NEPAL 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 Nepal case study analyses the past performance of hydropower in the country 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 Nepal and/or developing programmes which promote the sustainability of existing or new hydropower schemes in this or similar political, socio-economic or geographical contexts.

Country context

Nepal is a Least Developed Country (LDC) (GoN, 2013) with a predominantly rural population (83%) that is poorly served by infrastructure. Its mountainous terrain makes infrastructure development particularly challenging and costly. The financial and technical capacity of the government to carry out such development is also low. Recent instability and armed conflict has only exacerbated the problem of low investment, particularly from the private sector. Despite this, the country has achieved impressive reduction in a number of metrics relating to Millennium Development Goals, many of which it has or expects to meet by 2015 (Asian Development Bank (ADB), 2013). Most notable among these is the halving of the population living in poverty to 21%, which was achieved in 2013. Access to electricity is around 56% from grid and off-grid sources (Samuhik Abhiyan, 2011) and while excess power is produced in the coincident monsoon and snowmelt seasons, outages of 18 hours per day are common in the dry season. With an annual growth in electricity demand of 7-9% (Water and Energy Commission Secretariat (WECS), 2010), Nepal faces a dire need for a more reliable electricity supply.

Hydropower potential

One of Nepal's biggest challenges is finding ways to harness its enormous 42,000MW of economically viable hydropower resources to stabilise and increase power availability and drive broad and inclusive development. Of the currently installed 660MW (a mere 1.5% of the viable total), 28% is from small plants and 72% from medium sized plants; 28% is under private ownership and 97% is grid-connected (Nepal Electricity Authority (NEA), 2010). All but one of Nepal's hydropower projects are 'run of river' schemes and despite inefficiencies total system outputs exceed demand during the wet season but fall far short (up to 18 hours of outages) during the dry season (World Bank, 2013c). Without changes to its hydropower sector to include more storage projects, Nepal will be forced to import more and more electricity during its dry season to meet domestic demands. By developing storage hydropower the range of benefits may be increased including improved irrigation and better utilisation of the country's water resources, only 8% of which are currently utilised.

It is difficult to achieve inclusive growth from large hydropower with limited grid penetration, but over 20 MW of off-grid solutions have also been implemented through the government's Alternative Energy Promotion Centre (AEPC) (Batra, 2010). These are installed as community owned and run schemes across the country. The goal is to install a further 25 MW, but the financial sustainability of the model is questioned due to the investment required by communities themselves and the slow return on this. Significant developmental benefits have been realised through this programme however, including increased economic activity and raised living standards (Samuhik Abhiyan, 2011).

Financial and structural issues

The difficulty the government faces in developing a larger proportion of the potential is primarily financial but also structural. The country is stymied by the lack of a sizeable domestic industrial demand and lack of success in negotiating mutually beneficial power purchase agreements to sell across the border in India. Without reliable revenue from a major demand, it is difficult to obtain funding to develop a concession, many of which have been awarded (Consultees, 2013). By carefully selecting the most economically efficient schemes for priority development, it may be possible to offer cheaper tariffs which better promote export deals. Debate continues over whether the best strategy is to develop power exclusively for export while the country faces such severe dry season shortages of electricity itself (e.g. Shrestha, 2014). The Nepal Electricity Authority (NEA) is in a poor financial position, making losses and requiring an overhaul to make sure it is profitable enough to invest in the power sector for the national benefit. Reform of the energy and other sectors is needed to incentivise private investment.

Climate change vulnerability

Nepal is particularly vulnerable to climate variability and climate change over the next 30 years, with vulnerable populations living in fragile mountain ecosystems and on floodplains. Floods, droughts and landslides are all on the increase (Government of Nepal (GoN) and United Nations Development Programme (UNDP), 2013) and must be managed to continue poverty reduction and protect development gains. General natural resource degradation resulting from over exploitation to meet increasing demands is also leading to shortages of water and energy, impacting most severely on the poor, women and marginalised groups.

Nepal's climate dictates that the two main sources of runoff in its rivers (seasonal snow melt and the monsoon rains) coincide to provide a single high flow season. A baseflow is supplied by melt from glaciers and this compensates for years with low snow cover, but rainfall dominates. This is expected to change in the long term so that less regulation is provided by depleted glaciers as a result of warming temperatures (widely agreed on by climate models). This will increase the influence of rainfall, which may become more concentrated in the monsoon period, although climate models disagree about the magnitude of projected changes. Without climate adaptation and resilience measures, more intense rainfall and greater seasonality could further decrease crop productivity on Nepal's agricultural land and exacerbate problems with seasonality of hydropower generation.

Conclusions

There is a clear need for Nepal to develop storage-type hydropower projects to take better advantage of the potential of its large water resources in the wet season for generating much needed electricity in the dry season. This will also increase the country's resilience to climate change and provide potential benefits to agriculture by storing irrigation water. Storage-type projects have much greater potential for social and environmental impact than do run-of-river projects. In order to ensure that the best overall value and efficiency is achieved for Nepal, in terms of the broad water, energy and food security benefits, it will be necessary to carefully select which schemes are developed with reference to these factors. The JICA Master Plan (2014) undertakes such an analysis and we recommend it forms the basis of future storage developments due to its consideration of a broad range of important factors. It will be necessary to undertake further analysis, in terms of both the impacts of climate change and any resulting changes to trade-offs involved in these developments. This will help to maximise water, energy and food security and ensure the sustainability of the broader system.

Actions to address the complex water, energy and food security needs of Nepal's population must take into account the diverse tapestry of human culture and environments which make the country unique. Success is most likely to be found through appropriate actions partnering with existing local institutions and integrating the approaches of agencies at different scales.

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

1	Action	Assess environmental and social impacts and climate change resilience of development at promising sites identified by the storage-type hydropower master plan.
	Rationale	There is a need to develop storage-type hydropower projects to meet Nepal's dry season electricity demands and it should be ensured that those developments maximise benefits in terms of water, energy and food security in the context of climate change. Previously the schemes selected for development have not provided the best value for money available, even in economic terms (e.g. Udall, 1995, Gyawali, 2006). The master plan has provided a plan for storage-type hydropower development over the next 20 years (from 2013) and recommend further studies on environmental and social impacts and planning for climate change.
	Precedent	Environmental and social impact assessments (ESIAs) are common requirements for planning hydropower developments internationally, but it is important that they are carried out to recognised standards. Himachal Pradesh has carried out a basin-wide cumulative ESIA for the Sutlej basin as a large number of developments have been planned and some built without considering the cumulative impacts (Indian Council of Forestry Research and Education, 2014). Some basins in Nepal may also benefit from this type of assessment. There is a body of knowledge building around planning infrastructure in the context of climate change internationally, on which Nepal could draw (e.g. IDS-Nepal et al., 2014; Harrison, 2002a and 2002b).
2	Action	Improve silt load monitoring/flood forecasting
	Rationale	Silt loads can be very high in Himalayan rivers, with concentrations having been measured in the Jhimruk river of almost 60,000 ppm (Pradhan, 2004). Without effective control measures or shutdown of turbines, high silt loads can cause significant damage to machinery and loss of generation efficiency in run-of-river hydropower plants. Forecasting high flows can help to prevent damage by shutting down before a flood wave arrives carrying high silt loads. Monitoring over time can also help to design sedimentation basins to remove damaging sediments before they reach turbines, to calculate the dead storage required in storage-type hydropower schemes or to design mechanisms for preventing storage reservoirs losing their capacity (e.g. check dams described by Hada, 2007).
	Precedent	Dam operators on the Sutlej River in Himachal Pradesh for example, have procedures for shutting down turbines when sediment concentrations exceed a specified level (Hurford et al., 2014a). Nepalese operators would benefit from defining and following similar procedures.
3	Action	Develop robust methodology for analysing climate change impacts on existing and new hydropower projects and incorporating in planning/adaptation decisions
	Rationale	It is very important that this analysis of climate change impacts is undertaken and used to inform development decisions. Without such analysis, returns on investment could be vulnerable to unexpected changes in flow conditions, affecting the economic efficiency of investments. Analysis of the uncertainties will allow the most robust and resilient design/adaptation options to be identified and implemented.

	Precedent	There is a body of knowledge building around this type of assessment internationally, on which Nepal could draw (e.g. IDS-Nepal et al., 2014; Harrison, 2002a and 2002b).
4	Action	Analyse trade-offs associated with water storage developments to ensure sustainable resource use and equitable sharing of benefits
	Rationale	Storage type hydropower projects are not currently a major feature of the hydropower sector in Nepal, but they are needed to address seasonal shortages of electricity and could potentially provide additional benefits such as irrigation. Owing to the position of Nepal in the headwaters of the Ganges basin, there is high potential for storage dams and their operation to impact on downstream users. Trade-offs can 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. This is especially important in the context of climate change. This Action is in line with the NAPA (MoE, 2013) project on promoting community-based adaptation through integrated management of agriculture, water, forest and biodiversity sectors.
	Precedent	Various 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).
5	Action	Further develop community level hydropower by increasing the number of schemes and their impact
	Rationale	Building on the success of the Alternative Energy Promotion Centre's (AEPC) developments of community micro-hydro, the World Bank sees further potential to increase the development benefits of these schemes by involving more professional management (Box 5). This should be carried out in addition to planned expansion of the successful programme, which may become more challenging now that the 'low hanging fruit' have been developed (Consultees, 2013). This Action is in line with the NAPA (MoE, 2013) project to empower vulnerable communities through sustainable management of water resources and clean energy supply.
	Precedent	The precedent for success in implementing community level micro-hydropower schemes has been set by AEPC, but support may be needed to increase coverage and benefits further.
6	Action	Reduce land degradation and erosion issues by working with local institutions.
	Rationale	There are significant issues with land degradation and erosion in the mountains of Nepal. These have impacts on water, energy and food security by for example, reducing the regulating capacity of soil, causing high sediment loads in rivers with hydropower schemes and reducing agricultural productivity. The complex nature of Nepalese society in terms of institutions, ethnicities and languages means addressing these problems is challenging. This Action is in line with the National Adaptation Programme of Action (NAPA) (Ministry of Environment (MoE), 2013) project on forest and ecosystem management for supporting climate-led adaptation.
	Precedent	Extensive research has been undertaken on this subject and the implementation of community forestry management practices has had a significant positive impact on the problem (Thompson et al., 2007) although it remains a major challenge. In their book "Uncertainty on a

		Himalayan Scale" Thompson et al. (2007) describe, some of the major challenges they uncovered through their systems analysis of Nepal's environment and development needs. They believe the diversity of human and natural environments in Nepal means large scale problems simply cannot be solved by a blanket approach and there is a need for in-depth understanding of local situations and work to help existing institutions recognise and drive win-win changes from within (Box 5). They believe this approach is the only one capable of creating sustainable development and tackling deforestation and erosion problems. These lessons could also inform hydropower development strategies both in Nepal and other countries.
7	Action	Research and develop payments for ecosystem services approach for Nepalese context
	Rationale	Payments for ecosystem services (PES) are intended to redress balances of benefits between disparate groups of people, or motivate changes in the behaviour of a group through payments from those who stand to benefit. There seems to be potential for such relationships to be formed in Nepal such as where the impacts of land degradation in Nepal's mountains is felt particularly strongly in the Terai region, vulnerable to flooding and sediment deposition. This Action is in line with the NAPA (MoE, 2013) project on forest and ecosystem management for supporting climate-led adaptation.
	Precedent	UNDP (2014) has demonstrated potential for PES to work. PES is necessarily context specific, so it is necessary to define causative effects and the parties exerting an influence on the provision of an ecosystem. This requires significant research and development. 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.

Table 1 Prioritised interventions for harnessing hydropower in Nepal

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. Three countries, Malawi, 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

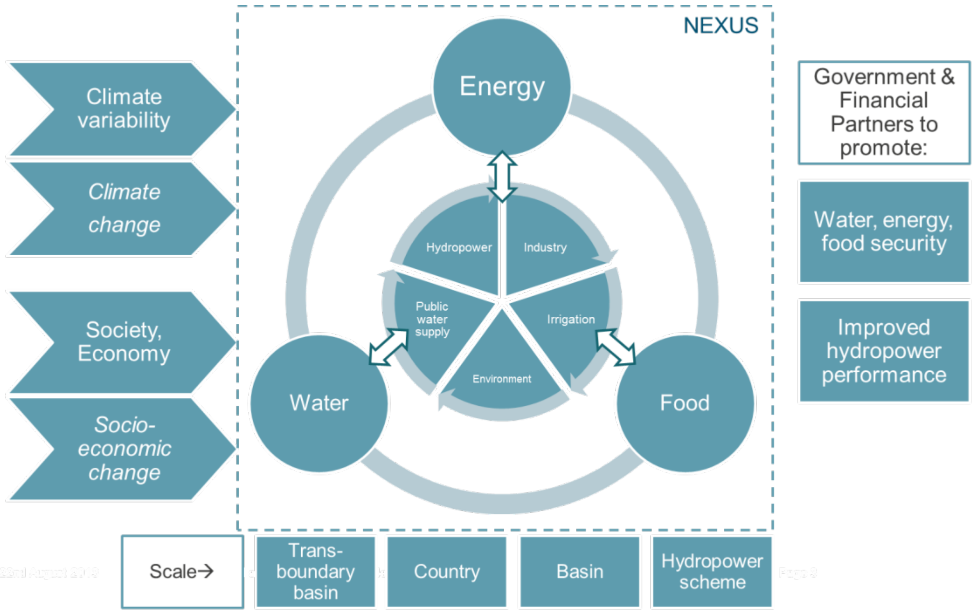
This report presents findings from the case study that focused on Nepal. It is intended to be useful to those with an interest in understanding the issues surrounding hydropower development in Nepal and/or developing programmes which promote the sustainability of existing or new hydropower schemes in 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 ADB, 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

Nepal is a landlocked country of almost 27 million people from a wide range of ethnic, linguistic, caste and religious groups (GoN and UNDP, 2013). The country has five major physiographic landscapes which extend from the east to west (Figure 2):

1. Terai plains, ranging from around 50 to 330 m and forming part of the Gangetic plain. They cover around 14% of Nepal's surface along its border with India.
2. Chure hills (or Siwalik zone) below the middle mountains, enclosing around 13% of the country in cultivated valleys and plains between around 120 to 2000 m.
3. Middle mountains, covering about 30% of the country with ridges and valleys and only a small proportion of flat land.
4. High mountains, below the Himalaya from around 2,300 to 3,000m, covering about 20% of the surface.
5. High Himalaya, above 3,000m and covering around 23% of the country's area with almost permanent snow and ice.

(WECS, 2010)

Climate varies with physiographic zone, transitioning from a hot monsoon climate on the Terai to an arctic climate in the High Himalaya.

The rural population, which comprises 83% of the total, is under-served by very poor infrastructure and in mountainous regions has nutritional requirements exceeding agricultural productivity (Food and Agriculture Organisation (FAO), 2010). The population has grown rapidly and reached the limits of the land to support more people within an agricultural society without technological improvements. This has led to food shortages in the mountains and migration to the Terai. Nepal's population have low access to electricity, with around 56% having grid or off-grid access. This figure drops to only 5% for the rural population (Bergner, 2012). However, electricity comprises only 1% of Nepal's total energy consumption, with 91% coming from traditional biomass (e.g. wood, dung, agricultural residue) and a further 8% from fossil fuels (Bergner, 2012).

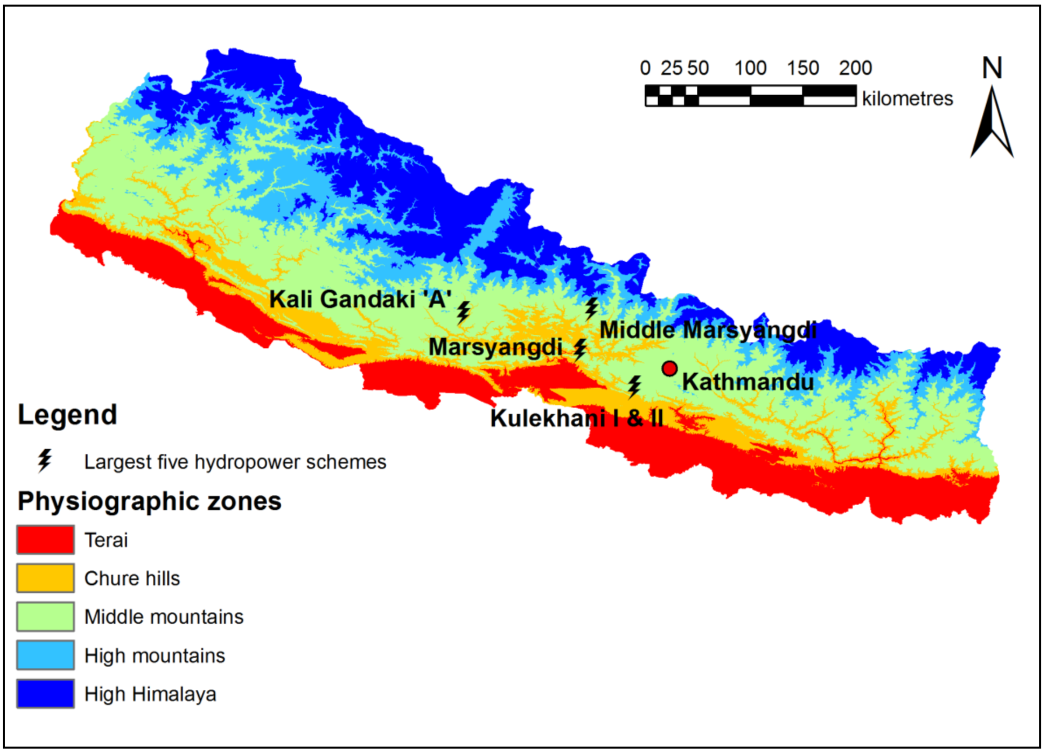
2.1.1 Recent conflict

The country suffered 10 years of armed conflict, ending in late 2006 and the political priority remains the establishment of a new constitution despite four years of failed attempts between 2008 to 2012. The country is being restructured as a Federal Democratic Republic with the aim of addressing traditional hierarchies and inequalities and decentralizing power to provincial and local levels. The precise model for federalisation is a matter of dispute (GoN and UNDP, 2013).

2.1.2 Achievement of development goals and economic growth

Nepal has made developmental progress despite the challenges of conflict and is on course to achieve many of its Millennium Development Goals (MDGs), including halving absolute poverty to 21% by 2013. At the present rate of reduction, poverty could be eradicated in the next decade (World Bank, 2013a). GDP growth was 4.6% in 2012 as compared to the South Asia average of 6.5%. Growth has been limited by a number of factors, including recovery from conflict, inadequate electricity and irrigation infrastructure, labour market rigidities and weak governance. Development is unevenly distributed among the population across gender, ethnic and geographic divides (GoN and UNDP, 2013), but the recent reduction in poverty levels has resulted from a reduction in inequality Indeed, most of the poverty reduction has been achieved in rural areas (World Bank, 2013a).

Figure 2 Map of Nepal, illustrating how physiographic zones each extend the width of the country and the location of the five largest active hydropower stations by installed capacity



Note: Zones have been classified according to elevation data alone, but in fact land of equal elevation in different areas of the country can be part of different physiographic and climatic zones

2.1.3 Impact of migration

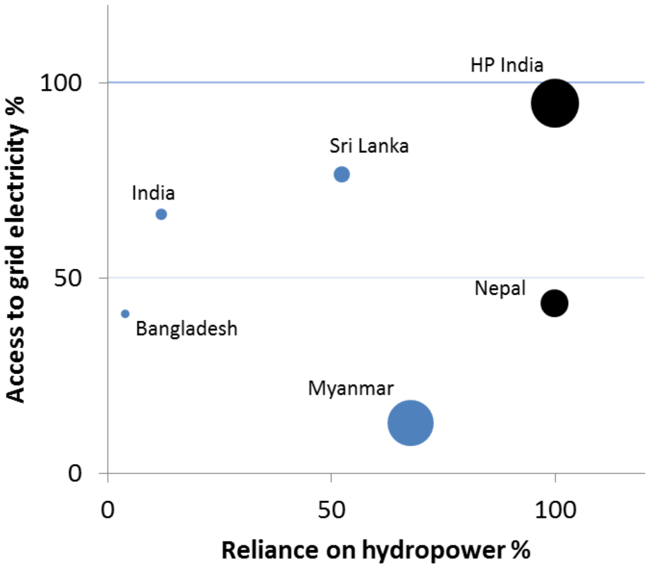
Remittances from workers abroad sending money home have played a key role in supporting Nepal's growth. Nepal is the world's largest recipient of these kinds of funds as a proportion of GDP where population is over 10 million. The proportion of households receiving remittances in the fiscal year (FY) of 2011 was 56%, and remittances comprised almost a third of those households' income. In total these remittances amounted to over a quarter of GDP in 2013 (World Bank, 2013a).

Nepal is particularly vulnerable to climate variability and climate change over the next 30 years, with poor populations living in fragile mountain ecosystems and on floodplains. Floods, droughts and landslides are all significant risks and must be managed to continue poverty reduction and protect development gains. General natural resource degradation resulting from over exploitation to meet increasing demands is leading to shortages of water and energy, impacting most severely on the poor, women and marginalised groups (GoN and UNDP, 2013).

2.2 Regional context

Nepal as a country has an electricity system with particularly high reliance on hydropower for South Asia (Figure 2). Its reliance on hydropower is matched by Himachal Pradesh state in India, although its electricity grid reaches half the proportion of the population. This puts it at a disadvantage in sharing the developmental benefits of grid electricity. Only Myanmar has higher water availability per head of the countries in the region with data available (Figure 3).

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



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

2.3 Development policy and planning

This section summarises two of the key national plans affecting hydropower development in Nepal.

2.3.1 Five year plans

Prior to the armed conflict which ended in 2006, Nepal used a system of five year plans for development. From 2007 to 2010 an interim three-year plan was developed. A national three year plan was subsequently developed covering the period 2010 to 2013 and this has recently been supplemented with an Approach Paper to the Thirteenth Plan (APTP) (GoN, 2013).

The APTP reflects on some good performances in the previous three year plan (e.g. micro-hydro and other alternative energy uptake) and aims to set Nepal on course for moving from 'least developed' to 'developing' country by 2022. It incorporates goals of eradicating poverty and improving living standards while also meeting commitments to achieve Millennium Development Goals and address fundamental issues of sustainable development, climate

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change and human rights. It further promotes a green economy. Nepal now receives Clean Development Mechanism income in relation to micro-hydro schemes registered under the mechanism (GoN, 2013).

Hydropower and energy are some of the highest priorities in the APTP along with agricultural diversification and commercialisation. The APTP recognises that rural electrification has positive contributions to make to agricultural growth targets of 4.5% and estimates growth in the electricity sector will be 8.2% through private and public hydropower projects completed and connected to the grid. There is a strong emphasis on benefits for local people throughout the APTP with expectations of public-private partnerships and creation of an investor-friendly environment for funding infrastructure development (GoN, 2013).

The APTP states a strategy of promoting development of extensive and multipurpose hydropower projects, funded by foreign investments. This is expected to generate electricity to export. In terms of impacts on local affected people, it states that shares should be allocated to local users in both small and large hydropower projects. Furthermore, there is recognition that past experiences with hydropower projects need to be incorporated into plans for new projects. Particularly relevant to this project is the statement that it will be mandatory for big hydropower projects to consider the effects of climate change and that the watersheds of big rivers will be protected (GoN, 2013).

Specific targets in the APTP are that 668MW of completed hydropower projects will have become operational and a further 584MW of projects will have been started by 2017. Addressing the access issues, 400km of new transmission lines will have been constructed, transmission losses will be reduced to 21% (from current 26%) and access will have increased to 65% of the population across 3,000 Village Development Committees (VDCs), driving per capita consumption to 140kWh (GoN, 2013).

2.3.2 National Adaptation Programme of Action (NAPA) to Climate Change

The Government of Nepal's assessment of climate change impacts on water resources proposed that impacts may be addressed by focusing on:

- Research into climate risks and adaptation responses
- The development of an optimum observation network and 'strong data-base'
- A range of research based action oriented program/projects.

Example projects included the development of sector climate change policies and guidance, reviews and refinements of engineering design criteria, stronger regulation, identification of vulnerable areas and hazard assessments for landslides, debris flow, floods and droughts (Ministry of Environment (MoE), 2010).

Under the umbrella of the United Nations Framework - Convention on Climate Change (UNFCCC) NAPA programme a number of projects have been promoted, a number of which are relevant to the performance of hydropower (*):

- Promoting community-based adaptation through integrated management of agriculture, water, forest and biodiversity sector (*)
- Building and enhancing adaptive capacity of vulnerable communities through improved system and access to services related to agricultural development
- Community-based disaster management for facilitating climate adaptation
- GLOF monitoring and disaster risk reduction (*)
- Forest and ecosystem management for supporting climate-led adaptation innovations (*)

- Adapting to climate challenges in public health
- Ecosystem management for climate adaptation (*)
- Empowering vulnerable communities through sustainable management of water resources and clean energy supply (*)
- Promoting climate smart urban settlement (*)

(Source: MoE, 2010)

2.4 Water, energy and food security

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

2.4.1 Water security

The Water and Energy Commission Secretariat (WECS) (2011) reports that 72% of the country's population has access to improved water supply although the Non-Governmental Organisation (NGO) Nepal Water for Health (NEWAH) (2014) reports a higher figure of 85% access while also citing Ministry of Physical Planning and Works (MPPW) figures that only around 53% of these supplies are believed to be functional.

Nepal has significant water resources derived from monsoon rains, snow melt and glacier melt from the Himalayas. Its rivers can be classified into three types:

1. First category – Nepal's main river systems, originating from glaciers and snow-fed lakes (Karnali, Gandaki, Koshi, and Mahakali rivers). These carry almost 80% of average annual flows.
2. Second category – rivers originating from the Mahabarat range (1,500 to 2,700m) parallel to the Himalaya (e.g. Babai, West Rapti, Bagmati, Kamala, Kankai rivers).
3. Third category – streams and rivulets originating mostly from the Chure Hills, which cause flash floods during monsoon rains but have very little or no flow during the dry season.

(WECS, 2011)

Although the Ganges as a whole is classified as moderately to highly water stressed the headwaters in Nepal have much lower levels of water stress and only around 7% of the country's water resources are abstracted for agriculture, water supply and industrial use. 96% of the abstracted water is used for agriculture. The first category rivers have been shown to have surplus flows, while second category have a deficit in the dry season. A volume of groundwater equivalent to half the abstracted surface water volume is also available for irrigation and domestic purposes (WECS, 2011).

Nepal is highly vulnerable to a number of types of catastrophic flood events, including:

- Continuous rainfall and cloudburst floods
- Glacial Lake Outburst Floods (GLOFs (Box 1))
- Landslide Dam Outburst Floods (LDOFs)
- Infrastructure failure floods

(WECS, 2011)

Box 1 Glacial Lake Outburst Flood (GLOF) impacts

The Zhangzangbo GLOF (July 11, 1981) caused substantial damage to the diversion weir of the Sun Koshi Hydropower Plant, the Friendship Bridge at the Nepal-China border, two other bridges and extensive road sections of the Arniko Highway. These amounted to a total loss of more than US$ 3 million. Similarly, the Dig Tsho GLOF (4 August 1985) in the Khumbu region (Eastern Nepal) destroyed, over a distance of 42 km, the Namche small hydroelectric plant with an estimated loss of US$ 1.5 million, 14 bridges, 30 houses, trails, farmlands and the properties of many families, including three human lives. On 3 September 1998, the Tam Pokhari GLOF in the Dudh Koshi Basin (Eastern Nepal) destroyed 6 bridges and farmlands (with an estimated loss of US$ 2 million), including two human lives.

(Source: Mool et al., 2001)

2.4.2 Energy security

Only 56% of the population has access to electricity (Samuhik Abhiyan, 2011). Most rural people depend on fuel- and fire-wood for their energy needs, although electrical grid penetration is increasing. Hydropower comprises 92% of installed grid capacity in Nepal (World Bank, 2013c) (proportion of generation is higher as alternative sources are used more in the dry season) and around 20MW of small-hydropower schemes are also serving off-grid rural communities. Demand growth is estimated as 7 to 9% annually (Independent Power Producers' Association, Nepal (IPPAN), 2014).

In rural areas, most people are using biomass (e.g. wood, dried dung, crop residues) for both heat and light, particular woods are burnt for light (Consultees, 2013). Use of dung for burning must be balanced against its use as a fertiliser, which supports agricultural productivity (WECS, 2010). This is slowly phasing out to be replaced by kerosene and mustard oil lamps. In urban areas people use electricity and Liquid Petroleum Gas (LPG) for light and heat respectively, although power outages mean candles and kerosene lamps are also needed, especially in the dry season when flows are insufficient to generate electricity to meet demand. Industry uses coal and agricultural residues for generating heat, and electricity or diesel generators for light. Energy security can therefore be said to be low across society, both urban and rural.

Nepal's best hydropower generating potential occurs during the monsoon rains and simultaneous snow melt season. This coincides with Nepal's lowest demand for electricity, meaning it has a surplus of power during this period. During the winter months when it most needs electricity, the rivers are at their lowest and long periods (12 to 18 hours per day) of load shedding is required (World Bank, 2013a). These outages are compensated by the use of diesel generators for those homes and businesses that can afford them. The total import of petroleum products is US$900 million, of which a high proportion is for electricity generation. This constitutes a high demand for foreign exchange which is very vulnerable to price variations and a drain on the economy (World Bank, 2013c). Existing hydropower plants are run at full capacity owing to the shortage of electricity, and this means implementing normal maintenance routines is a challenge. This in turn places the system at higher risk of outage and additional costs of rehabilitation (World Bank, 2013c)

Micro-hydro schemes are being used to provide off-grid access to electricity in rural areas, although in limited supply. The Alternative Energy Promotion Centre's (AEPC) activities have provided around one million people with some form of off-grid electrical system, around 40% of which is hydropower based (totalling around 20MW) and the rest solar photovoltaic

(Consultees, 2013). This is slowly reducing reliance on biomass although increased quantities will be required to replace this altogether for providing heat as well as light.

2.4.3 Food security

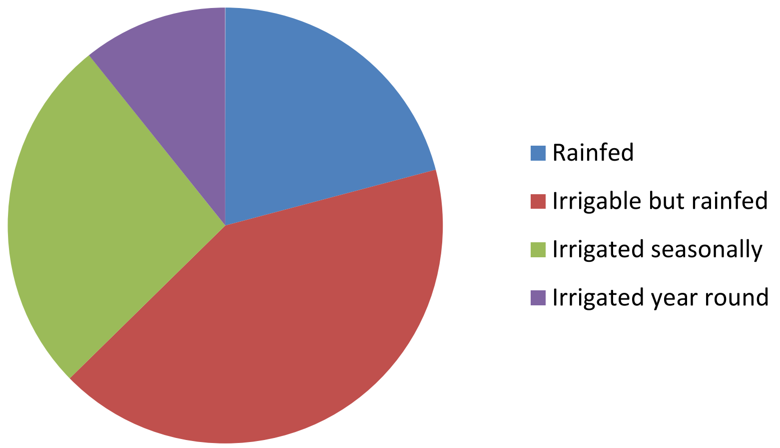
Nepal has 2.6 million ha of cultivated land of which 66% is irrigable. However, only 42% has any sort of irrigation and only 17% has year round irrigation (Figure 4) (WECS, 2011). Nepal's economy is predominantly agricultural and the sector contributes 40% of GDP, employing two-thirds of the population. Until 1990 the country was self-sufficient in food grain production, but floods, droughts, extreme rainfall and other climatic events have since led to significant shortfalls. Both rainfed and irrigated areas have been negatively affected and productivity is widely acknowledged to be declining (WECS, 2011; GoN and UNDP, 2013). In 2008, the World Food Programme and Nepal Development Research Institute (2008) estimated that the poorest rural families were spending around 78 % of household income on buying food. This would make them highly vulnerable to changes in food prices.

The most recent food security bulletin available from the World Food Programme (WFP) (2013) is for the period July-November 2013, and states:

- Most parts of the country were classified as minimally food insecure, a situation where households can secure food and non-food needs without changing livelihood strategies.
- Most parts of the country have experienced an improvement in the food security situation this period, particularly in the Karnali, Far-Western Hill and Mountain, Rapti-Bheri Hills, and Eastern Hill and Mountain clusters.
- Key factors contributing to the improvement include sufficient household food stocks, daily wages, remittances, and income from vegetables, fruits and Non-Timber Forest Products (NTFPs). Most of the districts in the Mid and Far Western Development Regions also harvested the main season paddy crop, thereby increasing food stocks.

(Source: WFP, 2013)

Figure 4 Proportions of irrigated, irrigable and rainfed agricultural land



(Source: WECS, 2011)

There are concerns regarding water rights, as the impacts of hydropower schemes on riparian water users (mostly irrigators) are not being considered (Consultees, 2013). Local level agreements on use were developed over centuries and cannot simply be replaced. Depletion of resources through storage behind upstream hydropower dams could place these systems under severe stress. Irrigation and water supplies are vital to climate change adaptation in a largely agricultural economy (Consultees, 2013).

2.5 Nepal's power sector

The Nepal Electricity Authority (NEA) is the vertically-integrated public utility responsible for the generation, transmission and distribution of electricity in Nepal. It is in the process of unbundling and privatisation, with separate entities envisaged for transmission, distribution and generation (WECS, 2010) in order to increase competition and therefore efficiency (Shrestha, 2009). NEA owns 473MW of generating capacity connected to the grid and a further 4.5MW of mainly small hydropower plants off-grid. This represents 75% of the country's hydropower capacity. The remaining 25% (158MW) are owned by Independent power producers (IPPs), selling electricity to NEA. For domestic consumption, the NEA is the sole buyer of the major part of power generated by the IPPs (WECS, 2010).

Average annual consumption of electricity per head in Nepal is around 70 kWh, less than one-tenth that in India (World Bank, 2013c). Access to electricity, both on and off-grid, is 90% for the urban and 30% for the rural population. Supply has not been able to keep up with recent rapid growth in demand, leading to average 12 to 18 hours of load shedding per day in winter (World Bank, 2013c). Nepal imports US$900 million of petroleum products annually, a high proportion of which is to fuel captive thermal power generation plants (Consultees, 2013; Shrestha, 2014). In addition, arrangements are in place to import 50MW from India (WECS, 2010), although in FY2012/13 power imported from India amounted to 173 MW (NEA, 2013).

2.5.1 The role of hydropower

Much of Nepal is mountainous and rich in water, and has a theoretical hydropower potential of 83,000MW, approximately half of which (42,000MW) is considered to be economically viable. Of this economically viable potential, 55% lies on only two rivers, the Karnali and Mahakali (WECS, 2010). Only 1.5% of this (636MW) is actually being exploited, mainly by relatively small-scale plants. Only one plant (Kali Gandaki) exceeds 100 MW. Kali Gandaki (144 MW), currently being rehabilitated with World Bank finance, provides 40% of the electricity for the national grid, and 25% of Nepal's entire power production (World Bank, 2013c). This makes the entire system highly reliant on the plant and vulnerable to its failure. Table 2 shows the largest five hydropower stations by installed capacity, these are also shown in Figure 2.

Hydropower station	Installed capacity (MW)	Scheme type
Kali Gandaki 'A'	144	Run of river
Middle Marsyangdi	70	Run of river
Marsyangdi	69	Run of river
Kulekhani I	60	Storage
Kulekhani II	32	Storage

Table 2 Five largest active hydropower stations in Nepal and their installed capacities

Nepal's hydropower sector has a diverse structure of medium (defined in Nepal as 300 MW or less), small (25MW or less) and micro hydro plants (100KW or less). Of the installed capacity, 28% is from small plants and 72% from medium sized plants; 28% is under private ownership; and 97% is grid-connected (NEA, 2010).

Nepal's current hydropower capacity connected to the national grid is 660 MW, out of a total generating capacity of 714 MW[1] (World Bank 2013c). It has the following defining features:

- Capacity is predominantly run-of-river, out of 28 hydropower plants in operation (in May 2011) only one (Kulekhani) involved storage. Run-of-river plants are affected by hydrological variability. 80% of rainfall occurs in the four monsoon months, coinciding with seasonal snow melt.
- During winter the available water can only support 35% of the hydropower capacity.
- Hydropower production is highest in summer, when demand is lowest, and lowest in winter, when it is most needed. The electricity surplus in summer cannot be stored, nor used for domestic consumption, nor exported because of the lack of a transmission network to India.
- Storing water during the wet season and producing power in the dry season is crucial for the viability of the power sector and for meeting the country's needs, but there are currently no major storage projects in operation.
- Despite the planned addition of 1,375 MW of hydropower capacity in 2017 a deficit of 900 MW in that year is still likely.

(Source: World Bank, 2013)

2.5.2 Private hydropower projects

Since 1992 the hydropower sector has been open to private developers. In its current form, the relevant policy provides a comprehensive array of features and incentives, based mainly on the Build, Own, Operate, Transfer (BOOT) concession model, or close variants. A number of small (1 to 10MW) private schemes have been implemented, totalling 148 MW (in May 2011), plus several larger ones (Khimti 60 MW, Bhotekoshi 34 MW, Kabeli 30 MW). In addition, the publicly owned Butwal Power Co was privatised in 2003 and is currently operating several projects, and is developing a few more (Acharya, 2011).

There are three licencing processes in Nepal:

- Apply for a licence on basis of a desk study.
- Feasibility studies carried out by Government then awarded to Independent Power Producer (IPP).
- Competitive bidding, e.g. Upper Karnali.

The context for the Government's efforts to engage the private sector in developing hydropower is the country's severe energy crisis and the poor financial status of the Nepal Electricity Authority (World Bank, 2014). However, the obstacles to rapid change in this situation are daunting, and have been described in the following terms:

"Generation capacity development is facing significant barriers, because of the long-lasting political instability, the lack of institutional capacity of the policy and regulatory institutions, the remoteness and difficulty of the terrain, the lack of necessary infrastructure (roads and transmission lines), the speculative outlook of many of the [private] license holders, weak financial capacity of the Nepal Electricity Authority, and the lack of an alternative market for the electricity, especially in view of the economies of scale required by the large hydropower schemes." (World Bank, 2013c)

[1] These figures differ from those reported by WECS (2010), most likely due to recent capacity addition

These overall problems are echoed by the specific challenges faced by private entrants into the hydropower sector, which include:

- Physical site-specific features, including difficult geology, landslide risk, high rate of sedimentation, strong and very seasonal discharges, active seismic conditions, limited accessibility to machinery, steep slopes, etc.
- Lack of transmission lines: scattered projects, few concentrated demand points.
- Environmental and social issues, including resettlement (although this is mainly a problem for stored water schemes).
- Financial and economic risks: high initial cost, local banks lacking lending capacity and with no risk appetite, purchasing rate by grid (PPA) not very attractive, no official fund for hydropower and an absence of Government guarantees for foreign borrowing.

(Source: Acharya, 2011)

It also seems that many private developers, particularly locals, have little experience or financial capacity to develop productive hydropower concessions, and some are attracted into the sector for purely speculative reasons with no intention of developing generating capacity (Consultees, 2013).

2.5.3 Expansion of the hydropower sector

In its 2011 water resources and climate change study Water and Energy Commission Secretariat (WECS) reports that:

The targeted development plan for hydropower by 2017 includes:

- Up to 2,035 MW hydropower electricity is developed to meet the projected domestic demand, excluding export,
- 50% of the households are supplied by Integrated Nepal Power System (INPS) electricity, 12% by isolated (micro and small) hydropower systems and 3% by alternative energy,
- Annual per capita electricity consumption of 160 kWh is achieved; and
- NEA is corporatized.

And by 2027:

- Up to 4,000 MW of hydropower is developed to meet the projected domestic demand at base case scenario, excluding export.
- 75% of the households are supplied with INPS electricity, 20% by isolated (micro and small) hydro systems and 5% by alternative energy.
- Annual per capita electricity consumption of over 400 kWh is achieved.
- Substantial amounts of electricity exported to earn national revenue.
- NEA unbundled (split into generation, transmission and distribution utilities) and privatized.

(Source: WECS, 2011)

The 6,000 MW of hydropower projects currently being planned are likely to cost US$12 billion, and a further $5 billion would be needed for transmission-related infrastructure. Private finance for these sums is unlikely, since the local financial market is small, technical and non-technical system losses are high (26%), the rate of revenue collection is low and operating costs are increasing. Funding packages are likely to be configured around loans from the International Financing Institutions such as the World Bank and Asian Development Bank against a sovereign guarantee, plus other project finance from local and international commercial banks and export credit agencies, including state-owned lenders such as the Chinese Export-Import Bank. In view of these financial constraints, applying particularly to new projects, it would be sensible to give priority to maintaining and rehabilitating existing infrastructure, functions which are currently neglected (World Bank, 2013c).

Gippner (2013) reports the difficult situation in Nepal and other least developed countries (LDCs) for obtaining Clean Development Mechanism (CDM) funding under the Kyoto Protocol. CDM funding depends on the concept of 'additionality', i.e. that a project will reduce emissions from power stations which would otherwise not be economical to replace with cleaner technology. As Nepal generates almost all its grid electricity from hydropower, it is difficult to establish a baseline for greenhouse gas emissions from the power sector. However, companies and wealthier individuals are running generators to supplement the grid electricity during periods of load shedding. This requires the import of large quantities of fossil fuel (US $880 million in FY 2010/11) which drains the economy of foreign exchange and leads to a lot of emissions which cannot be used as the target of emissions reductions for CDM funding applications. It is suggested that a change in the CDM application process be made for LDCs to allow them to take overall energy consumption into consideration for baseline calculations. Nepal is arguing for such a change, but this is an ongoing debate among many others relating to the workings of the CDM (Chokkalingam, 2013)

Transmission lines

Transmission lines are lacking, land owners are either not allowing the towers to be built or demanding a high price. In the last interim plan, 450 km of high tension transmission lines were planned as Public Private Partnerships but only 750 m actually achieved (Consultees, 2013). The policy is to offer more money to land owners to buy their land but many projects in the pipeline are delayed by lack of transmission lines, independent producers are responsible for connecting their project to the grid. At present the grid also has insufficient capacity to receive the power (Nepal Electricity Authority (NEA), 2013).

Rural electrification is particularly needed in the Terai plains where local micro-hydropower schemes are not possible because of a lack of hydraulic head. This region could benefit from prioritised grid expansion which would also provide additional demand for the Nepalese grid to meet. Negative impacts on this downstream region or others in India and Bangladesh from upstream land and water management could be mitigated through the use of payments for ecosystem services. Initial trials of such schemes have demonstrated that this could work in Nepal (UNDP, 2014).

Development planning

In the Nepalese Government, the Ministry of Energy has responsibility for sector policy formation, regulation and oversight of development and implementation of projects. It also issues licences for generation, transmission and distribution, in conjunction with the Department of Electricity Development. Since 2011 a new National Investment Board (NIB) has been created as a one-stop-shop for large projects of national priority including major hydropower projects (>500 MW) . The NIB is actively developing five such projects.
The focus in the sector has been on small and medium scale projects but all political parties are promising large hydropower schemes to address the shortfall in generation (Consultees, 2013).

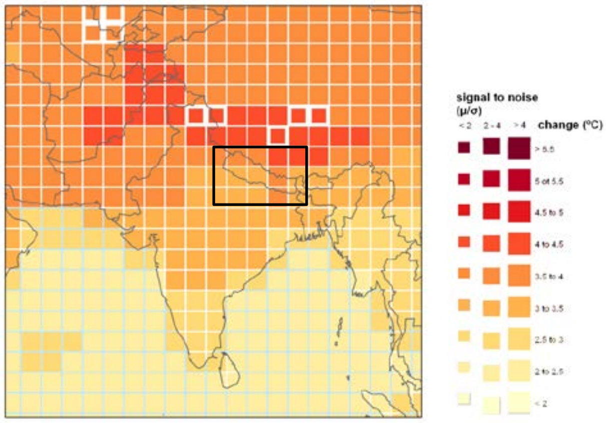
2.6 Climate Change impacts and adaptation

2.6.1 Projected changes

Projections of climate change in Nepal indicate significant warming by the end of the century but there is less certainty of the magnitude and even direction of changes in annual precipitation. The lack of agreement between climate models on precipitation is due to difficulties modelling the monsoon and complex topography. Recent Met Office studies suggest an increase in annual average precipitation (Figure 5) but with very little agreement between models and other studies have suggested ensemble mean decreases in precipitation (Stenek et al., 2011 using data from McSweeney, 2008).

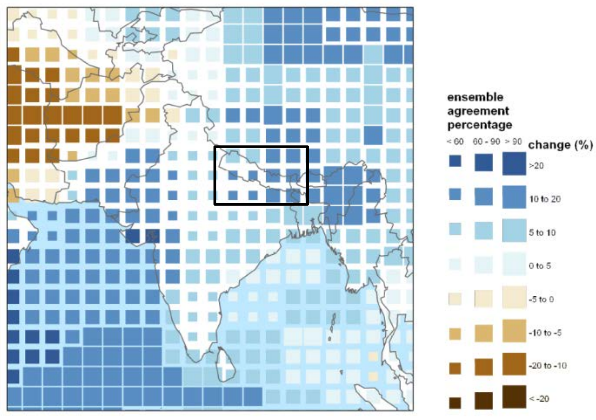
Figure 5 Climate change projections for Nepal shown with a black box (Met Office, 2011)

Temperature change °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.

2.6.2 Impacts and opportunities

Glacier melt and faster snow melt

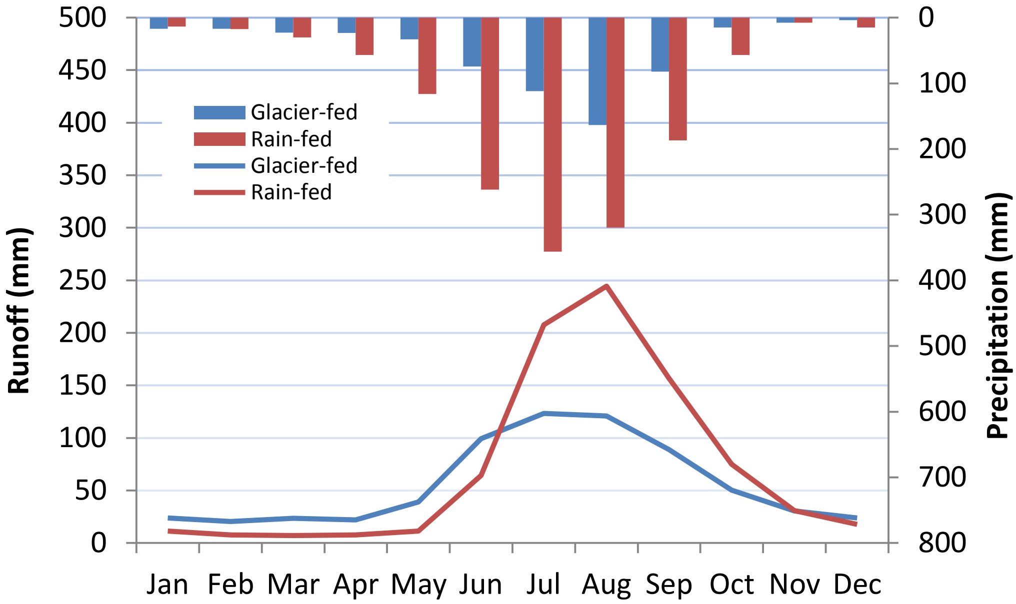
Warmer temperatures are likely to lead to faster rates of glacier melt and snow melt, although the combined impacts of temperature and precipitation is complex and some melting may be balanced by increases in snow fall. There is strong evidence of a declining glacier mass balance in Nepal, an increased contribution of snow melt in runoff and increase in the volume of glacial lakes and associated flood risks (IDS-Nepal et al., 2014).

Changing seasonal flows

It is likely that climate change will increase the average annual flows, the year to year variation of flows and, perhaps more significantly, the seasonal flow regime, which is important with respect to the reliability of run-of-river hydropower and irrigation schemes. Currently snow and glacier fed basins offer storage and the relatively slow release of resources but as the melt-water contribution decline flows will be less reliable in the December to April period.

Figure 6 shows the different characteristic responses of rain-fed versus glacier-fed rivers in Nepal. There is a greater variability of flows and arguably a higher likelihood of floods and droughts in the rain-fed Bagmati River than in the glacier-fed Langtang Khola. It is likely that the response of glacier-fed rivers will change to become more like rain-fed rivers as warming increases rates of glacier and snow-melt (Chaulagain, 2006).

Figure 6 Comparison of monthly rainfall hyetographs (top) and-runoff hydrographs (bottom) for the rain-fed Bagmati and glacier-fed Langtang river basins



(Source: Chaulagain, 2006)

Increased flood risk

The Government of Nepal's assessment of climate and water resources suggested that increased variability has already led to more floods and droughts (IDS-Nepal et al.,, 2014. The numbers of flood events have increased (GoN, 2011) and there is considerable concern on risks to life of Glacial Lake Outburst Floods (GLOFs) and other floods caused by cloud bursts, landslides that can displace water from reservoirs or damage dam structures and potential dam spillway failure.

Risks for hydropower

Changing seasonal flows, increased flood risk, landslides, elevated silt loads in the monsoon season and increased demand for upstream irrigation may all impact on the performance of hydropower schemes. Research by WWF showed none of the Environmental Impact Assessments (EIAs) for dams were taking climate change into account (Consultees, 2013).

The International Finance Corporation (IFC) completed a climate risk assessment of the operational Khimti 1 hydropower scheme. This is a 60 MW run-of-river hydropower facility, generating 350 GWh of electricity per year. The study identified a range of potential climate risks, including GLOFs, changes in seasonal flow, extreme floods and landslides and proposed adaptation options. For the most part these measures are focused on building the capacity of organisations to adapt their activities, rather than delivering adaptation itself (Stenek et al., 2011).

The glaciers in the Nepal Himalaya have been retreating so fast in recent decades that there will be a 6% decrease in hydropower potential by 2100 even without any further warming. Assuming that 32% of the total hydropower potential in Nepal will be sourced from snowmelt and the rest from rainwater, the theoretical hydropower potential of Nepal will rise with a warming of 0.06°C/year by 5.7% by the year 2030. However, by the end of this century, it will decrease by 28% (Chaulagain, 2006).

IDS-Nepal et al. (2014) carried out some modelling of climate change impacts on hydropower generation, but found it very challenging to project daily river flows, owing to the complex nature of Nepal's climate, the uncertainty in rainfall projected by climate models and uncertainty from glacial meltwater. Because of the large differences projected, their analysis compared two different model outputs. One model simulation used lower dry season flows than observed historically and this led to a need for increased generating capacity of 2,800 MW (by 2050), with an increased cost above baseline of US$2.6 billion (present value). The second model simulation used higher flows in the wet and dry seasons, leading to increased energy availability from climate change. This scenario would provide a benefit of reduced generation capacity expansion costs of US$170 million. The study highlights the uncertainty on exact impacts, but the high vulnerability of the hydropower sector to climate change (IDS-Nepal et al., 2014).

Impact on agriculture

Changes in winter snowfall could affect the availability of meltwater for irrigation during the growing season. Increased melt rates or an earlier melt season could mean that even with high levels of winter snowfall, water is not available at the right time. While high winter snowfall is beneficial from a water resources perspective, it can threaten the lives of both people and livestock.

Timing of winter snowfall can impact on crop growing seasons if it intrudes too far into spring. This has been observed in recent years and is believed to have resulted in the re-emergence of pests and diseases. Changes in cropping patterns could lead to conflict with the tourist season, leading to a reduction in cash income.

Rapid melting of snow and ice and the debris associated with such flows could cause damage to agricultural fields, forests and pastures. However, the associated warming, trends of which have already been observed, could present an opportunity for new crops to be grown.

Impact on livestock

Reduced water availability resulting from winter snowfall reduction could lead to less pasture being available for livestock in the summer months. This may force adaptation including reduced herd sizes, and associated reductions in income from what is an important component of rural livelihoods. The integrated nature of the crop production system means that less livestock would lower fertility of agricultural land through reduced manure inputs. Reduced herd numbers could include transportation animals which are still a backbone of the trekking industry and source of income for some.

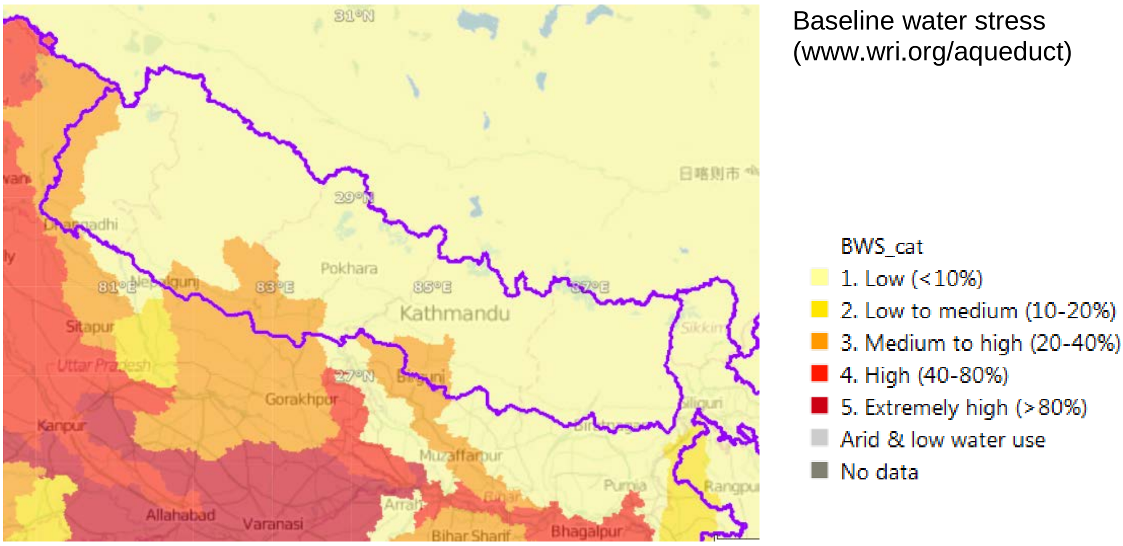
Impact on ecosystems

WWF has also modelled how vegetation will change in Nepal due to climate change. This showed big changes in forest cover types by 2080 and river valleys acting as refuges for wildlife and corridors for them to migrate northwards. Further pressure on rivers for development could hamper these functions – it is not practical to put fish passes in the largest dams (WWF, 2013).

2.7 The water balance

Nepal has significant water resources derived from monsoon rains, snow melt and glacier melt from the Himalayas. Although the Ganges as a whole is classified as moderately to highly water stressed the headwaters in Nepal have much lower levels of water stress and only around 8% of the country’s water resources are abstracted for agriculture, water supply and industrial use (Figure 7).

Figure 7 Baseline water stress for Nepal (outlined in purple)



The hydrological seasons in Nepal can be categorized into three seasons; (a) a dry pre-monsoon season (March to May) with almost no rain, (b) a rainy monsoon season (June-September) and (c) post-monsoon season (October to February) with little rain. The monsoon brings about 80% of the total rainfall. The eastern part of the country experiences more rain than the western part (GoN, 2011).

In both spring and autumn, Nepal can be affected by the tail of cyclones generated over the Indian Ocean and which reach the country through the Bay of Bengal. These can give several days of heavy rain. The mean annual precipitation ranges from more than 6,000 mm along the southern slopes of the Annapurna Range in central Nepal to less than 250 mm in the north-central portion near the Tibetan plateau. Amounts varying between 1,500 and 2,500 mm predominate over most of the country. (GoN, 2011).

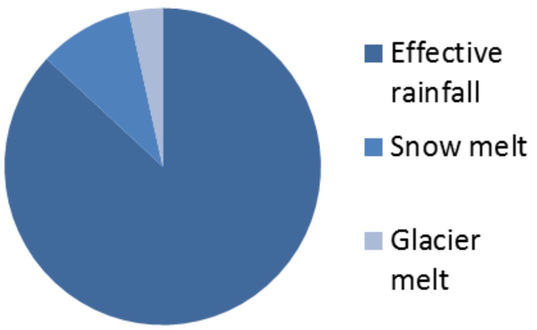
There are four major river basins and five medium sized basins in Nepal. Estimated mean annual runoffs are shown in Table 3. It is seen that around 80% of the average flow in the country is available in the four major basins, 9% in the medium basins and 13% in the numerous small southern rivers of the Terai (GoN, 2011).

No.	River	River length	Drainage area (km²)		Estimated mean annual runoff (m³/s)	
			Total	Nepal	Total	Nepal
*1	Mahakali	223	15,260	5,410	698	247
*2	Karnali (West Nepal)	507	44,000	41,890	1441	1371
3	Babai	190	3,400	3400	103	103
4	West Rapti	257	6,500	6,500	224	224
*5	Narayani (Central Nepal)	332	34,960	28090	1753	1409
6	Bagmati	163	3,700	3,700	178	178
*7	Sapta Koshi (East Nepal)	513	60,400	31940	1658	878
8	Kankai	108	1330	1330	68	68
9	Other rivers		24921	24921	1001	1001
	Total		194,471	147,181	7125	5479

Table 3 Major(*) and medium sized river basins in Nepal

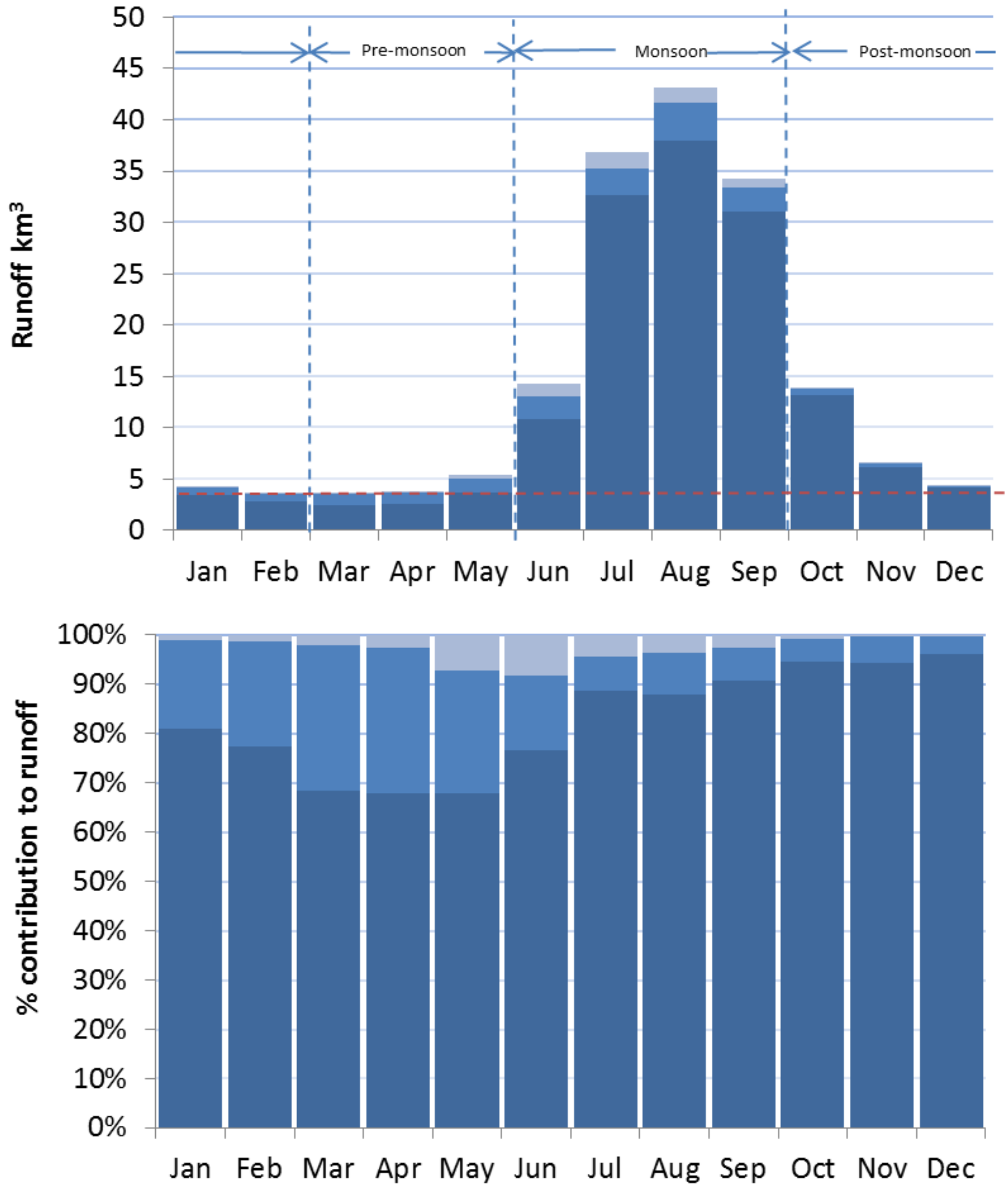
An average national monthly water balance is shown in Figure 8 and the importance of the monsoon rains is clear with about 74 % of the total annual surface runoff occurring in the four months of June to September. The dry season comprises both the pre- and post-monsoon periods. The glacier contribution to the total stream flow of the basins in which they are situated varies widely among basins, from approximately 30% in the Budhi Gandaki basin to approximately 2% in the Likhu Khola Basin. The large seasonal and year to year variation is significant as run-of-river hydropower schemes and other water infrastructure that needs to be used all year round are typically designed for low flows (indicated by the red dashed line in Figure 8). Therefore the significant volumes of monsoon rains in major river basins are untapped unless there is significant storage.

Figure 8 Estimated long term water balance of Nepal (assuming no change in storage)



Notes: These estimates are based on long term observations based on Chaulagain (2006).

Year to year variability is high and that the balance between rainfall, snow and glacier melt will vary considerably at higher elevations with snow and glacier melt being more significant.



2.8 Section summary

This section has shown the following main points:

- Nepal has recently emerged from conflict and instability which has not prevented the country achieving economic growth and redistribution of wealth, but which has affected investor confidence.
- Remittances from migrant workers overseas is having an impact on development, being valued at over a quarter of GDP in 2013 (World Bank, 2013c).
- Climate change is on the agenda in Nepal, which has produced a National Adaptation Programme of Action. It has not been incorporated in the NEA and JICA (2014) Master plan on storage-type hydropower schemes; however, NEA and JICA recommended this for individual schemes' feasibility studies.
- Water security is relatively high in terms of resource availability and Nepal is only utilising around 8% of the water available in its rivers. Flood risks are high; however,

and glacial lake outburst floods (GLOFs) are a particular concern with increased glacier melt.

- Energy security is low, with only 56% of the population having access to electricity which comprises only 1% of total energy use. 91% of overall energy use comes from limited biomass resources.
- Food security has declined since 1990 when the country was self-sufficient in food grain production. Population growth has outstripped progress in agricultural productivity, particularly in the mountains putting strain on land and other natural resources and causing migration to the Terai.
- Hydropower is the obvious choice for significantly increasing grid electricity generation in the country owing to the abundant potential and the prohibitive costs of importing fossil fuels.
- The pattern of river flow variability in Nepal means that increased storage infrastructure is needed to spread availability of water for hydropower generation throughout the year. To date the majority run-of-river schemes have only been able to meet demand during the high flow season.

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 Nepal. 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

Figure 9 presents a simplified system diagram for Nepal, illustrating some of the interactions which can lead to water, energy and food insecurity. It is important to acknowledge that there are deeper underlying interactions between water, energy and food security which might dictate for example that energy security impacts on food security through ability to pump irrigation water. Where the diagram shows a decrease in energy security, water and food security can also be considered to be affected to some extent. Key issues are described in more detail in subsequent subsections.

3.1.1 Hydropower system

The hydropower sector in Nepal can be divided between two main types of system the impacts of which differ with respect to water, energy and food security:

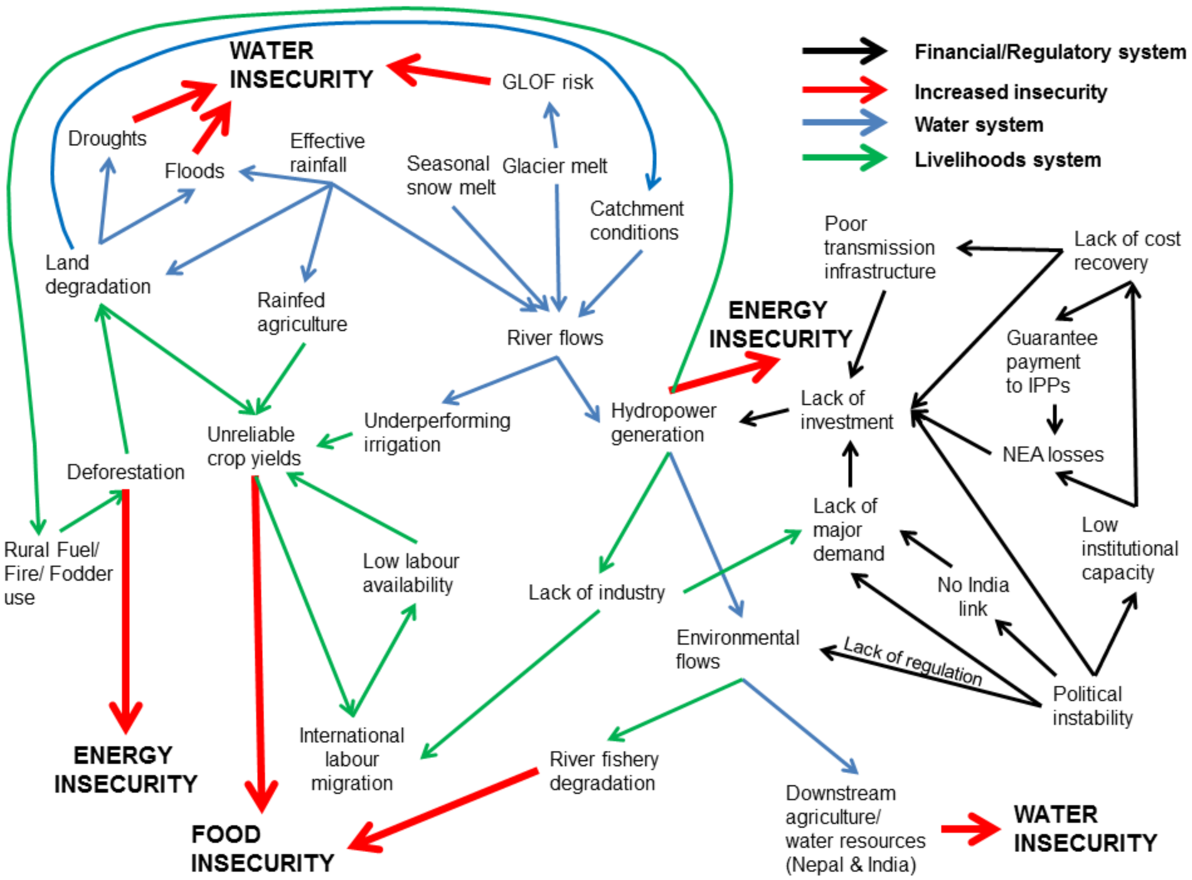
1. Owned and managed by communities as off-grid local solutions

The small scale local solutions provide benefits directly to the communities involved while having limited negative environmental impacts. In addition to the domestic energy security improvements, food security can also be enhanced by increased and diversified economic activity in the area served. Women are primary beneficiaries of domestic energy supplies as their time for collecting fuel wood can be reduced by electrification. Similarly, environmental benefits are to be expected from a reduced demand on wood. There is a need to increase the amounts of electricity produced in order to further decrease reliance on wood for cooking, only 9% of households in a survey had been able to use an electric rice cooker (Samuhik Abhiyan, 2011).

2. Private or government owned schemes connected to the grid

Large hydropower schemes are much more strongly affected by the lack of a significant market to assure large loan providers of a return on their investment. These large schemes are also vulnerable to changing flow conditions and particularly catchment degradation due to erosion. This constitutes another negative feedback in the system, whereby if the demands on the environment for fuel wood cannot be reduced by increased access to alternatives such as hydropower, then the performance of hydropower systems will be further reduced or their operating costs will increase through outages and damage from silt and floods.

Figure 9 Simplified system diagram of the contributing factors to water, energy and food insecurity in Nepal and downstream



3.1.2 Water system

Hydrology

The water system in Nepal depends to some extent on complex mountain hydrological processes but to a greater extent the monsoon. In the mountains 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 mountain environment in terms of runoff generation. In Nepal, the snowmelt season coincides with the monsoon to give a single flow peak. Much of the country is below the seasonal snowline however, so rainfall has a greater influence on river flows.

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. This does not seem to be happening in Nepal, and improved sediment monitoring and control is part of the World Bank's rehabilitation project for Kali Gandaki 'A' (World Bank 2013c).

Erosion of the land leads to its degradation, which influences hydrological processes. Degraded land tends to allow less water to infiltrate, leading to less regulation of runoff. Erosion of agricultural land leads to loss of nutrients, soil structure and soil water stores, which in turn reduce productivity. Erosion is difficult to control in Nepal, especially remote, inaccessible and unforested areas.

Forest and vegetation cover are recognised as providing protection against erosion. The continuing demand of the rural population for fuel- and fire-wood, livestock fodder and land for agricultural conversion have led to deforestation and associated land degradation. Growing populations and increasing demands for agricultural land have also contributed to the clearing of forest land. Where forest areas become degraded, sustainability of the supply of essential forest products also declines. Community forest management, which now covers 25% of national forests and involves 40% of the population (WECS, 2010), has had some success in reversing these trends. Ghimire et al. (2013) conclude that ongoing management of reforested areas is necessary to balance watershed functions with product abstraction. Reforestation alone will not necessarily restore hydrological function.

Environmental flows

Hydropower is not well regulated for its environmental flow releases at present and there is evidence that environmental flow standards downstream of dams are not being adhered to or monitored for compliance. This is leading to the drying out of rivers, potentially devastating local ecology (Consultees, 2013). Hydropower schemes have also stopped migration of fish along the rivers, so removing a source of livelihood and sustenance for local people (Consultees, 2013). Environmental flow levels are not currently based on scientific evidence. If a more scientific approach was taken to defining environmental flows specific to individual rivers then negative impacts of hydropower schemes on the aquatic environment could be reduced, even if this required trade-offs with hydropower generation.

Future hydropower development may need to be more integrated with local needs including possible multipurpose use of dams rather than purely hydropower use. Government 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, they could certainly help with the timing of supply and demand for electricity. Additionally, catchment management may be able to provide some increased regulation through storage in soils.

Water sources

River water is utilised for both hydropower generation and irrigation within Nepal and irrigation and water supply downstream in India and Bangladesh. Various sizes of water bodies support a range of sizes of hydropower and irrigation schemes. Lifting with pumps either from rivers or boreholes 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. This study did not find any information suggesting innovative ways of sourcing water are being promoted in Nepal, such as rainwater harvesting.

Climate variability currently presents a large source of insecurity in terms of agricultural production. Increased glacier melt is likely leading to increased higher than expected flows but in Nepal benefits are not being realised for hydropower owing to the asynchronous peaks of generation potential and demand. As glacier melt coincides with monsoon rainfall, it is possible that the increased melt signal is lost in variations of monsoon rainfall intensity. No river flow data were available to analyse this. Increased glacier melt is not sustainable however, and as glacierised extent decreases further then reliability of water resources supply will decline to some extent. This will affect hydropower generation in the basin (if a demand materialises for monsoon season electricity) 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 Nepal and downstream in India and Bangladesh. 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.

3.1.3 Rural livelihoods system

Agriculture

Agricultural productivity is low in Nepal and three million Nepalese are now working overseas to support their families because there is no industry in Nepal (Consultees, 2013). This is primarily a result of the lack of reliable power supply. Land degradation largely through erosion resulting from rainfall runoff continues to reduce soil productivity. Migration of labour overseas impacts on the management of farm land, further constraining productivity.

It is hoped that improved irrigation schemes could increase agricultural productivity, but there are additional needs of improved agricultural extension services and supplies of fertilisers which must support improved irrigation (ADB, 2013). Irrigation schemes themselves require energy for pumping water and with such restricted availability this is difficult to achieve, especially on higher ground.

Lack of electricity supply means farmers cannot preserve their harvests by cold storage, allowing them to sell when the market price is high. Instead they have to sell when the market price is low at the end of the harvest and buy at other times when the price is high. Otherwise they risk losing some or all of the crop due to spoiling. Another example impact of low electricity availability is that tea grown in Nepal is exported to India for processing, then sold as Darjeeling (Consultees, 2013). Tea processing is energy intense but the profit margin for processed tea is much higher than for raw leaves. Tea is one of the most profitable commodities of the Indian export market.

Forestry

Forested land constitutes around 40% of Nepal (GoN, 2013). Increased quantity/quality of forest cover is likely to provide better regulation of the water cycle, which in turn can have positive benefits for maintaining perennial streams for irrigation, water supply and micro-hydro generation.

Fisheries

Hydropower schemes have blocked migratory routes for fish and in places the low environmental flow releases from dams are insufficient to support healthy fish populations. Nepal currently imports fish from India, although genuine environmental flows in rivers could support native fisheries.

3.1.4 Regulatory/political system

The major factor influencing the regulatory system depicted in Figure 9 is political instability. It is difficult to summarise the broad range of negative impacts this has had on Nepal.

Although development has managed to continue despite this, it is highly likely the situation would have been different had stability prevailed.

The political system has failed to monitor and enforce environmental flows, leading to degradation of fisheries and other aspects of the aquatic ecosystem downstream of some hydropower dams.

Lack of political action has failed to break the negative feedback between lack of electricity and lack of investment in industry, so this has largely maintained the status quo. The lack of institutional capacity, particularly of the NEA, is also likely to be caused to some degree by a lack of stability of purpose and governance which could otherwise have made the necessary reforms. NEA must find a way to recover its full costs and start to invest strategically in both generation and transmission capacity.

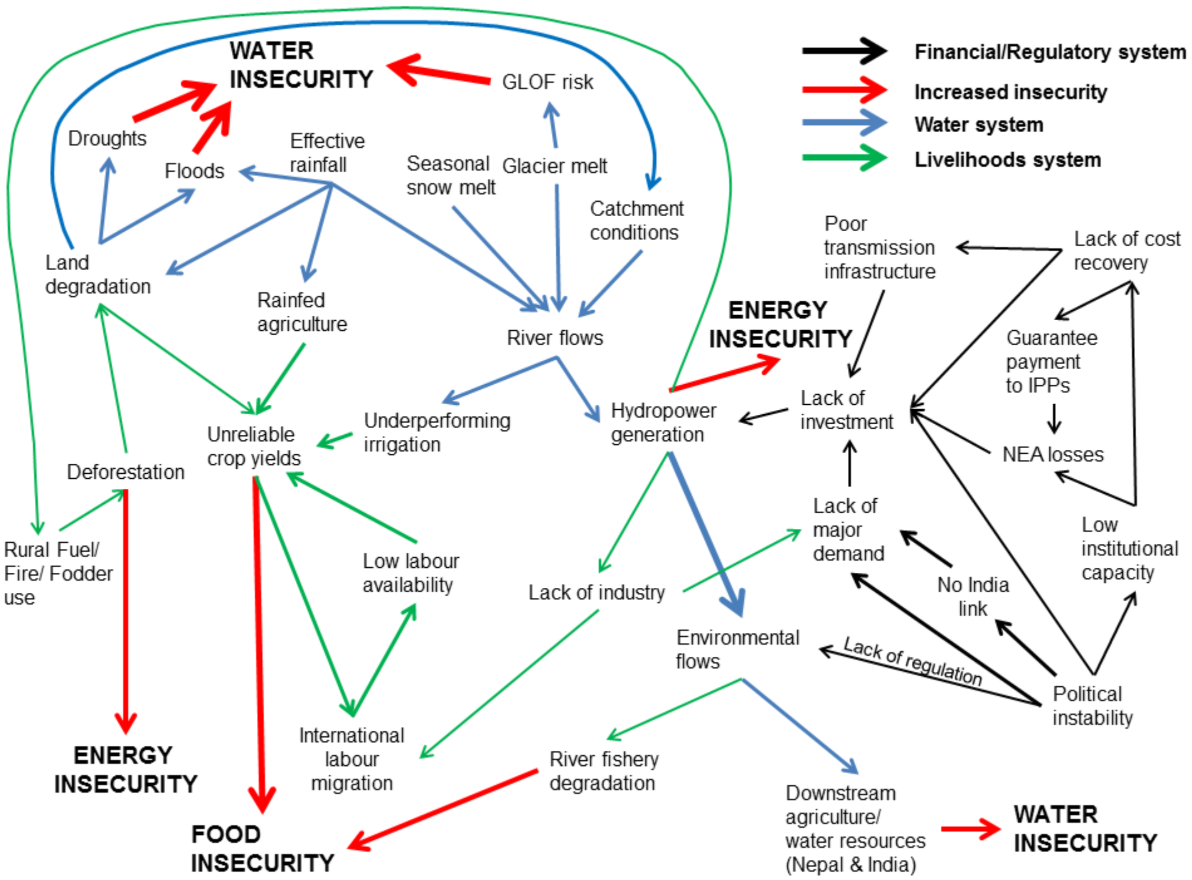
3.2 Future forcing of the system

The system described above is dynamic and subject to many influences both inside Nepal and downstream. Below we discuss how socio-economic changes and climatic changes might impact on the system. A direct visual comparison of the three schematic diagrams relating to current and changed interactions can be found in Appendix B.

3.2.1 Socio-economic change

It is assumed here that socio-economic change is likely to be beneficial in terms of improving support for hydropower development at national and local levels. There is of course the possibility that changes could be unfavourable or a mix of favourable and unfavourable changes with respect to promoting hydropower development. Figure 8 shows how these effects, in isolation, might influence the simplified system shown in Figure 7.

Figure 10 Potential influences on the system shown in Figure 9 from socio-economic change alone



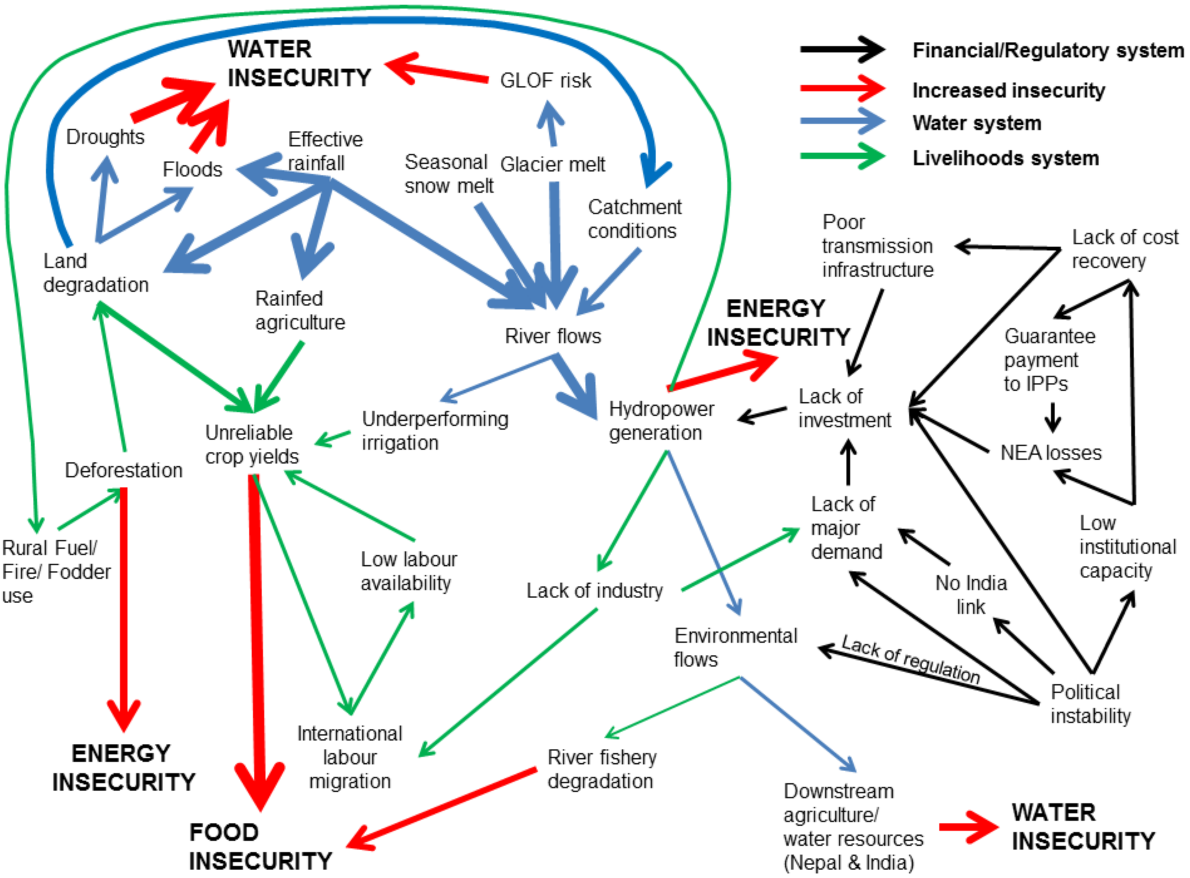
Note: Arrow thickness increase/ decrease compared to Figure 9 indicates increased/ decreased influence

Figure 10 shows reduced restrictions on hydropower development from the financial and regulatory system. Many of the factors in this area are currently major obstacles to development. The expected impact of this is increased hydropower development at both small local scale and larger run-of-river and storage scale. This would increase energy security for the population and reduce pressure on natural forestry resources. Increased development could further threaten environmental flows in the river, but it is assumed that a strengthened regulatory regime would be better able to prevent this. Fisheries may therefore be able to recover or be re-established, increasing food security in areas where these fisheries have been lost. Little impact would be felt in terms of water security in the Nepalese mountains, but depending on the proportion of storage-type developments, water security could be improved downstream. Increased hydropower availability is expected to stimulate industry in Nepal and provide increased employment for those currently migrating overseas.

3.2.2 Climate change

The projected impacts of climate change, particularly on temperature and rainfall are described in Section 2.6. Figure 11 shows how these changes in isolation might affect the system shown in Figure 7. Increased variability of rainfall would impact on incidence of floods and droughts, both directly and indirectly by increasing erosion. Rainfed agriculture may become more vulnerable through this increased variability also. Increased temperatures could lead to changes in snow melt timing and rates, affecting hydropower production but potentially increasing it. In the short term increased temperatures could increase the glacier melt flow component, but longer term, this component is likely to be depleted like the glaciers themselves. Maintenance requirements of hydropower turbines are likely to be increased by high silt loads, higher flows and increased floods.

Figure 11 Potential influences on the system shown in Figure 9 from climate change alone



Note: Arrow thickness increase/ decrease, compared to Figure 9, indicates increased/ decreased influence.

SECTION 4

Hydropower performance and its influencing factors

This section looks at the performance of hydropower in Nepal 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

4.1.1 Grid connected hydropower performance

Hydropower provides almost all Nepal's grid electricity, but is failing to meet national demands (World Bank, 2013c). All but one of the hydropower schemes connected to the national grid are run-of-river and therefore highly dependent on river flows for generation. This means Nepal's generating potential is greatest in the wet (summer) season when its demand for heat and light is lowest, and vice versa. The installed capacity provides power in excess of domestic demand during the wet season, but outages ('load shedding') of up to 18 hours a day are common in the dry season (World Bank, 2013c). Load shedding hours during the dry season depend primarily on the availability of water in the Kulekhani reservoir, as the only storage hydropower project in the system (WECS, 2011).

The timing of India's peak annual demand correlates more closely with supply availability in Nepal. International transmission interconnectors do not have the capacity to take large quantities of excess power from Nepal to India however, and it is estimated that from 2016 800 MW will go to waste in the wet season evenings from 22:00 to 06:00 (Khadka, 2014). In fact, the transmission lines within Nepal are also lacking capacity, requiring some schemes to be run below their maximum capacity (Nepali Times, 2005)

It is difficult to see how this situation can be changed without further investment in politically divisive storage-type hydropower schemes. Storage dams can offer multiple benefits, although it is inevitably more expensive to ensure benefits are shared equitably at local, regional and national levels or identify win-win opportunities so that all are better off. Nepal is caught in a vicious circle, needing reliable energy to justify investment in industrialisation, but needing an industrial demand to support investment in energy generating capacity. This situation is likely to continue for some years, and there is an ongoing debate about the suggested strategy of developing large hydropower schemes for exporting to India and Bangladesh (e.g. Shrestha, 2014).

Only basic qualitative information have been obtained relating to the relative quantities of supply and demand. Some of these are related below.

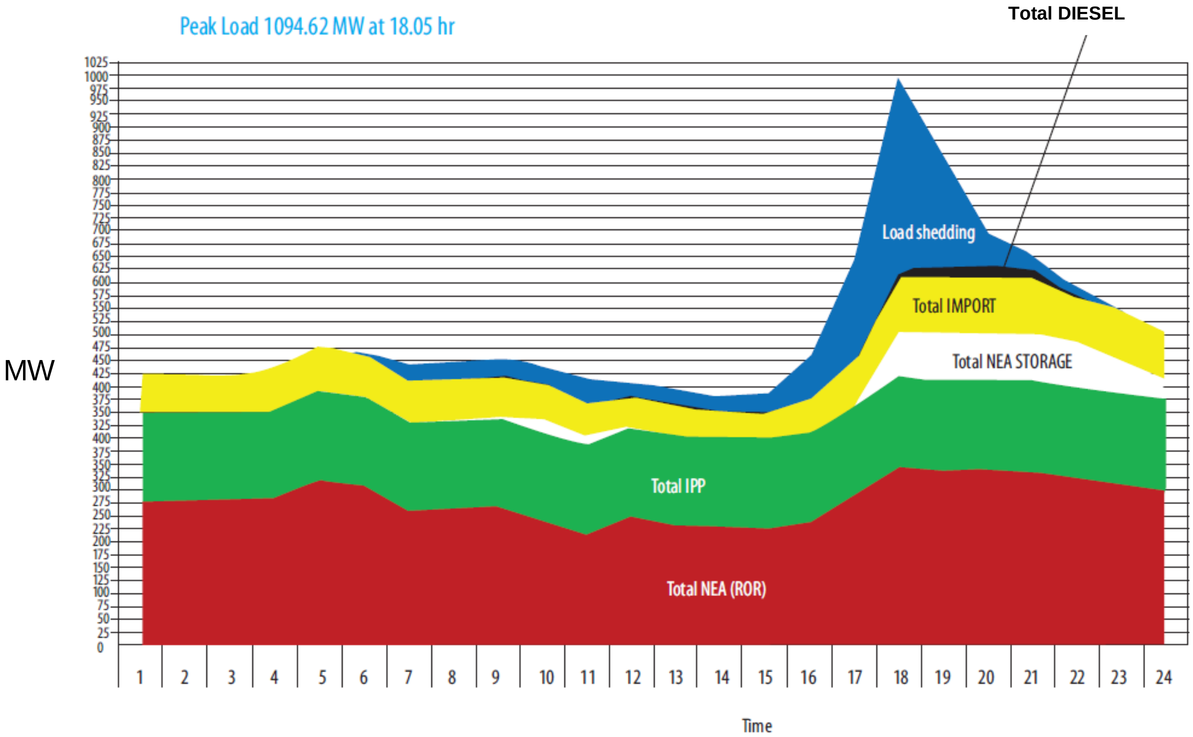
Reliability of energy supply (energy duration curves)

Data were not obtained to make a quantitative assessment of the reliability of the energy supply in Nepal. It is clear from documents obtained that there is a correlation between flows and hydropower generation, whereby run-of-river schemes are unable to generate at their full capacity during low flow seasons. Additional reliability issues arising from lack of maintenance of damage caused by heavy silt loads (for example) are unquantifiable without appropriate data. Reliability is fundamentally tied to river flows at present but river flow data were also unavailable for quantitative analysis.

Energy generated (% of target demand)

Little data were obtained relating to the amount of energy generated as a proportion of the target. It is clear from the various documents obtained however that there is an excess of power in the wet season, but a serious shortfall of electricity availability in the dry season when run-of-river hydropower plants are unable to generate at their full capacity. Figure 12 shows how the supply and demand varied throughout the annual peak demand day in November 2012, illustrating how the various supply sources contribute to the total available. Also indicated is the magnitude of the load shedding required due to inability to meet demand.

Figure 12 Load curve throughout the peak demand day of 2012 illustrating the shortfall of electricity as load shedding, the supplies from different sources, including imports

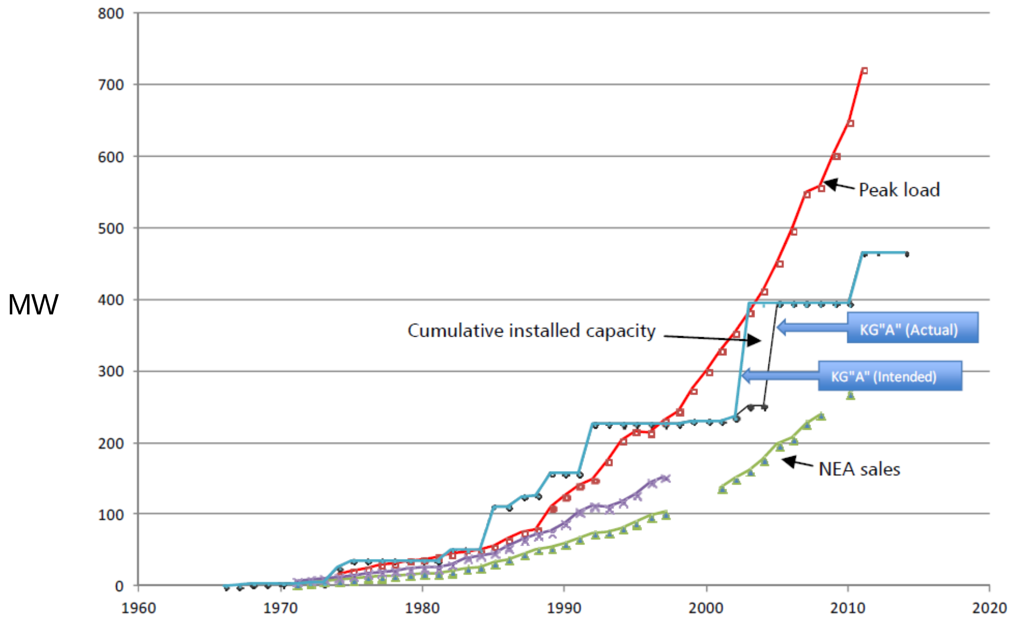


(Source: NEA, 2013)

The data show that demand for power had outstripped Nepal's cumulative installed capacity even at commissioning of the Kali Gandaki 'A' scheme (Figure 13). While the project still helped meet demand as intended, the delayed commissioning of 21 months due to scope changes and difficulties in management with the contractor means the project was not as helpful as it could have been in terms of peak power supply, which was the rationale for constructing Kali Gandaki "A" as noted in the RRP.

Figure 13 shows the net jump in cumulative installed hydropower capacity due to the commissioning of Kali Gandaki "A" in 2002. In addition to imports from India and thermal plants, NEA had managed to alleviate load shedding in the early years of production from Kali Gandaki "A" until demand once again outgrew production. Kali Gandaki "A" therefore played a significant role in supplying energy for Nepal and the project's benefit to the country is undeniable. Kali Gandaki "A" came on board some 21 months late and, in comparison to peak load, this delay shows a missed opportunity to provide timely service over that period.

Figure 13 Comparison of peak load with cumulative installed capacity for Nepal highlighting the impact of late commissioning of the Kali Gandaki 'A' hydropower plant

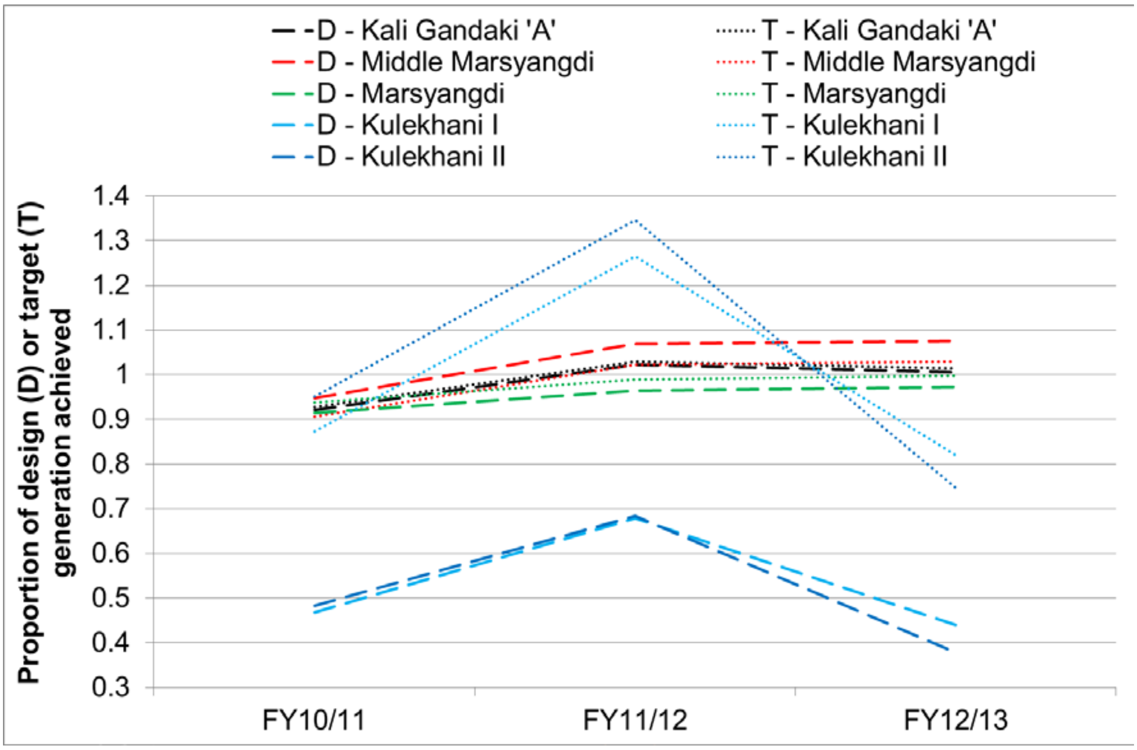


IED = Independent Evaluation Department, KG "A" = Kali Gandaki "A," MW = megawatt, NEA = Nepal Electricity Authority.
Note: Peak load: red line; Cumulative installed capacity: black line; and NEA sales: green line.
Source: IED; NEA data.

(Source: Foerster, 2012)

Simple figures from NEA (2013) also show the performance of the five largest active hydropower stations against target generation for the three years to 2013. These data are plotted in Figure 14. Run of river schemes performed consistently with each other over these years and the latest two years in the record were better than the first. This could suggest hydrological differences between years. NEA (2013) report satisfaction with the way these three plants are operating. The high performance of storage schemes against target generation but low performance against design generation is not explained by NEA (2013). The drops in performance from FY2011/12 to FY 2012/13 are attributed to breakdowns in both plants which form a cascade. Kulekhani I is upstream of Kulekhani II, meaning the latter is dependent on release from the former in order to operate. Likewise, problems in the lower plant may require releases from through the upstream plant to be reduced or ceased (NEA, 2013).

Figure 14 Generation performance of the five largest hydropower stations in Nepal against their design generation and target generation for the period FY2010/11 – FY12/13



Days with unplanned outage (%)

No data were available for the assessment of this metric. However, it should be noted that all days have planned load-shedding schedules[2] during the dry season when river flows are low and little hydropower is generated. Schedules are publicly available so that people can plan their activities around them. Load shedding can lead to blackouts of up to 18 hours per day in individual areas (World Bank, 2013c).

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

As discussed above, during the dry season there are insufficient flows to make full use of the country's hydropower generating capacity. No data were available to demonstrate or analyse this situation further.

4.1.2 Off-grid generation

Consultees (2013) reported that generation is not being maximised from some of Nepal's small community hydropower schemes because some communities are not finding uses for the power which can be supplied when domestic demand is low. This was attributed partly to inexperience and the fear that the community will not be able to maintain or repair the systems, leading them to try and minimise wear and tear.

4.1.3 Maintenance issues

The lack of NEA capacity to invest in maintenance of hydropower plants is leading to poor condition and associated reductions in hydropower production. Project specific reviews are reported to be necessary to clearly define the needs (Consultees, 2013).

[2] See http://www.nea.org.np/loadshedding.html

4.1.4 Sedimentation issues

Sediment loads can be very high in Himalayan rivers and the proportion of this sediment which is quartz can be over 60%. Quartz is harder than the base material of turbine blades so leads to a lot of abrasion damage (Pradhan, 2004). The damage caused leads to economic losses and under-performance. Based on the experience from some Indian hydropower plants, Naidu (1997) reported that the annual operation and maintenance costs of sediment-affected power plants could be as high as 5 % of the capital costs against 1.5 % in normal cases.

Research (Pradhan, 2004) showed that sediment concentration as high as 57,000 parts per million occur in the Jhimruk River. Costs are likely to increase from damage to turbine blades and loss of efficiency. This demonstrates the need to establish concentration cut-off limits for power plants in order to prevent costs climbing higher than benefits.

In its assessment of the Kali Gandaki A project, the World Bank (2013c) noted in particular the "…low availability of generation capacity from erosion and cavitation[3] leading to severe damage to its power generation equipment and safety management issues". Severe damage was found in critical parts of the turbines caused by both erosion and cavitation. Erosion is due to sediment dominated by quartz particles passing through the generation units. Floating debris can block intake screens. This reduces the efficiency of sediment settling basins because inflows pass more quickly through a narrower (i.e. partially blocked) intake. These problems are endemic in Nepal's hydropower development, and signify the need for greater care in maintenance of plant, implying higher O&M budgets (World Bank, 2013c).

Sedimentation is also a problem for storage type hydropower plants, decreasing the storage available and potentially the energy which can be generated. The Kulekhani reservoir is reported to have decreased from a capacity of 85 million m^3 to 60 million m^3 in around 30 years (The Kathmandu Post, 2013). After fears that the dead storage in the reservoir would be completely lost after another large flood like that which struck in 1993, civil works were undertaken to install check-dams. These successfully trap sediment in the reservoir's upper reaches so it cannot affect power stations (Hada, 2007).

4.2 Economic impacts

4.2.1 National capacity development constraints

There are multiple constraints on developing Nepal's hydropower capacity at present. These are described below first addressing off-grid micro-hydro development before moving on to larger schemes.

Off-grid/micro-hydropower

The off-grid/mini-grid micro-hydro sector has been expanding rapidly with government funding, supported by Norwegian and Danish finance. There are some questions about the sustainability of the model however, in which communities are expected to contribute around 20% of costs and construct the scheme themselves. This cost is not expected to be recouped for 25 years, which is a significant burden on communities (Consultees, 2013). There is an argument that urban or on-grid communities do not have to fund their own generating capacity so rural communities should not have to. Increasing funding for communities in the future would raise concerns among those who have funded their own in the past however. It was suggested that examining the details of different subsidies obtained

[3] The formation and collapse of an air pocket in water due to pressure change which reduces efficiency of hydropower turbines and damages their structure over time.

from different sources, the government is actually already funding the vast majority of these schemes. Channelling all funds through a single entity could change the perception to be more favourable towards the government in terms of the proportion contributed. It is expected to take 10 years to install the next 25MW of these schemes for various reasons, including that the easiest schemes were developed first (Consultees, 2013).

A big restriction to further implementation of small private schemes has been the requirement to obtain Ministry of Forest and Soil Conservation approval for schemes of any size if their water sources are within a forested area, national park, wildlife reserve or conservation area. The same policy restricts the same schemes from connecting to the grid and requires 50% of monthly natural flow to be released to the downstream channel, limiting diversion for power production (Consultees, 2013).

Law enforcement and corruption are big issues for hydropower developers. Nothing gets done without bribes and investors are only interested in short-term gains (Consultees, 2013).

More awareness of carbon credit systems could be used to promote hydropower projects among government, local government and local communities (Consultees, 2013). The carbon credit system is not simple however, as carbon reduction needs to be quantified for each project. This is extremely challenging without a standard methodology and baseline emissions, so there would be value in developing this (Gippner, 2013).

Larger, grid connected hydropower

Constraints on larger scale hydropower projects are more diverse. Generally, the political instability suffered by the country has presented an unfavourable environment for business investment. The country has long encouraged private investment in the hydropower sector, but prospects for investment are hampered by lack of domestic industrial demand and difficulty in forming power purchase agreements with India (Consultees, 2013). The lack of domestic demand comprises one half of a vicious circle, whereby loans cannot be obtained to develop hydropower projects without a reliable source of income from selling the energy which will be produced. Without a reliable and substantial source of electricity; however, there is no incentive to invest in industrial activity (i.e. create demand). Although there is clearly an unmet domestic and small business demand as evidenced by the extensive load shedding implemented, the Nepal Electricity Authority (NEA) is not in a strong financial position to provide power purchase agreements. The sector needs restructuring, including the proposed unbundling and privatisation of NEA into generation, transmission and distribution entities (WECS, 2010) to reduce or prevent loss-making (Shrestha, 2009).

Difficulties in forging contracts for India to purchase power have faltered on the basis that the tariffs India is willing to pay are not high enough to make certain concessions financially viable (Shrestha, 2014). One view is that this problem has been created by selecting higher cost hydropower projects for development, resulting in Nepal having some of the most expensive hydropower in the world (Gyawali, 2006). Some of the major problems are:

- The location of projects in remote areas, requiring expensive access roads.
- Donor requirements for consultants, contractors and equipment as a condition of loans.
- Private companies face high government interest rates which must be passed on to customers.
- Private developers have to transfer projects to the government after 30 to 40 years despite design lives of schemes being 75 to 100 years.

(Source: Nepali Times, 2005)

Public resistance has historically been high in relation to storage hydropower projects, owing to the higher social and environmental costs than typically related to run-of-river projects. This has been a further barrier to some large storage-type hydropower schemes which have been proposed. The lack of basic infrastructure such as roads in remote areas has contributed to the costs of these projects being extremely high for the amount of power to be generated. The Arun-III dam for example was abandoned on the basis of financial viability and compliance with the World Bank's own policies and procedures after much controversy (Udall, 1995).

4.2.2 Institutional/Regulatory performance issues

The financial situation of the NEA is poor, due to accumulated arrears from public institutions buying electricity, and the low level of cost recovery (the 20% tariff increase in 2012 was the first in 11 years (NEA, 2013)). The NEA has many existing contracts to buy power from independent producers with terms in dollars. This means NEA is exposed to currency value fluctuations. It also means there are times when the NEA has to shut down publicly owned hydropower plants in order to not waste their production while electricity is being bought from private producers. The parlous financial position of NEA reduces its credibility as a potential offtaker for new privately produced power (Consultees, 2013).

Insights into the performance of the sector can be derived from an independent evaluation under the auspices of the Asian Development Bank (Foerster et al., 2012) of the largest project, the 144MW Kali Gandaki A project, that has been operating since 2002. Ten years on, the project showed a recalculated Economic Internal Rate of Return of around 16%, similar to the original estimate of 15%. Its capital cost came in well below (by around $100 m) the level budgeted for. Its equivalent Financial Internal Rate of Return was recalculated as 6%, well below the 9.8% estimated at appraisal, but somewhat greater than the relevant average weighted cost of capital (5.7%). The difference between the economic and financial returns is mainly due to the under-pricing of electric power, i.e. lack of full cost recovery in setting tariffs (Foerster et al., 2012).

4.3 Social and environmental impacts

4.3.1 On-grid hydropower impacts

On-grid hydropower has clearly provided the vast majority of Nepal's electricity, without which it would be a much less developed country. In terms of environmental impacts, there are concerns however, that environmental flows are not being adhered to, monitored or enforced (Consultees, 2013). Environmental flows are usually considered to be 10% of natural flows, but some existing schemes are reported to occasionally leave riverbeds dry downstream of their dams (Consultees, 2013). There is limited research on cumulative impacts of dams in Nepal or their operations but this is closely linked to the environmental flows issue.

A project performance evaluation of the run-of-river Kali Gandaki "A" Hydroelectric Project financed by the Overseas Economic Cooperation Fund and the Asian Development Bank (ADB) came to the following conclusions:

- The project was 'successful' overall but the Technical Assistance (TA) operations were less than successful because, 10 years on, the study found little evidence of lasting capacity in master planning or in environmental and social management of hydropower relevant to the needs of the country.

- Increasing the availability of power was relevant to economic development and poverty reduction, and consistent with the country's development goals.
- The project contributed to economic growth by producing on average close to 592 GWh/year since commissioning, which has been fed into the grid, thus benefiting consumers nationwide. While 4,142 households were also found to have been electrified as a part of the project, Nepal continues to endure severe power shortages.
- The project was rated as 'efficient'. While least cost was not demonstrated because of higher than expected maintenance costs, in turn due to possible design errors, the total capital cost was significantly below the engineer's estimate and, as such, beneficial to the country. Construction funding was sufficient, with the project being finalized about $98 million under budget (underspends are not uncommon according to research for the World Commission on Dams (2000)). The environmental and social programme budget was limited to 1.2% of project estimated cost.

(Source: Foerster et al., 2012)

4.3.2 Off-grid hydropower impacts

An independent report to the Alternative Energy Promotion Centre (AEPC) analysed the impacts of mini-grid electrification on 2,600 households across ten districts of Nepal. Detailed findings are presented in Box 2, but in summary the study found:

- A positive impact on income from livestock and small business, but no evidence of an impact on agricultural income
- Direct and indirect health benefits
- Positive impacts on the educational outcomes of children between 5 to 15 years old
- Improved access to information
- Positive impact on women's involvement in household decision making processes.
- Increased business activity, job creation and improved general livelihood optimism
- Positive environmental impact
- Household expectations have been met

(Source: Samuhik Abhiyan, 2011)

4.3.3 Compensation for project affected families (PAFs)

Since 1999 the government has been sharing 10% of royalties from electricity sales to District Development Committees in the District where the power house is located (Ministry of Law and Justice, 1999; Ministry of Federal Affairs and Local Government, 1999). This increased to 12% in accordance with an amendment to the policy in 2004. The same amendment states that 30% of royalties should be given to the Development Region concerned. Additionally, 1% of royalties should be shared with Village Development Committees (VDCs) to promote rural electrification.

Private hydropower development companies sometimes sell shares in a project to local communities to reduce opposition and sometimes the government receives shares too, e.g. Upper Karnali. Shareholders are unlikely to protest about projects but those outside the share scheme sometimes demand greater compensation. Corporate Social Responsibility has also driven companies to provide schools, roads etc. so that communities have increased access to markets.

If more storage-type projects are to be developed, then there may be a greater need to engage with local communities to share benefits with them and avoid resistance.

Box 2 Detailed findings of the study of impacts of micro-hydro mini-grid installation

Income: It is suggested that lack of increase in income from agriculture in communities benefitting from micro-hydropower may result from a preference for higher value livestock farming with greater access to information on how to profit. Furthermore, electricity is seen as more of an indirect input to agriculture than some of the livestock and business incomes which benefit more directly, farming poultry requires significant lighting energy for example. This issue requires further investigation.

Health: a statistically significant reduction of 1.4% disease incidence among households with a micro-hydro connection compared to those without is consistent with findings from Bhutan (where it is suggested to be the result of larger schemes providing enough power to substitute traditional cooking as well as lighting fuels). In Nepal few schemes are large enough to substitute cooking fuels. Evidence was also found to suggest increased access to information from electrification has indirect health benefits.

Education: Statistically significant differences were found between electrified and non-electrified households for higher literacy and lower school dropout rates. Encouragingly, study time is no less in electrified households which suggests TV and radio access is not distracting students as might be expected.

Access to information: Statistically significant increases in ownership of televisions, mobile and non-mobile phone and DVD players were observed along with increased television watching. It is proposed that greater access to information is empowering for rural communities.

"Earlier I used to sell my vegetable products at low price because I was not aware of the market price but after electrification and by watching certain TV programmes at my home, I I am aware of the recent national prices of the vegetable products and can adapt to this price, which often results in more money." A woman from Mechhe VDC, Kavre.

Gender empowerment: A requirement for women to be involved in running community hydropower schemes is credited with empowering women to participate more in other community activities and decisions.

"*As a result of my membership in the micro hydro user group I have developed a confidence to participate in other meetings in the village, and I am also able to raise my voice in those meetings*." A focus group participant from Kumpur VDC, Dhading

Kerosene and firewood replacement: Around 3 litres per household per month of kerosene is saved by electrification, the cumulative impact of which is a large reduction in dependence on petroleum imports. In 9% of households, electricity has replaced firewood by running an electric rice cooker. Greater quantities of electricity are expected to further reduce firewood dependence.

Stimulating business: Only one of twenty schemes was found to have no non-domestic applications, while others were using power for agro-processing mills, computers in schools, sawmills, communication centres, bakeries, poultry farms, cable TV networks, cinemas, a cheese factory and irrigation from the tail race canal.

Employment: Each hydropower plant requires at least one operator, although on average 3 people are employed for each scheme. The various business activities growing up around the power is providing indirect employment - on average 4 people per village are employed in this way.

(Source: Samuhik Abhiyan, 2011)

4.4 Water use

4.4.1 Over-abstraction upstream

Over-abstraction upstream is not currently a problem in Nepal but there are laws restricting abstraction upstream of hydropower schemes. This is intended to prevent problems with generating hydropower but creates a potential for conflict between local water needs and the needs of those benefitting from increased hydropower generation (Consultees, 2013).

4.4.2 Evapotranspiration

As all but one of the existing hydropower schemes are run-of-river, there is little storage associated with them and so little potential for evaporative losses. Coupled with this, the latitude and elevation of the pondages[4] means evaporation rates would be low.

4.5 Greenhouse gas emissions

As Nepal's hydropower projects are almost all run-of-river, there is less potential for greenhouse gas generation than there would be from a similar number of storage plants. The climate in Nepal is not conducive to the generation of greenhouse gases at the locations of hydropower schemes outside the tropical climatic zone. Depending on the amount of vegetation in areas chosen for development in the future and to what extent it is cleared prior to inundation, storage schemes could increase the emissions from hydropower in Nepal (Lumbroso et al., 2014). Compared to fossil fuel alternatives this is likely to be extremely low however, so of little concern.

4.6 Section summary

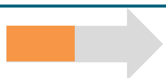
This section has made the following main points:

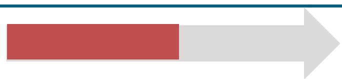
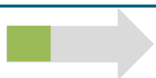
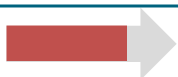
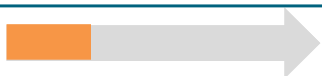
- Nepal's existing installed capacity is falling far short of meeting electricity demand in the dry season (winter) when heat and light are most needed. Imports from India are required to limit load shedding.
- Lack of cost recovery by the Nepal Electricity Authority (NEA) and the need to maximise generation from the existing installed capacity has prevented necessary maintenance and reduced generation efficiency at a number of plants.
- High silt loads in rivers are a major issue for hydropower plants in Nepal, causing damage to run-of-river plant turbines which are not shut down and decreasing storage capacity behind storage scheme dams. More information on silt loads is needed to combat these problems.
- The transmission grid does not have the capacity to carry the maximum amount of power which can be generated and links to India limit both exports and imports.
- There are a number of financial, institutional, regulatory and technical issues with the power sector which have prevented more rapid development of the hydropower potential.
- Poor choices about which of the available hydropower schemes to develop has led to Nepal having some of the most expensive hydropower in the world.
- Small community hydropower has been a notable success in Nepal, providing a wide range of benefits to off-grid communities.

[4] Relatively small-scale storage upstream of a run-of-river hydropower dam

- There is potential for conflict between different water users owing to laws which prohibit abstraction upstream of hydropower schemes.
- Greenhouse gas emissions may increase as the system includes more storage-type hydropower schemes, but, the climate is not very conducive to greenhouse gas production and vegetation can be cleared before inundation to minimise decomposition effects.

Table 4 illustrates the baseline and future risks of a range of hydropower performance issues. Grey arrows indicate the possible scale of the performance issue in the 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 provides almost all Nepal's electricity and there is little incentive to change this, with such large potential and prohibitive costs of importing alternative fossil fuels.
Demand exceeds capacity		Electricity generation is far from high enough to meet national dry season power demand. Demand growth of 7 to 9% presents an ongoing challenge.
Generation efficiency		Generation efficiency is being compromised by lack of investment in maintenance and failure to shut down turbines during flows with high silt loads.
Other operational issues		NEA has existing contracts for purchase of power from private producers which are paid in dollars and so vulnerable to currency value fluctuations, this reduces financial capacity of NEA to maintain publicly owned plants etc. (Consultees, 2013).
Unplanned outage		No data were available to assess the current risks associated with unplanned outages.
Upstream abstraction		The proportion of available water abstracted for irrigation is low so unlikely to impact on hydropower schemes. Current laws restrict abstraction upstream however, so new hydropower development could impact on both upstream and downstream irrigation 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 Nepal and this is considered unlikely due to environmental conditions.

Performance issues	Baseline and future risks	Comments
		The schemes in Nepal are almost exclusively run-of-river at present but plans for more storage/multi-purpose type dams could lead to increased evaporation. This is still likely to be low relative to that in tropical countries.
		Nepal has a strongly seasonal flow regime with monsoon rains coinciding with mountain snowmelt in the main rivers. This leaves insufficient flows to drive the run-of-river hydropower schemes in the low-flow season. Climate change could exacerbate this effect.
		HEP is reported to be causing significant environmental degradation as environmental flows are poorly understood, monitored and enforced (Consultees, 2013).
		Approximately 50% of the population have access to grid electricity, but transmission losses are high. National development plans state the intention to improve access to 65% and transmission losses from 26% to 21% by 2016 (GoN, 2013).
		Institutional capacity is generally very low in Nepal, the structure of the power sector is not conducive to rapid development of available hydropower resources.
		Public resistance has historically been high in relation to storage-type projects. Run-of-river schemes do not seem to have faced such fierce resistance. The proposal for storage dams in future is likely to stimulate resistance which will need to be managed through compensation/benefit-sharing mechanisms.

Notes: The table provides a qualitative summary of the key issues, with traffic light colours indicating baseline issues - 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 4 Summary of issues relating to hydropower performance in Nepal

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SECTION 5

Ongoing interventions to improve hydropower performance

Nepal has wide ranging development needs, and a large number of actors are supporting the government or acting independently to improve conditions for the Nepalese people. This section describes some of the interventions that are ongoing or recently completed which relate to the sustainability of hydropower and its interactions with water, energy and food security.

Points of leverage exist within the system originally described by the schematic diagram in Figure 7. 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 5 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.

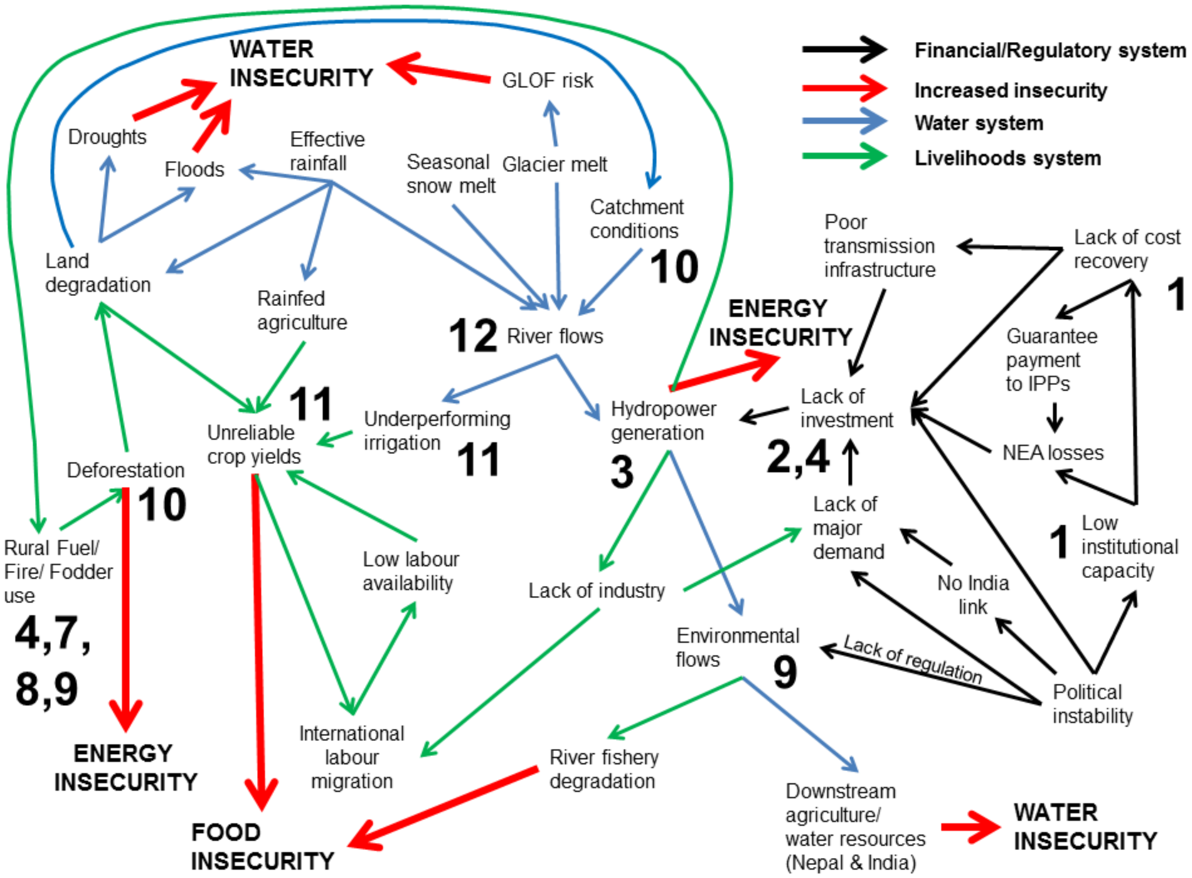
Table 6 shows the ongoing interventions identified by this study in Nepal. The table also indicates through a colour coding system, the resilience of different actions to climate and socio-economic change.

The remainder of this section provides further information on issues surrounding the on-going interventions.

5.1 Implementation of micro-hydropower

A notably successful (Box 2) and ongoing intervention in Table 6 is the funding of community micro-hydropower through the Alternative Energy Promotion Centre (AEPC). This promotes all kinds of alternative energy but community hydropower has been the second most common type of scheme funded, after solar. Hydropower is more expensive to install per MW generated so necessitates community involvement to fund and manage it. This contrasts with solar systems which can be installed and owned by individuals, avoiding the complications of negotiating between groups of people. One way to avoid community negotiations is to allow a company to develop the scheme then hand it over to the community. In actual fact, the communities only want access to electricity rather than to project manage a hydropower scheme construction. There is also a greater opportunity cost to investing time in such endeavours than there was in the past, this is because of the choice people have of going to work overseas. Some of the technology involved in hydropower schemes is beyond the technical capacity of some communities to manage. Similarly, the financial aspects of managing a community scheme can promote corruption. It was suggested by Consultees (2013) that rural electrification is an effective tool in preventing the influx of rural people to the cities and therefore politically beneficial. The model is nevertheless an excellent example for reference in other countries looking to expand their off-grid electricity access, as there are a wide-range of benefits reported. Sufficient water availability is a pre-requisite which cannot be taken for granted however. This is affected by catchment conditions and management which need attention to ensure the impacts of climate change are minimised.

Figure 15 Simplified system diagram from Figure 9 with numbered intervention type points outlined in Table 5



No.	Group Name	Sub-groups	Comments	Agency most likely to lead for Nepal	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	Nepal Electricity Authority, Ministry of Energy	3	5	15
		b) Cost reflective tariffs	Help to spread load more evenly by differential pricing	Nepal Electricity Authority, Ministry of Energy	4	4	16
		c) Restructuring power sector	Focussing institutions on incentivising private investment	Ministry of Energy	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 owing to returns on investment	Private banks and investors	4	4	16
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, International Financial Institutions or Government	3	5	15
		b) Run of river	Low/No storage so tend to have lower environmental and social impacts. Depend on reliable flows.	Private investors, International Financial Institutions, Nepal Electricity Authority, or Government	4	3	12
		c) Micro	Best suited to off-grid solutions	Private investors or Alternative Energy Promotion Centre	5	4	20
4	Diversify	a) Renewables	Diversification of the renewable sources of electricity can help increase resilience to climate related system shocks.	Private investors or Alternative Energy Promotion Centre	5	4	20
		b) Thermal	Including coal, heavy fuel oil, diesel, waste to energy. Expensive to import and	Private investors, Nepal Electricity Authority, International Financial Institutions	2	5	10

No.	Group Name	Sub-groups	Comments	Agency most likely to lead for Nepal	Ease (1 Low - 5 High)	Impact (1 Low - 5 High)	Priority (Ease x Impact)
			especially as Nepal landlocked.				
		c) Nuclear	No plans at this stage – very expensive and technically challenging, also requiring expensive imports of uranium	Private investors, Nepal Electricity Authority, International Financial Institutions	1	5	5
5	Grid extension/ capacity increase		Extending the grid on a planned basis to increase ability to evacuate power from currently remote concessions, facilitating development	Nepal Electricity Authority	3	5	15
6	Improve grid manageme nt		Reducing the transmission losses from the grid and extending its reach to promote IPP connections to it	Nepal Electricity Authority	3	4	12
7	LPG/ Sustainable Charcoal		Replacements or enhancements to current fuelwood use could reduce pressure on forestry resources	Ministry of Energy	3	3	9
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.	Ministry of Forest and Soil Conservation	5	5	25
9	Payment for Ecosystem Services (PES)		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.	Ministry of Forest and Soil Conservation, Ministry of Science, Technology and Environment	3	4	12
10	Afforestatio n		Direct planting of trees to increase slope stability, reduce erosion and impact on water	Ministry of Forestry and Soil Conservation	5	4	20

No.	Group Name	Sub-groups	Comments	Agency most likely to lead for Nepal	Ease (1 Low - 5 High)	Impact (1 Low - 5 High)	Priority (Ease x Impact)
			flows can be integrated in wider programs or implemented in isolation				
11	On-farm practices	a) Increased irrigation	Could intensify outputs to reduce requirements for new land	Ministry of Agricultural Development	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	Ministry of Agricultural Development, Ministry of Forest and Soil Conservation	4	4	16
12	Water manageme nt	a) Supply	Development of new small and large scale infrastructure to make use of available wet season flows.	Ministry of Irrigation, Ministry of Urban Development – Department of Water Supply and Sewerage	3	4	12
		b) Demand	Improving demand management and increasing water efficiency	Ministry of Irrigation, Ministry of Urban Development – Department of Water Supply and Sewerage	4	4	16
		c) Quality	Improving water quality, reducing silt loads	Ministry of Forest and Soil Conservation, Ministry of Agricultural Development, Ministry of Energy	4	4	16
		d) Capacity building	Increasing capacity of river basin authorities and other water managers.	Ministry of Irrigation, Ministry of Forest and Soil Conservation, Ministry of Agricultural Development, Ministry of Energy	3	4	12

Table 5 Description of the numbered intervention points shown in Figure 15

Agency	Intervention	Intervention point(s)	Impact on: Water Security	Energy Security	Food Security	Resilience to: Climate Change	Socio-economic Change
Alternative Energy Promotion Centre (AEPC)	Providing loans to local communities to install small hydropower schemes	2a, 3c					
Nepal Rural Renewable Energy Project (NRREP)	Giving strong emphasis to water conservation - Reducing runoff/erosion, increasing infiltration, retaining water in drains to replenish groundwater	11b, 12a, 12c					
WWF	Promoting use of the International Hydropower Association (IHA) sustainability protocol	3					
	Identifying No-Go policy areas and investigating 'smart dams' requiring minimal infrastructure but providing maximum benefits.	3					
Scaling-up Renewable Energy (SREP)	Increasing the uptake of renewable energy technologies	4a					
DFID	Supporting NAPA implementation - community management, forestry and renewable energy	4a, 8, 10					
World Bank/ IFC/ IBRD	Working to deliver transformative medium and large hydropower projects and transmission lines	3a, 3b, 5					
	Advisory programmes on improving the investment environment	1c, 2b					
	Agriculture and Food Security Project	11					
	Building resilience to climate related hazards project	12d					
	Irrigation and water resources management project	11a, 12a, 12b					
	Kali Gandaki 'A' rehabilitation project	2a, 3b					
	Biogas promotion program	4a					
UNDP	Increasing access to renewable energy and energy-based services	4a					
	Mainstreaming climate change and disaster risk management, Reducing vulnerability to climate change	N/A					
	Community-based GLOF and flood management	12d					
Asian Development	Technical Assistance for River Basin Master Plan	12d					

Agency	Intervention	Intervention point(s)	Impact on:			Resilience to:	
			Water Security	Energy Security	Food Security	Climate Change	Socio-economic Change
Bank (ADB)	Finance both national and cross-border generation and transmission facilities	3, 5, 6					
	Support reforms of NEA and revision of tariff regime	1a, 1c					
	Provide technical support to AEPC to improve systems and management	1c					
	Advise on implementation of agriculture development strategy and support selective investments	11					
	Advise government on creating a business enabling environment	1c					
	Build institutional capacity and ensuring infrastructure resilience to manage climate change risks	1c, 12d					
	Help develop an integrated water resources management system	12d					
European Commission	Renewable Energy Project - supplying solar panels to community energy service provider groups	4a					
GIZ	Energising Development - connecting communities to the national grid	5					
	Advisory towards energy efficiency - electricity/biomass	7					
	Irrigation and rural development programme – erosion reduction	11a,b					
NEA & JICA	Nationwide Master Plan Study on Storage-type Hydroelectric Power Development in Nepal						

Table 6 Ongoing, planned or recently completed interventions. Impact and resilience scale is red (strongly negative) to green (strongly positive) via amber (no impact).

5.2 World Bank involvement

The World Bank has been involved in significant controversy surrounding large hydropower schemes in Nepal, notably its proposed funding of the Arun-III dam, from which it later withdrew (Udall, 1995). Negative perceptions persist on the part of some Nepalese that money assigned to Arun-III which was reported to be remaining available as a fund for smaller hydropower development in Nepal never materialised (Consultees, 2013). In 2012, the World Bank concluded its Ganges Strategic Basin Assessment with the publication of a report, the findings of which are summarised in Box 3

It was reported in Hydro Nepal (Gautam, 2012) that the World Bank's report on the Ganges Strategic Basin Assessment had stirred further controversy. Gautam (2012) reports that a meeting of the Jalsrot Vikas Sanstha (JVS)[5], Nepal Forum agreed that the World Bank report has:

"*concluded that the benefit of Nepal's water resources exclusively depends on the sale of hydro-electricity. It strategically ignores any irrigation, flood, various other use benefits including conservation benefits from high dam projects*." Furthermore, Hydro Nepal reports that "*The GON and the National Planning Commission (NPC) had constituted an 11 member committee under the Irrigation Ministry Secretary Ms. Binda Hada's coordination. This committee also seems to have concluded that the World Bank Report is biased and deliberately ignores principles of water science, characteristics of the river basins, advances in water technology, integrity of research work and discipline and objectivity in a model application*." and "*In the view of Joint Secretary of Water and Energy Commission Secretariat (WECS), Mr. Shriranjan Lacoul, the Report was not acceptable to Nepal, because the Report was based on untenable data, very incomplete and weak analysis lacking in rigors of research and model use."*

5.3 Hydropower strategy debate

The view that Nepal should centre its development strategy on the export of hydropower to India has been challenged on several grounds (Shrestha, 2014). Firstly, it is alleged that India does not really have an effective demand for power on the scale assumed- rather, it is more interested in the flood control and dry season irrigation benefits from the construction of water storage projects in Nepal. Secondly, that Nepal would be better served by the construction of multipurpose storage dams and reservoirs that could not only cater to the large local energy deficit but also provide a solution to the major municipal water needs of Kathmandu, and the growing local demand for irrigation water. Thirdly, the contractual terms of existing and proposed hydropower projects, including power sales, are unfavourable to Nepal (Shrestha, 2014).[6]

An alternative view expressed during consultations for this study (Consultees, 2013) is that the priming effect of a few 'starter' hydropower schemes is necessary to unlock the larger potential. If the country loses out a bit on the first schemes then this is can be counted as the cost of learning, it is not necessary to get things perfectly right first time. Nepal cannot generate without a market to sell to, but should be able to negotiate a strong enough deal to make it worthwhile, "Even unfavourable terms bring benefits." The revenue generated from a

5 JVS established in 1999 is reputed for critically supporting policy initiatives and community efforts to harness Nepal's water resources.

6 A specific criticism is that under current contractual terms, a licence for the production of electricity is guaranteed that no upstream consumptive use of water should be allowed that reduces the flow to the project site. The large number of private run-of-river contracts being awarded, many of them to foreign operators, has fuelled suspicion that this clause might be invoked to pre-empt future use of the river for domestic or irrigation water

first few schemes exporting power to India could then help to stimulate other markets which in the longer term might provide the domestic demands Nepal needs for further investment in hydropower.

Another view expressed was that there is nothing international agencies can do to help Nepal harness its hydropower potential. The basis for this was the assertion that the debate is a highly political one for Nepal and outsiders like to try and depoliticise the issues through more technical assistance. It was suggested that the history of outsiders applying pressure, first to nationalise, then to privatise the energy sector (and so on) leaves them with little respect from within Nepal with which to influence matters (Consultees, 2013).

Box 3 Summary of the findings of the Ganges Strategic Basin Assessment

A comprehensive model of the Ganges Basin (World Bank, 2012) produced a number of conclusions, including some which are counter-intuitive:

- There is substantial untapped hydropower potential in the basin, amounting to c. 25,000MW, mostly in Nepal. The potential value of power produced in Nepal alone would be approximately US$5 billion annually. Upstream hydropower would provide the overwhelming share of the benefits from dams under present conditions.
- Large multipurpose dams would be unable to regulate the extreme flows of the Ganges: the largest 23 dams in the model scenario would only hold an additional 18% of the river's annual flow
- Thus, more storage in the Himalayas would be too little to regulate the main stem of the river, and, within sub-basins, would reduce peak flows but may not reduce floods (which are mainly caused by local rainfall and embankment failures). The Full Development Scenario in the model would have a "negligible" impact on flooding in the delta in Bangladesh and only a "modest" impact on flooding in Bihar.
- Large infrastructure is not everywhere and exclusively the most effective and reliable way of protecting communities from flooding. A mixture of hard and soft, local and transboundary, methods are called for, including management of embankments, drainage, land zoning, safe havens, insurance, communications, etc.
- Although monsoon waters can be held upstream and released in the dry season, only a small portion of the floods needs to be retained to make a difference. Water is probably not a key factor limiting agricultural productivity, and in waterlogged areas extra low season water could actually cause harm.
- Natural underground water storage, sustainably managed, could be used on a scale comparable to the full set of dams being modelled. For instance, in the Ghaghra-Gomti Basin of India, 2.5 million new boreholes could be sustainably used providing groundwater storage of over 20 billion m^3.

Climate change does present great uncertainty for the basin, but likely future changes, on average, will be similar to historical variability. Temperatures will probably increase, glaciers melt faster (though only account for 2% of the basin's flow), sea levels rise, but with precipitation scenarios varying widely.

5.4 NEA & JICA Master Plan on storage-type hydropower

Beginning in June 2011, this collaborative study by the Nepal Electricity Authority (NEA) and Japan International Cooperation Agency (JICA) aimed to:

- Prepare a power development plan for 20 years from 2013, and clarify the importance of storage-type hydroelectric power development.
- Select promising storage-type hydroelectric power projects from 65 candidate projects in a long list prepared by the NEA. The development scale of these promising projects needed to be between 100 MW to 300 MW.
- Study the order of development, development scale and timing, methods of funding, etc. of the promising projects and to prepare a master plan for storage-type hydroelectric power development for the next two decades.

(Source: JICA, 2014)

A comprehensive evaluation of all candidates was undertaken from technical, economic, environmental and social perspectives to select 10 promising sites. Detailed analysis was carried out, including a site survey, to confirm the promise of these 10 sites and a power development plan was developed to schedule investments in hydropower at the sites. The Power Development Plan considered a number of subsidiary factors such as development of run-of-river generation capacity, small-scale hydropower development and continuing imports of electricity from India. It also considered necessary expansion of the transmission network. The first of three steps of screening criteria are shown in Table 7. These criteria were used to exclude 36 of the 67 candidate project sites. The project did not consider climate change but stated that this would need to be taken into account during the feasibility studies for the individual schemes which it recommended for development.

Items	Screening condition	Reason	Further explanation
Installed capacity	More than 1,000MW	It is too big because the total installed capacity of Nepal at the end of fiscal year (FY) 2010/11 was about 700MW and that the power demand in FY 2027/28 expected by the NEA is about 3,700MW	Vulnerability can be introduced into a system by over reliance on large schemes whose failure would have a big impact. Demand projections suggest multiple schemes of a few hundred MW would provide a robust system.
Dam height	Higher than 300m	It is too big because the maximum dam height in the world at present is 300m (Nurek dam in Tajikistan)	There are technical challenges to building dams of innovative size, which can increase risks and delay projects.
Project cost	More than US$ 2,000 million	It is too expensive because the national budget of Nepal in FY 2009/10 was equivalent to about US$ 4.5 billion and that the current project costs are higher than those at the time point of estimation because of price escalation	
Regulating capacity of reservoir	Less than 5%	It will not work effectively for dry season energy. The main role of projects	

Items	Screening condition	Reason	Further explanation
		in this study is annual regulation of river flow, which is to store excess river flow in the rainy season and to discharge the stored water in the dry season	
Number of households submerged	More than 5,000 households	It is too big, because resettlement issues might be the biggest obstacles for the development	This was deemed an acceptable threshold to balance local impacts with the need to reduce load shedding and increase living standards nationally.
National park and protected area	Projects located in the area stipulated in "National Parks and Wildlife Conservation Act, 2029"[7]	JICA Guidelines for Environmental and Social Considerations (April 2004) stipulate as follows: "Projects must, in principle, be undertaken outside protected areas that are specifically designated by laws or ordinances of the governments for conservation of nature or cultural heritage."	Projects needed to comply with JICA guidelines
World heritage	Projects located in world heritage sites	Ditto	Projects needed to comply with JICA guidelines

(Source: NEA and JICA, 2014)

Table 7 **JICA Master plan criteria for excluding 'inappropriate' storage-type hydropower dam proposals**

This study is a significant step towards redressing an historical problem with the selection of hydropower schemes to develop, which has led to relatively expensive options being selected for development while others were available (e.g. Udall, 1995, Gyawali, 2006). The study recognises that storage type projects are needed to address Nepal's seasonal energy shortages, but also recognises the need to carefully select from the available options, to balance benefits from increased generating capacity with social and environmental disruption and damage which can be associated with storage-type schemes (NEA and JICA, 2014; Lumbroso et al., 2014).

5.5 Section Summary

This section has made the following main points:

- International agencies are heavily involved with Nepal, recognising the development challenges it faces in terms of agriculture, natural resource management and electricity provision.
- Controversy persists around the multiple benefits received by Nepal and downstream countries of storage-type hydropower dams in Nepal and how these should be developed.

[7] Nepal uses a lunar calendar called 'Nepal Sambat'

- There is a perception among some Nepali's that they have been let down by International Funding Agencies and that their real interests have not been represented in strategic studies.
- A master plan has been developed to add a number of storage-type hydropower schemes to the national generating capacity. Schemes were selected against a broad range of economic, social and environmental criteria to try and maximise benefits and minimise costs of all kinds.

SECTION 6

Conclusions

Despite its political instability, Nepal has achieved impressive developmental progress and is likely to meet many of its Millennium Development Goals. At the current rate of poverty reduction, poverty could be eradicated within the next decade (World Bank, 2013a). Nepal has 42,000MW of economically viable hydropower potential (WECS, 2010), which is largely untapped and a potential solution to the country's dry season energy shortfall requiring outages up to 18 hours per day. The need for a dramatic increase in electricity generation must be traded off against possible social, environmental and political impacts of hydropower development. Nepal faces some difficult and strategic decisions in terms of its exploiting large scale hydropower opportunities. Furthermore, successfully implementing the current pipeline of hydropower projects will call for drastic improvements to Nepal's administrative and regulatory institutions, which are currently very weak. The government will need to further revise electricity tariffs, both to improve the dire financial position of its power utility, and to attract the private operators on which it has set its hopes.

Climate change could have both positive and negative impacts on the country's water, energy and food security. The complex impacts of climate change mean improving resilience of the rural population to it is not a simple task. Safeguarding and improving the quality of agricultural lands on which so many will continue to depend is an important focus however, as is the mainstreaming of climate change impact analysis into hydropower planning and other infrastructure development.

This section concludes the case study, identifying seven prioritised recommendations for improving the performance of hydropower in Nepal, 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 8 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 Assess environmental and social impacts and climate change resilience of development at promising sites identified by the storage-type hydropower master plan

There is a need to develop storage-type hydropower projects to meet Nepal's dry season electricity demands and it should be ensured that those developments maximise benefits in terms of water, energy and food security in the context of climate change. Previously the schemes selected for development have not provided the best value for money available, even in economic terms (e.g. Udall, 1995, Gyawali, 2006). The master plan has provided a plan for storage-type hydropower development over the next 20 years (from 2013) and recommend further studies on environmental and social impacts and planning for climate change.

Environmental and social impact assessments (ESIAs) are common requirements for planning hydropower developments internationally, but it is important that they are carried out to recognised standards. Himachal Pradesh has carried out a basin-wide cumulative ESIA for the Sutlej basin as a large number of developments have been planned and some built without considering the cumulative impacts (Indian Council of Forestry Research and Education, 2014). Some basins in Nepal may also benefit from this type of assessment. There is a body of knowledge building around planning infrastructure in the context of climate change internationally, on which Nepal could draw (e.g. IDS-Nepal et al., 2014; Harrison, 2002a and 2002b).

6.2 Improve silt load monitoring/flood forecasting

Silt loads can be very high in Himalayan rivers, with concentrations having been measured in the Jhimruk river of almost 60,000 parts per million (Pradhan, 2004). Without effective control measures or shutdown of turbines, high silt loads can cause significant damage to machinery and loss of generation efficiency in run-of-river hydropower plants. Forecasting high flows can help to prevent damage by shutting down before a flood wave arrives carrying high silt loads. Monitoring over time can also help to design sedimentation basins to remove damaging sediments before they reach turbines, to calculate the dead storage required in storage-type hydropower schemes or to design mechanisms for preventing storage reservoirs losing their capacity (e.g. check dams described by Hada, 2007).

Dam operators on the Sutlej River in Himachal Pradesh for example, have procedures for shutting down turbines when sediment concentrations exceed a specified level (Hurford et al., 2014a). Nepalese operators would benefit from defining and following similar procedures.

6.3 Develop robust methodology for analysing climate change impacts on existing and new hydropower projects to inform adaptation planning decisions

It is very important that this analysis of climate change impacts is undertaken and used to inform development and adaptation decisions. Without such analysis, returns on investment could be vulnerable to unexpected changes in flow conditions, affecting the economic efficiency of investments. Analysis of the uncertainties will allow the most robust and resilient design/adaptation options to be identified and implemented.

There is a body of knowledge building around this type of assessment internationally, on which Nepal could draw (e.g. IDS-Nepal et al., 2014; Harrison, 2002a and 2002b).

6.4 Analyse trade-offs associated with water storage developments to ensure sustainable resource use and equitable sharing of benefits.

Storage type hydropower projects are not a major current feature of the hydropower sector in Nepal, but they are needed to address seasonal shortages of electricity and could potentially provide additional benefits such as irrigation. Owing to the position of Nepal in the headwaters of the Ganges basin, there is high potential for infrastructure developments and their operation to impact on downstream users. These impacts may be close to the dam in Nepal or further away in either India or Bangladesh. Trade-offs can 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. This is especially important in the context of climate change. Consideration of the broader impacts of any development may improve sustainability and could foster increased cooperation locally, regionally and internationally.

Various 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).

6.5 Further develop community level hydropower by increasing the number of schemes and their impact.

Building on the success of the AEPC investments in community micro-hydropower, the World Bank sees potential to increase the development benefits of these schemes by involving more professional management (Box 4). This should be carried out in addition to planned expansion of the successful programme, which may become more challenging now that the easiest prospects have been developed (Consultees, 2013).

It was also suggested that there is a need to train individuals to do basic things like filling in forms which will get finance to them, to help them make the investments which interest them. This could lead to small scale private hydropower development. In this sense there are not necessarily 'technical' barriers which need international assistance programs to improve performance of the hydropower and other sectors needing investment. Rather, there are basic skills and training needs which can help people unlock opportunities (Consultees, 2013) Increased use could be made of carbon credits to drive investment towards hydropower projects by making them more profitable. The major obstacle to achieving this is reported to be the considerable analysis required to assess the quantity of carbon emissions which would be saved by a project (Consultees, 2013; Gippner, 2013).

The precedent for success in implementing community level micro-hydropower schemes has been set by APEC, but support may be needed to increase coverage and benefits further.

Box 4 The Anchor-Business-Community (ABC) approach to harnessing hydropower in rural communities of Nepal

The World Bank is supporting the Alternative Energy Promotion Center (AEPC) to identify at least 10 to 15 communities among the 2,000 who have micro-hydropower schemes through the AEPCs funding scheme, who are interested in increasing the benefits from their hydropower system. The hypothesis is that the benefits will be increased if a professional operator is engaged, whose incentives are to operate the plant around the clock by finding continuous demand and generating revenues from different types of loads. Communities on their own typically require power for a limited number of hours every night and the plant is shut off in the daytime. Communities themselves are responsible for Operation and Maintenance, as well as bearing the cost of any repair and spare parts, so they often tend to minimize the number of hours that the plant is run. Engaging a private operator who is proficient in plant operation and has the capacity to make repairs when needed, would reduce the risk perception to the community of trying to maximize power production and generate local economic development impact. In order to make a commercially viable proposition that would attract a private operator, these communities must also either have an 'anchor' demand, or be in the vicinity of a potential 'anchor' demand.

Anchor demands represent a more or less continuous revenue stream and are considered to be businesses already reliant on a significant quantity of diesel fuelled electricity generation. In this sense there is a win-win opportunity for the community to sell electricity and the business to reduce costs. Obvious candidates for anchor demands are mobile telephone networks, and weather or other monitoring stations which need to operate in remote off-grid areas, operating sensitive electrical equipment that cannot be turned off due to an absence of power. If hydropower is substituted for diesel as the source of such continuous power, it is a win-win for the community that is able to sell the hydropower and the customer that is able to (i) lower the cost of power and (ii) relieve itself of the burden to procure and store diesel to meet its continuous requirement, as well as take responsibility for regular maintenance of the diesel generator. In other words, if the Anchor customer decides to outsource its power requirement to an asset owned by the community, then both sides win. However, the Anchor customer is unlikely to do so if a member of the community with very basic skills proposes to be the Operator of the asset. Since the Anchor needs "four nines reliability" (99.99%) it will expect to see a professional operator in charge of the community's asset.

Forming a power purchase agreement (PPA) to sell a regular quantity of power to an anchor demand business could allow a loan to be obtained for further investment in/expansion of the hydropower scheme or the local grid. Whether investment is required or not, the community would have an additional source of income at little extra cost. The community could either allow the professional operator to keep a portion of the PPA revenues for itself in lieu of payment, or alternatively, it could "lease" its asset to a professional operator for a flat rental payment, and allow the operator to find and acquire as many customers as possible to maximize the revenues earned (the operator would keep the surplus over and above the steady and fixed lease payment to the community).

The next step is to identify other businesses who could make use of daytime electricity, but perhaps haven't done so due to the costs of diesel or maintenance of a generator. Entities who require power only during the day, (rather than continuously, like Anchors), are most likely to be shops and small local businesses, creating local jobs. The local development impact of electricity mostly comes from daytime users. They are absent from many community owned micro-hydro areas for reasons explained above, i.e. when communities are also the owners and operators they tend to strictly limit the operation to only a few hours of household lighting and phone charging in the evening hours. These daytime users who would be likely to materialize if a professional operator were engaged by the communities, can be offered a supply of electricity which might allow them to run a fridge or small power tools, or find some other beneficial use of electricity. There could be links with micro-finance here to allow people to make use of the electricity available.

This approach will always benefit the community as the owners of the micro-hydropower infrastructure. Whether the best model is for the community to manage business relationships themselves, hire a manager to do this, or rent the scheme to a company so that they can market the energy may vary from community to community. These options are less important than making more economic use of the potential power available to drive development in an area.

(Source: Consultees, 2013)

6.6 Reduce land degradation and erosion issues by working with local institutions

There are significant issues with land degradation and erosion in the mountains of Nepal. These have impacts on water, energy and food security by reducing the regulating capacity of soil, causing high sediment loads in rivers with hydropower schemes and reducing agricultural productivity, respectively. The complex nature of Nepalese society, in terms of institutions, ethnicities and languages means addressing these problems is challenging.

Extensive research has been undertaken on this subject and the implementation of community forestry management practices has had a significant positive impact on the problem (Thompson et al., 2007) although it remains a major challenge.

In their book "Uncertainty on a Himalayan Scale" Thompson et al. (2007) describe, some of the major challenges they uncovered through their systems analysis of Nepal's environment and development needs. They believe the diversity of human and natural environments in Nepal means large scale problems simply cannot be solved by a blanket approach and there is a need for in-depth understanding of local situations and work to help existing institutions recognise and drive win-win changes from within (Box 5). They believe this approach is the only one capable of creating sustainable development and tackling deforestation and erosion problems. These lessons could also inform hydropower development strategies both in Nepal and other countries.

Box 5 Recommendations from Thompson et al.'s book "Uncertainty on a Himalayan Scale"

In the 2007 edition of their book 'Uncertainty on a Himalayan Scale' Thompson et al. describe the diverse nature of the Himalayan environment (human and natural) and its corresponding needs in terms of development approach. Their work is based on extensive systems analysis work in the Himalaya for UNEP.

Apart from the deep uncertainty in all types of measurements suggested by the title, the heterogeneity of Himalayan environments, and socio-economic contexts is emphasised. The authors believe that broad brush high level solutions are not likely to be successful across large swathes of the Himalaya, for the basic fact that it is impossible to identify 'the problem' at such a scale. There is a multitude of contradictory and contending problems resulting from the variability and diversity at every level from individuals to village or district. 'Grand design' solutions are only appropriate where there is a shared understanding of 'the problem' and complete knowledge of its causes. Neither of which exists in the Himalaya. Attempts to develop integrated (i.e. blanket) solutions in the face of such diversity and ignoring local institutional realities are likely to experience resistance. The trick, they suggest, is knowing where and how to tweak the existing institutional system to drive its own positive change. This means it is necessary to 'get hands dirty' in understanding the real issues on the ground.

The authors make the following recommendations, acknowledging that institutional characteristics should be matched to roles. They contrast big international donors with lots of internal regulations, to smaller organisations able to get into the field and achieve development aims by 'any means necessary'.

1. Agencies should avoid integration and coordination and look for a distinctive approach which will increase diversity of approaches.
2. Focus on institutions and recognise biophysical uncertainties
3. Aim to integrate the complementarity of distinctive approaches rather than approaches themselves.
4. Engage in a two-way learning process and preserve modesty by avoiding commitments to new projects.
5. Start small-scale and modest to facilitate consensus building, flexibility, adaptability and opportunities. Avoids embarrassing large-scale failures.

6.7 Research and develop payments for ecosystem services approach for Nepalese context.

Payments for ecosystem services (PES) are intended to redress balances of benefits between disparate groups of people, or motivate changes in behaviour of a group through payments from those who stand to benefit. There seems to be potential for such relationships to be formed in Nepal such as where the impacts of land degradation in Nepal's mountains is felt particularly strongly in the Terai region, vulnerable to flooding and sediment deposition. UNDP has demonstrated potential for PES to work (UNDP, 2014). PES is necessarily context specific, so it is necessary to define causative effects and the parties exerting an influence on the provision of an ecosystem. This requires significant research and development.

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.

Intervention	Intervention point(s)	Impact on:			Resilience to:				
		Water Security	Energy Security	Food Security	Climate Change	Socio-economic Change	Ease (1 Low - 5 High)	Impact (1 Low - 5 High)	Priority (Ease x Impact)
Assess environmental and social impacts and climate change resilience of development at promising sites identified by the storage-type hydropower master plan	3a						4	5	20
Improve silt load monitoring/flood forecasting	12c						4	4	16
Develop robust methodology for analysing climate change impacts on existing and new hydropower projects to inform adaptation planning decisions	3a, 3b						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
Further develop community level hydropower by increasing the number of schemes and their impact	3c						5	3	15
Reduce land degradation and erosion issues by working with local institutions	11a, 11b, 12c, 12a						3	5	15
Research and develop payments for ecosystem services approach for Nepalese context	9, 11b, 12a, 12c						3	4	12

Table 8 Prioritised interventions identified by this case study for improving hydropower performance or water, energy, food security. Impact and resilience scale is red (strongly negative) to green (strongly positive) via amber (no impact).

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Appendix A People and organisations consulted

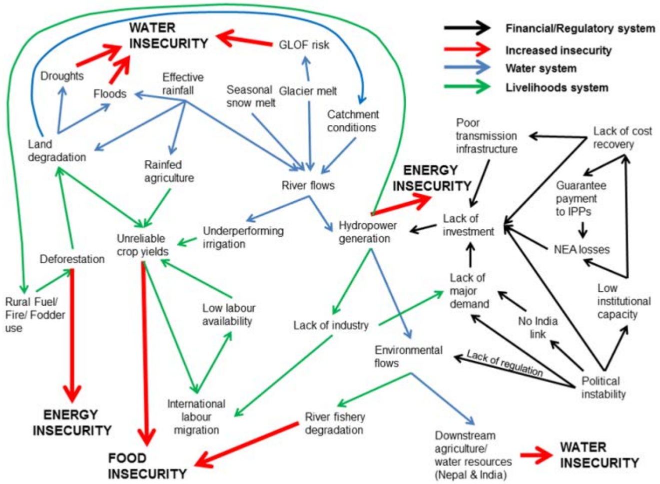
This appendix lists the people and organisations consulted as part of this study.

Name	Position	Organisation
M. Mukherjee	Senior Energy Specialist	World Bank
D. Gyawali	Chairman	Interdisciplinary Analysts
R. Sansar Shrestha	Visiting Faculty Chairperson Director	Kathmandu University Audit Committee, Butwal Power Co.Ltd NepalHydro & Electric Limited
J. Oglethorpe	Chief of Party	WWF Nepal
M Adhikari	National Advisor, Community Electrification Sub-Component	Alternative Energy Promotion Centre
S.P. Singh	Director	Generation, Operation and Maintenance Department, Nepal Electricity Authority
G. Pokharel	Small hydropower producer	
Akiko Urago		JICA Study Team
		Water and Energy Commission Secretariat

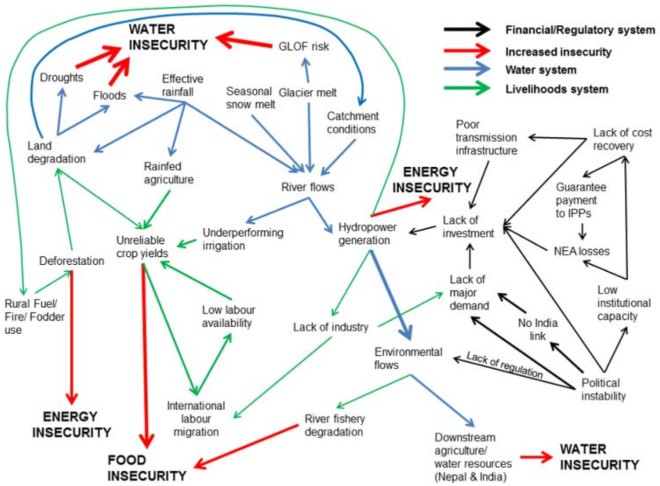
Table 9 Consultees for the Nepal case study

Appendix B System schematic diagrams

This Appendix displays the three system schematic diagrams from Figure 7, Figure 8 and Figure 9 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