USD 2 billion**, which is currently externalised to the society and taxpayer.

4.9. Decomissioning

With the emerging knowledge on the significance of flowing rivers and the river-dependent ecosystems, it is becoming more and more evident that dams should be removed to restore the natural flow regimes of the rivers. In USA, for example, the dams which have lived their useful life are being removed. A rule of thumb for the cost of dam decommissioning and removal is about the same as building the main structure - i.e., the embankment or the wall.

The dam must be removed through sophisticated engineering practices after 2060 in order to eliminated the risks it poses to the society and the environment.

In order to remove Tarbela Dam and restore the natural flow of the river, the ball park cost will be about 30% of TDP cost. This gives us a ballpark figure of **USD 4billion**.

4.10. Other Externalities & Risks

Cost overruns in the accounting books may just be one issue related to large hydel projects, but there are many unintended but unavoidable consequences of large dam with huge costs which are inevitably borne by one or more segments of society (Abbas 2018).

4.10.1. Engine of Social Discord

Tax payers of Pakistan foot the bill whenever delegates from Punjab, Sindh and Federal Government have to meet over the water disputes between upper and lower riparians within the country. Each year in early summers, there is a history of Sindh blaming Punjab for holding back their due share of water as per the 1991 Apportionment Accord, whereas Tarbela keeps filling its reservoir, holding back the early summer flows crucial for Kharif sowing in Sindh (Abbas .2022).

4.10.2. Biodiversity Loss

The construction of a dam brings about immediate changes to the river ecosystem upstream. The previously free-flowing river is transformed into an impoundment, altering the habitat from shallow and fast-moving lotic to deeper and slower-moving lentic conditions. These distinct environments support different species adapted to their specific characteristics, leading to a turnover in the plant, invertebrate, and vertebrate assemblages (Duda and Bellmore 2022).

Reservoirs further impact downstream waters by modifying the temperature regime (Duda and Bellmore 2022), dams without provisions for fish passage impede the migration of fish along the river breaking the connectivity of the river and causing the disappearance of upstream migratory fish populations and negatively impacting the overall health of the river system. Changes in the stream temperature, in turn, impacts dissolved oxygen concentrations, both within the reservoir and downstream from the impoundment (Petts, 1984; Nilsson and Berggren, 2000; Elosegi and Sabater, 2013) which impacts native species.

The construction of dams has a significant impact on river systems due to the substantial obstruction of sediments and nutrients in reservoirs. This alteration enhances the biomass production capacity within the reservoir, but it also leads to a reduction in sediment and nutrient inputs to the downstream ecosystem, potentially posing an oligotrophic threat to the downstream environment. As a result, dam construction induces changes in the ecosystem health conditions of both the reservoir and the downstream areas, highlighting the ecological consequences of these blocking effects (Fang et al., 2015).

These interconnected factors highlight the complex and diverse impacts of dams on river ecosystems and emphasise the need for further investigation within the literature review chapter of this report (Cooke et al., 2020).

Deep sea species depend on the river deltas for spawning and protection of their offsprings. These life systems are connected all the way from the glaciers to the deep seas. But dams and barrages fragment them, deteriorate their water quality and change the natural flow rhythms around which species and human-adaptation had evolved.

As per a WWF report,, *pallo* (hilsa shad), a prized fish for its taste, comes to spawn in Indus Delta from Arabian Sea in monsoon and accounted for 70% of the catch in Indus Delta, but now barely constitutes 15% of the catch. Detailed studies are required to quantify such impacts on local economy, food security and natural environment. Although these impacts are not added to the true cost of Tarbela Dam in this study, nevertheless, they have cost and must be studied.

4.10.3. Social Damages

Tarbela Dams has not only resulted in the displacement of thousands of people but have also impacted the river-dependent livelihoods fishing communities of Indus. The decline of fish populations downstream were vital for both commercial production and local consumption. These detrimental impacts fishing communities highlight the broader repercussions of dam construction on livelihoods and food systems (Randell 2022).

Paradoxically, while the fisheries in the Indus downstream of Tarbela declined, fishing permits are awarded for fishing in Tarbela Lake. With no local expertise of catching fish, folks from Sindh are hired by contractors to fish in Tarbela Reservoir. Those communities who once owned the fishing businesses in the river are now called upon to fish in the lake as ‘labourers’. Sindhi families camp on the lake in poor conditions.

Figure 05: Folks from Sindh camp on Tarbela Lake, weaving their nets is in July [Photo © Abbas].

We interviewed some of these families and another sad aspect came up. They cannot send their children to schools - the government schools don't admit them because they do not have domicile for Khyber Pakhtunkha while private schools for them are not affordable.

Figure 06: Sindhi children at Tarbela cannot go to schools.

4.10.4. Risks of Modernisation and Emerging Global Mind

Large hydropower is the technology of previous century which was not environment friendly. It wrecked the environmental systems and ecosystem serves without knowing their value nor their role. Huge cost has been paid by society and environment because of the loss of environment and ecosystem services which has now become increasingly clear and global mind on undertakings such as TDP is changing in favour of social and environmental sustainability (Gore 2013). Hydropower, once touted as clean, does not enjoy that rhetoric anymore (Deemer et al. 2016; Maavara et al. 2017, Hudson 2016).

Consequent to the changing global mind, the US Bureau of Reclamation (established in 1912) - responsible construction of maximum number of dams in the world - changed its mission statement

from:

> *... help federal efforts in the large-scale planning and construction of storage, diversion, and development of waters in arid and semiarid lands for irrigation.*

to:

> *The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.*

It is further interesting to note that 'dam removal is now part of Bureau's toolkit (Randle et al., 2021a).

Solar energy is already a hundred times cheaper than hydropower and revolution in MW battery storage is on the horizon. Such disruptive technologies can render the even the existing dams redundant, let alone nullifying the on going investments.

The issues related to forced displacements and resettlement of indigenous communities are getting serious attention. There are global movements working for indigenous rights of not just land, but also water. There is growing awareness of healthy water future through indigenous knowledge and practices and culturally respectful ways of knowledge sharing (Leonard et al., 2023).

Last, but not the least, are the emerging legislations with respect to rights of nature and crimes against nature. 'Ecocide' is an emerging crime against nature which covers 'long term and or widespread damage done to the environment through wanton acts'. Large dams invariably cause both long term and widespread harm to the environment. And when decisions are made to build dams wilfully ignoring the environment, the decision makers could be tried under the crime of ecocide.

Each of these modern developments pose the risk to existing large dams including Tarbela. The dam risks being redundant due to better and cheaper energy options/alternatives earlier than the estimated life until 2060.

Although the costs of other externalities discussed in this section have not been discussed in dollar terms, but studies should be carried out for better assessment of these externalise.

As a plug-in we have put USD 1bn to represent additional externalities on record.

4.11. Total Lifecycle Cost

The following table summaries the total estimated costs in the preceding sections. These costs, as discussed, are conservative. Assumption and data have been discussed and remains open to further discussions after this study to fine-tune the cost estimates.

The lifecycle costs presented in Table 03 below are not all inclusive in any sense, but give an idea, for the first time, how much it costs the environment and the society to build and operate such a facility as Tarbela Dam.

Tarbela Dam will cost plus of **USD 350 billion** to the environment and the society over its lifecycle.

Item	Section of this report	Costs (billion USD)
Total direct cost	4.1	15.961
Cost of financing	4.2	19.792
Feasibility exaggeration and lost water	4.3	194.567
Lost Income	4.4.2	0.646
Land Lost in Indus Delta	4.4.2	50.000
Trauma	4.4.3	0.019
Secutiry	4.5	0.120
O&M	4.6	2.146
CO_2e	4.7	58.660
Risk/insurance	4.8	5.000
Decomissioning	4.9	4.000
Other externalities	4.10	1.000
Total Cost		**351.911**

5. TRUE COST OF HYDROPOWER FROM TARBELA DAM

As per WAPDA's data already mentioned in Section 3.2 and plotted in Figure 01, the mean annual energy generation of from Tarbela powerhouse is 9,651million KWh or 9,651 million units of electricity received by the consumers.

From the table in Section 4.3, the estimated loss from water supply function of the dam is USD 194.567 billion over the lifecycle of the dam. If losses due to water supply function of the dam are separated from its power supply function, then the net cost of power supply over the lifecycle of dam is USD 157.344 billion.

The unit cost, ie., cost per kWh of energy supply over the lifecycle of the dam is USD 0.192. Converted to current PKR value, it is **PKR. 53.61.**

We may conclude here that True Cost of Tarbela is way more than generally believed to be. Its irrigation function alone is a staggering loss of almost USD 200 billion over the lifetime of Tarbela Dam. The energy produced has a significant carbon foot print costing almost USD 50billion during its life time. And finally, a unit of electricity supplied to the consumer costs the society and the environment PKR 53.61.

The Dam is neither producing green, nor cheap electricity -nor it is doing any good to supplement the irrigation in the country. TDP is a net loss to the economy of Pakistan.

The IBRD Engineers were right. Pakistan did not need this Dam.

CASE STUDY 02

TRUE COST OF NEELUM-JHELUM HYDROPOWER

6. HISTORICAL BACKGROUND

Neelum-Jhelum hydropower (NJHP) was conceived more in response to IWT's provisions for development of hydropower on the Western Rivers than for the sake of hydropower alone in Pakistan. NJHP Project is a reaction to India's Kishenganga Hydro Electric Project (KHEP) which is built under the provisions of IWT.

According to the provisions of IWT, India can only built run-of-the-river hydropower plants on the Western Rivers and their tributaries, without impacting any existing/prior hydropower facilities of Pakistan. When the treaty was signed, there was no hydropower facility on the Neelum River (called Kishenganga in India) - a tributary of Jhelum River. However, its hydropower potential was known and both countries had plans to exploit it in future before the other country does.

If Pakistan already had a hydropower facility on Neelum River, then, as per the IWT, India could only build a hydropower facility on the same river which does not impact the 'existing' or 'prior' facility by Pakistan. On papers, Planning Commission Form-1 (PC1) of NJHP was prepared in 1989 for the 969MW hydropower plant. WAPDA started collecting Neelum-Jhelum Surcharge from its customers in their electricity bills from 2003 onwards.

Meanwhile, India conceived her own hydropower facility, KHEP, for 330MW. With KHEP built upstream, NJHP would lose its power generation potential by more than 10% and the river flows will be reduced between 13 and 21 per cent (Tanaka 2012).

India started construction of KHEP in 2007 with planned completion in 2014. Pakistan started construction of NJHP in 2008. The contract for NJHP was awarded to a Chinese consortium in 2007. Pakistan wanted to put her hydropower facility on ground earlier than India does, and halt the construction of KHEP as violation of the IWT - on grounds of 'prior' use.

On the Pakistani side, therefore, there was an urgency of completing the project ahead of India. By 2011, the cost of project had already tripled, and at tunnel boring machine (TBM) was being planned for speeding up the project. Prime Minister's Inspection Committee (PMIC) for NJHP noted that (Rana 2011):

> *"The inordinate delay has not only caused cost escalation and time overrun, it has placed Pakistan at a disadvantageous position vis-à-vis India,"*

The Express Tribune, on 29 October 2011, noted that:

> *"The fate of priority rights over Neelum and Jhelum rivers' water, for electricity generation, hinges on early completion of the hydropower projects."*

Pakistan could have stopped the development of KHEP if she had build her own facility prior to KHEP, invoking her priority rights as stipulated in IWT.

In 2010, Pakistan took the case to the Permanent Court of Arbitration at The Hague, under the IWT provisions (Iqbal 2018). and in 2011, India's KHEP was halted.

The Court, in two awards, decided the case. First, in a partial award in March 2013, it found that KHEP was not in violation of IWT and allowed India to go ahead with the project. In its final award in Dec 2013, the court agreed that India should change its silt flushing design to sluice gates and ensure a minimum environmental flow of 9 cubic meter per second in the lowest flow season (PCA 2013). The tribunal projected that this level of environmental flow would result in a 5.7 percent average annual reduction in the KHEP's energy production (Crook 2014).

Pakistan is still not happy with this award and has taken the case to the International Court (Ahmed 2018); Climate Diplomacy 2018).

7. ENERGY BENEFITS OF NJHP

7.1. Total Energy Generation

Annual generation from NJHP is 4,630 GWh

7.2. Net Energy Received by Consumers

After taking into account 18% losses (transmission and distribution), the net energy received by the consumers is 3,797 GWh.

8. LIFECYCLE COSTS OF NJHP

8.1. Direct Costs

Total cost of building the project is estimated at **USD 5.1billion**[12].

8.2. Time and Cost Overruns

According to Auditor General of Pakistan (2018), NJHP was delayed by 21 years and had abnormal cost overrun of PKR 389 billion.

Key Audit Findings of the Auditor General's reports were:

- Loss due to non-achievement of envisaged financial benefits of Rs. 236.93 billion.
- Irregular / unjustified award of construction contract of Rs. 90.90 billion before the appointment of consultants.
- Non obtaining of performance guarantees resulting into suspension of foreign loans and delay of the project - costing Rs. 48.80 billion.
- Loss of revenue amounting to Rs. 30 billion
- unjustified claim of Rs. 175.06 million on fatal incident of rock burst.
- Unjustified and uneconomical deployment of Tunnel Boring Machine resulting into non-achievement of envisaged benefits - Rs. 23.15 billion.
- Poor performance of the consultants of NJHP engaged at a cost of Rs.16 billion.
- Non-recovery of liquidated damages amounting to Rs. 9.90 billion from the Contractor.
- Annual recurrent loss of Rs. 5.15 billion due to losing of water rights on the western river under Indus Basin Treaty (Kishanganga case).
- Extra burden of Rs. 380 million due to unjustified use of 27 vehicles at Project office by NJHP and recurring expenditure on account

12 https://en.wikipedia.org/wiki/Neelum–Jhelum_Hydropower_Plant

of rented vehicles amounting to Rs. 2.80 million per month.

- Loss of Rs. 110.48 million due to compensation on account of delayed payment of IPCs.

The life of NJHP reservoir is estimated at 45 years (Jamil 2015). The sum total of these costs (static and recurring) over the life of the project come out to be PRK 714.182 billion.

Given the devaluation[13] of PRK by 46.71% since 2017, the current value is PKR 1,528.969 billion or **USD 5.47 billion**

The National Economic Council's executive committee set away the misconduct and corruption accusations. The Prime minister of that time Shahid Khaqan Abbasi refuse the request by the planning secretary to solve the problems related to the delay of project and cost boom (Khan 2022). In other words, the costs identified by the Auditor General have been externalised to taxpayers as loss to the State.

8.3. Costs of Financing

Debt to equity ratio of NJHP, as reported in NEPRA Petition of 2021 is 74:26

The interest rate on debt varies between 12% and 15%. Repayment is scheduled in 20 years.

To get a ball park figure, we make following simplifications/assumptions:

- After equity, the external debt is USD 3.774billion.
- Interest is 12%, compounded semi-annually.
- Loan term is 20 years.

With these assumptions, the cost of financing is **USD 6.259billion**.

8.4. O&M Costs

Neelum Jhelum Hydropower Company (Private) Limited (NJHPC), in their Tariff Petition to NEPRA in 2018, has estimated their recurring O&M costs as PKR 11.394 billion per annum. In todays value, this is PKR 25.549 billion or USD 0.091 billion.

Over 50 years life of the project the total cost will be **USD 4.570billion**.

8.5. Legal Battle with India

The project was primarily initiated to be completed before KHEP, to prevent India taking control of Neelum River. So far, Pakistan has not been able to succeed. The objections raised regarding violation of IWT by India, however, were not accepted in the court and India got a green light to move ahead with the project.

The objections regarding dead storage flushing, which may significantly alter the timings of flow downstream, and the requirement of environmental flows, were accepted by the court and India has to abide by these requirements.

There is cost these legal proceedings to the national tax payers. Pakistan appointed Jan Paulsson and Judge Bruno Simma to the panel; India appointed Lucius Caflisch and Judge Peter Tomka, president of the International Court of Justice (ICJ). Judge Stephen Schwebel (former ICJ president) was appointed as chairman and umpire by the United Nations secretary-general; Franklin Berman was appointed as legal member and umpire by the lord chief justice of England; and Howard S. Wheater was appointed as engineer member and umpire by the rector of the Imperial College of Science and Technology. The costs of the tribunal were divided equally between India and Pakistan (Crook 2014).

Since no information on the legal fees paid by Pakistan is available, we just put a plug-in figure of **USD 10million** spend on these legal proceedings. The proceedings are on going as Pakistan is still looking for another arbitration in the International Court of Justice.

8.6. Social Impacts

Both Neelum -Jhelum and Kishenganga projects have caused local unrest and protests have been recorded.

In Kishenganga, the protesters issued a press statement, saying that a total of 38 hectares of land has been taken over by the project. Only Rs

[13] https://www.worlddata.info/asia/pakistan/inflation-rates.php

40 lakh was paid as compensation per hectare. The land taken in Gurez for the project costs as much as Rs 1.20 crore per hectare. The Indian government had imposed restrictions on the movement of civilians around the project site when it was under construction (Basu 2013).

Protests against NJHP, were of different nature. There is local opposition to the dam (Climate Diplomacy 2018). The city of Muzaffarabad observed complete strike when waters of Neelum River were diverted in the tunnel, leaving the once roaring river to a trickle over a distance of 40 km downstream from Nusehri to the town of Muzaffarabad where it meets the Jhelum River. The protesters wanted to draw attention of concerned authorities to the serious environmental issues due to the reduced water discharge in Neelum River downstream of diversion dam at Nusehri (Kashmir Observer 2019).

Acquirement of approximately 2400 Kanal state's and private land for the project Muzaffarabad District (Khan 2022).

Four workers including Chinese engineer were killed by breakage of wall near reroute tunnel intake on 24th December 2014.

Minor clashes with inhabitants who still resist the cleaning of area in spite of full compensation, results in disfiguring of construction of critical disinter at cove of project. As local authorities try to clear clash close the LOC the first module of project faced one-year delay.

Excerpts from in-depth interviews of locals published by Khan (2022) are copied below which highlight the concerns of the local community:

A local journalist said:

> *At first people were not accepting the fact that the river can be diverted. ... Neelum Jhelum power project disturbed approximately six lack people of the surroundings. ... the project brought drastic environmental hazards.*
>
> *Now when Government is further extending it and working on Kohala Hydropower project people started protests and "Darya Bachao Tehreek" was initiated*
>
> *after Neelum Jhelum Hydropower task the temperature of the area rose... and ...the surrounding glaciers are melting heavily*
>
> *Government approved the project on running river but then diverted the river from Nauseri to Chattar kalas then how they can claim that this is a project on running river? ... for locals and for environment this project bought more harms then benefits*
>
> *The major part of the project is tunnel which affected all the surrounding areas. ... the people of surrounding areas like Khawra migrated in thousands due to lack of water*
>
> *Government promised the local people that they will be provided with free electricity that is the reason locals have not opposed the project but lately it never happened.*

A student of Muzaffarabad University, Department of Environmental Sciences said:

> *This project gave rise to the environmental pollution*

An old employee of a river view hotel, who had witnessed the deterioration in river over the years said:

> *The water level of the river decreased to a noticeable point after the construction of these projects ... Due to unpleasant weather in summers the tourists in the area are decreasing.*

A lawyer said:

> *Neelum Jhelum Hydropower project undoubtedly affected the environment I personally witnessed the change in temperature and unhealthy environment after the water level was controlled due to the project"*

A doctor and a writer, said:

> *If there was no Dam or any mega construction then, the natural environment [had] flourish[ed].*
>
> *Natural habitat was disturbed immensely during the construction and after the diversion of the Neelum river.*
>
> *Azad Kashmir Government ... have no control or role in this matter. ...Pakistani Government ... have delegated powers to WAPDA; and this white elephant do not care what is good for the people and environment. They are only interested in exploiting the resources with impunity.*
>
> *They want to protect their investment and get best returns by producing the targeted megawatts*

… every household of AJK had to pay about 15 to 20 rupees per month for many years for the construction of Neelum Jhelum Dam.

[but the locals don't get direct power from the project. Instead, NJHP feeds the National Grid at a Grid Station in Gakhar Mandi near Gujranwala.]

[This is] worst kind of exploitation. The WAPDA will not take any measure to help AJK people.

Another doctor in his interview said:

The diversion of water will deprive a large area from its surface water for most part of the year. The populations living along the riverside including that of Muzaffarabad city will be affected extremely from water shortage they use for everyday purposes as visiting the riverside is part of the cultural life of the towns and villages located around the course of the river. This will affect aquatic habitat ecology and human environment with regards to downstream water supplies to human communities and sewage dilution needs for Muzaffarabad city.

[For]seven months of a year the downstream discharge of water will be reduced to a bare minimum that is considered incompatible to maintain the needs of human life.

A large area was prone to land sliding since the earthquake the incidents of land sliding have increased since. Depriving the area of its naturally occurring moisture would have an adverse impact on the environment. The terrestrial riparian habitat would be adversely affected along the riversides. It would negatively impact on the wild life and the forest population that is already under threat due to increased human movement and mismanagement of the forests.

The ESIA report has indicated that fish population would be adversely affected in particular the population of Kashmir cat fish would become extinct that is one of the sources of food for deprived local communities.

There are concerns among the local people that during the rainy season the risk of mud sliding, and flash flooding would be greater that could endanger the populations living on the hilly terrains of rural areas

If each family is compensated for only PKR 32,000 per month (which the minimum wage in Pakistan[14]) over 50 years life of the dam plus 10 years of construction time (total 60 years), this bill comes out to be PKR 2,074 billion or **USD 7.42 billion.**

8.7. Environmental Impacts

The environmental impacts of NJHP include river fragmentation, low flow in 40km reach downstream of the Dam, impact on seeps and springs in the area, impact on native fish species, impact on other flora and fauna, disruption in ecological services, silt trapping in the reservoir, eutrophication in the reservoir, decay of dead organic matter in reservoir and release of GHGs, the impact of water quality (including water temperature) where tail-race tunnel discharges the water into Jhelum River - the list goes on. No comprehensive studies have been done evaluating these impacts, but the impacts are there never the less.

Figure 07: Pollution trapping in the reservoir

Figure 08: There is no passage for fish in the dam. The river has been fragmented.

For now, we assume a plug-in cost of **USD 2billion** in environmental and ecosystem damages due to NJHP. This figure could be fine-tuned with more comprehensive studies.

[14] https://efp.org.pk/minimum-notifications/

8.8. Seismic Risks

The earthquake of 2005 amply brought home the risk of seismicity at the location of NJHP project, especially the site selected for the dam at Nusehri. The design of the dam was revised after 2005 earth quake, significantly increasing the cost of the project. The changes made were summarised in NJHPC (2018) as:

> *The dam was changed from an all-concrete structure with four radial spillway gates and one flap-gate to a composite concrete gravity plus clay-core rock-fill dam. The concrete structure was also shifted away from the Main Boundary Thrust (MBT) fault".*

The improved design mitigated the risk of dam failure - the wall of the dam lies over an active fault line by introducing a hybrid structure of the wall. One half is a concrete gravity wall while the other, which sits on the fault line, is made with compacted earth/gravel. In case of shear movement of the fault, the core-clay/rock-fill part of the dam would break, realising about 400 million cubic meter of water from the reservoir, but the concrete structure will stay and the more expensive penstock and gates of diversion tunnels will not be damaged. In case of such an event, the breached wall of dam can be rebuilt and the facility could be resorted.

Figure 09: Composite structure of dam wall. Gates and spillway is in concrete while fault line is under the clay-core rock-wall

There is an insurance component envisaged in recurring O&M expenses of NJHP which covers machinery breakdown, all natural calamities, sabotage, and consequential business interruption, etc. at the current estimate value of USD 19.25million per annum, or almost USD 1 billion over 50 years life of the project. However, this does not seem to include coverage of downstream infrastructure, public/private properties and people at risk in case of dam bust.

In other words, the dam is designed to breach under shear movement of the fault with minimum damage. The risk has not been eliminated, but mitigated for the dam structure, and covered by insurance.. The deluge of 400 million cubic meter of water that would gush through the valley looms at large for the down stream communities.

The extensive and recent landslides along the active fault line are clearly visible on right bank of the valley.

Figure 10: The dam is built right over an active fault. Right next to the dam is mountain face with a number of recent landslides due to fault movement

We interviewed many people if they know about this risk in the valley and have they been informed of a warning system. We found that the public is completely obvious of this looming risk. No demarcation of the extents of the flood wave released from the dam in case of breach has been done in the valley downstream. Properties, businesses, infrastructure, public facilities and people who would be in the harms way have not been informed. No insurance exists for downstream infrastructure, properties and peoples' lives under this 'seismic design' of the dam.

As The risks to be covered through insurance will include machinery breakdown, all natural calamities, sabotage, and consequential business interruption, etc. for the facility. .

We put a ball park cost for insurance premium for the down steam communities at **USD 1 billon** as a plug-in in this report.

8.9. Decomissioning

With the emerging knowledge on the significance of flowing rivers and the river-dependent ecosystems, it is becoming more and more evident that dams should be removed to restore the natural flow regimes of the rivers. Dam builders reap the benefits and next generations bear the cost of removing it. This makes dam removal an intergenerational externality.

The dam must be removed through sophisticated engineering practices when its life ends, or even earlier to prevent the communities from seismic risks and protect/restore the environment. A ball park figure of **USD 500 million** can be plugged in as the cost of decommissioning and removal of this structure.

8.10. Total Lifecycle Cost

The following table summaries the total estimated costs in the preceding sections. Assumption and data have been discussed and remains open to further discussions after this study to fine-tune the cost estimates.The lifecycle costs presented in Table 03 below are not all inclusive in any sense, but give an idea, about the cost of electricity being generated at NJHP.

NJHP will cost plus of **USD 26 billion** to Pakistan over its 50 years of estimated lifetime..

Item	Section of this report	Costs (billion USD)
Total direct cost	8.1	5.100
Time/cost orverruns	8.2	5.470
Financing cost	8.3	6.259
O&M	8.4	4.570
Legal battle	8.5	0.010
Social cost	8.6	7.420
Environ. Impacts	8.7	2.000
Seismic risk	8.8	1.000
Decomissioning	8.9	0.500
Total Cost		**32.329**

9. TRUE COST OF HYDROPOWER FROM NEELUM-JHELUM

The annual generation capacity of NJHP is estimated at 4,360 GWh. After 18% transmission and distribution losses, the consumers will receive 3,575 GWh per year. Over the 50 year lifetime of the facility, it will generate 179 billion units of electric power.

The unit cost, ie., cost per kWh of energy supply over the lifecycle of the dam is USD 0.181. Converted to current PKR value, it is **PKR. 50.55**.

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