# HIMACHAL PRADESH, INDIA CASE STUDY

## Harnessing Hydropower

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# Report Summary

The Harnessing Hydropower study aims to provide an analysis of the historical performance of hydropower in selected countries and an assessment of the risks and opportunities related to future climate change in the context of water, energy and food security. The Himachal Pradesh, India case study analyses the past performance of hydropower in the state and identifies priority interventions to help improve performance. It is intended to be useful to those with an interest in understanding the issues surrounding hydropower development in India and/or developing programmes which promote the sustainability of existing or new hydropower schemes in this or similar political, socio-economic or geographical contexts.

## Case study context

India as a whole suffers from electricity shortages of around 8.5% overall (FY2011-12) and 11% of peak demand (FY2011-12) (World Bank, 2012). These shortages are unevenly spread across the country however and the state of Himachal Pradesh (HP) in northern India is actually generating around 12.5% more than its own demand. While almost all HP's rural communities have access to grid electricity, many people can only afford the most basic use for lighting, meaning there is potential for an increase in the state's demand.

HP is home to around 25%[1] of India's total hydropower potential of 84,000MW (Himachal Pradesh State Electricity Board (HPSEB), 2014; National Institute of Hydrology, 2014). Commissioned plants in HP, for example the 1500MW Nathpa Jhakri on the Sutlej River, are exceeding expectations for generating potential. This is attributed to higher than expected river flows, which may represent an early benefit of climate change. Development of HP's 20,000MW of hydropower potential could make an important contribution to reducing India's power shortage issues and supporting low carbon growth aspirations (World Bank, 2012). The Government of HP is promoting 'sustainable', 'green' and 'inclusive' economic growth based around the development of this potential at various scales and in the near future, which presents some major challenges.

## Challenges of hydropower development in HP

### Small scale hydropower developments

As of 2011, almost 500 small scale hydropower[2] concessions have been awarded in HP, but less than 50 have been developed (Himachal Pradesh Energy Development Agency (HIMURJA), 2014), owing to various technical and administrative difficulties. For example, grid connections are not always available close enough for developers to access at reasonable cost and fines were not levied (as stated by regulations) for failure to develop a concession within a two year period from award. The latter particularly, led to financial speculation on concessions as assets, rather than their development. Competitive tendering is now used and the system has been changed to prevent speculation on new concessions. Problems persist however, with developers failing to obtain sufficient capital to develop a concession after bidding high to win it. The option to sell up to a 49% stake in the concession to other parties may help with this.

1 Uncertainties relate to different perspectives on viability, e.g. technical, economic
2 Up to 5MW capacity

A further problem is the lack of cost recovery by state owned distribution companies, meaning they are unable to guarantee payment for power generated by independent power producers (IPPs). It is difficult for IPPs to obtain loans for construction without a guarantee of future income. The costs of transmission to distant buyers also limits the opportunities for smaller producers to obtain power purchase agreements (PPAs). Compounding all the above issues is the need to obtain clearances from a range of government departments, and a detailed project report assessment from the Directorate of Energy which can take over two years, rather than the two months intended.

### Large scale hydropower developments

In HP, larger hydropower developers face challenges with obtaining the approval of local communities for their schemes and an increasing array of charges levied by the state government aiming to counter negative social and environmental impacts:

- IPPs are required to deposit 1% of project capital expenditure with the Local Area Development Fund to be used for local infrastructure projects.
- A 2.5% levy is charged for Catchment Area Treatment (CAT), i.e. catchment improvement.
- A further 1% of operating revenue must be provided as a cash incentive to project affected families, for the lifetime of the project.
- IPPs are additionally required to provide percentage royalties to the state government depending on the capacity of the project. Those less than 5MW provide 6% for the first 12 years of operation after which it increases to 15% and then after 30 years increases to 24%. For schemes over 5MW the royalties are 15%, 21% and 33% respectively. After 40 years schemes revert to state ownership.

HP has been progressive in developing many of these charges to compensate affected peoples and protect the environment. Some are subject to legal challenge, particularly by those objecting to retrospective application of new laws to operational projects.

## Impacts of climate change

Climate change was not of great concern to consultees for the case study in HP's hydropower sector. Immediate needs for development funded by hydropower revenue seem to be more pressing and first hand evidence suggests an opportunity to harness increased river flows for greater revenue generation. This contrasts with a future likely to involve less reliable flows from glaciers, although the timescales for this are subject to substantial uncertainties. In the longer term trade-offs may have to be made if more storage is required to combat increased climate and runoff variability or provide a greater range of benefits. Storage dams have much greater impacts downstream than the run-of-river dams currently favoured. They also require much greater acquisition of land for inundation, which can increase needs for resettlement and rehabilitation.

## Water, energy and food security

The picture for water, energy and food security of the largely rural population is complex. Pressures are being exerted by the state government to move away from subsistence agriculture to irrigated, high efficiency farming of high value crops. HP's climate is ideal for supplying the off-season fruit and vegetable market but the topography of the state means that getting water where it is needed for irrigation often involves costly pumping. Efforts are underway by the state government to promote this shift which it is hoped will improve livelihood prospects for many people, resulting in greater energy and food security. Livelihoods have had to be diversified as crop productivity has declined, in part through loss of efficiency on farmlands fragmented by inheritance traditions. Intensification of production is hoped to compensate somewhat. Increased income from developing the state's hydropower potential could further support such development of the agricultural sector. Energy security is high in terms of access to grid electricity but progress is needed in terms of increasing people's capacity to pay for sufficient quantities for heating and cooking. Increasing the affordability of electricity for the poorest people could help to reduce dependence on biomass energy for heating and cooking with positive knock-on impacts for environmental sustainability.

## International influence

There is limited involvement from international organisations in HP's hydropower sector, perhaps owing to the state's impressive set of development indicators and the good prospects for it to meet Millennium Development Goals (MDGs). The World Bank is leading a Climate Investment Fund project; however, supporting the state in its efforts to ensure its future development is 'green' and sustainable. This is also important for downstream states and Pakistan which depend on the headwater catchments of the Himalaya which constitute a majority of HPs territory.

## Conclusions

A more integrated approach to planning and operation of the state's hydropower potential, including an improved climate change strategy and action plan could help HP to stay at the forefront of developing country efforts to harness hydropower. The increased river flows owing to glacier melt likely over the next century present an opportunity to employ HP's hydropower potential to maximise growth and development in the state. It is important that development of the state's hydropower potential does not compromise the ability of its environment to support sustainable development.

Much can be learned from the example set by HP about progressive policies to support hydropower development in other countries/regions, but the basic conditions of a well-developed, decentralised democracy and land ownership rights seem particularly strong foundations. Efforts to restructure the Indian power sector to provide greater incentives for sustainable hydropower development will be extremely challenging but no less important in the long term.

This study suggests the interventions shown in Table 1are priorities to help harness HP's hydropower potential.

| | | |
|---|---|---|
| 1 | Action | Build on the State Strategy and Action Plan for Climate Change, filling gaps identified to help integrate hydropower planning and development |
| | Rationale | Stronger planning and strategy components will help to increase the resilience of the State and its hydropower infrastructure to climate change. Currently, the document reports ongoing activities and identifies gaps which need to be addressed, but lacks a coherent strategy. |
| | Precedent | There is increasing international experience of developing climate resilience and adaptation strategies. For example, The Global Water Partnership (GWP) has a South Asian Water, Climate and Development Programme with the overall goal of improving resilience of South Asian countries to climate change. One of its objectives is developing "no regrets" financing and investment strategies for water and climate change adaptation |
| | | |
| 2 | Action | Build partnership approach between people and hydropower projects |
| | Rationale | Greater support from local communities is likely to be generated by making them genuine partners in the development of the natural resources on which their |

| | | |
|---|---|---|
| | | livelihoods depend. The profitability of good hydropower schemes means that a small dividend on revenue (~2.5%) could double the income of project affected families. Such partnerships could streamline local approvals for development. |
| | Precedent | HP provides its own precedent in this respect, having moved closer towards such an approach incrementally. Sanan and Mitra's (2011) 2.5% dividend proposal supports the assertion in the Land Acquisition Act (2013) that affected families should be socially and economically better off as a result of hydropower development. The World Bank has also recently produced a guide for local benefit sharing on hydropower projects (Wang, 2012). |
| | | |
| 3 | Action | Establish coordination bodies to promote integrated water management and soil and water conservation practices |
| | Rationale | In HP there is a need to better coordinate water resources issues. Although the government has made some progress towards this with the establishment of a State Water Management Board, this lacks effectiveness without a department to work through. Asian Development Bank (ADB) (2010) proposed the need for coordination be filled by two bodies. |
| | Precedent | ADB (2010) has suggested a water resources working group comprising representatives from the Department of Irrigation and Public Health (DIPH), Department of Environment, Himachal Pradesh State Electricity Board, and Himachal Pradesh Energy Development Agency (HIMURJA), and a catchment and agriculture working group consisting of representatives from the Environment, Forestry, Agriculture, Horticulture and Rural Development Departments. The former would coordinate water resources development and the latter soil and water conservation, agriculture and forestry. |
| | | |
| 4 | Action | Support definition, monitoring and enforcement of appropriate environmental flows in rivers affected by hydropower projects |
| | Rationale | This will help regulators protect river basin biodiversity which relies on flows. Avoiding environmental damage from hydropower schemes will increase overall water, energy and food security in a catchment. |
| | Precedent | Work has been undertaken by the International Water Management Institute (IWMI) in Sri Lanka (Smakhtin and Anputhas, 2006) which could be applied to the HP context. The approach rapidly defines environmental flows based on scaling flow duration curves. The definition and implementation of environmental flows is a challenging topic globally and particularly in the context of climate change. |
| | | |
| 5 | Action | Analyse trade-offs associated with water storage developments to ensure sustainable resource use and equitable sharing of benefits |
| | Rationale | Owing to the position of HP in the headwaters of the Indus basin and the high proportion of Indus flow from its rivers, there is high potential for their management to impact on downstream users. Trade-offs exist between different uses of water and it is important to understand these in order to make best use of available resources at a basin scale, ensuring sustainability of environmental and social systems. Consideration of the broader impacts of any development is likely to improve stability and could foster increased cooperation locally, regionally and internationally. This action is in line with the State's Strategy and Action Plan for Climate Change. |
| | Precedent | Different approaches to trade-off analysis are being developed in the research literature (e.g. Räsänen et al., 2013; Gómez et al., 2013; Hurford and Harou, 2014) and the World Conservation Union (IUCN) is leading an innovative project in Kenya's Tana Basin and Ghana's Volta Basin (IUCN, 2014) using many-objective trade-off analysis to identify portfolios of built and natural infrastructure which achieve the best possible (i.e. Pareto-optimal) trade-offs between a broad range of benefits including hydropower. |
| | | |

| | | |
|---|---|---|
| 6 | Action | Identify opportunities to develop payments for ecosystem services (PfES) approach |
| | Rationale | It may be possible to increase incentives for farmers to undertake soil and forest conservation measures if payments can be negotiated between them and those who stand to benefit downstream. This action is in line with the State's Strategy and Action Plan for Climate Change. |
| | Precedent | The Millennium Challenge Corporation (MCC) has included the concept of payments for ecosystem services in its compact with the Malawian Government to revitalize the power sector. This is intended to address sedimentation issues in the Shire river by having hydropower producers fund catchment conservation measures by farmers in the upper catchment. This can help incentivise making the investment in changing practices. There are positive examples from Cambodia (Arias et al., 2011) and the South West of the UK (South West Water, 2014) where a water company has paid for adaptation measures on farms upstream of reservoirs to improve water quality arriving at the reservoir and thereby reduce their water treatment costs. Measures have included fencing off rivers to prevent cattle incursion and providing covered sheds so that heavy rainfall does not lead to runoff highly polluted with dung. Overall these measures are cheaper for the water company than the costs of water treatment. |
| | | |
| 7 | Action | Restructuring of the power sector in India as a whole |
| | Rationale | This is needed to incentivise private investment. It can only be achieved from the top down as the entrenched positions of the States and the benefit they accrue from the current system will make it very difficult for them to change anything. |
| | Precedent | Templates for success in this area are not available in any of the case study countries for this project, but Best Practice Guidelines are available from organisations such as Energy Charter Secretariat (2003). Sanan and Mitra (2011) have suggested a revised strategy for the Ministry of Power to improve the performance of the energy and hydropower sectors, including:<br><br>• Emphasising enabling rather than doing, to allow market forces to play out<br>• Addressing market failures jointly with other stakeholders<br>• Facilitating clearances with environment and forestry ministry<br>• Coordinating renewables development with Ministry of New and Renewable Energy<br>• Promoting hydropower with Ministry of Water Resources and Ministry of External Affairs (for Nepal and Bhutan)<br>• Promoting regional power sharing (Ministry of External Affairs)<br>• Better catalysis of inter-state cooperation<br><br>They recommend a small inter-ministerial professional body to help expedite clearances and harmonise legal requirements and a regional water resources authority could help to resolve inter-state issues relating to benefit sharing and trade-offs.<br><br>In terms of technical issues, Long-term planning needs to be undertaken and implementation expedited to provide power evacuation on a river basin level rather than on a project by project basis. Funding mechanisms need to be devised to promote this. |

**Table 1 Prioritised interventions for harnessing hydropower in Himachal Pradesh**

# SECTION 1

## Introduction

### 1.1 Hydropower's role in world energy systems

Access to affordable, sustainable and reliable energy systems has been recognised as an important part of the post-2015 development agenda (UN, 2013). Hydropower currently provides around 16.5% of the world's electricity (REN21, 2013) and is the main energy source for more than 30 countries (IUCN, 2012). Hydropower could contribute towards climate mitigation through low carbon energy production and adaptation, i.e. where water storage reduces hydrological variability, but it will also likely be impacted by climate change in sometimes complex ways. At its simplest, the availability of water and its changing distribution in space and time are of primary importance.

The significant increase in hydropower generation capacity over the last 10 years is expected to continue over the next two decades with various environmental and social concerns representing the largest challenges to major hydropower developments (Kumar et al., 2011). Given the potential expansion of hydropower schemes to meet local, national or regional energy demands and reduce carbon emissions, it is important to understand how the performance of hydropower schemes can be maximised. This means making the best use of available water resources to meet different needs while protecting the environment and ensuring that hydropower developments are resilient to future climate change.

### 1.2 Objectives of the project

The overall objective of this project is to analyse the past performance of hydropower in selected countries and assess the risks and opportunities presented by future climate change in the context of water, energy and food security. Four countries, Malawi, Ethiopia, India and Nepal, were selected as case studies, providing a wide range of political, socio-economic and geographic settings from which to draw evidence. The case studies aim to identify priority interventions for partner governments and donors to improve performance.

### 1.3 Objectives of the report

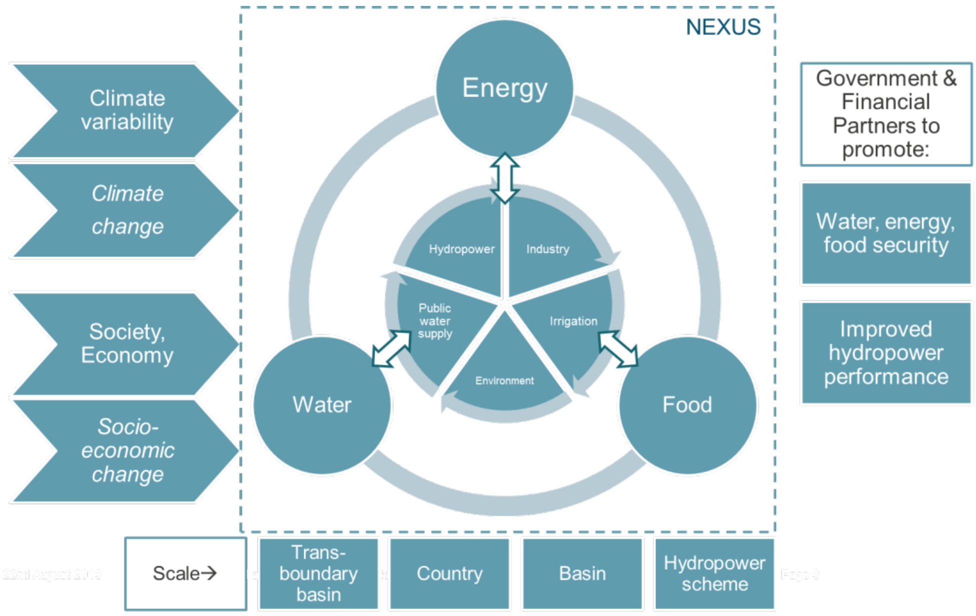
This report presents findings from the case study that focused on Himachal Pradesh in northern India. It is intended to be useful to those with an interest in understanding the issues surrounding hydropower development in Himachal Pradesh (HP) and/or developing programmes which promote the sustainability of existing or new hydropower schemes in this or similar political, socio-economic or geographical contexts.

### 1.4 A framework for analysis

For each country case study we have adopted a common framework to organise the collection of evidence, frame the analysis and to consider the issues related to hydropower in the context of the broader water-energy-food security debate.

Figure 1 provides a framework based on the research literature on the water-energy-food security nexus (e.g. Jägerskog, 2013). This considers the impacts of climate variability and climate change, future energy demands and the outcomes promoted by governments and financial partners that aim to promote water, energy and food security.  It indicates that the performance of hydropower needs to be considered in the broader context of water, energy and food (WEF) security considering the trade-offs between the use of natural resources for different purposes and at different scales from large trans-boundary basins to local small-scale hydropower schemes.

**Figure 1 A framework for assessing hydropower performance in the context of water, energy and food security.**




*(adapted from IADB, 2011)*

Collecting and interpreting evidence on hydropower performance at national, basin and scheme scales is a challenging task. Many previous studies have involved detailed river basin modelling using various water resources, energy systems and land allocation models to simulate the performance of river basins and in some cases optimise the use of water and land resources to meet specific targets (e.g. McCartney 2007; Tilmant et al., 2010; Mulatu et al., 2013).

We have adopted a different approach focused on understanding the historical performance of hydropower schemes, describing the linkages between water-energy-food issues for selected case studies and then considering options for development interventions to promote sustainable hydropower development.

## 1.5 Structure of the report

Evidence was drawn from available literature and information gathered by consulting a wide range of stakeholders during case study country visits (Appendix A) and analysis was carried out to illustrate the key issues. This information is presented in five sections outlined below:

- Case study context: A summary of national water, energy and food security literature to provide background information on each case study (Section 2).

- Systematic mapping: Highlighting the interactions between water-energy-food issues supported by some qualitative assessment of potential impacts of climate and socio-economic change (Section 3).
- Hydropower performance and its influencing factors: A review of information and data relating to past hydropower performance provided by documents and through consultations during the country visit (Section 4).
- Ongoing Interventions: Identification of the types of interventions already being undertaken which will influence the performance of hydropower. (Section 5)
- Conclusions: Based on the key issues identified by the case study, seven priority interventions are identified and described. (Section 6)

# SECTION 2

## Case study context

This section describes the political, socio-economic and geographic characteristics of the state which relate to its hydropower potential and water, energy and food security.

### 2.1 Development status

Himachal Pradesh (Figure 2) was selected as the Indian case study as it has large hydropower potential 25% of India's total 84,000MW (Himachal Pradesh State Electricity Board (HPSEB), 2014; National Institute of Hydrology, 2014) and extensive experience of hydropower development at various scales. This, in conjunction with the potential for conflict between water use for hydropower and agriculture, makes it a rich source of information for this study. HP is nationally important for its custodianship of the headwaters of three major rivers critical to 200 million people in North India. Its hydropower potential, together with its large forested area, give it a crucial role in India's Green Economy and low-carbon development ambitions. The Sutlej River (Figure 2) was chosen for hydropower performance analysis as the state's most significant hydropower resource which is also utilised for irrigation.

HP is a small state by both size (55,670 $km^2$) and population (6.8 million), 90% of whom live in rural areas and depend primarily on agriculture. It has some of India's best development indicators and is on track to meet most of its MDGs. From its inception in 1971 it has had a higher income per head and better social indicators than much of the country. Supportive policies have facilitated investment in infrastructure and achieved per capita social expenditures of approximately double the Indian state average.

Much of HP is inaccessible and uninhabitable. Its elevation ranges from 400m to 6,600m above sea level, with rugged terrain and a high level of forest cover. Its net sown area is only 15% of the total area and it is estimated that over 40% of cultivated land is prone to very high erosion (Department of Environment, Science and Technology, 2009). HP is classified as a "special category" jurisdiction, which gives it access to special central government grants and other incentives.

### 2.2 Regional context

Himachal Pradesh is in a unique position regionally, and contrasts with India as a whole, in terms of its high reliance on hydropower and high access to grid electricity (Figure 3). Only Myanmar has similar water availability per head of the selected countries in the region with data available.

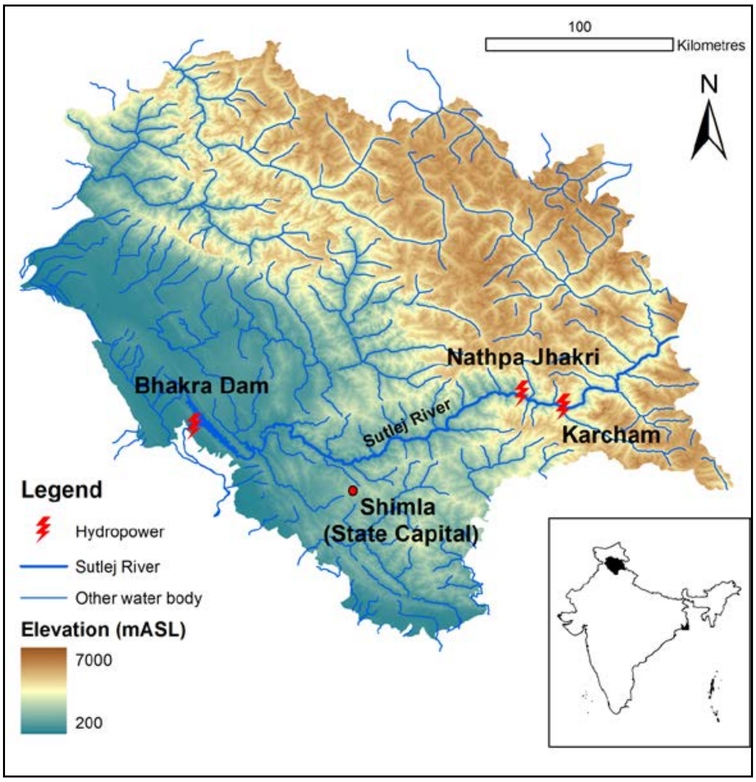
### 2.3 Development policy and planning

A number of policies and plans affect development of hydropower in HP and three of the key ones are summarised here.

## 2.3.1 Five year plans

Development planning has been undertaken by India through five year plans, since its independence. The eleventh plan ended in March 2012, when the twelfth plan also began.

**Figure 2 Topographic map of Himachal Pradesh showing the location of major hydropower dams in operation on the Sutlej River. Inset map shows location of the state (black) within India.**




There are two major policy challenges addressed by the 12th Plan:

1. Reverse the observed deceleration in growth by reviving investment, e.g. tackling implementation constraints in infrastructure which is highly relevant to the hydropower sector.
2. Put in place policies that leverage the economy's strengths to bring it back to full potential.

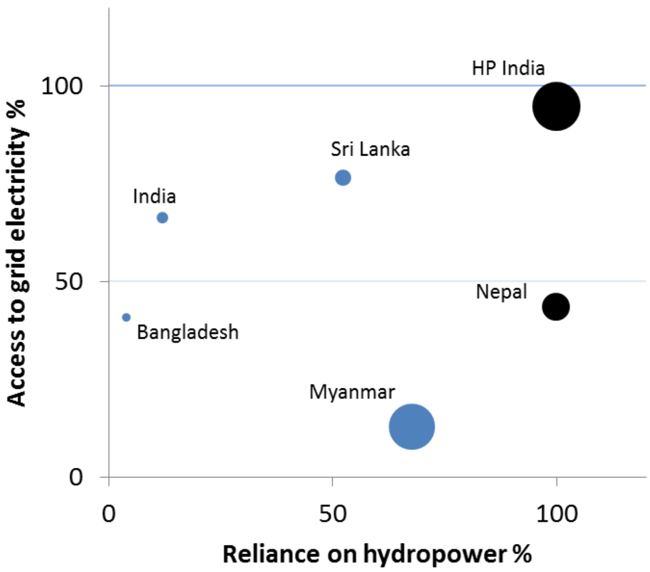
Statements from the 12th Plan relevant to this research include:

- "Development cannot take place without additional energy and the energy requirement of development will have to be reconciled with the objective of protection of environment. The economy depends heavily on coal and hydropower to meet its energy needs and the development of each of these energy sources involves potential trade-offs with conservation of forests and the objective of avoiding displacement of people. We need to manage these conflicting objectives more efficiently, with adequate compensation for those dispossessed and appropriate remedial steps to correct for loss of forest cover where this is unavoidable."
- "…the motivation for accelerated development of hydropower is two-fold: first, it is required for meeting India's peak power demand; and second, it is vital for large-scale integration of solar and wind capacity into the grid."

- "The Himalayas are comparatively young mountains with high rates of erosion. Their upper catchments have little vegetation to bind soil. Deforestation has aggravated the problem. Rivers descending from the Himalayas tend, therefore, to have high sediment loads. A 1986 study found that 40% of hydropower dams built in Tibet in the 1940s had become unusable due to siltation of reservoirs."
- "Studies by engineering geologists with the Geological Survey of India record many cases of power turbines becoming dysfunctional following massive siltation in run-of-the-river schemes. Climate change is making predictability of river flows extremely uncertain. This will rise exponentially as more and more dams are built in the region. Diverting rivers will also create large dry regions with adverse impact on local livelihoods (fisheries and agriculture)."

*(Planning Commission, Government of India, 2013)*

**Figure 3 Reliance on hydropower and access to electricity with water availability per headrepresented by the size of the circles**




Note: Black circles are Harnessing hydropower case studies, blue are other countries in South Asia (Data source: World Development Indicators 2013, World Bank)

The Government of India promotes universal access to energy and aims to achieve an annual minimum consumption of 1000 kWh for all its citizens by 2012. However, supply has not kept pace with the increasing demand, and the electricity deficit is in the order of 8.5% (FY2011-12) with a peak deficit approaching 11% (FY2011-12), and growing in severity (World Bank, 2012).

The 12th five year plan proposes to deal with intermittency of electricity from other renewables such as wind by the development of pumped storage hydropower. This allows excess electricity to be used to pump water to a reservoir at elevation from where it can be released through a hydropower plant when it is needed.

### 2.3.2 National Action Plan for Climate Change (NAPCC)

In addition to the 12th Five Year Plan which guides India's general development, a National Action Plan for Climate Change (NAPCC) has been developed. This recognises a need to maintain high levels of growth while sharing the benefits of this growth to achieve sustainable development. This is guided by principles of protecting the poor, balancing economic development with environmental protection and bringing down demands and carbon emissions. These are all relevant to hydropower development. It also says new market, regulatory and voluntary mechanisms must be developed to deliver this sustainable development. The action plan identifies eight "national missions" through which to combat climate change, some of which are relevant to this study:

1. National Solar Mission – significantly increase share of solar energy in total mix.
2. National Mission for Enhanced Energy Efficiency.
3. National Mission on Sustainable Habitat – improving energy efficiency, solid waste management and public transport.
4. National Water Mission – increase water use efficiency by 20%; ensuring integrated water resource management (IWRM) through new regulatory structures, entitlements and prices; and expanding irrigation and associated storage.
5. National Mission for Sustaining the Himalayan Ecosystem – promoting community ecosystem management, monitoring and understanding of the mountain ecosystems and changes to water storages.
6. National Mission for a Green India – enhancing ecosystem services and carbon sequestration by forests, increase forest cover from 23% to 33%.
7. National Mission for Sustainable Agriculture – technological approaches to combatting climate change impacts on agriculture such as breeding new crop varieties, understanding changes and adaptation options.
8. National Mission on Strategic Knowledge for Climate Change – technical and social research on challenges and adaptation relating to climate change.

*(Government of India, 2014)*

### 2.3.3 State Action Plan on Climate Change

HP's state strategy and action plan on climate change is somewhat limited in its reporting of strategic thinking and planning. It does however, report a number of ongoing actions being taken by the State government intended to address climate change adaptation and mitigation. Relevant to this study in terms of hydropower development and water, energy and food security are the following:

- Energy efficiency measures and emphasis on developing renewable sources of electricity generation and in the case of hydropower, specifically run-of-river projects with Environmental Impact Assessments (EIAs), Cumulative EIAs, and Environment Management Plans.
- Rainwater harvesting has been made mandatory in HP and non-conventional methods are being used to maintain water resource availability, such as inter-basin transfers and artificial recharge of groundwater. Inter-basin transfers particularly could affect the availability of river flows for hydropower generation.
- Traditional flood defences are being installed to protect communities, such as embankments and gabions, as of March 2011 17,600 ha had been protected. This is relevant to the potential flood control function of dams and the prevention of dam failures.
- A state disaster management plan is being finalised, suggesting mitigation measures and a State Emergency Operation Centre (SEOC) has been established. Again, relevant to the potential flood control function of dams and the prevention of dam failures.
- A Weather Based Crop Insurance Scheme (WBCIS) has been introduced to compensate for climate variability's impacts on crop yields and provide credit facilities where crop failure puts them at risk

- Programme for the production of cash crops through precision farming and poly-tunnel cultivation and micro-irrigation to diversify the agricultural sector
- It mentions the Horticulture Technology Mission programme funded by the Government of India which is taking care of adaptation actions to combat climate change
- Capacity development of local communities to plan, implement and manage the rural water supply scheme of their own choosing is being carried out.

The document identifies a number of knowledge gaps, including:

- The magnitude and rate of climatic changes and their subsequent impacts,
- Techniques for conserving biodiversity,
- Detailed analysis for priority vulnerable sectors such as agriculture and ecosystems.

The knowledge gaps are all relevant to the impacts of hydropower development, so there would be clear benefits to addressing these gaps. The Strategy document acknowledges that there is:

- No systematic monitoring or research on biodiversity,
- Insufficient evidence to understand impacts of climate change on human lives,
- Limited research on the auto-adaptive strategies being taken by those already affected by changes (to take advantage of them),
- Insufficient human resources and skills to deal with the issues, and
- A lack of institutions structured to tackle such complex issues and policy imperatives.

It is suggested that sharing and accessing mechanisms are required for the wide range of data which are being collected by different organisations and that observations must become systematic to track longer term changes.

*(Department of Environment, Science and Technology, 2012)*

## 2.4 Water, energy and food security status

This section describes the current status of HP in terms of water, energy and food security.

### 2.4.1 Water security

#### Water resources

Around 17% of the Indian Himalayan Region (IHR), of which Himachal Pradesh is a key part, is glacierised or permanently snow-covered. A further 30 to 40% is under seasonal snow cover and the combination of permanent and seasonal cover constitutes a huge water reservoir (Asian Development Bank (ADB), 2010). Inter-annual variations in seasonal snow melt are balanced by permanent snow/glacier melt providing a relatively consistent flow from year to year. There is robust evidence of decreasing glacierised extent and in the longer term (beyond 2100) this could impact on both the generation of runoff in the local rivers and the livelihoods of millions downstream (Immerzeel et al., 2013). River flows will not be as dependable with reduced buffering effects of glaciers against annual variations in precipitation. Over time the rivers will become predominantly rainfed. Water resources security is generally high in terms of availability in rivers at present.

There are differences however, between water security of those living in river valleys and those on higher terrain. The latter, although mostly supplied with government standard clean water may rely on springs or small rivers which are vulnerable to drought and reduced dry season flows. There have been reports of spring and tube well water supplies being disrupted by engineering works for hydropower schemes. Tunnelling for head and tail races[3], which can run tens of kilometres under the mountains, is believed to sometimes interrupt and effectively drain aquifers or create new fractures in the rocks confining them. Cement lining of the tunnel can restore aquifers as intended, but sometimes this has not happened (Consultee, 2013).

#### Flooding

Glacial lakes can form as glaciers retreat and under certain circumstances, the moraine dams which contain them can destabilise or be overtopped causing catastrophic failure. Water security in terms of flood risk is low, resulting from the hazards presented by both Glacial Lake Outburst Floods (GLOFs) and cloudburst floods[4], both of which can be highly destructive. Other flood events can also occur due to the instability of the Himalayan environment. One such event resulting from breaching of the banks of Lake Parechu in Tibet almost lead to the cancellation of construction of the 1500MW Nathpa Jhakri dam, now India's largest hydropower scheme, owing to the destruction caused (Consultee, 2013).

### 2.4.2 Energy security

It is reported that Himachal Pradesh achieved 100% electrification in 1987 as a result of loans from the Indian Rural Electrification Corporation. This figure is disputed by some sources including Aggarwal and Chandel (2010) who claim a contemporary figure of 94.8%. This is still well above the national average of 55.9%. It is important to recognise however, that this does not mean that the population's homes are entirely electrified and few other sources of energy are required. The costs of electricity compared with freely available fuel- and fire-wood and subsidised Liquefied Petroleum Gas (LPG) for example, mean there is plenty of potential for electricity demand to increase. Monthly average expenditure on electricity is only Rs. 267 (US$ 4.3).

The state currently generates 12.5% more than its own electricity demand, so already has an excess of energy on which to generate revenue. The revenue from the excess production is used to subsidise electricity and Liquefied Petroleum Gas (LPG) for domestic use. Although 22% of the population have shifted to use of LPG from fuelwood for cooking, the majority are still reliant on fuelwood. As the cheapest form of energy available, fuelwood still constitutes 52% of energy use in Himachal Pradesh (Aggarwal and Chandel, 2010), although this use is said to be sustainable (Consultee, 2013). During the cold winters, rural homes are heated by fire-wood while urban homes use coal, kerosene, LPG and electricity. The state government provides wood at highly subsidised rates to tribal and remote areas by importing it from lower elevations.

The state government has banned the felling of trees, causing an energy crisis for those reliant on fuelwood although achieving the desired goal of increasing forest cover. Cover increased from 21% in 1991 to 26% in 2003 (Aggarwal and Chandel, 2010). The national government is trying to avert this energy crisis by promoting access to renewable electricity generation (solar, biomass, wind, etc.) through establishment of a new Ministry of New and Renewable Energy. To implement renewable energy programmes in Himachal Pradesh, a State Energy Development Agency (HIMURJA) was established.

3 Tunnels transporting water to and from turbines

4 Cloudbursts are poorly understood but very intense rainfall events over a short duration and small geographical area, often causing flash floods. They are common events, occurring "every couple of years" (Consultee, 2013)

### 2.4.3 Food security

Almost 70% of employment is in agriculture, but less than 22% of the state's Gross Domestic Product (GDP) is generated through it (ADB, 2010). Average land holdings are less than one hectare per family and often on steep slopes unsuitable for mechanisation with yields highly dependent on climate. Productivity and incomes are low and especially vulnerable to climate change. There is a concern that the state's low poverty levels could be increased by climatic problems affecting agriculture.

Agriculture is mostly for subsistence but insufficient as a sole livelihood strategy, so most rural families supplement their income with tourism, craft industry or jobs in urban centres outside the state. Animal husbandry is common, providing subsistence and cash income benefits. Small land holdings mean people are reliant on communal fodder resources including forests. Forests are also under pressure for medicinal plants and firewood. The state is promoting a shift to higher return vegetable crops instead of subsistence farming but rural jobs are being lost faster in the agriculture sector than alternatives are being created. Irrigation investment can be justified by the higher revenues from particularly off-season fruit, vegetable and flower growing and a number of government schemes are promoting such strategies.

It is estimated by the Indian Council of Agricultural Research (ICAR) that medium-term projections show a likely reduction in crop yields due to climate change of between 4.5 and 9% by 2039, and possibly up to 25% or more by 2099. Though the rainfall records available with the India Meteorological Department (IMD) do not indicate any perceptible trend of change in overall annual monsoon rainfall in the country, noticeable changes have been observed within certain distinct regions (ADB, 2010).

## 2.5 Hydropower in HP

Himachal Pradesh (HP) has a crucial role in India's renewable energy ambitions. In 2012 the World Bank noted that "With this Program, HP will be the first state to make a tangible contribution to the Government of India's (GOI) objective on greenhouse gas emission intensity" (World Bank, 2012). Hydropower is a priority of the GOI's 12$^{th}$ Five-Year Plan (Section 2.3.1), which has the goal of building 20 GW of this renewable capacity over the period 2012-17. In the opinion of the World Bank "much of this goal could be achieved in HP" (Ibid, p.23). HP is estimated to contain 25% of India's total hydropower potential.

The state of HP has a large number of dams and many more proposed schemes, mostly run of river HEP schemes on the main river and its tributaries. This results in a relatively high density of dams of 1.5 per 1000 km$^2$ (Table 2).

HP formulated its first Hydropower Policy in 2006. This statement, and subsequent additions and modifications, have set out:

- Policies towards environmental management.
- A bidding process for the allotment of new hydro projects.
- The promulgation of river-basin planning and implementation.
- Principles for dealing with community risks and benefit sharing.

The current set of policies seek to promote Integrated Watershed Management in this nationally-sensitive catchment. HP's Himalayan ecosystem forms the catchment of major Indian Rivers such as the Sutlej, Beas, Ravi and Yamuna. Their waters support 200 million people in Punjab, Haryana and Uttar Pradesh, "these rivers are crucial in sustaining livelihoods and assuring food and water security for irrigation and domestic use across much of North India...Hence consideration of downstream impacts is critical to the State's development strategy." (World Bank, 2012).

| State/Basin | No. of dams | Area ($km^2$) | Dam density per 1000 $km^2$ |
|---|---|---|---|
| Arunachal Pradesh | 80 | 83,743 | 0.96 |
| Sikkim | 29 | 7,096 | 4 |
| Jammu and Kashmir | 23 | 222,236 | 0.1 |
| Himachal Pradesh | 81 | 55,673 | 1.5 |
| Uttarakhand | 79 | 53,484 | 1.5 |
| Himalayan States | 292 | 422,232 | 1.612 |
| Ganga | 89 | 861,452 | 0.102 |
| Indus | 94 | 321,290 | 0.290 |
| Brahmaputra | 109 | 194,413 | 0.583 |
| Himalayan Basins | 292 | 1,377,155 | 0.325 |
| Global basins* | 194 | 36,591,693 | 0.0053* |

*Note *On the basis of 23 major basins distributed across the seven continents. (Source: Pandit and Grumbine, 2012).*

**Table 2 Comparison of dam density for heavily dammed Indian states, Indian Himalayan States in total, major Indian basins and a total for major basins worldwide**

### 2.5.1 Hydropower projects

Projects are allocated to central, state and private sponsors. There is also a separate category of small scale producers (up to 2MW, which for certain purposes is stretched to 5MW) having a special incentive regime, applying mainly to private producers.

Current hydropower generating capacity in HP is estimated to be 6370 MW (Himachal Pradesh State Electricity Board, 2014), the largest proportion of which is under the control of the central government. This capacity will soon be increased with the imminent commissioning of the 800MW Kol Dam project implemented by the National Thermal Power Corporation, incorporating a new 40 $km^2$ reservoir. HP's state sector comprises 20 projects under operation, with total capacity of 467 MW.

HP's ambition to sell surplus hydropower profitably to the rest of India is being constrained by the financial problems of its potential customers. Almost all of India's state electricity boards are "cash strapped and prefer to resort to outages, euphemistically called load shedding, than buying electricity to meet the peak demands", according to a news report (Hindustan Times, 2013) corroborated by consultations for this study. The state currently produces a surplus over local demand of approximately 12.5%, which is being disposed of partly in unprofitable open market sales and partly in bulk contracts to other states (Hindustan Times, 2013).

### 2.5.2 Private sector involvement

Since the 1990s HP has had a policy of encouraging private involvement in the hydropower sector. Based on competitive tendering, its typical model has been Build-Own-Operate-Transfer (BOOT), with concession periods of 40 years. The royalties due to the State for different sizes of projects and different time periods of the concession are shown in Table 3. The royalty takes the form of free power made available to the state power authority. An additional royalty has been added for all independent power producers since the 2006

Hydropower Policy, requiring that 1% additional free power be made available for the state to sell to contribute to the Local Area Development Fund (LADF) (Consultees, 2013).

Independent Power Producers are required to deposit 1% of project capital expenditure with the Local Area Development Fund (LADF) to be used in local infrastructure projects. A 2.5% levy is charged for Catchment Area Treatment (CAT) plans, i.e. catchment improvement. Introduced recently, a further 1% of operating revenue must be provided as a cash incentive to project affected families, for the lifetime of the project (Consultees, 2013).

| | Hydropower scheme installed capacity | |
|---|---|---|
| **Time period** | **<5MW** | **>5MW** |
| 0-12 years | 6% | 15% |
| 12-30 years | 15% | 21% |
| 30-40 years | 24% | 33% |

**Table 3 Royalties due to the State according to installed capacity and period of concession**

LADF funds are not always spent in the area they are supposed to be and this may be a reason for communities to sometimes force a developer to pledge more than 1% either to the LADF or in terms of specific infrastructure investments. Likewise, CAT funds which are paid to the forestry department only require the department to provide a utilisation certificate. These sometimes show the money has not been used directly for reforestation as required.

### 2.5.3 Expansion of the hydropower sector

The abundant water resources mean that there are sufficient flows to operate large numbers of hydropower schemes in series. Increased rates of glacier melt with climate change has been presented as an opportunity for harnessing power and water resources for water scarce parts of India (Sharma and de Condappa, 2013).

However, the cumulative impacts of large numbers of dams concerns environmental groups, for example, in a review of Himalayan dam building Pandit and Grumbine (2012) reported:

- Nearly 90% of Indian Himalayan valleys would be affected by dam building and 27% of these dams would affect dense forests.
- Projections that 54,117 ha of forests would be submerged and 114,361 ha would be damaged by dam-related activities.
- Most dams would be located in species-rich areas of the Himalaya. By 2025, deforestation due to dam building would likely result in extinction of 22 flowering plant (angiosperm) and seven vertebrate taxa.
- Disturbance due to dam building would likely reduce tree species richness by 35%, tree density by 42%, and tree basal cover by 30% in dense forests.

These results, combined with relatively weak national environmental impact assessment and implementation, point toward significant loss of species if all proposed dams in the Indian Himalaya are constructed (Pandit and Grumbine, 2012). A cumulative environmental impact assessment (CEIA) is being undertaken for the Sutlej Basin by the Indian Council of Forestry Research and Education (ICFRE) (2014) to provide baseline information and help to manage cumulative impacts in the future.

## 2.6 Climate change impacts and adaptation

Climate change projections for India suggest that rates of warming will be greater in the Himalayas than India as a whole. There is still considerable uncertainty related to the rate of retreat of glaciers and the overall impacts of changes in the hydrological cycle on Himalayan rivers that are a source of water for a quarter of the global population that lives in south Asia. Box 1 and Figure 4 present some headline changes in the Indian climate by 2100. More detail on phenomena and trends relating to climate change impacts on water resources in Himachal Pradesh are given in Appendix B. The section below highlights some potential impacts on hydropower. The climate projections presented are based on UK Met Office research using models developed for the IPCC Fourth Assessment Report but these are very similar to projections for the more recent Fifth Assessment (Chaturvedi et al, 2012).

**Box 1 Climate change projections and impacts in India**

- For a Medium High scenario projected temperature increases are lower in the south of India, up to 3°C, compared to the north where changes of up to 4.5°C are projected.
- India is projected to experience increases in precipitation across most of the country. Increases of up to 20% or higher could occur in western regions with more widespread increases of 5 to 10% over the rest of the country. Agreement between climate models is moderate to low.
- The Intergovernmental Panel on Climate Change's (IPCC) Fourth Assessment Report (AR4) noted a general increase in mean and extreme precipitation across India under climate change scenarios. Two key factors affecting Indian precipitation are the Asian Monsoon system and tropical cyclones, and future projections of these mechanisms are both subject to high uncertainty.
- Several studies suggest that by the end of the 21st century, extreme and currently rare floods could occur more frequently in India. Generally there is still considerable uncertainty in projections of extreme precipitation with climate change as well as potential changes to the strength of the monsoon.

*Source: Met Office, 2011.*

### 2.6.1 Impacts on Himalayan rivers

#### Temperature and precipitation

Basins are projected to receive an increase in precipitation, with most still falling as snow and contributing to the seasonal surface water reservoir. Increased temperatures are very likely to increase the rates of snow melt and therefore the distribution of river flows during the year. Very early snow melt may result in the loss of some perennial streams used for drinking water or irrigation (ADB, 2010).

#### Glaciers

Impacts on glaciers are still not fully understood but it is clear that ice cover is decreasing across the Himalayas. Between 2003 and 2009, Himalayan glaciers lost an estimated 174 giga-tonnes of water (Laghari, 2013) and, combined with heavy monsoon rains, this contributed to catastrophic floods of the Indus, Ganges and Brahmaputra rivers. Data are sparse but field, satellite and weather records confirm that 9% of the ice area present in the early 1970s had disappeared by the early 2000s (Laghari, 2013).

## Flood risks

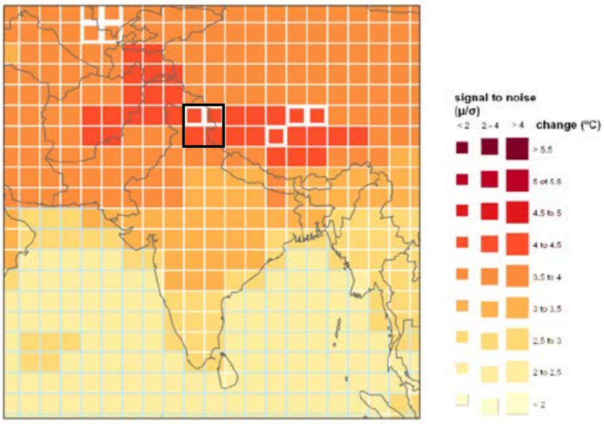
There are systemic flood risks in the Sutlej River Basin resulting from a combination of (i) higher sediment loads that may reduce storage volumes and thereby flood retention capacity, (ii) Glacial Lake Outburst Floods (GLOFs) that could result in very large floods and (iii) spillway designs for very different maximum flows in a cascade of dams on the main river. The latter means that a large flood passed safely by one reservoir may damage spillways downstream possibly leading to a failure of the dam.

More rapid melting of ice increases the flood risks associated with Glacial Lake Outburst Floods (GLOFS). There have been catastrophic GLOF floods in Himachal Pradesh in the last few decades and there are reported to be 156 GLOFs in the basin of which 16 were classified as potentially dangerous (ADB, 2010). The ADB have promoted mechanisms to reduce the risks of GLOFs by draining them and installing spillways.

Any increase in extreme monsoon rainfall is likely to increase the flood risk, landslide risks and much higher sediment loads that will impact on hydropower schemes. Heavy rainfall is the most frequent trigger of high-discharge events with peaks in suspended sediment concentrations (SSC) that account for the bulk of the suspended sediment flux (Wulf, 2011).

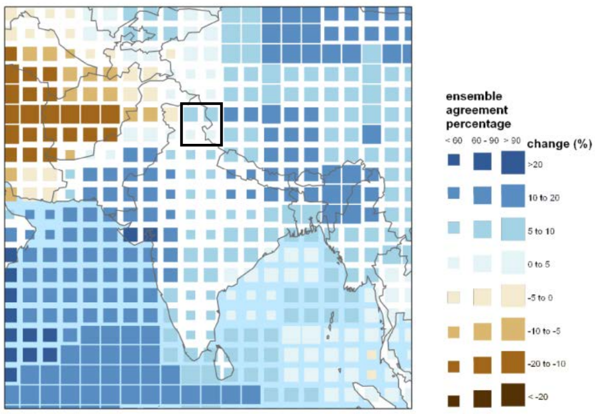
**Figure 4 Climate change projections for India with HP shown in the north of the country**

**Temperature change $^{O}$C**




*Percentage change in average annual temperature by 2100 from 1960-1990 baseline climate, averaged over 21 CMIP3 models.*

**Precipitation change %**




*Percentage change in average annual precipitation by 2100 from 1960-1990 baseline climate, averaged over 21 CMIP3 models.*

*Note: The size of each pixel represents the level of agreement between models on the magnitude of the change.*
*(Source: Met Office, 2011)*

## Opportunities afforded by increased flows

The increased melt-waters are also regarded as an opportunity for harnessing flows in hydropower schemes and for providing irrigation (Sharma and de Condappi, 2013). In the context of this study, increased glacial melt may present a short term opportunity but it is also clear that snow-melt and rainfall are the main components of the water balance and it is changes in these components that are the most important for current and future hydropower development.

Earlier studies on the Indus (e.g. Miller et al., 2012) estimated an initial increase in river runoff owing to increased glacier melt, followed by a decline in flows as glacier contributions cannot be sustained. The latest modelling based on more detailed modelling of the Baltoro catchment of the Indus (Immerzeel et al., 2013), suggests there is unlikely to be a decrease in water availability until after 2100. This results from increases in precipitation along with temperature and more sustained glacier melt contribution. It should be noted that there is considerable uncertainty around climate change impacts on precipitation in the region and that as glacier melt becomes less significant, precipitation changes will more directly affect water availability.

### 2.6.2 Impacts on hydropower schemes

Future hydropower performance is likely to be affected by both climate change and socio-economic change. For example, potential challenges include:

- Changing quantities and spatial/temporal patterns of rainfall and river flows may increase or decrease the period when turbines can operate at full capacity
- Changing evaporation rates, particularly from reservoir surfaces, may reduce the water available for generation
- Changes in sediment loads in rivers due to more intense rainfall and land use change in basin headwaters may lead to greater silt loads and rates of sedimentation in reservoirs
- Risks to infrastructure and people from increased flood magnitudes and potential failure of dams
- Population growth increasing demands across the water, energy and food sectors so that energy demand out-strips supply and greater competition for water reduces the water available for hydropower
- Further development of emerging economies and associated increased demands that affect the imports/exports of energy and may present significant risks (or opportunities) for energy providers
- The ability to maintain and rehabilitate older hydropower schemes that may require high operational expenditure (opex) to control sedimentation, manage upstream abstraction and replace components.

*(MWH,2009)*

## 2.7 Selected case study basin: the Sutlej Basin

The Sutlej**Error! Bookmark not defined.** River basin was selected for hydropower performance analysis as it is presently HP's major hydropower resource. It is the eastern most tributary of the River Indus with headwaters in Western Tibet (near Mount Kailash). It enters India through the Shipki La pass and flows west and south west through the Indian state of Himachal Pradesh. The catchment area within India is approximately 23,000 $km^2$ upstream of the Bhakra Dam (Deshpande et al., 2008). It passes through Kinnaur, Shimla, Mandi, Bilaspur, Solan and Kullu districts of HP before reaching Bhakra Dam near HP's border with Punjab. The basin drains the Western Himalayas and is therefore characterised by steep relief with elevations ranging from around 200 m above sea level (asl) to 8,000 m asl (Figure 5), a pronounced seasonality in precipitation and large variability in river discharge and sediment loads. The basin includes 945 glaciers covering an area of approximately 1217 $km^2$ and has an estimated 94 $km^3$ of glacial 'ice reserves'[5].

[5] As an indication of the freshwater resources in the basin's glaciers, these would provide London's water supply for around 120 years.

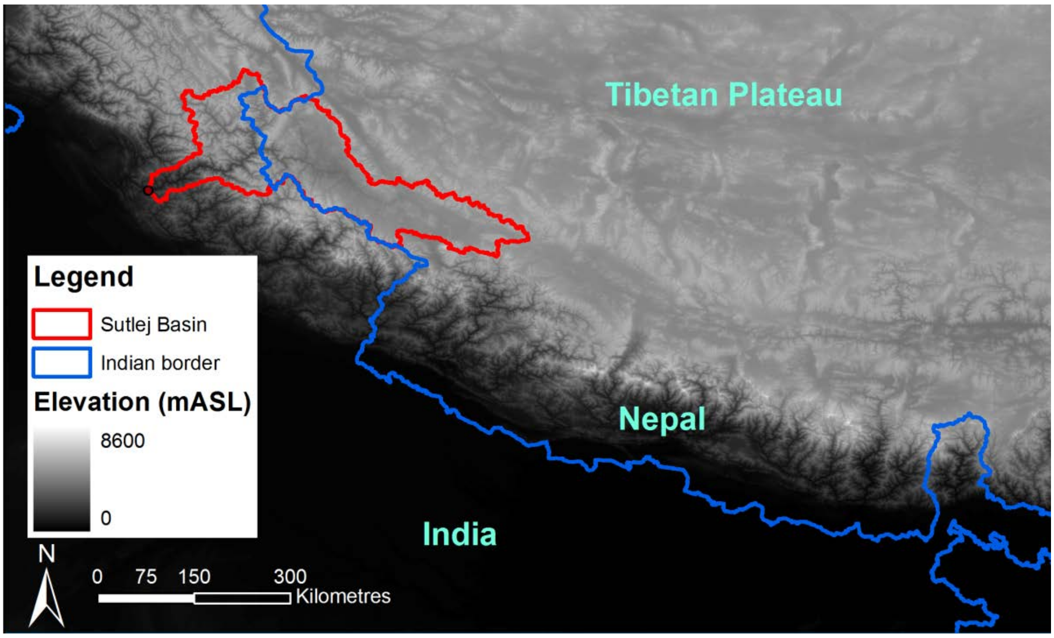
## 2.7.1 The water balance

Sutlej river flows are derived from rainfall, snow melt and glacier melt with strong seasonal variations between winter (December to March), pre-monsoon (April to June), monsoon (July to September) and post-monsoon (October to November) periods. Over 50% of rainfall falls during the monsoon and is an important component of the water balance, particularly in the lower basin. The basin water balance is summarised in Figure 9 based on sources of information in the peer reviewed literature[6].

The Gobind Sagar Reservoir behind Bhakra Dam (Figure 3) on the Sutlej River has 6,900 million $m^3$ 'live' storage and was completed in 1963. The project, located on the border with Punjab, is a major source of hydropower and irrigation. There are some groundwater reserves both in alluvial gravels and confined and unconfined aquifers and groundwater development is well below its potential (ADB, 2010).

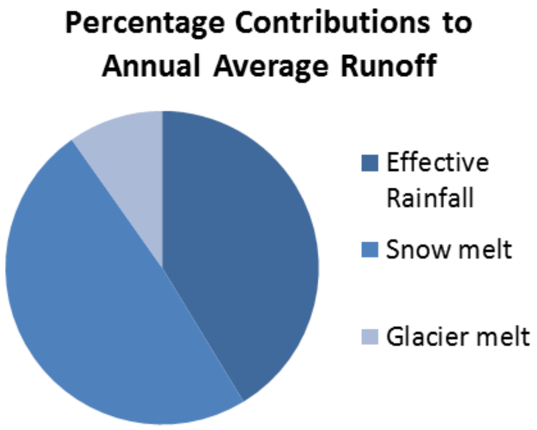
Water availability varies considerably across the basin with elevation and the steep rainfall gradient, which mean annual monsoon rains of approximately 3,000 mm on the Western Himalayan front are reduced ten-fold to 300 mm in the north east. Due to the rainfall gradient and low temperatures runoff at very high elevations on the Himalayan Plateau is much lower than the average figures presented in Figure 6.

**Figure 5 Topographic overview of the Himalayan mountains, showing the location of the Sutlej Basin straddling the Indian border.**



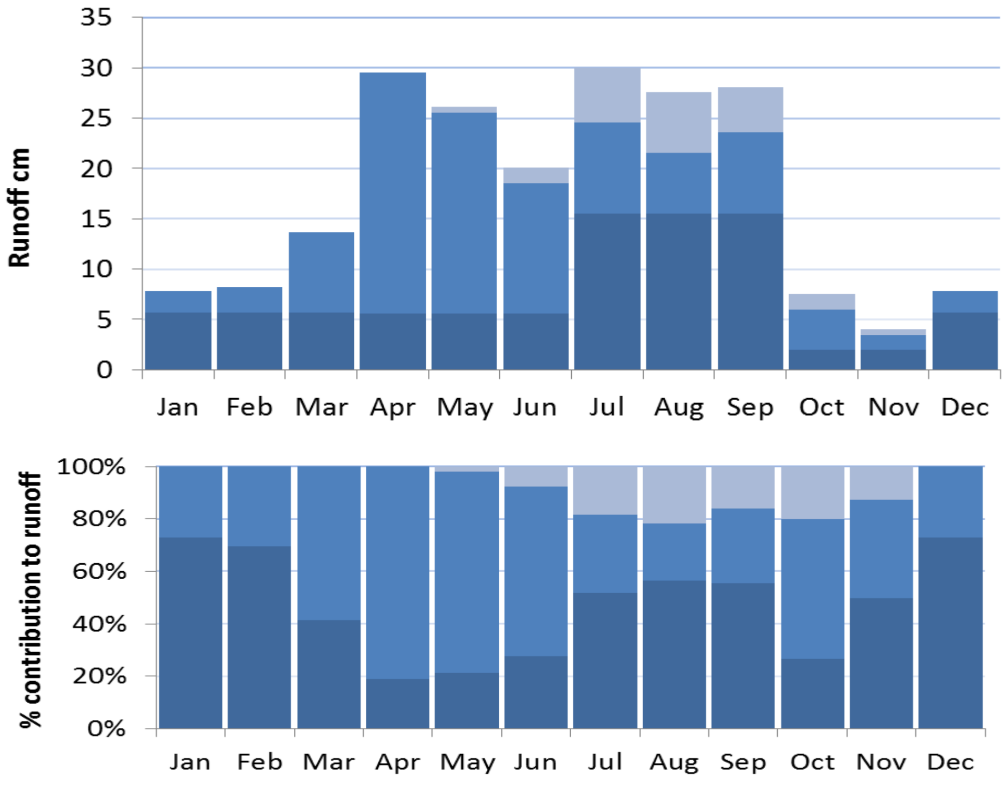

6 It was not possible to get access to HP state river flow records to estimate the frequency of flows (floods/droughts); data access and sharing of river flow information is an important issue that is considered in Section 5.

**Figure 6  Estimated long term water balance of the Sutlej basin to Bhakra Dam (assuming no change in storage)**




Notes: 1)These estimates are based on long term observations and modelling of river flows at Bhakra using data from Deshpande et al, 2008 and Wulf, 2011.

2) Year to year variability is high and the balance between rainfall, snow and glacier melt will vary considerably at higher elevations, with snowmelt dominating above Karcham Wangtu Dam (Table 4, Figure 7). Runoff is substantially reduced on the Himalayan plateau.



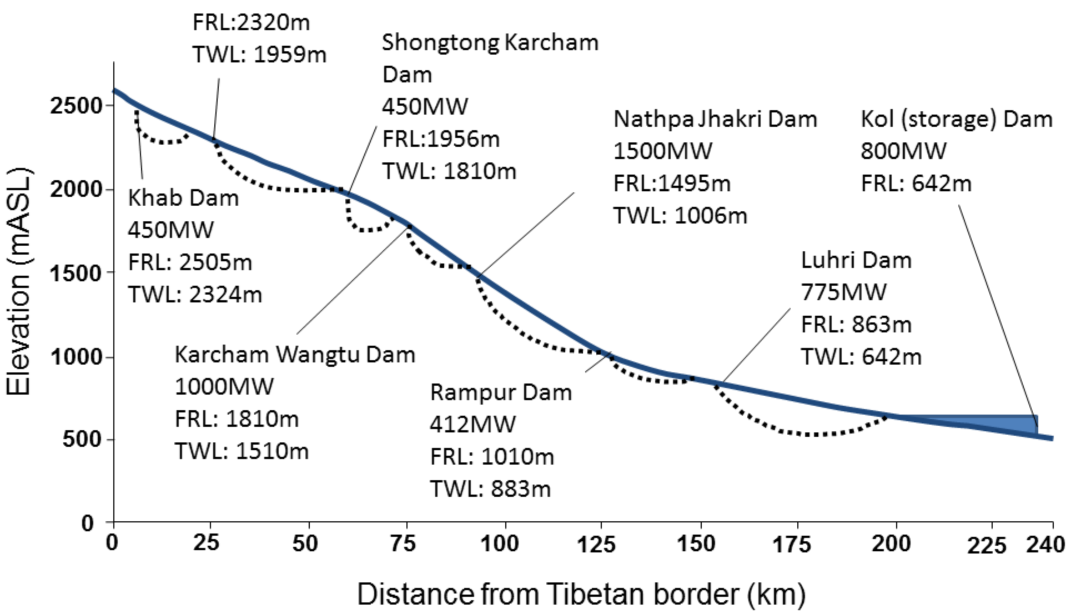

## 2.7.2 Installed hydropower capacity

Table 4 shows the status of the large dams which are proposed, approved or operational on the Sutlej River's main channel. Figure 7 shows how they are arranged along the channel and indicates that the river's length and elevation change will be fully exploited for hydropower production. The tail water level (TWL) is the elevation at which water is discharged from the hydropower plant's tail race tunnel. The full reservoir level (FRL) is the elevation of the reservoir's water surface when full. Many tail water levels are only a short distance upstream of the next scheme's full storage level, meaning the water is transferred almost directly from one to the next. Without properly regulated environmental releases from dams large reaches of rivers could be left with little flow.

| Site | Turbine Capacity (MW) | Cumulative capacity (MW) | Cumulative theoretical output GWh/day | Status |
|---|---|---|---|---|
| **Khab** | 450 | 450 | 11 | Proposed |
| **Jangi Thopan Powari** | 960 | 1,410 | 34 | Proposed |
| **Shongtong Karcham** | 450 | 1,860 | 45 | Recommended for approval by Environment and Forestry Department |
| **Karcham Wangtu** | 1000 | 2,860 | 69 | Operational |
| **Nathpa Jhakri** | 1500 | 4,360 | 105 | Operational |
| **Rampur** | 412 | 4,772 | 115 | Under Construction |
| **Luhri** | 775 | 5,547 | 133 | Recommended for approval by Environment and Forestry Departmentr |
| **Kol Dam** | 800 | 6,347 | 152 | Under Construction |

**Table 4 Hydropower turbine capacities on the Sutlej main channel**

**Figure 7 Cross section of the Sutlej main river channel and the proposed, approved and operational dams showing how the river length and elevation will be fully exploited**




*Note: FRL is Full Reservoir Level, TWL is Tail Water Level, broken lines indicate the combined length of tunnels feeding and discharging from the powerhouse*
*(Source: ICFRE, 2014)*

## 2.8 Section summary

This section has shown the following main points:

- Himachal Pradesh has around 25% of India's economically feasible hydropower potential of 84,000MW (Himachal Pradesh State Electricity Board (HPSEB), 2014; National Institute of Hydrology, 2014) and strong governance to promote its development, but significant remaining development needs with a 90% rural population reliant on agriculture and vulnerable to climate variability/change.
- Water security is high in terms of resource availability, but lower in terms of flood risk. The former is expected to be maintained in Himachal Pradesh while the latter may be exacerbated by Glacial Lake Outburst Floods (GLOFs) as glaciers melt or if rainfall intensities increase.
- The flow in the Sutlej River (a tributary of the Indus) is assigned to India by the Indus Waters Treaty and is highly utilised in HP for hydropower and irrigation and the Punjab for irrigation. Over half of the flow originates from snow and glacier melt. This is because of the timing of precipitation which leads to greater snowfall in winter than in eastern/central Himalayan basins where precipitation coincides with the snow melt season.
- Energy security is high in terms of generation capacity and access to electricity, but affordability remains an issue for a large proportion of the population who are unable to use it for heating or cooking. This maintains degradation of alternative forest resources.
- Food security is vulnerable to climate variability in rural areas and yields are reducing partly through fragmentation of farmlands through inheritance and loss of labour due to diversification of employment and migration.
- HP's hydropower potential has a vital role to play in India's energy sector and the State's own development, but further care must be taken to safeguard the environment if this development is to be sustainable.
- India's development plans promote hydropower partly to address huge shortfalls in peak demand electricity but the structure of the power sector hinders this development.
- The geology of the Himalaya contributes uncertainty to planning and financing of hydropower developments and contributes high sediment loads in the rivers, especially during floods.
- Climate change will lead to increasing temperatures but uncertain changes in precipitation in HP. Recent research suggests water availability will not be reduced until after 2100, despite increased glacier melt and changing precipitation. This suggests an opportunity to use hydropower to benefit from increased flows.

# SECTION 3

# Systematic mapping

This section takes a look at where hydropower sits within the system of interactions between water, energy and food security in Himachal Pradesh. It begins by providing a schematic map of current interactions, before considering how climate change and socio-economic change might perturb the system.

## 3.1 Systemic interactions between water, energy and food security

The Government of HP accords hydropower fourth ranking in its (draft) priorities for the allocation of water, after drinking water and sanitation, irrigation, and ecology/ afforestation/ biodiversity and tourism (Himachal Pradesh Irrigation and Public Health Department, 2013). . In practice, this is unlikely to be detrimental to hydropower production since it is invariably an upstream riparian user, it is a non-consumptive water user, most projects are of the run-of-river type with relatively minor environmental and social impacts, the state is not currently water-stressed, and there is low irrigation demand relative to the river flows. Any impact of hydropower on local agriculture and food production in HP would be dwarfed by its potential to impact downstream water users on the North Indian plain, home to 200 million people and vital to India's food needs.

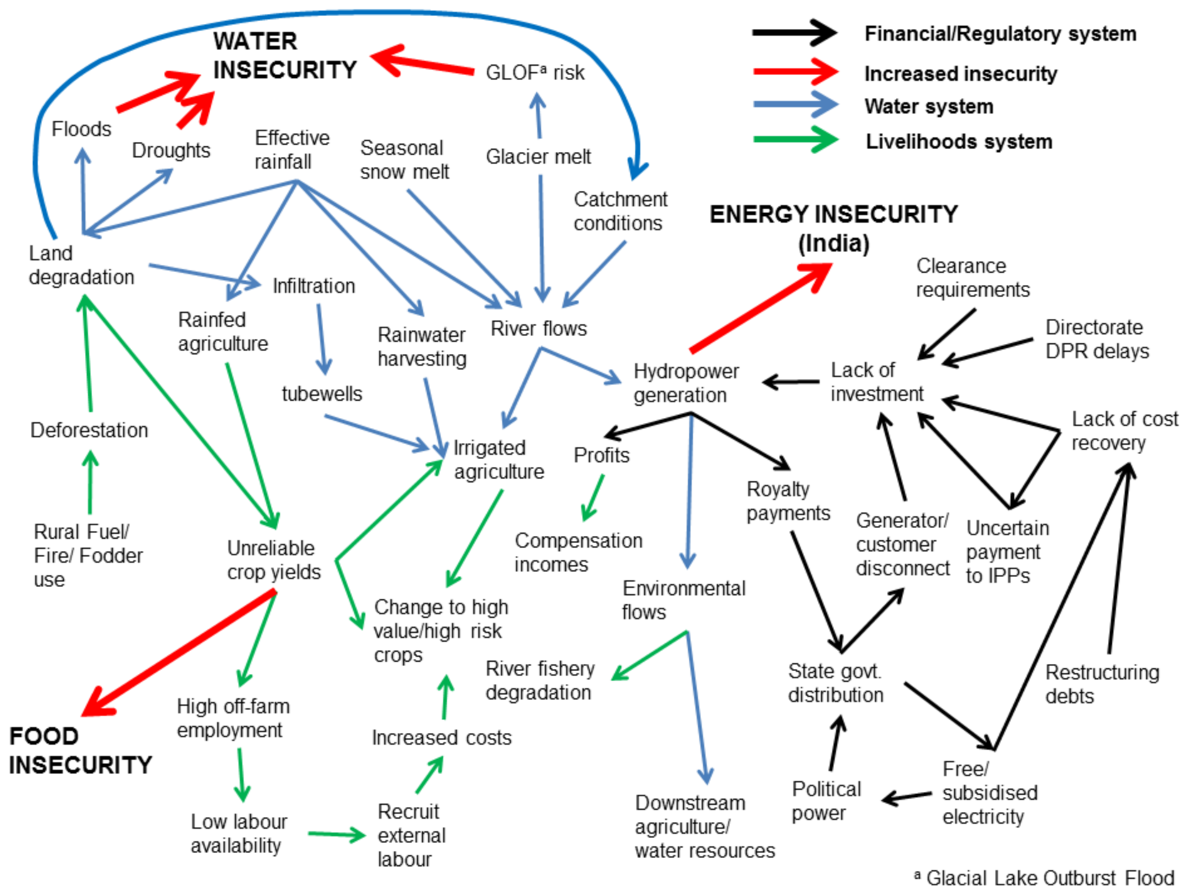
There are a number of interactions between water, energy and food sectors in the Sutlej Basin and these extend beyond the state boundary. Figure 8 outlines some of the current system interactions which impact on water, energy and food security. This is necessarily simplified but is intended to capture the main features of the system. Key issues are described in more detail in subsequent subsections.

### 3.1.1 Water system

#### High mountain hydrology

The water system in Himachal Pradesh as in other northern Indian states depends on complex mountain hydrological processes. Precipitation occurs as rain or snow, depending mostly on air temperature, and the runoff generation process which follows depends on a large number of factors including existing snow cover, local topography, slope, aspect and elevation. Rain falling on snow covered, bare or forested land will undergo very different processes before becoming runoff. Snow may become part of seasonal snow cover, undergoing melt to form runoff during the melt season. Alternatively it may become part of a glacier and not convert to runoff for tens or hundreds of years. It is difficult to overstate the complexity of the environment in terms of runoff generation.

**Figure 8  Hydropower system interactions in Himachal Pradesh impacting on water, energy and food security both within the state and downstream.**




## Catchment conditions

Because the Himalayan mountains are geologically young, they are extremely prone to erosion. This means that runoff from the surface picks up large amounts of silt and carries it to the rivers downstream. During flood events the rivers experience extremely heavy silt loads meaning hydropower turbines need to be shut down to protect them from damage. Settling tanks are being designed into new major dams to limit the time for which turbines must be out of use by removing sediments before they reach turbines. Silt loads can reach 100,000 parts per million (ppm) in the Sutlej during floods. The Nathpa Jhakri hydropower plant has to shut down above 4,000 ppm (ADB, 2010).

Erosion of the land leads to degradation, which further influences hydrological processes. Degraded land tends to allow less water to infiltrate, leading to less regulation of runoff. This usually increases flood peaks and because less water is stored in the soil, increases the likelihood of droughts. Where erosion of farmed land occurs, it leads to loss of nutrients and soil structure, which in turn reduces crop yields. Erosion is difficult to control over such a large area in a geologically unstable environment such as the Himalaya which is largely remote, inaccessible and un-forested.

Forest and vegetation cover are recognised as providing protection against erosion. The continuing demand of the rural population for fuel- and fire-wood and livestock fodder has led to deforestation in the past, and associated land degradation. A state law against felling of trees has been passed in an attempt to reverse this trend. Forest cover was increased from 21% in 1991 to 26% in 2003 as a result. This is believed to have precipitated an energy crisis among the rural poor however (ADB, 2010).

## Environmental flows

Hydropower is not well regulated at present and there is evidence that environmental flow standards downstream of dams are not being adhered to or monitored for compliance (Consultees, 2013). This is leading to the drying out of rivers, potentially devastating local ecology. Hydropower schemes have also stopped migration of fish along the rivers, so removing a source of livelihood and sustenance for local people. Environmental flow levels are currently set at 15% of minimum flow observed in the dry season, but this is not based on scientific evidence that it can support the local ecology. There is therefore potential to reduce the negative impacts of hydropower schemes on the aquatic environment, even if this requires trade-offs with profits from hydropower (Consultees, 2013). The State Hydropower Policy was updated in 2009 to require all existing and upcoming hydropower projects to install real-time online continuous flow measurement and data logging devices by the end of that year, with a view to monitoring environmental releases. Flow monitoring for some dams is now available online but it is unclear how successful this is in ensuring compliance.

HP is facing major dilemmas in balancing hydropower development with environmental sustainability. Development needs to be more integrated including possible multipurpose use of dams rather than purely hydropower use. Government of India policy is currently focussed on run-of-river schemes as they have much lower environmental and social impacts, but this may have to change if large amounts of storage are deemed necessary. Additionally, catchment management may be able to provide a certain amount of regulation through storage in soils.

## Water sources

River water is utilised for both hydropower generation and irrigation within the state and irrigation and water supply downstream. Various levels of the river network support a range of sizes of hydropower schemes, but water supplies (usually for irrigation) on higher ground must be lifted by pumps from rivers or collected locally from streams and tube wells or rainwater harvesting. Lifting with pumps either from rivers or tube wells requires energy, and the greater the lift required, the more energy is needed. This increases costs and decreases sustainability and security of water for food.

Climate variability currently presents a large source of insecurity in terms of agriculture and food. In the short term, increased glacier melt appears to be leading to increased higher than expected flows and associated benefits for hydropower production. This is not sustainable in the long term however, and as glacierised extent decreases further then reliability of water resources is likely to decline. This could be exacerbated by increased variability of rainfall due to climate change. This will affect hydropower generation in the basin and water resources availability on the downstream plains, with significant impacts for water, energy and food security. Glacial lakes may increase in number as glaciers retreat, potentially leading to an increased threat of Glacial Lake Outburst Flood (GLOF). This can be considered a risk to water security in terms of flooding.

## Downstream impacts

It is widely recognised that the ecological condition of the basin must be maintained or improved to ensure that water resources benefits are maximised for the long-term, both within and downstream of the basin. As glaciers melt, it will be necessary to maintain or increase the amount of water which is stored in the basin, to compensate to some extent for the lack of regulating capacity of the glaciers.

### 3.1.2 Rural livelihoods system

#### Agriculture

Around 760,000 ha of land is cultivated in Himachal Pradesh and of this only around 100,000 ha are currently irrigated. Members of many families have been forced to find off-farm employment in response to the declining profitability of small plots of land – most families own plots less than 1 ha. This is caused in part by unreliability of subsistence crop yields resulting from climate variability in largely rainfed systems and land degradation (ADB, 2010).

Off-farm employment and migration to towns/cities reduces the amount of free labour available for working the land. Recruiting outside workers can prove costly and reduce the financial viability of growing certain crops. Higher value crops can justify investment in irrigation, which can also help avoid unreliable yields related to the increasingly erratic climate. The winter growing season which is often vulnerable to climatic variability can be stabilised through the use of irrigation.

#### Irrigation

Although water is not in short supply in rivers, communities live and farm in areas commonly 100m to 150m above river level and sometimes as high as 300m above the nearest irrigation water source. Lift irrigation is technically possible in these areas, but economic viability and sustainability is questionable. Lift irrigation also has a very poor track record in terms of performance, which is important if investments are to be made. As such, the state prioritises gravity irrigation wherever possible, and only 16% of existing projects are served by lift irrigation schemes and 3% of projects served by tube wells (ADB, 2010).

Other sources of irrigation water, combined with efficient application methods such as sprinklers and drip irrigation are therefore preferable. There is a strong emphasis on water conservation in HP, so technologies such as rain water harvesting and check dams are being used and research is being carried out into cost effective methods of storing water for irrigation use.

Around 228,000 ha of land are currently served by constructed irrigation schemes, but this area is under-utilised. The overall potential irrigated area is estimated at 335,000 ha but it is unclear how much of this is included in the 760,000 ha currently cultivated (ADB, 2010).

#### Forestry

Forested land constitutes around 26% of Himachal Pradesh and this and other natural ecosystems are vital for its environment and water resources. The Forest Policy of 1988 states that 66% of geographic area is 'forest land' but this is considered unfeasible as 20% of this land is inaccessible. Watershed modelling shows that forests play a crucial role in sustaining river baseflows, and the Forestry Department aims to increase forest cover to 35% of geographic area including 5% under horticulture or farm forestry.

Hydropower projects in HP are required to pay not less than 2.5% of investment costs towards Catchment Area Treatment (CAT) plans. This money is to be used for afforestation, fuel, fodder, plantation, soil and water conservation, erosion control and awareness. The CAT plan should cover at least 15% of the catchment with 1% earmarked for eco-tourism and wildlife protection. Infrastructure is covered by separate Local Area Development Funds (LADF), funded by different payments from project developers (Consultees, 2013). ADB (2010) report a shift toward a more holistic approach conducive to livelihood support and participative community action, called "river basin works".

### Fisheries

Hydropower schemes have blocked migratory routes for fish and the low environmental flow releases from dams are insufficient to support healthy fish populations. A stable commercial fishery has been established around the Bhakra and Pong dams which are able to maintain populations of coldwater fish due to their receiving water directly from the mountains. Catch from Bhakra dam accounts for up to 60% of all fish production in the state. This fishery employs over 4000 fishermen, traders, retailers and other professions (ADB, 2010). Climate change is unlikely to affect these as air temperature increases will not dramatically affect water temperatures. Glacial lakes could be stocked and used for sport fishing which is becoming more popular in the higher elevation rivers.

### 3.1.3 Regulatory/political system

State governments are in positions of political power and keen to maintain this. The electricity distribution networks are also run by the state governments. For a long time these state-run distribution utilities have had a policy of providing free and subsidised electricity, essentially as a form of patronage, particularly to farmers for their irrigation systems. This patronage is further facilitated by the royalty payments from commissioned hydropower projects, starting with 12% of production and increasing to 30% of production after 30 years. This patronage helps to maintain political influence but means that distribution utilities are unable to recover their costs.

Lack of cost recovery means state distribution utilities are keen to hold onto paying customers (who could be served by private companies) to prevent themselves falling further behind financially. It also means they cannot guarantee payments to independent power producers (IPPs) or invest in new distribution infrastructure themselves. Without guarantees of payment for power generated, private companies are unable to make investments in new infrastructure because they cannot obtain sufficient loans without such a guarantee.

The way the distribution network is organised in India also makes it very difficult for a private power producer to sell power generated to a customer in another state particularly if that state is far away. While there is a huge demand for more power in India, the system is not setup to incentivise investment. If a company holding an allotment (concession) for a hydropower scheme in HP were able to obtain a power purchase agreement (PPA) from a customer in another state and transmission costs were not too high to make it unviable, then they could obtain a loan to develop that concession.

To compound the problems of lack of cost recovery, the Indian central government is assisting with restructuring of debts for the worst performing utility companies. This can be considered as incentivising the lack of cost recovery.

Other forms of disincentive for developing allotted concessions for hydropower schemes are the plethora of clearances need from government departments during the detailed project report (DPR) stage of development and delays in approval by the Directorate of Energy. While DPRs should be assessed within two years, this can take more than two years, during which costs are increasing but no benefits are accruing (Consultee, 2013).

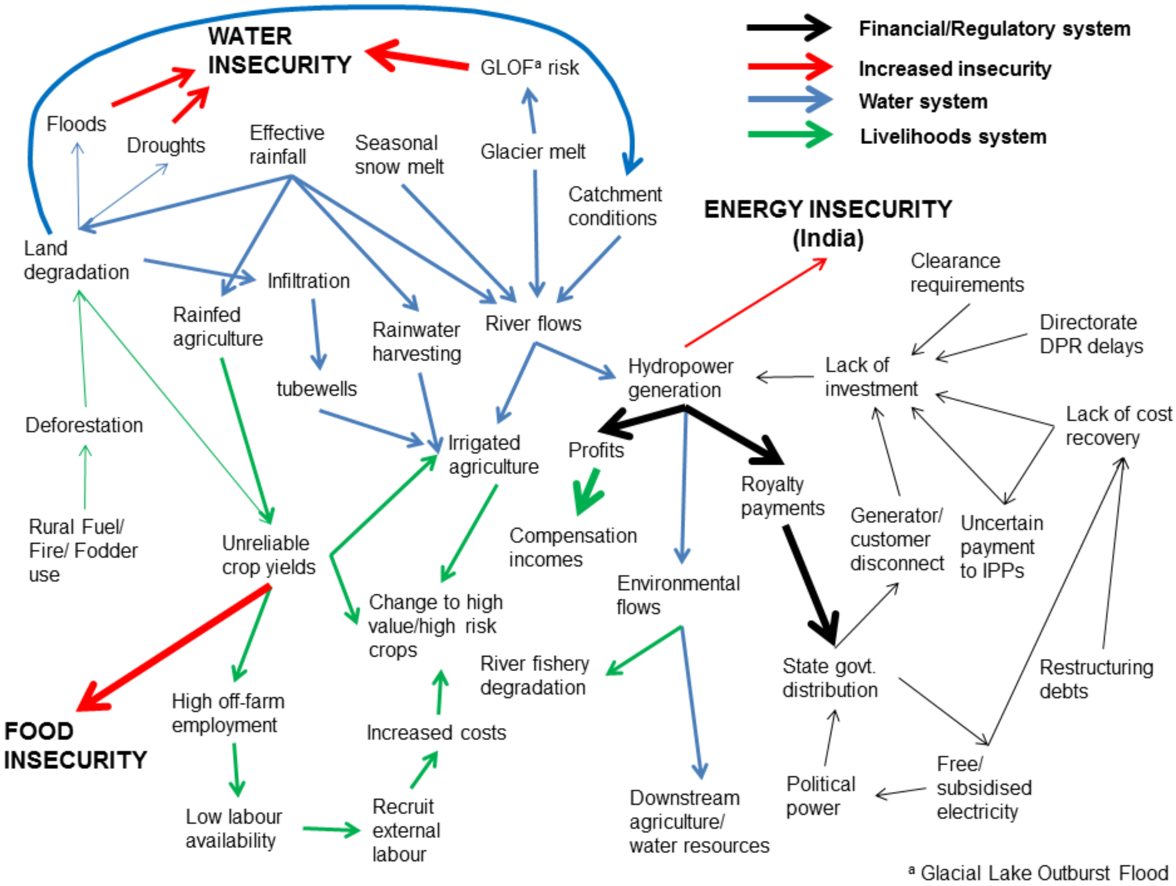
## 3.2 Future forcing of the system

The system described above is dynamic and subject to many influences both inside Himachal Pradesh and beyond its borders. Below we describe how socio-economic changes and climatic changes might impacts on the system. A direct visual comparison of the three schematics relating to current and changed interactions can be found in Appendix C.

### 3.2.1 Socio-economic change

According to development plans for Himachal Pradesh socio-economic change in the basin is likely to be achieved for the rural population by growing higher value crops and developing the state's plentiful hydropower resources. With increasing incomes from hydropower schemes to the areas affected and the state government purse, Himachal Pradesh is likely to build on its advanced stage of development. Some changes to regulatory systems are needed to promote this development of hydropower, but the capacity of the state to make such changes appears to be high. Changes needed at a central government level may be more difficult to achieve. Changes are vital to get the private sector more heavily involved in actually bringing the hydropower online however. These developments could increase food security through revenues from irrigated crops, rather than subsistence agriculture. The increased income could facilitate increased electrical demand and reduced reliance on fuel- and fire-wood. The state will be well-placed to cater for this with both its small and large hydropower resources exploited. Population is not expected to be a significant challenge with proportion of urban population expected to increase by less than 4% by 2026 (Government of India, 2014) . The thickness of arrows in Figure 9 is varied compared to the 'present case' in Figure 8 to indicate possible impacts of socio-economic changes on the system.

**Figure 9 Changes to the current system shown in Figure 8 resulting from socio-economic changes – arrow thickness increase/ decrease compared to Figure 8 indicates increased/ decreased influence**

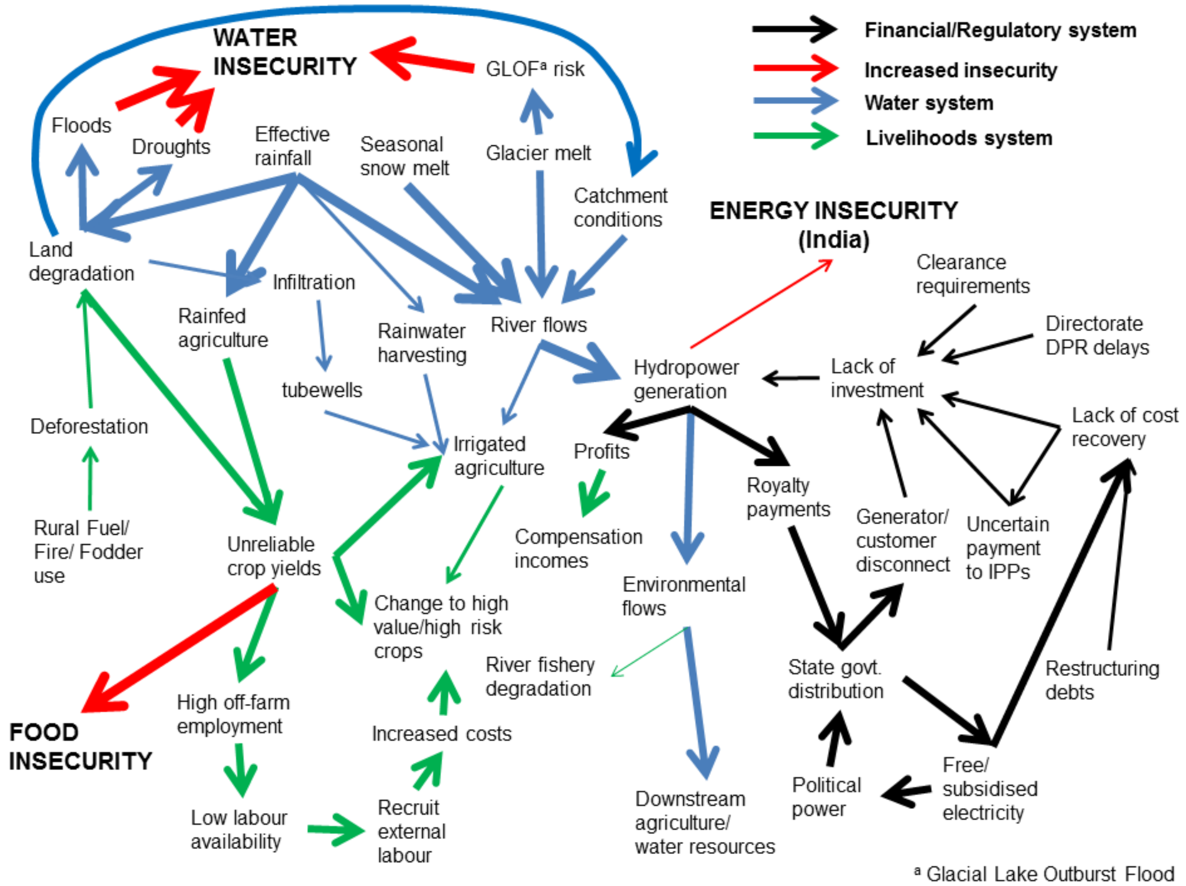



## 3.2.2 Climate change

Climate change is likely to exacerbate climate variability in the mountains, so further reducing the water and food security of rural populations and especially those on higher ground. Increased temperatures leading to earlier and faster snowmelt could leave some communities without the perennial water sources they have depended on historically.

Rainfall events are likely to increase in intensity and overall volume. Silt loads are likely to increase with rainfall intensity meaning that land degradation could accelerate on unprotected soils. Storage schemes may allow benefits to be gained from increasing and earlier melting of snow and higher rainfall volumes. Storage type schemes lead to greater environmental impacts both in the area of inundation and downstream, than their run-of-river equivalents. Difficult trade-offs will have to be assessed with regard to the balance between different uses of available water. The thickness of arrows in Figure 10 is varied compared to the 'present case' in Figure 8 to indicate possible impacts of socio-economic changes on the system.

**Figure 10 Changes to the current system shown in Figure 8 resulting from climate changes – arrow thickness increase/ decrease compared to Figure 8 indicates increased/ decreased influence**



# SECTION 4

## Hydropower performance and its influencing factors

This section looks at the performance of hydropower in HP in relation to the measures of performance identified in Section 2 of the Harnessing Hydropower Literature Review (Lumbroso et al., 2014)

### 4.1 Power generation

Detailed generation data for the operational hydropower stations on the Sutlej River were not forthcoming from the consultees in Himachal. Some data are publicly available for the Sutlej basin through the Central Electricity Authority (CEA) however, which provide some perspective on generation in the basin. There are also some data relating to the hydropower sector in India as a whole which are considered below.

A series of dams are either in operation or under construction on the Sutlej River (Table 4, Figure 7). The performance of those already in operation is captured in Figure 11. This shows a very slight trend for declining generation per MW installed over the last 27 years and considerable variation between years with a range of 3.5 to 6 GWh/MW. The duration of this record is not long enough to represent statistically significant trends, although it would be useful to try and understand what is causing variations. No reasons are given for this, although a number of factors could be responsible, including declining river flows and operation of the individual schemes independently, rather than as an integrated and optimised system. There may be advantages to be gained by allowing schemes with higher installed capacity greater priority over the water available, for example. Consultees (2013) reported that plant factors[7] can sometimes be over 100% owing to higher than expected flows in the river.

#### 4.1.1 Reliability of energy supply (energy duration curves)

Data were unavailable to allow us to assess this metric. The inter-annual reliability of the energy supplied by plants on the Sutlej River is indicated by the variability of the plot in Figure 11. Higher resolution would allow firm energy to be defined, although run-of-river plants on the Sutlej are used primarily to provide peak demand power.

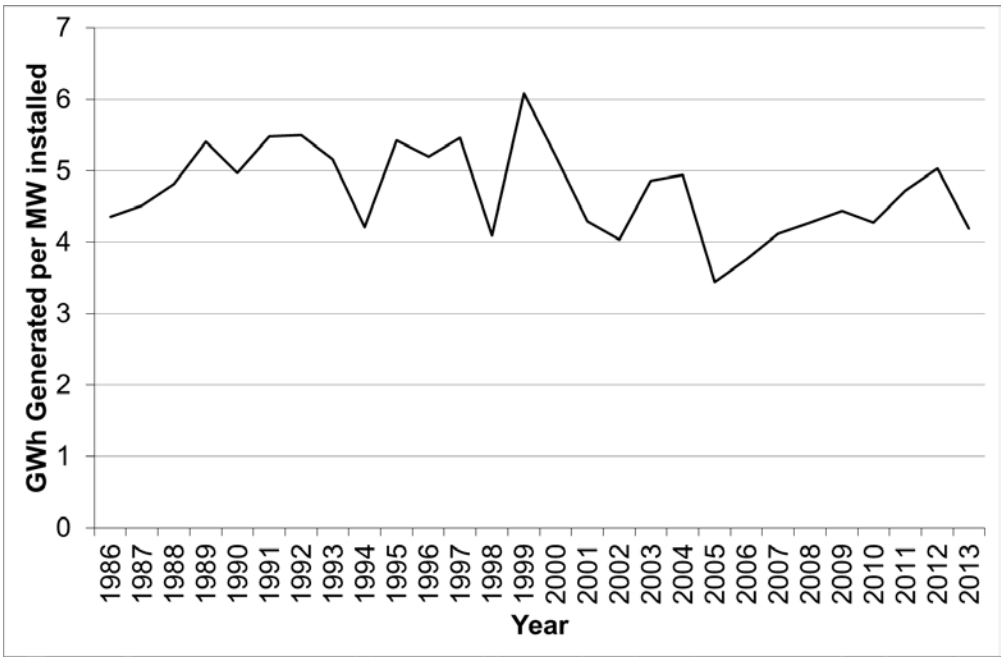
#### 4.1.2 Energy generated (% of target demand)

It is reported that the state is generating 12.5% more than its own demand but that the structure of the energy market and difficulties in finding buyers in states further away in India makes it hard to maximise profit from this excess generation. Two power trading exchanges are available but as stated above, there is a trend for buyers to prefer outages over purchasing of additional power (Hindustan Times, 2013). Consultation for this research suggested the problem was additionally challenging for small power producers unable to

[7] The proportion of time a plant is expected to operate, based on the expected water availability

supply the local market but facing prohibitive costs for long distance transmission (Consultee, 2013).

**Figure 11 Hydropower generation on the Sutlej River standardised by the installed capacity in MW between 1986-2013.**

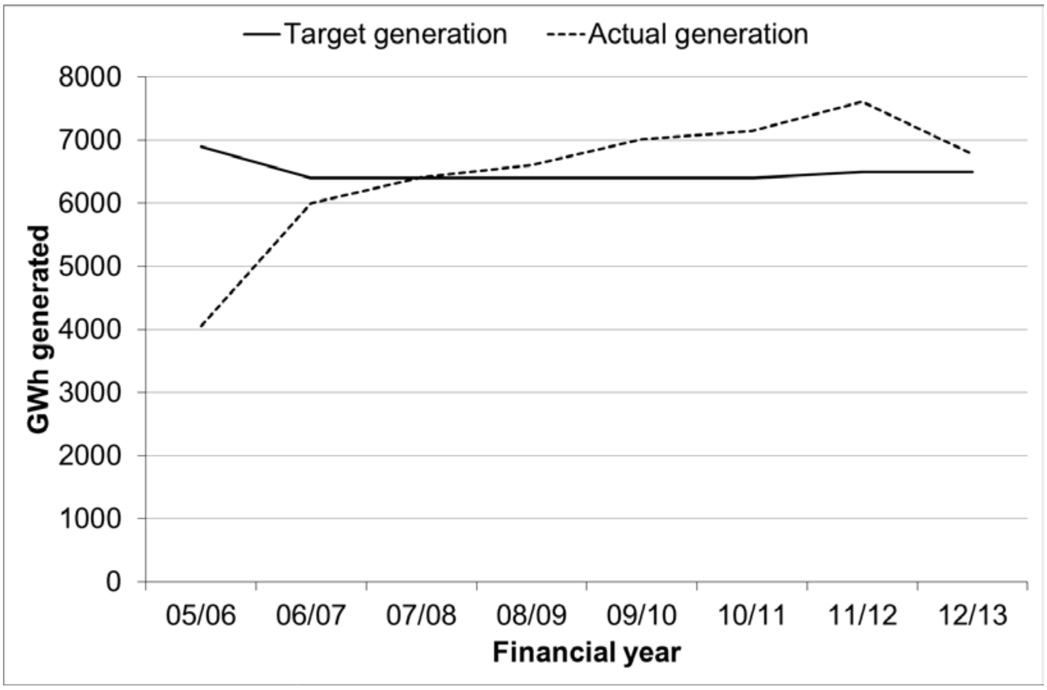



Data are available from CEA comparing actual with target generation and reported by utility or by sector nationally (central, state, private). Generation data for the utility which owns and operates the 1500MW Nathpa Jhakri hydropower project (SJVN Ltd), show that the plant was unable to meet its target in the early years of operation (the plant was fully commissioned in March 2004) (Figure 12). The Central Electricity Authority (CEA) reports that the 2006/07 generation was reduced due to high silt content in the Sutlej River flows during the monsoon (CEA, 2007). Since these early poor performances against targets, the plant has consistently exceeded targets. This is reported to be due to higher than expected flows on the river (Consultee, 2013). In its 2012-13 Annual Report however, SJVN, the company which operates the Nathpa Jhakri dam states that:

“The gross generation during the fiscal has decreased by 10.94% over previous year due to less discharge of water.”

This fall is relative to the previous year only and Figure 12 indicates this was an exceptional year. It was not possible to verify the relationship between generation variability and flow variability to assess whether other factors are also likely to be influencing generating performance.

**Figure 12 Actual generation compared to target generation for the Nathpa Jhakri hydropower plant – India's biggest, on the Sutlej River.**




A comparison of the target vs actual generation performance for different sectors at national level illustrates the relative scale of generation by each sector (Figure 13) and the relatively poor performance of central sector projects in FY 05/06 and 06/07 before coming more in line with the other sectors since then (Figure 14). It could be that central sector projects were not in areas with particularly high flows in FY 05/06 and 06/07 or there could have been other factors which prevented the sector achieving higher generation performance. Figure 14 shows that changes in performance relative to targets have been similar in all sectors since FY07/08 except for a decline for the private sector in FY10/11. This suggests exogenous factor(s) such as river flow variability may have affected all types of plants similarly, dominating any differences in performance owing to management. The decline for the private sector in FY10/11 could be a function of the relatively low overall generation of the sector, whereby poor performance at a small number of plants could impact the total more easily. Without detailed information it is difficult to draw conclusions.

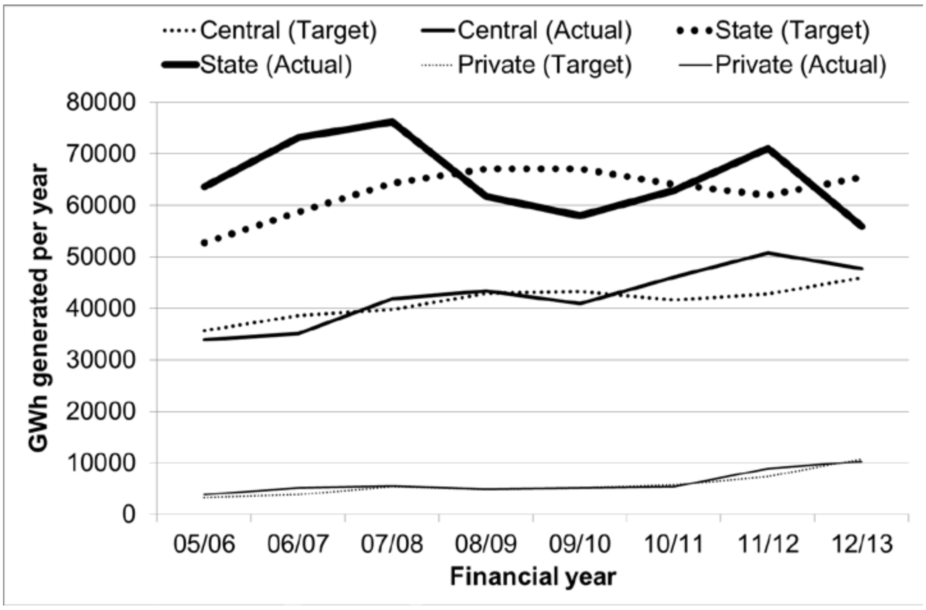
### 4.1.3 Days with unplanned outage (%)

Outage data are available from Central Electricity Authority (2014) for individual utility companies such as SJVN Ltd which owns and operates the Nathpa Jhakri hydropower project. Table 5 shows that over time the Nathpa Jhakri has suffered from fewer forced outages. This is likely to have contributed to achieving the above target generation illustrated in Figure 12.

| Financial year | Total forced outage (hours) |
|---|---|
| 05/06 | 13955 |
| 06/07 | 10941 |
| 07/08 | 1170 |
| 08/09 | No data |
| 09/10 | No data |
| 10/11 | No data |
| 11/12 | 960 |
| 12/13 | 96 |

**Table 5 Annual total forced outage (hours) of the Nathpa Jhakri hydropower station (source: Central Electricity Authority, 2014)**

**Figure 13 Comparison of actual central, state and private sector generation against targets for FY 2005/06 to 2012/13**




### 4.1.4 Days with flow below the volume required for hydropower production (%)

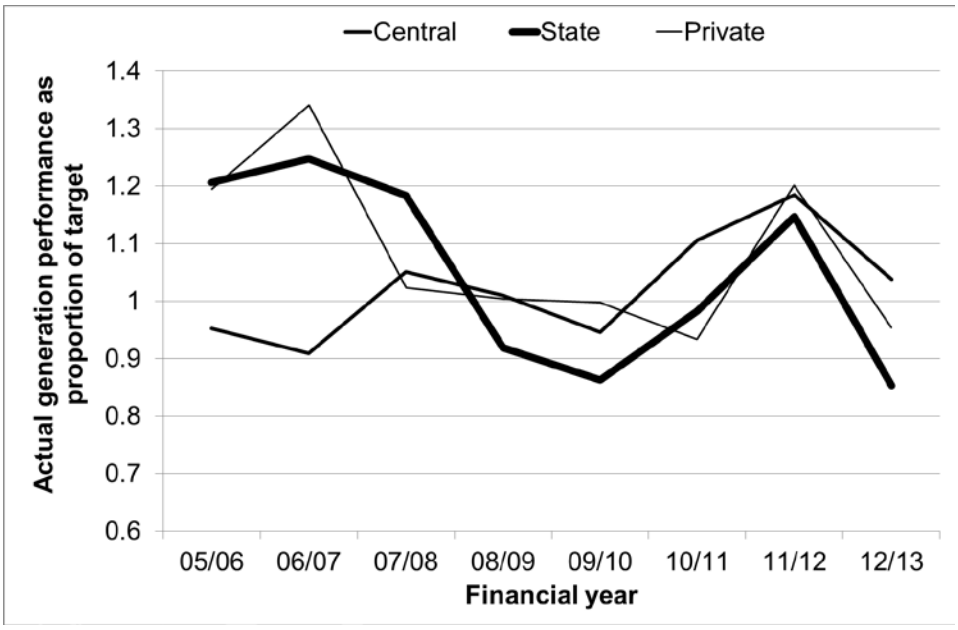
Data were unavailable to allow us to make either a quantitative or qualitative analysis of the periods during which flows are insufficient to drive hydropower turbines.

## 4.2 Economic impacts

The economic performance of the Nathpa Jhakri hydropower plant on the Sutlej River can be considered high on account of the generation performance being above target. The Annual Report of SJVN describes incentives for achieving Plant Availability Factor (PAF) higher than 82% and in 2012-2013 the PAF was 105% leading to a 2,220,000,000 Rs. (US$ 36.4 million) 'bonus' in addition to tariff payments for electricity generated. A similar incentive fee was also earned in the previous year and these are attributed by the company to high river flows (SJVN Ltd, 2013).

In terms of economic impacts on the country, the performance of the hydropower sector nationally and in HP could be said to be poor. The sector has not contributed as much energy as possible to the national deficit, thereby perpetuating a major constraint on the economy. The reasons for this are discussed below.

**Figure 14 Comparison of performance of central, state and private sector generation as a proportion of targets for FY2005/06 to 2012/13**




### 4.2.1 National capacity development constraints

In the last few national Five-Year Plans, the power sector has underperformed against its targets by a substantial margin (Table 5):

| Five Year Plan period | Target for power sector installed capacity | Outcome |
|---|---|---|
| Ninth Plan | 40,000 MW | 19,119 MW |
| Tenth Plan | 44,000 MW | 21,000 MW |
| Eleventh Plan | 78,700 MW | 54,964 MW |
| Twelfth Plan | 88,537MW | N/A |

**Table 6 Indian power sector Five Year Plan targets and outcomes**

#### Thermal - hydropower generation ratio

India's power generation capacity connected to the grid comprises 65% thermal, 22% hydropower and 13% other (World Bank, 2010). The share of hydropower in the generating capacity mix has been steadily declining in recent decades, from 44% in 1970 to the current level of 22% (Council on Energy, Environment and Water, 2013; Water Power and Dam Construction, 1999). The share of hydropower in actual energy generated is even lower, at 14% in 2011.

The national goal of the thermal-hydropower mix has been 60:40 but in practice the proportion of thermal has grown to be in excess of this. The current annual per capita consumption of electricity in India is approximately 600 units (kWh), well below the global average of 2800 (Sanan and Mitra, 2011). Around 40% of households remain to be electrified. Most parts of the country experience regular load shedding and poor quality of service (Sanan and Mitra, 2011). At the core of the explanation for this underperformance has been the failure of the power sector to raise resources from its activities, in short to recover sufficient tariff revenues, "..the finances of utilities have always been parlous and the situation has not changed despite various initiatives over the years" (Sanan and Mitra, 2011).

### Core problems unaddressed by promoting private sector

Liberalisation, the keynote of economic reforms in the 1990s, led to the encouragement of private sector entry into power, the "unbundling" of the different segments of the industry, and the creation of tariff regulatory bodies. None of these policies, nor the Accelerated Power Development Programme introduced in 2000/01, has succeeded in overcoming the basic core problems of "free power, unmetered supplies to agriculture and the basic mismatch between costs and tariffs" (Sanan and Mitra, 2011).

### Clearance requirements

One of the most serious constraints on new hydropower developments is the need to obtain clearance on environmental and forestry criteria. The following legislation has been enacted to protect forests and the environment: The Environmental (Protection) Act 1986, the Forest Conservation Act 1980, the Environmental Impact Assessment Notification Act 1994, the Panchayats (Extension to the Scheduled Areas) Act 1996, the National Green Tribunals Act 2010, and the Right to Fair Compensation and Transparency in Land Acquisition, Rehabilitation and Resettlement Act 2013 (Pandit, 2014).

The existence of this legislation, and the way it is interpreted in the courts, has impeded the implementation of major projects of all kinds, including hydropower schemes. In the words of one commentator:

"*Obtaining environmental clearance is itself very difficult. But the clearance is always accompanied by a set of terms and conditions that are difficult to comply with and even more difficult to demonstrate compliance with. This means that the clearance can be revoked at the slightest complaint of a violation of any of the terms and conditions of a clearance. Almost every project faces litigation for violating some law or other.....All this increases project costs, makes infrastructure projects vulnerable to manipulation by activists, and generally creates a climate hostile to infrastructure building.*" (Pandit, 2014)

Others echo this view: "Environmental concerns have emerged as a major constraint to capacity addition in the case of both thermal and hydropower projects......on the hydropower side, the delays consequential to a new concept of basin wide environmental studies, is likely to prove detrimental to speedy development" (Sanan and Mitra, 2011). Actually, 19 hydropower projects in several states including HP are held up pending environmental and forestry clearances.

### Resettlement and rehabilitation

Another factor blamed for project delays is the need to manage resettlement and rehabilitation (R&R) of Project Affected Persons and Families (PAPs and PAFs). This typically occurs on an *ad hoc* basis, and a national framework for R&R is lacking. Attempts to "compensate" PAPs and PAFs by compelling their employment on the projects is backfiring, since project sponsors are unwilling to take onto their payrolls large numbers of relatively unskilled workers (Sanan and Mitra, 2011).

### Sustainability of development

To put the above points into perspective, it should be stressed that the HP catchments represent a vital buffer for the river systems of North India on which 200 million people depend. These ecosystems are fragile. The World Bank is supporting the Indian Government in developing integrated basin and catchment approaches to planning, project implementation and management, the absence of which weakened previous hydropower initiatives in this state (Haney and Plummer, 2008). Moreover, the majority of hydropower projects in HP are run-of-the-river schemes that do not entail extensive resettlement nor environmental or forestry losses, and many schemes are small. HP, to name but one state, is seeking to defuse potential local opposition with a number of measures to compensate local communities and share the benefits of development (see below).

## 4.2.2 HP's institutional/regulatory performance issues

The hydropower sector in HP has under-performed in terms of developing capacity, and is experiencing a number of problems:

- Fragmentation and overlapping responsibilities of the many institutions responsible for planning, approving and implementing power projects, and lack of a central framework for key issues such as Resettlement and Rehabilitation

- The delays inherent in hydropower projects (geological, environmental, political, social) appear to have been aggravated by a vexatious application of environmental and forestry legislation, with excessive challenges by interested parties and civil society groups.

- The aim of attracting serious private developers has not been totally successful, a number of the earlier entrants were "new to the sector, and their ability to manage the hydrological, geological, construction and commercial risks of the sector is still untested" (Haney and Plummer, 2008). There have been a large number of small projects, some of which may well be sub-economic.

- There is widespread dissatisfaction over loss of homes, agricultural land, avocations and social infrastructure. Affected people are ever more aware of the huge revenue earning potential of hydropower schemes and demanding a fairer distribution of the proceeds. Both government enterprises and private producers are experiencing problems with getting communities to endorse projects because they feel unable to satisfy demands whether expressed directly or through environmental and forestry concerns.

- The incentive packages offered to private sponsors have had to be modified several times in the light of the response. Some of the features intended to soften local opposition and spread the benefits of development (e.g. size of "free" power given to power authority, preference to local sponsors, obligation to take on local workers) could have raised costs and discouraged entrants.

- One of the weaknesses of the Indian power sector, the chronic financial weakness of distributors, has fed back to HP in a disappointing uptake of its surplus hydropower from other states.

### World Bank assessment

The World Bank recently carried out a study specific to HP which identified the following major issues with the current planning and development of hydropower schemes:

- Current focus on individual developments and lack of coordination means benefits are not maximised.
- Substantial hydrological and geological risks are associated with hydropower developments. Lack of data and sharing of information is largely responsible.
- Design flood methodologies are not consistent and could lead to incorrect spillway sizing in cascades. No provision is made for failure of an upstream dam.
- More effective measures for managing silt are required to ensure the viability of hydropower investments.
- Simple modelling showed optimisation of cascade of hydropower projects as a system can provide greater energy output with less physical footprint than individual design and operation.
- Upstream storage would bring benefits to existing and planned projects via regulation of flows, flood control and sediment trapping. Khab storage dam studies show good economic returns and reduce sediment loads.
- A diversity of developers has created confusion and lack of coordination in relation to regulations. Many are new to hydropower and lack appreciation of issues such as environmental flows.
- Other infrastructure such as roads are stressed by hydropower development, impacting on fragile Himalayan ecology
- Success is variable in social, environmental and CAT plans. CAT funds are often reallocated to other catchments.
- Strategic EIAs at basin level are recommended to address environmental and social issues.

## 4.3 Social and environmental impacts

The Nathpa Jhakri dam is a run-of-river facility and its social and environmental impacts are considerably less than a storage type dam would have at the same site. There are plans for a number of other dams on the Sutlej River however, and the cumulative impacts of multiple run-of-river dams has been recognised as a cause for concern. This led to the commissioning of the Sutlej Cumulative Environmental Impact Assessment (ICFRE, 2014).

The Kol Dam under construction (Table 3, Figure 10) is a storage dam, as is the Bhakra Dam which has been in operation for hydropower generation since 1960. Storage type dams are recognised as having greater potential for environmental and social impacts (Lumbroso et al., 2014) as are those on main channels of rivers rather than upper tributaries (Ledec and Quintero, 2003). Dharmadhikary and Sheshadri (2005) make the important point that it is extremely difficult to ascertain the level of environmental and social impacts from such developments without baseline data. These baseline data do not exist for the Bhakra Dam, but owing to the Sutlej CEIA (ICFRE, 2014) they will exist for future dams, including the Kol Dam. Unfortunately as the CEIA has been carried out after construction of the Kol Dam began this information will not have been taken into account when planning the dam.

The development of Nathpa Jhakri took place in a very different regulatory environment from that in place when Bhakra Dam was built. As such, the company was forced to comply with a number of requirements for compensating Project Affected Families (PAFs). Based on the World Bank's 2002 Implementation Completion Report for the Nathpa Jhakri project, Schneider (2005) reports the following failures in the environmental and social safeguarding process for planning and construction:

- "…construction workers received differential treatment and pay, with the majority of workers being underpaid. This led to unrests and worker strikes."
- "By the time Nathpa Jhakri was approved by the World Bank, the project had neither a resettlement plan, nor a rehabilitation and environmental mitigation plan."
- "No Environmental Assessment was carried out before appraisal of the project by the World Bank. The Environmental Assessment that was finalised later did not cover the entire project area, nor did it examine the majority of the substantial environmental impacts. The implementation of the Environmental Management Plan remained unsatisfactory up to 2002."
- "The land acquisition and resettlement impacts of the project were incorrectly assessed at the start of the project. Eight years after project appraisal it became evident that full scale resettlement impacts were much higher than estimated. Throughout those eight years, almost no compensation was given to the affected people and no resettlement activities were carried out."

There are therefore significant reasons for concern that the social and environmental performance of the project may not be in line with World Bank requirements or other international standards.

## 4.4 Water use

### 4.4.1 Over-abstraction upstream

Over-abstraction upstream is unlikely to be a key issue in the context of Himachal Pradesh as large scale irrigation is not practical in the mid- or high-Himalayan mountains. A similar effect is being experienced however in terms of the cascade of dams in operation or under construction on a small number of rivers, notably the Sutlej. Minimum environmental flow releases are proscribed as 15% of minimum observed lean season flow, but there are a number of issues with this:

1. It is unclear what the actual definition of the minimum lean season flow rate is, records are often incomplete so relying on 'observed' flows is problematic
2. There is no scientific basis for prescribing this level of flows as 'environmental'.
3. There is no incentive to adhere to the regulation.
4. There is no enforcement of the regulation.

### 4.4.2 Evaporation

Evaporation is not a significant issue for the dams on the Sutlej River as they do not store more than a few hours of release to allow meeting of peak power demand. Additionally, evaporation rates are not high in this temperate climate.

### 4.4.3 Sedimentation issues

Turbine damage from silt loads in the river are addressed by regular maintenance, with 1.5% of annual revenues allocated to maintenance and insurance against damage (Consultees, 2013). Annual flushing of sediment trapped behind the dams are carried out so that there is little or no impact on overall performance from lost storage volume behind barrages. The Nathpa Jhakri dam has an innovative silt deposition chamber before flow reaches the turbines. This prevents damage under normal conditions but the turbines may still need to be shut down during very high silt loads to protect them.

## 4.5 Greenhouse gas emissions

It is presently unclear how much greenhouse gases are emitted from impoundments of water relating to hydropower projects in India or Himachal Pradesh. A World Bank Study in 2008 concluded that previous estimates circulated in the press has overstated the emissions and that hydropower reservoirs are mostly located where natural conditions restrict methane production (World Bank, 2008). The study did however recommend that efforts continue to better define the emissions and particularly whether release of water stratified in reservoirs through hydropower turbines is a significant release mechanism. Associated with this there is a need to gather information on stratification of reservoirs and sedimentation rates including their organic contents (the decay of which tends to produce greenhouse gases).

## 4.6 Section summary

This section has shown the following main points:

- Only two of eight planned dams on the Sutlej River are currently commissioned. When completed these eight dams will leave very little naturally flowing water in the Sutlej from the point where it enters India.
- There is currently little coordination of planning and operation between companies responsible for hydropower dams. Efficiency and output could be increased with more coordination, and flood risk could be reduced if planning approaches were harmonised.
- The need for government clearances, financing and the compensation of local populations have all been barriers to more rapid development of hydropower potential.
- The financial weakness of the state-run distribution utilities and incentives to provide free and subsidized electricity are a major factor in the inability of the power sector to promote investment in new generation and transmission capacity.
- The Nathpa Jhakri hydropower plant has exceeded its target generation for the last six years and unplanned outages have been reduced from thousands to tens of hours since the initial period after commissioning, to only 96 hours in FY2012/13.
- High sediment loads in rivers are the biggest problem for hydropower plants in the region, with the potential for severe damage to turbines. Catchment management could help to alleviate the problem, but technical solutions like the settling tanks at Nathpa Jhakri and monitoring of sediment loads to enable preventative turbine shutdowns are also likely to be necessary.

Table 7 illustrates the baseline and future risks of a range of hydropower performance issues. Grey arrows indicate the possible scale of the performance issue in future, while the size of coloured portions indicate the current scale and traffic light colourings indicate the level of concern associated with it, from red (high) to green (low).

| Performance issues | Baseline and future risks | Comments |
|---|---|---|
| **Energy outputs** | | Hydropower is an increasingly small proportion of national generation, although plans are to increase this. |
| **Demand exceeds capacity** | | Around 10% excess electricity is being generated in HP but a good return is not available for this owing to problems with distribution contracts and the national distribution system. |
| **Generation efficiency** | | The large schemes on the Sutlej are new and well-maintained so perform in line with expectations |
| **Other operational issues** | | Lack of integrated or consistent planning and operation means system outputs are non-optimal. Risks are high from dam spillways sized by different methods. |
| **Unplanned outage** | | There have been unplanned outage events due to high silt levels during floods. |
| **Upstream abstraction** | | The volume of water abstracted for irrigation is low so unlikely to impact on hydropower schemes |
| **Heavy silt loads** | | Heavy silt loads mean turbines must be shutdown to protect them from damage. High mountains are typically sources of heavy silt loads, especially in a 'young' range such as the Himalaya. |
| **Aquatic weed growth** | | There are no reported issues with aquatic weed growth in this area. |
| **Evaporation from reservoirs** | | The major schemes on the Sutlej river are run-of-river types and evaporation rates are low at this altitude |
| **Low river flows** | | Over the last few years river flows have been higher than expected so generation has exceeded expectations. Beyond 2100 reduced glacier melt may reduce flows, especially in the dry season. |
| **Environmental flows** | | Hydropower is reported to be causing significant environmental degradation as environmental flows are poorly understood and enforced. |
| **Transmission grid** | | ~95% of the HP population have access to grid electricity, but there are issues with the proximity of the grid to potential generation sites, hindering development. Inter-state transmission costs also reduce opportunities to sell power to remote customers. Transmission losses are not excessive |
| **Institutional capacity** | | Institutional capacity is generally high in HP but the wider Indian context presents problems, the structure of the power sector is not conducive to rapid development of available hydropower resources |
| **Public resistance to hydropower projects** | | Public resistance is high but being dealt with by increasing resettlement and rehabilitation compensation. A more standardised approach which links revenues to benefits may be required. |

Notes: The table provides a qualitative summary of the key issues, with traffic light colours indicating baseline levels of concern from red (high) to green (low) – the length of the traffic light colour indicates magnitude and the grey arrows indicating the potential for increased risks under some climate or socio-economic scenarios.

**Table 7 Summary of issues relating to hydropower performance in HP**

# SECTION 5

# Ongoing interventions to improve hydropower performance

This section looks at the interventions which are already underway to improve hydropower performance or water, energy and food security in HP.

Owing in large part to Himachal Pradesh's relatively developed status in Indian terms, steps have been taken and are being refined to reduce the vulnerability of the largely rural population to climate variability and change. Himachal Pradesh's capacity to deal with local issues and reform markets is considered to be high and this study discovered relatively little international assistance within the hydropower sector. As such, much of the work being undertaken to combat climate change and increase the performance of the hydropower sector is being carried out by state or central government agencies, or some combination of the two. Civil society groups are increasingly active in protesting infrastructure developments and negotiating settlements between local populations and developers. The authors were unable to make contact with any such groups to get their perspectives on the issues.

Points of leverage exist within the system originally described by the schematic diagram in Figure 5. These represent opportunities to improve the performance of hydropower in terms of its contributions to water, energy and food security. The locations of some of these leverage points are numbered in Figure 15 with different numbers representing different types of interventions. Table 8 outlines the intervention type which relates to each number, the agencies most likely to take responsibility for it and an indicative rating on a scale of 1 to 5 of both ease of implementation and impact.

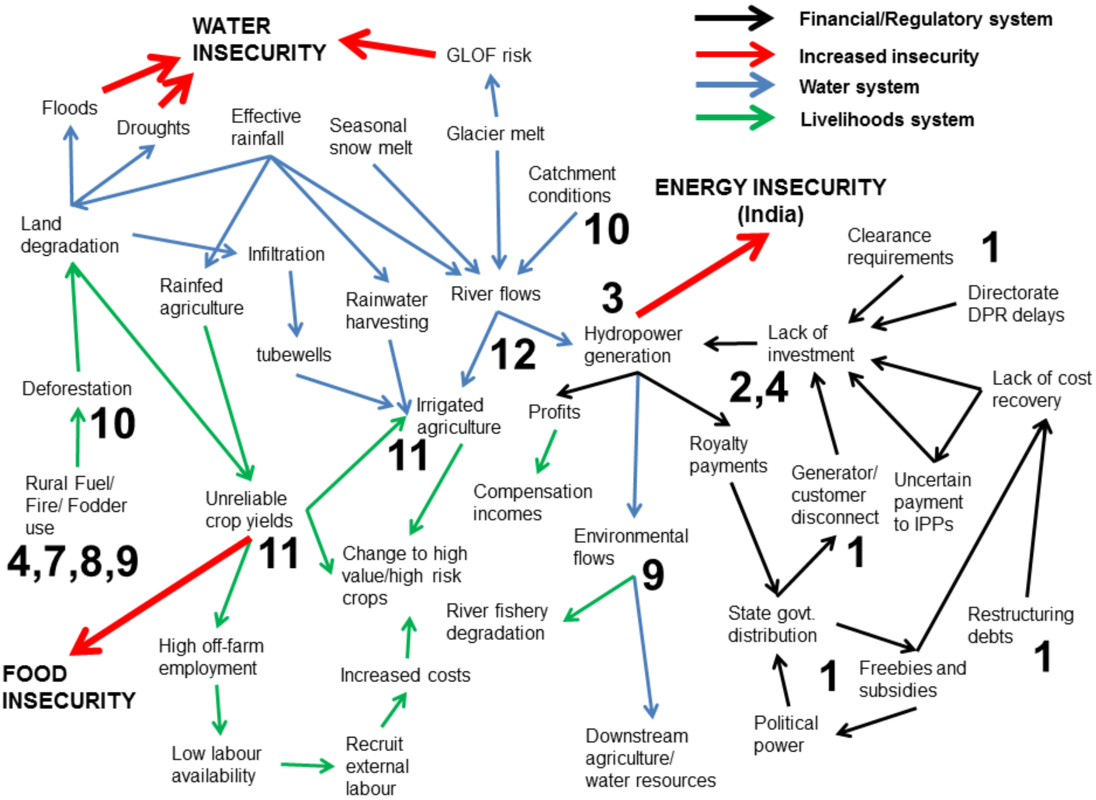
Table 9 shows the ongoing interventions identified by this study in the Sutlej Basin and Himachal Pradesh more widely. The table also indicates through a colour coding system, the resilience of different actions to climate and socio-economic change.

The remainder of this section provides further information on areas in which progress has been made at state or national level.

## 5.1 Addressing clearance delays

In total it can take 8 to 10 years for hydropower project development from inception to commissioning. After the initial submission of a detailed project report (DPR) the document is often returned to the developer to add more information. This can add one to two years to the approval process at central level. A 'first consultation' has recently been introduced for developers, meeting with relevant government stakeholders to discuss requirements for the DPR relating to geology, water and soils. This is intended to help guide developers so that they know what will be expected and can hopefully avoid having to provide more information. There will also be a meeting 17 months after first consultation to assess progress. Developers have up to 39 months to submit their DPR (Consultee, 2013).

**Figure 15 Hydropower system interactions in Himachal Pradesh from Figure 8 showing numbered intervention points, described further in Table 8 and the text.**



| No. | Group Name | Sub-groups | Comments | Agency most likely to lead for HP | Ease (1 Low - 5 High) | Impact (1 Low - 5 High) | Priority (Ease x Impact) |
|---|---|---|---|---|---|---|---|
| **1** | Policy reform | a) Full costs recovery | Promotes investment in new and existing infrastructure | Central Electricity Authority, Ministry of Power, State utility companies | 3 | 4 | 12 |
| | | b) Cost reflective tariffs | Help to spread load more evenly by differential pricing | Central Electricity Authority, Ministry of Power, State utility companies | 3 | 4 | 12 |
| | | c) Restructuring power sector | Focussing institutions on incentivising private investment | Ministry of Power | 1 | 5 | 5 |
| **2** | Investment to maintain and operate infrastructure | a) Public | May require economic measures in-country to achieve development of new and maintenance/ rehabilitation of existing infrastructure. | International Financial Institutions and other donor organisations | 4 | 3 | 12 |
| | | b) Private | A more sustainable solution to securing ongoing investment | Private banks and investors | 3 | 4 | 12 |
| **3** | New hydropower | a) Storage | Tend to have significant potential environmental and social impacts so consideration of trade-offs in design and operation important to maximise win-wins & multiple benefits. | Private investors, Utility company or Government | 2 | 4 | 8 |
| | | b) Run of river | Low/No storage so tend to have lower environmental and social impacts. Depend on reliable flows. | Private investors, Utility company or Government | 4 | 4 | 16 |
| | | c) Micro | Best suited to off-grid | Private investors or Government | 5 | 4 | 20 |

| No. | Group Name | Sub-groups | Comments | Agency most likely to lead for HP | Ease (1 Low - 5 High) | Impact (1 Low - 5 High) | Priority (Ease x Impact) |
|---|---|---|---|---|---|---|---|
| | | | solutions | | | | |
| **4** | Diversify | a) Renewables | Diversification of the sources of electricity can help increase resilience to climate related system shocks. Diversification could take the form of other renewables such as solar, wind, biogas or geothermal | Private investors, Ministry of New and Renewable Energy, Central Electricity Authority, State Directorate of Energy, Himachal Pradesh Energy Development Agency (HIMURJA) | 3 | 3 | 9 |
| | | b) Thermal | Including coal, heavy fuel oil, diesel, waste to energy | Private investors, Central Electricity Authority, State Directorate of Energy | 2 | 2 | 4 |
| | | c) Nuclear | No plans at this stage | Private investors, Central Electricity Authority, State Directorate of Energy | 1 | 2 | 2 |
| **5** | Grid extension/ capacity increase | | Extending the grid on a planned basis to increase ability to evacuate power from currently remote concessions, facilitating development | HP Power Transmission Corporation Ltd (State government undertaking) | 4 | 4 | 16 |
| **6** | Improve Indian grid management | | Improving the ability of IPPs to trade electricity across large distance on the Indian grid to facilitate hydropower development through increased options for power purchase agreements | Ministry of Power | 2 | 4 | 8 |
| **7** | LPG/ Sustainable Charcoal | | Replacements or enhancements to current fuelwood use could reduce pressure on forestry resources | State government | 3 | 3 | 9 |

| No. | Group Name | Sub-groups | Comments | Agency most likely to lead for HP | Ease (1 Low - 5 High) | Impact (1 Low - 5 High) | Priority (Ease x Impact) |
|---|---|---|---|---|---|---|---|
| **8** | Community forestry | | Land degradation can be reduced and sustainability of benefits increased by giving complete or partial management control of natural resources to the local communities which depend on them. | State Forestry Department, Ministry of Forestry | 4 | 5 | 20 |
| **9** | Payment for Ecosystem Services (PFES) | | Downstream users of a resource such as water may find it is better value for money to make direct/indirect payments to users/polluters upstream to safeguard the resource quantity or quality. | State Forestry Department, Department of Environment, Science and Technology | 3 | 5 | 15 |
| **10** | Afforestation | | Direct planting of trees to increase slope stability, reduce erosion and impact on water flows can be integrated in wider programs or implemented in isolation | State Forestry Department | 5 | 4 | 20 |
| **11** | On-farm practices | a) Increased irrigation | Could intensify outputs to reduce requirements for new land | State Irrigation and Public Health Department, State Department of Agriculture | 4 | 4 | 16 |
| | | b) Conservation practices | Changes can be made to the way land is farmed or managed which have positive impacts on land quality and runoff generation | State Department of Agriculture, State Department of Forestry | 4 | 4 | 16 |

| No. | Group Name | Sub-groups | Comments | Agency most likely to lead for HP | Ease (1 Low - 5 High) | Impact (1 Low - 5 High) | Priority (Ease x Impact) |
|---|---|---|---|---|---|---|---|
| **12** | Water management | a) Supply | Development of new small and large scale infrastructure to make use of available wet season flows. | State Irrigation and Public Health Department | 3 | 3 | 9 |
| | | b) Demand | Improving demand management and increasing water efficiency | State Irrigation and Public Health Department | 4 | 4 | 16 |
| | | c) Quality | Improving water quality, reducing silt loads | State Irrigation and Public Health Department | 4 | 4 | 16 |
| | | d) Capacity building | Increasing capacity of river basin authorities and other water managers. | State Irrigation and Public Health Department, Central Water Commission, Ministry of Water Resources | 3 | 4 | 12 |

**Table 8  Description of the numbered intervention points shown in Figure 15. Ease of implementing the type of intervention is rated from low (1) to high (5) as is Impact on water, energy and food security. The Ease and Impact scores are multiplied to give an overall priority rating from low (1) to high (25).**

| Agency | Intervention | Intervention point(s) | Impact on: | | | Resilience to: | |
|---|---|---|---|---|---|---|---|
| | | | Water Security | Energy Security | Food Security | Climate Change | Socio-economic Change |
| Department of Agriculture | Soil and water conservation - Gabion/stone check dams, planting of berms, tree planting, extending/levelling terracing | 10, 11b, 12c | | | | | |
| | Developing lift irrigation schemes - Financial subsidies and support for pumps, tanks and sprinklers/drip distribution for schemes up to 50ha | 11a, 12b | | | | | |
| | Supporting development of high yielding varieties - University research in close collaboration with DoA and extension staff | 11b,12b | | | | | |
| | Introducing precision farming - drip irrigation, polytunnels etc. Subsidies applied to certain models | 11a,12b | | | | | |
| Department of Forestry | Soil and water conservation | 10, 11b, 12c | | | | | |
| | Afforestation on private and community land - Rs 4,000/ha/year for 30 years through carbon credit funding | 9, 10 | | | | | |
| | Reverse the process of degradation of natural resources and improve the productive potential of natural resources and incomes of rural households | 11a, 11b | | | | | |
| National Bank for Agriculture and Rural Development (NABARD) | Offering financial support for capital cost of irrigation and polyhouses | 2a | | | | | |
| National Action Plan for Climate Change | Promoting 20% increase in irrigation efficiency | 11a, 12b | | | | | |
| Department of Irrigation and Public Health | Developing lift irrigation schemes - Constructing and directly operating larger schemes with distribution mainly by open channel and flood irrigation (also some drip/sprinkler systems) | 11a | | | | | |
| State of Himachal Pradesh | Giving strong emphasis to water conservation - Reducing runoff/erosion, increasing infiltration, retaining water in drains to replenish groundwater | 8, 10, 11b | | | | | |
| World Bank | Development Policy Loan (DPL) to Promote Inclusive Green Growth and Sustainable Development | 2, 9,10 | | | | | |

**Table 9 Interventions planned or ongoing. Impact and resilience colour scale is red (strongly negative) to green (strongly positive) via amber (no impact).**

## 5.2 Integrating development

At the institutional scale, the various overlapping agencies involved have agreed to follow a common approach to processes and procedures. A Hydropower Producers Forum has been constituted, starting with the Sutlej Basin, to provide coordination on social, environmental, water flow and other catchment area issues:

1. Joint efforts to pursue the goal of eco-friendly energy development and to evolve an integrated Catchment Area Treatment (i.e. management) (CAT) plan for the Sutlej Basin.
2. Join hands for comprehensive planning of operations of power stations in the Sutlej Basin for unhindered operation, optimised utilisation of runoff and to pool the expertise to tackle eventualities of operation outages due to floods or mishaps.
3. Create, upgrade and share facilities to generate data in respect to discharge, silt and meteorological observations and sharing of common laboratory testing facilities.
4. Jointly develop and implement effective flood warning and disaster management systems.
5. Share views and derive a common approach towards implementation of guidelines and statuses of the state and union government and forward constructive suggestions for modifications and improvements.

It is hoped that this can be rolled out for other basins through similar producers' forums.

## 5.3 Resettlement and Rehabilitation

Potential local opposition to hydropower development is being addressed through several policies to provide compensation, share benefits and restore livelihoods. Resettlement issues are minimal, since most developments are run-of-the-river types involving relatively little land acquisition. In relation to this, the Land Acquisition Act, 2013 requires an expert group to assess whether:

- The project will serve any public purpose.
- The potential benefits outweigh the social costs and adverse social impacts.
- The amount of land required is the bare-minimum for the project.
- There are any other options which would displace less people.

In a special provision to safeguard food security, the Act also requires:

- Irrigated multi-cropped land should not be acquired under the Act, unless under exceptional circumstances as a demonstrable last resort
- If acquired as last resort, an equivalent area of cultivable wasteland should be developed for agriculture or equivalent amount to value deposited with government for investing in agriculture and enhancing food security.
- The aggregate of all acquired agricultural land should not exceed total net sown area of district or state.

Where the land acquired totals more than 100 acres, a Resettlement & Rehabilitation (R&R) Committee will be formed to monitor and review progress of the R&R scheme implementation. The Committee must include women, all castes represented in the area affected, a voluntary organisation working in the area, a nationalised bank representative, the Member of Parliament for the area concerned, the chair of the local planning committee, the land acquisition officer and the chair of the communities.

## 5.4 Forestry

Forestry is recognised as having potential benefits for the economy through growing of medicinal plants and improvement of pasture and firewood supply. The new policy also allows forestry to evolve towards multifunctional use rather than solely timber production. This is not an easy transition, requiring the development of market mechanisms and incentives for forest management. New approaches to financing are required to support this transition, recognising the value of ecosystem services at local, state and national levels. A participatory forest management notification came into place in 2001 which aims to involve communities more in forest management. This was built on by a 2005 policy directed at balancing the needs of local people and the environment. There are positive precedents for community management of forestry resources in Nepal (Ojha et al., 2009) and water resources in the Kangra Valley of Himachal Pradesh (Box 2).

**Box 2 Example of community management of water resources**

The *Kuhl* system of community irrigation management in Kangra valley demonstrates the ability of traditional communities to manage water projects. This system has been maintained for generations despite being physically destroyed by earthquakes and floods on numerous occasions. The biggest threat to the system has been state intervention, weakening the system by taking over full management responsibility of some larger *kuhls*. Formalisation of the system has influenced local patterns of power and support for repairs through male farmers resulted in loss of female participation and engagement in operations. Community common property management is able to respond much quicker and more flexibly to environmental impacts than government is. This is evidenced by the *kuhl* system's repeated recovery from destruction by earthquakes. Strengthening and re-establishing community institutions is seen as an important climate adaptation measure.

*Source: Baker, 2005*

## 5.5 Water management

A major policy issue for the potable water in HP is the near zero charging for it. Gravity water schemes have low operation and maintenance costs but for pumped schemes, costs are of the order of Rs. 6 (US$ 0.1) per cubic metre. The Department of Irrigation and Public Health (DIPH) is now initiating a gradual handover of drinking water schemes to the Panchayat Raj Institutions (PRI) or Urban Local Bodies (ULB). There is a need however, to build up the capacities of these institutions to effectively take on the real responsibilities of water supply management including put ting effective cost recovery systems in place to meet the basic operation and maintenance costs" (ADB, 2010).

ADB (2010) identify seven key areas to support development of a robust water resources strategy in HP:

1. Effective institutions to support integrated water resources planning and management. Need to establish wide support for IWRM and establish participatory mechanisms, regulatory agencies and 'apex bodies'.
2. Establishment of integrated data and information systems. Data from across government departments and private companies needs to be collated to provide a common knowledge pool of all available information relating to natural and built features of the water environment.

3. Integrated catchment and agricultural planning.
4. Integrated water resources planning. Need to establish workable planning processes where projects are identified and planned rationally, incorporating needs of various sectors and environment.
5. Disaster preparedness.
6. Rural employment and diversification. Around 70% of population is involved in agriculture which is susceptible to climate change impacts, market changes and other risks. Strategy is to diversify rural economies.
7. Investments.

## 5.6 Cumulative Environmental Impact Assessment (CEIA)

This is ongoing for the Sutlej basin (ICFRE, 2014) with a view to providing baseline information from which to judge future impacts. Detailed information has been gathered relating to the diversity of plant and animal life in the basin and the other natural resources which may be affected by development of hydropower and water resources schemes.

There is a clear need to define more appropriate environmental flow levels and ensure these are enforced. At the same time there is a need for integrated development of hydropower resources and ideally integrated operation to make best use of available resources. New environmental flow requirements are under development (Consultee, 2013) but owners of existing allotments or operational schemes are not happy with the proposal that new requirements will apply to them.

HP has also finalised an integrated Catchment Area Treatment (CAT) plan for the Sutlej basin and work is current on three other river basins to provide baseline data on forest cover, erosion and silt load (Consultee, 2013).

## 5.7 Section summary

This section has shown the following main points:

- International agencies are largely absent from Himachal Pradesh, owing largely to the capacity of the central and state governments to address the problems identified.
- Departments of Agriculture and Forestry are already engaged with the issues of water and soil conservation, this has important implications for water and food security as well as for reducing sediment loads in rivers and floods and droughts which affect hydropower performance.
- Intensification of agriculture through irrigation among other things is hoped to stimulate a step change in productivity in Himachal Pradesh. A significant investment will be required to achieve this, primarily in terms of irrigation systems but done well it could transform the sector. Increasing farm incomes could increase ability to pay for electricity and reduce pressure on forestry resources for energy.
- There is recognition of the need for more integrated planning, evidenced by the instigation of cumulative environmental impacts assessments and a hydropower producers' forum.
- Stakeholders in Himachal Pradesh are actively engaged in finding betters ways to manage the planning and implementation of hydropower projects.

# SECTION 6

## Conclusions

There are significant challenges to be met in harnessing the potential of HP's hydropower, but there are also clear actions which can be taken towards this goal. This section concludes the case study, identifying seven prioritised recommendations for improving the performance of hydropower in HP, based on the key issues identified by the case study. An assessment of the ease of carrying out each intervention, combined with an assessment of the likely impact of that intervention gives an overall priority score. The scoring system assumes that easily implemented interventions with a high impact are preferable. The opportunities are summarised in Table 10 in order of priority and indicating their impact on water, energy and food security and resilience to climate and socio-economic change. Each is described in more detail under a sub-section heading, identifying the logic behind them and any precedent for this kind of intervention.

### 6.1 Build on the State Strategy and Action Plan for Climate Change

The State Strategy and Action Plan for Climate Change document is extensive in its recognition and analysis of the potential impacts of climate change and the need to build resilience and adapt. Its strategy and planning component is somewhat weaker, focussing mainly on ongoing activities which relate to climate change adaptation. Stronger planning and strategy components will help to increase the resilience of the State and its hydropower infrastructure to climate change. Currently, the document reports ongoing activities and identifies gaps which need to be addressed, but lacks a coherent strategy.

There is increasing international experience of developing climate resilience and adaptation strategies. For example, The Global Water Partnership (GWP) has a South Asian Water, Climate and Development Programme with the overall goal of improving resilience of South Asian countries to climate change (GWP, 2014). One of its objectives is developing "no regrets" financing and investment strategies for water and climate change adaptation. International expertise could help to develop this document into a more useful guide to decision-making in the context of climate change. Improved planning and strategy should help to improve the positive contributions of hydropower to the State's water, energy and food security as part of a more integrated approach to planning.

### 6.2 Build partnership approach between people and hydropower projects

Rehabilitation and resettlement (R&R) are an important part of many power related projects (generation and transmission). Issues have so far been dealt with in an ad hoc fashion but two recent laws on land acquisition and R&R should help to define a national framework.

Building on HP's record of innovation in terms of compensating local populations and funding catchment protection measures from hydropower projects, it is proposed by Sanan and Mitra (2011) that only a mechanism that specifically links project revenues with direct monetary well-being of affected people will ultimately work. They propose that each family is provided with a bank account to which a proportion of revenues are automatically credited in accordance with a pre-defined and agreed formula over the full life of the project. The example in Box 3 shows how 10,000 families could be made twice as well-off for only 2.5% of annual revenue. This is suggested as a minimum. Corruption would be avoided in terms of dispersing funds and uncertainty faced by developers would be greatly reduced if families identify directly with the well-being of the project. Largely in agreement with the proposal above, the Land Acquisition Act of 2013 states that:

"…the cumulative outcome of compulsory acquisition should be that affected persons become partners in development leading to an improvement in their post-acquisition social and economic status…"

Himachal Pradesh has implemented such a scheme at a level of 1% of revenue, but without direct account transfer payment. Some independent power producers (IPPs) are taking the state government to court to protest that they should not have to pay it if their concession was allotted before the policy came into force (Consultees, 2013).

A more established scheme requires developers to contribute 1.5% of project development costs to a Local Area Development Fund (LADF) during construction, which was the first of its type in India (Consultees, 2013). HP therefore provides its own precedent in this respect, having moved closer towards such an approach incrementally. The World Bank has also recently produced a guide for local benefit sharing on hydropower projects (Wang, 2012).

**Box 3 Potential benefits for project affected families (PAFs)**

Operating on an annual 30% load factor and assuming an average sale price of Rs 3.5 per unit (kWh), the project could earn revenues of close to Rs. 9 billion (US$145 billion) every year. Further, if we assume that all the 10,000 PAFs are below the poverty line, that is they have annual household incomes of Rs 25,000 or thereabouts and that the project ought to make them twice as well-off, that is they should get an additional income of Rs 25,000 each year, then a mere 2.5% of the annual project revenue would suffice.

*Source: Sanan and Mitra, 2011*

## 6.3 Improve water and catchment management coordination

In HP there is a need to better coordinate water resources issues. Although the government has made some progress towards this with the establishment of a State Water Management Board, this lacks effectiveness without a department to work through. ADB (2010) proposes the need for coordination be filled by two bodies:

- A Water Resources Working Group to coordinate water resources planning including hydrology, irrigation, water supply, and hydropower. The agency would support the State Water Management Board and be the apex unit to support the water aspects of IWRM. The working group would comprise representatives from DIPH, Department of Environment, Himachal Pradesh State Electricity Board, and HIMURJA.

- A separate Catchment and Agriculture Working Group to coordinate all the soil and water conservation, agriculture and forestry – programs. The catchment and agriculture working group would consist of representatives from the Environment, Forestry, Agriculture, Horticulture and Rural Development Departments.

It is common practice in cross-sectoral coordination to establish working groups comprising representatives of different stakeholders (e.g. SADC, 2014). This type of coordination could also help share data and make them more accessible for research purposes, this study was restricted by the availability of data which could have facilitated further analysis.

## 6.4 Support definition, monitoring and enforcement of environmental flows

Sustainability in relation to environments reliant on river flows relies heavily on defining the necessary minimum flows throughout the year. The current environmental flow requirements are ill-defined, poorly monitored and poorly enforced. There is little incentive for dam operators to ensure flows support biodiversity which does not appear on their balance sheets, so without clear definitions and the threat of sanctions breaches are likely to occur. Hydropower developers and operators need to be able to estimate the economic viability of their schemes taking into account releases for environmental flows. Once these are established, operations can be optimised around those releases.

Environmental flows are recognised as a public policy imperative across the world, but in many cases they remain subject to policy debate rather than implementation (Le Quesne et al., 2010). HP's ambitions for sustainability and green growth will depend heavily on its success in implementing strong environmental flow limits. Nine case studies of setting environmental flows in the USA are presented by Kendy et al. (2012) while Smakthin and Anputhas (2006) have developed a simplistic method specifically for developing country contexts, based on scaling of the flow duration curve.

As an example, a study by Kumar (2007) designated the reach of the river most affected by Nathpa Jhakri dam (~30km between the dam and the powerhouse downstream) as low ecological sensitivity. Considering a range of international standards for environmental flows where sensitivity is low a minimum release for this reach of $7m^3/s$ was recommended to ensure there is bed submergence and flow throughout the year.

## 6.5 Analyse trade-offs associated with water storage developments

A storage type hydropower project is under construction on the Sutlej river and over time there may be a need to further consider the need for this type of development which can better regulate seasonal flows and provide a greater range of benefits than run-of-river schemes.

Owing to the position of Himachal Pradesh in the headwaters of the Indus basin and the high proportion of Indus flow from its rivers, there is high potential for their management to impact on downstream users. Trade-offs exist between different uses of water and it is important to understand these in order to make best use of available resources at basin scale, ensuring sustainability of environmental and social systems. Consideration of the broader impacts of any development may improve sustainability and could foster increased cooperation locally, regionally and internationally.

Different approaches to trade-off analysis are being developed in the research literature (e.g. Räsänen et al., 2013; Gómez et al., 2013; Hurford and Harou, 2014). IUCN is leading an innovative project in Kenya’s Tana Basin and Ghana’s Volta Basin using many-objective trade-off analysis to identify portfolios of built and natural infrastructure which achieve the best possible (i.e. Pareto-optimal) trade-offs between a broad range of benefits including hydropower (IUCN, 2014).

| Intervention | Intervention point(s) | Impact on: | | | Resilience to: | | Ease (1 Low - 5 High) | Impact (1 Low - 5 High) | Priority (Ease x Impact) |
|---|---|---|---|---|---|---|---|---|---|
| | | Water Security | Energy Security | Food Security | Climate Change | Socio-economic Change | | | |
| Build on the State Strategy and Action Plan for Climate Change, filling gaps identified to help integrate hydropower planning and development | N/A | | | | | | 5 | 4 | 20 |
| Build partnership approach between people and hydropower projects | N/A | | | | | | 4 | 5 | 20 |
| Establish coordination bodies to promote integrated water management and soil and water conservation practices | 11a, 11b, 12c, 12a | | | | | | 4 | 4 | 16 |
| Support definition, monitoring and enforcement of appropriate environmental flows in rivers affected by hydropower projects | 12b | | | | | | 4 | 4 | 16 |
| Analyse trade-offs associated with water storage developments to ensure sustainable resource use and equitable sharing of benefits | 3a, 3b, 9, 12a | | | | | | 4 | 4 | 16 |
| Identify opportunities to develop payments for ecosystem services (PfES) approach | 9, 11b, 12a, 12c | | | | | | 3 | 5 | 15 |
| Support restructuring of the power sector to incentivise investment. | 1c, 6 | | | | | | 1 | 5 | 5 |

**Table 10 Priority interventions identified for improving hydropower performance. Impact and resilience colour scales for climate and socio-economic change are red (strongly negative) to green (strongly positive) via amber (no impact). Ease of implementing the type of intervention is scored from 1 (low) to 5 (high) as is Impact on hydropower performance. Ease and Impact scores are multiplied to give an overall priority rating from 1 (low) to 25 (high).**

## 6.6 Identify opportunities to develop payments for ecosystem services (PES) approach

It may be possible to increase incentives for farmers to undertake soil and forest conservation measures if payments for ecosystem services can be negotiated between them and those who stand to benefit downstream.

The Millennium Challenge Corporation (MCC) has included the concept of payments for ecosystem services in its compact with the Malawian Government to revitalize the power sector (MCC, 2013). This is intended to address sedimentation issues in the Shire river by having hydropower producers fund catchment conservation measures by farmers in the upper catchment. This can help incentivise making the investment in changing practices. There are positive examples from Cambodia (Arias et al., 2011) and the South West of the UK where a water company has for example, paid for adaptation measures on farms upstream of reservoirs to improve water quality arriving at the reservoir and thereby reduce their water treatment costs (South West Water, 2014). Measures have included fencing off rivers to prevent cattle incursion and providing covered sheds so that heavy rainfall does not lead to runoff highly polluted with dung. Overall it is cheaper for the water company to carry out these measures than pay for the increased water treatment costs.

## 6.7 Power sector structural reform

Structural reform of such an extensive and important sector in the second most populist nation on earth is a huge task, but India’s electricity supply deficit and aspirations for low carbon growth depend on unlocking its potential. Although we recommend this as a priority intervention, we acknowledge the scale of the task.

Sanan and Mitra (2011) believe the vision of the Indian Ministry of Power is important for setting the agenda and compare the existing vision of “Reliable, adequate and quality power for all at reasonable prices.” with their suggested “Create an efficient and vibrant power sector geared to the needs of an inclusive and rapidly growing economy”. They stress that the emphasis should be on enabling, not doing, on allowing market forces to play out and on addressing market failures jointly with the other, very major set of stakeholders.

They believe the Ministry needs to address a number of cross-departmental issues:

- Facilitating clearances with environment and forestry ministry
- Coordinating renewables development with Ministry of New and Renewable Energy
- Promoting hydropower with Ministry of Water Resources and Ministry of External Affairs (for Nepal and Bhutan)
- Promoting regional power sharing (Ministry of External Affairs)

They note further that issues often arising from clearances from Ministry of Environment and Forestry do not have resolution mechanisms. A small inter-ministerial professional body could help to expedite clearances and harmonise legal requirements. The Ministry of Power could also better catalyse inter-state cooperation. A regional water resources authority could help to resolve inter-state issues relating to benefit sharing and trade-offs. Relations have become strained between Arunachal and Assam states because of under appreciation of downstream impacts, for example.

In terms of technical issues, Long-term planning needs to be undertaken and implementation expedited to provide power evacuation on a river basin level rather than on a project by project basis. Funding mechanisms need to be devised to promote this.

Templates for success in this area are not available in any of the case study countries for this project, but Best Practice Guidelines are available from organisations such as Energy Charter.

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**Appendix A Consultees in India**

This appendix lists in Table 11 the people and organisations consulted as part of this research.

| Name | Position | Organisation |
|---|---|---|
| Er. R.K. Sharma | Director (Projects) | H.P. Power Transmission Corporation Ltd. |
| Er. Kaushalesh Kapoor | Deputy General Manager (Contracts) | H.P. Power Transmission Corporation Ltd. |
| Deepak Sanan | Addl. Chief Secretary | Government of Himachal Pradesh |
| Kanwar Bhanu Pratap Singh | Chief Executive Officer | HIMURJA, H.P. Govt Energy Dev. Agency |
| K.N. Garg | Member (Hydro) & Ex-Officio, Additional Secretary to the Govt. of India | Central Electricity Authority |
| Ravi Uppal | Deputy General Manager (Corporate Planning & Monitoring Dept.) | SJVN Limited |
| Er. P.K.S. Rohela | Superintending Engineer | Directorate of Energy, Government of Himachal Pradesh |
| C.M. Walia | Secretary General | Forum of the Hydro Power Producers & Other Stakeholders in Satluj Basin (HPPF) |
| Devendra Sharma | Managing Director | Himachal Pradesh Power Corporation Ltd. |
| D. Mathuria | Director | Central Water Commission |
| P. Narayan | Director | Central Water Commission |
| | Director | Central Water Commission |
| | Director | Central Water Commission |
| | Director | Central Water Commission |
| | Director | Central Water Commission |

**Table 11 Consultees for the Himachal Pradesh case study**

## Appendix B Summary of Key climate change phenomena

This appendix gives a summary (Table 12) of the key phenomena and trends related to climate change in Himachal Pradesh, as reported by the Asian Development Bank (2010).

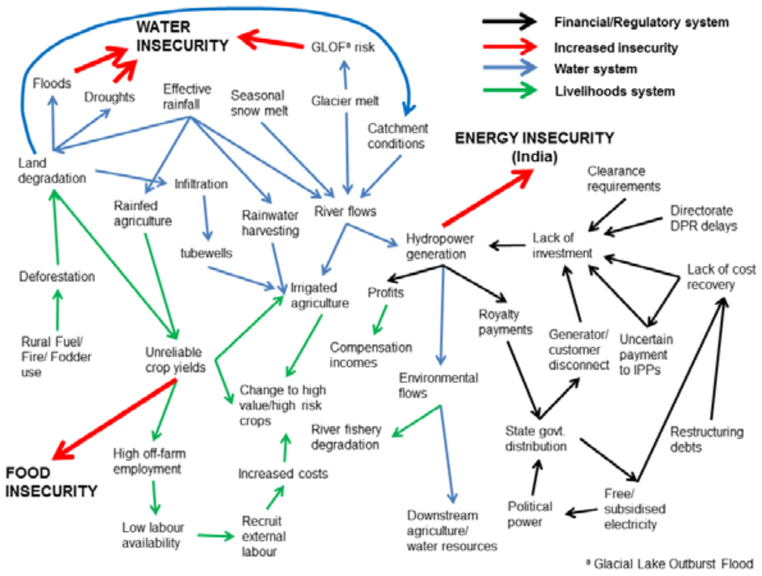
| Phenomenon and trend direction | Likelihood | Broad implications on sectors | | | |
|---|---|---|---|---|---|
| | | Water resources | Agriculture/Irrigation | other | Adaptation strategies |
| Increased frequency of heavy precipitation | Very likely | Increased runoff and higher levels of sediment loading, reduced groundwater recharge | Drainage to crops and increased soil erosion | Increased sedimentation will affect hydropower and potable water. Shutdown of hydropower may become more frequent | Soil and water conservation. Storage to reduce sediment levels. Groundwater management. |
| Increase in extreme rainfall intensity | Very likely | Increased flood flows | Damage to crops and severe economic loss for farmers | Disruption and damage to settlements, roads, infrastructure, and risks to human life | Soil and water conservation. Insurance. Flood management and protection. Disaster preparedness and management. Changes to design criteria for dam and other water structures. Sustainable urban drainage and land use planning. |
| Increased variability in rainfall patterns | Very likely | Erratic river flow patterns | Major impact on non-irrigated crops | Reduced hydropower production | Soil and water conservation. Water harvesting, irrigation and improved agricultural techniques. Improved seed varieties. |
| Increased likelihood of water shortages/droughts | Very likely | Reduced dry season flows. Drying up of some minor tributaries and springs. | Major impact on rainfed cropping. Some impact on irrigated cropping. | Reduction in water availability for some hydro power, irrigation, and water schemes. Loss of some perennial sources of potable water. | Soil and water conservation. Water harvesting, irrigation, improved agriculture technologies, and new seed varieties. Move from annual to perennial crops including agro-forestry. Improve irrigation and water supply efficiencies. |
| Reduced levels of precipitation as | Likely | Increased winter season runoff. | Irrigation and potable water schemes in | Loss of some perennial sources of irrigation and | Soil and water conservation. Adjustments in cropping schedules. |

| Phenomenon and trend direction | Likelihood | Broad implications on sectors | | | Adaptation strategies |
|---|---|---|---|---|---|
| | | Water resources | Agriculture/Irrigation | other | |
| snow | | Reduced dry season flows.<br>Drying up of some minor tributaries and springs.<br>Reduced dry season flows to neighbouring states. | snow-fed rivers and streams would have reduced summer flows. | potable water.<br>Higher winter rainfall will increase erosion. | |
| Loss of glacier volumes | Likely | Initially increased dry season flows.<br>Over the longer term, likely reduced dry season flows-time frame uncertain.<br>Long term reduced dry season flows to neighbouring states. | Uncertainty in supply of irrigation, water and hydropower. | Loss of some perennial sources of potable water.<br>Long term reduced hydroelectric power, irrigation and water supply. | Improvement in irrigation and water supply efficiency.<br>Optimisation of hydropower cascade dams.<br>Storage at selected hydro sites.<br>Change of water sources for potable water. |
| Earlier snow melt | Very likely | Increased spring flows and reduced summer flows. | Irrigation schemes in snow-fed rivers would have reduced summer flows. | Loss of some perennial sources of potable water and irrigation. | |
| Increased temperature | Very likely | Increased river and lake temperatures. | Changes in suitability of crops at different altitudes - eg. apples.<br>Possible impact on aquaculture. | Changes in aquatic ecologies including balance of phytoplankton/ zooplankton in rivers and water bodies.<br>Increased bacteria. | Application of land suitability analysis under new climatic conditions.<br>Estimation of temperature changes and impact in rivers and lakes. |

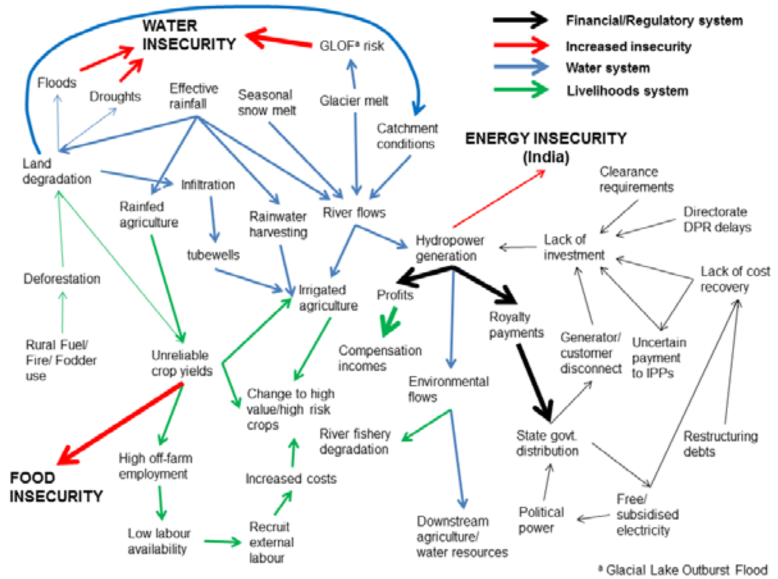
**Table 12 Phenomena and trends relating to climate change impacts on water resources in Himachal Pradesh (source: ADB, 2010)**

**Appendix C Comparing systemic interactions**

This Appendix displays the three system schematic diagrams from Figure 8, Figure 9 and Figure 10 to facilitate direct comparison of the changes in arrow thicknesses representing the changing influence of different factors. The top figure on the next page is the current situation and the other two figures are labelled above them according to the type of changes they represent.




## Socio-economic change




## Climate change