

CLIMATE CHANGE MITIGATION AND ADAPTATION CONSIDERATIONS FOR HYDROPOWER PROJECTS IN THE INDUS BASIN

INTRODUCTION

In Pakistan, the demand for power exceeds supply on a regular basis. The country is in a perpetual state of crisis, power cuts and rotational load shedding have become part of everyday life.

Pakistan is also experiencing concurrent water shortages and has been identified as one of the most water stressed countries in the world (ADB, 2013). Current water storage capacity is limited to a 30-day supply, well below the recommended 1,000 days for countries with a similar climate. Climate change is affecting snowmelt and reducing flows in the Indus River system (Figure 1), the main water supply source for the country. Increases in storage capacity to manage periods of low flow are essential; as is the rehabilitation of the distribution system to reduce losses from seepage and evaporation (ADB, 2013).

The inability of the country to provide a reliable, uninterrupted supply of power and water is discouraging foreign investment, impacting negatively on the economy, hampering efforts to alleviate poverty and fostering radicalisation in many rural areas.

Hydropower was first identified as a source of clean, low cost, renewable energy at the time of Pakistan's independence in 1947. However, 67 years later less than 12% of the identified hydropower potential in the country has been exploited.

In 2008, as a response to the deepening energy and water crises the Water and Power Development Authority (WADPA) announced plans for the development of an extensive portfolio of hydropower projects throughout the Indus Basin (WADPA, 2014). WADPA's "Vision 2025" program promises to develop 80 billion cubic metres (BCM) of additional water storage capacity and add at least 37,770 megawatts (MW) of hydropower generation capacity to the national grid by 2025 (WADPA, 2014).

VULNERABILITY TO CLIMATE CHANGE

Pakistan's geographical location and socioeconomic fragility has made it one of the world's most vulnerable countries to the environmental, social and economic ramifications of climate change (Burck *et al.* 2014).

The availability of flow in the Indus River system is critical for sustaining the country's economy by providing water and power and thus preserving food security in the region which is known as Pakistan's bread basket. Indus River inflows have pronounced seasonal variations; about 85% of the total occurs during Kharif (summer) season (April-September) and about 15% during Rabi (winter) season (October-March). There has been a consistent shortage of



Figure 1. Regional Map of Pakistan Showing the Indus River System

water during Rabi for the past 18 years, ranging from 1% in 1994-95 to 49% in 2001-02. The long term security of water availability and hydropower generation for Pakistan depends upon the continuous flow of the rivers of Indus Basin originating from Hindu Kush-Karakoram-Himalaya (HKH).

The HKH region is very susceptible to the effects of climate change as it is influenced by three major weather systems: the sub-Mediterranean regime of mainly winter, westerly storms; the Indian summer monsoon; and the Tibetan anticyclone (Huntington, 2006).

Lack of investment in infrastructure means that Pakistan's ability to capture and store monsoonal downpours is inadequate to secure power and water supplies throughout the year. As a result, for the remainder of this century and beyond, climate change and climate variability is predicted to play an important role in Pakistan's water resource planning in relation to reservoir management, power generation and the provision of environmental flows (IPCC, 2007).

PROJECTED IMPACTS OF CLIMATE CHANGE

Temperature Variation - Temperature records in Pakistan indicate a warming trend from 1960-2010. Trend analysis of data from 56 meteorological stations across Pakistan shows that the weighted mean daily temperature average over each year shows a sharp increase during the first decade of the 21st century (Rasul *et. al.* 2012). Analysis of seasonal data over this period shows significant increases in winter mean and maximum temperatures, while mean and minimum summer temperatures show a consistent decline (Fowler and Archer, 2006).

Precipitation – Climate change could have significant effects on the intensity and distribution of precipitation patterns in the Indus Basin. Analysis of records from 1951-2000 shows a negative trend in rain fall in the western highland and coastal areas and positive trends in all other regions (Khan, 2011). In the upper Indus there has been a statistically significant increase in precipitation since 1961 (Archer and Fowler, 2004). For the country as a whole, there has been an increase in annual precipitation of 63 mm (25%) between 1901 and 2000 (Faran and de Boer, 2008).

Extreme Events - Abnormally high monsoon rainfalls were recorded in Pakistan in 2010, 2011 and 2014. The subsequent flooding associated with the 2010 and 2014 events resulted in two of the most devastating flooding events in the country's history with death tolls of approximately 2000 and 360 respectively (Singapore Red Cross, 2010; Pakistan Red Crescent Society, 2014). Rasul *et. al.*, (2012) while investigating change in tendency of extreme events in the Sindh Province of Pakistan found that frequency of occurrence of "Extreme evens" has increased from the average between 1969-2009 during the two years 2010-2011. The variations in the monsoon rainfall in this region represent one of the largest variations of the global climate system (Turner and Slingo, 2009).

Climate change and the resultant modification of rainfall and temperature patterns will affect water availability and storage capacity of a hydropower project via several pathways. Higher precipitation could increase seasonal river flows, conversely higher evaporation could reduce water storage in the reservoir. Increased variability in weather (e.g. intensity of peak flows, changes in seasonal patterns) could increase uncertainty in river flows and the capacity of reservoir storage (e.g., days of stored water supply), disrupting expected supply patterns (Harrison *et al.*, 1998). Heavy rains and severe events could cause increased sediment mobilisation in the catchment resulting in siltation of the receiving reservoir and a reduction in storage capacity.

As the generation of hydropower is reliant on water supply, WADPA's proposed HPP program is very vulnerable to the effects of climatic changes.

INTEGRATION OF CLIMATE RESILIENCE

There are two principal strategies for developing climate resilience: mitigation, the limiting of greenhouse gasses to minimise further climate change; and adaptation, which accepts that some degree of climate change is already inevitable and seeks to limit the negative impacts (Ayers, 2008). Both mitigation and adaptation are necessary in any comprehensive approach to developing climate resilience; as mitigation measures alone cannot avoid future impacts, because of historically committed emissions, making adaptation essential (Klein *et. al.*, 2007; Dowlatabadi 2007; Willbanks *et. al.*, 2003).

In the context of hydropower development in Pakistan the historic focus has been on mitigating greenhouse gas emissions at the project level associated with construction; this is primarily because the issue has only been considered by project specific EIAs. However, the development of a climate resilient hydropower program will require system-scale climate change adaptation measures to be incorporated at the program, planning and project levels. This multi-tiered approach to system-wide planning is important, as gains in sustainability and improved performance will vary depending on the level at which adaptation measures are applied, as demonstrated in Figure 2.

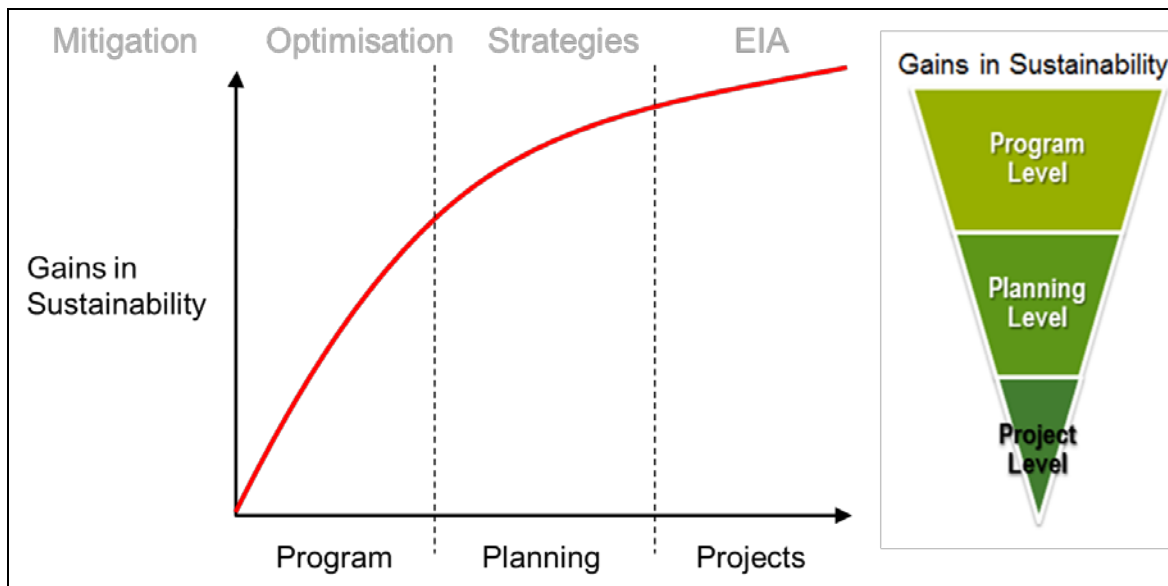


Figure 2. Gains in Sustainability Relative to the Level at which Adaptation Measures are Applied

Programmatic Options - The type and arrangement of hydropower projects included in a HPP program should be optimised to minimise the impacts of future climatic changes on generation capacity, performance and sustainability. One of the most effective mitigation measures for the impacts of climate change may be judicious long-range planning of the HPP program.

The elements of a HPP program that should be considered during the long-range planning process include:

- **Multipurpose Projects** – Impoundment projects which include a large dam and reservoir can be managed to produce a net effect of reducing the amplitude of water flow variance by containing water upstream during peak flows for flood control, or augmenting low flows in late summer. While primarily beneficial for flood control during extreme events, reservoir management can also be used in water release strategies for environmental flows, fish migration, cascade hydropower and irrigation.

- Run-of-River Projects - This design lacks significant water storage and flood attenuation capacity and is significantly affected by daily, seasonal, and annual changes in precipitation and therefore particularly susceptible to large variations in flows that may result from climate change.
- Cascade Arrangements – Arranging multipurpose and run-of-river designs in a cascade allows water release from the upstream impoundment dam to be used to generate power by the run-of-river projects located lower in the watershed.

System-scale Initiatives - Some impacts of climate change can only be addressed by the implementation of system-scale programs or initiatives as the impact is not localised or confined to a specific project or region. Examples of system-scale initiatives that should be considered for development in parallel with implementation of a HPP program in the Indus Basin include:

- Hydrological Forecasting System which incorporates telemetric monitoring of the basin hydrograph and responsive/adaptive management operating rules for HPPs in the system;
- Integrated Water Resource Management program which optimises water use by considering the needs of all primary users at the system level;
- Strategies to manage upstream land including afforestation to reduce floods, erosion, silting, and mudslides (e.g. Catchment Management Plans; Basin-wide Land Use Planning).

Project Design Options - A number of design options are available when attempting to integrate climate resilience in to the design of a hydropower project. These will not be suitable in all circumstances but should be considered when designing dams in a climate change vulnerable region, including:

- Increasing of dam height to accommodate expected increases in the intensity of runoff from source glaciers and provide some level of flood mitigation;
- Design more robust dams and supporting infrastructure for heavier flooding and extreme events;
- Modify spillway capacities and install controllable spillway gates to flush silted reservoirs and provide capacity for regulation of flow and flood attenuation during extreme events;
- Modify the number and type of turbines that are most suited for expected water flow rates and more resilient to performance reductions and turbine lifetime due to higher suspended sediment loads;
- Installation of multiple turbines of varying sizes to allow operation over a wide range of flows;
- Over design of canals and tunnels to accommodate projected extremes of water flow.

Operations Management - An integrated and coordinated operations strategy throughout the hydropower system will provide additional benefits to minimise the impacts of climate change, including:

- Water Storage – Impoundment dams high in the watershed will provide the capacity to store the intense flows and rains associated with the Kharif and release them as environmental flows during the Rabi. This will secure the annual water supply providing a reliable and continuous source of hydropower throughout the year.
- Flood Control – Climate change could increase the frequency and intensity of catastrophic floods in the future. The construction of upstream storage projects has the potential to offer some degree of downstream protection by reducing the amplitude of the hydrograph during extreme events.
- Irrigation – The existing irrigation system is vulnerable to the impacts of climate change, as the Rabi season becomes longer and drier the traditional crop varieties and rotational systems may not be sustainable due to water shortages. The release of monsoonal waters stored during the wet season should be used to sustain existing agricultural practices.

Project Level Options - At the project level the primary focus shifts from climate change adaptation to mitigation of construction and operational impacts that contribute to GhG emissions. As the adoption of hydropower over thermal generation is a major commitment to GhG reduction in itself, mitigation at the project level is the least efficient means of minimising the effects of climate change. Unfortunately, under the current Environmental Impact Assessment (EIA) focussed system of individual project assessment most of the resources available for climate change mitigation and adaptation are focussed at this level.

CONCLUSIONS

If WADPAs "*Vision 2025*" is to be sustainable, planners must anticipate future climatic changes and incorporate effective adaptive measures throughout the entire hydropower program. This will require a paradigm shift away from the current thinking of project level mitigation to basin-wide adaptation strategies that operate throughout the entire Indus River catchment. This will improve gains in terms of the long-term sustainability and climate resilience of the entire hydropower program at a system-scale.

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