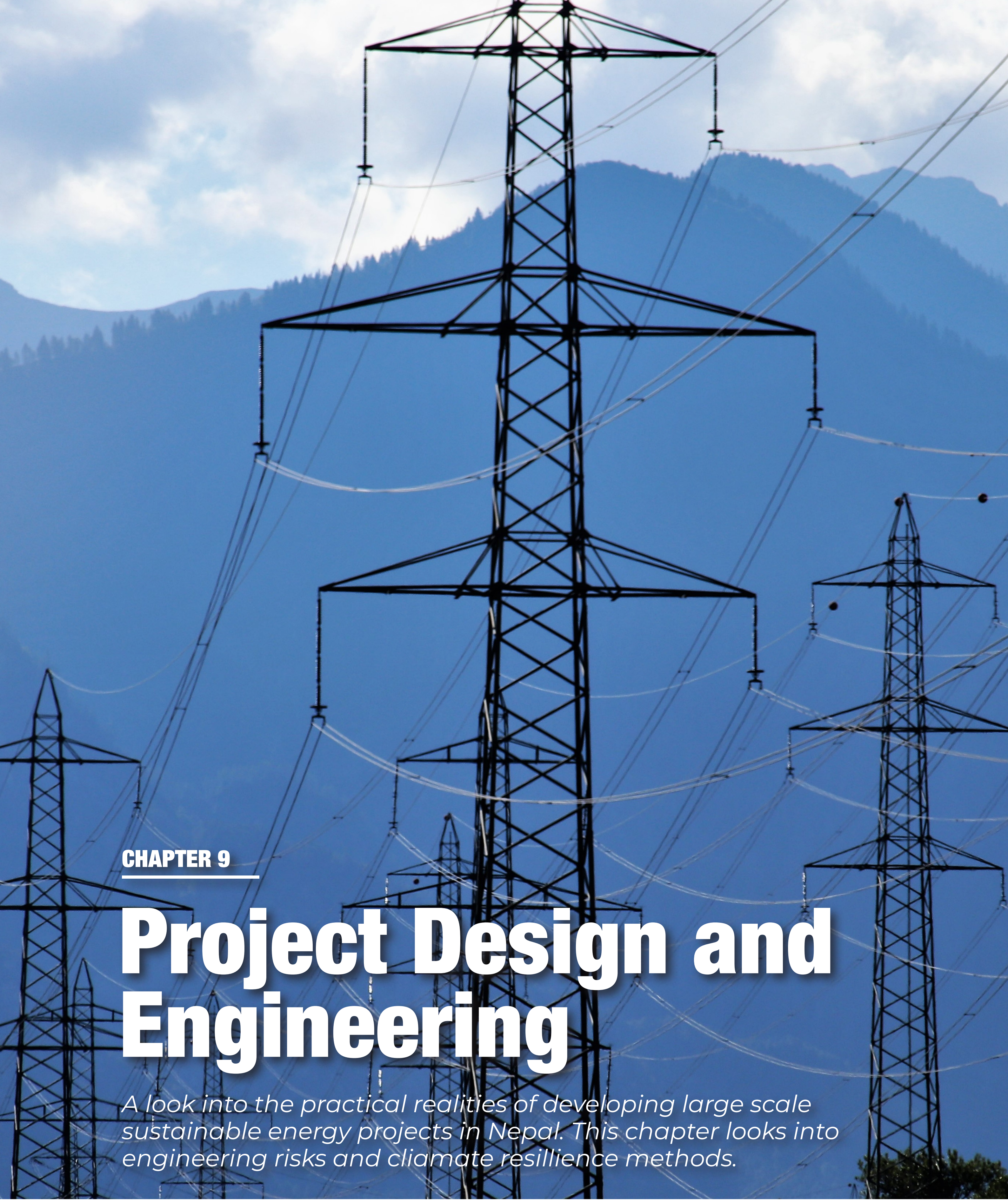

CHAPTER 9

Project Design and Engineering

A look into the practical realities of developing large scale sustainable energy projects in Nepal. This chapter looks into engineering risks and cliamate resillience methods.

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CHAPTER 9

Project Design and Engineering

This chapter is an excerpt from the publication: Lessons on how to promote and execute equity capital in the renewable energy sector of Nepal (Dolma Foundation, 2019).

The full publication can be accessed at: www.dolmaenergy.com/publication

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Dolma Foundation is a non-profit organisation, promoting prosperity by investing in education and sustainable business in Nepal that are risky for the private sector.
This report series was produced and authored by Matthew Ribeiro-Norley and Vishal Bista. The team is grateful for collaboration and data within Dolma and from various agencies in Nepal. The cut-off date for data in this report was January 2019.

SUGGESTED CITATION

This chapter is an excerpt from the publication: Lessons on how to promote and execute equity capital in the renewable energy sector of Nepal (Dolma Foundation, 2019).

DISCLAIMER

EXECUTIVE SUMMARY

CHAPTER 1: ENERGY MARKET ANALYSIS

Chapter 1 sets the tone for the series in highlighting that commercial institutional investors are the only sector with the capacity to finance this gap.

Nepal currently sits on a USD 17.8 bn infrastructure gap (excluding transmission and distribution) which needs to be addressed.

A prime solar belt region with 300 days of sunshine, and holding an economically feasible potential of ~43,000 MW of hydropower, Nepal boasts impressive renewable energy potential.

Despite this, Nepal's total installed capacity (March 2018) stands at 1,017 MW – 968 MW from hydro resources and 49 MW from thermal alternatives. Solar capacity is limited to 1.2 MW.

Electricity imports remain high in the dry season (Oct-Mar) for both peak load and base load energy, and as of March 2019 stood at 650 MW.

The Nepalese Rupee has remained pegged to the Indian rupee since 1993, primarily in the interest of price stability.

Based on Dolma's findings, the Project Internal Rate of Return for hydropower projects in Nepal range from 15-20%.

The main barriers to entry in Nepal include political stability, policy stability, currency, weak governance, climate change and bureaucracy.

Barriers to exit include the process of repatriating funds (whereby multiple authorities are required to sign-off after taxes are paid); as well as the lock-in period of up to three years after IPO on the Nepal Stock Exchange.

While there is a clear opportunity to export electricity to India in future, a clear framework agreed by both parties has not yet been enforced.

CHAPTER 2: CLIMATE CHANGE

Chapter 2 reflects on the environmental and social implications of a changing climate. Known for its pristine glaciers and abundant flora, the Himalayan region has witnessed an alarming number of climate-related tragedies in the last two decades. Between 2000 and 2015, ICIMOD estimates that 45,534 people died due to flooding, 10,893 to extreme heat, and 191 by drought, in Himalayan countries alone.

Higher temperatures have resulted in glaciers receding at alarming rates, adding volume to Glacial Lakes which pose a threat to those living downstream in the event of a burst. Moreover, unpredictable river flow can be a threat to farmers.

This chapter also puts into perspective that while $CO2$ rates remain high, the most immediate threat to the region – as identified in a series of recent reports from the Intergovernmental Panel on Climate Change (IPCC) and International Centre for Integrated Mountain Development (ICIMOD) – are short-lived climate pollutants, such as black carbon.

Despite its shorter life-span (approximately 50 years), black carbon is a warming agent with 1,500 times the warming effect of $CO2$. According to research, fossil fuel sourced black carbon appears to have twice the particle-specific warming potential of biomass sourced black carbon.

Based on conversations Dolma has had with regional climate scientists, prioritising the mitigation of short term climate pollutants is paramount to reversing Himalayan glacial melt – of which one third is expected to disappear by 2100 in a business-as-usual environment.

CHAPTER 3: TRANSMISSION AND DISTRIBUTION

Chapter 3 traces Nepal's energy infrastructure development and progress. Unlike energy generation, Nepal's transmission network grew at an annual rate of 8% from 2008 to 2012.

Electricity markets in Nepal are gradually un-bundling. Until 1990 all production, transmission and distribution were vertically controlled by the Nepal Electricity Authority.

Since 1990, Independent Power Producers have added ~500 MW to the grid.

Despite plans to un-bundle the NEA's transmission and distribution business following The Hydropower Development Policy 1992, it was only with assistance from the Asian Development Bank in 2015 that the National Transmission Grid Company was set up.

As this publication went to print, the newly-found distribution company had still not made any significant progress.

There are some USD 817 mn allocated to the enhancement of Nepal's transmission and distribution, mainly led by key donors such as ADB, Government of Norway, MCC and JICA.

A further USD 471.5 mn is being spent on policy and institutional reforms led mainly by the World Bank, ADB, and Canadian Government.

CHAPTER 4: REGULATORY ADVOCACY

Chapter 4 puts forward a number of recommendations to government that would facilitate the enabling environment for international investors.

Nepal has over the last five years (2013-2018) amended and introduced several regulations to facilitate public-private partnership and encourage further private sector investment.

Despite the government's best intentions to prioritise infrastructure, some have labelled the planning "erratic": since 2001 there have been five strategic documents on energy capacity targets, one every three years on average.

The most recent government plan, from 2016, calls for the construction of 10,000 MW by 2030.

The World Bank and others have argued that to attract and retain investment to the tune of tens of billions of dollars, an enabling environment is required.

"Quick-Win" regulatory reforms that would have a disproportionately positive impact on the infrastructure investment environment in Nepal:

Automatic route for foreign investment
Foreign currency power purchase agreements
Return on equity (ROE) clarifications
Alternative and auxiliary energy tariffs (new technologies such as batteries)

Long-term reform opportunities beyond the scope of this project:

Sovereign credit rating
Cost-plus approach
Competitive bidding
Protection for seasonality
Benefit sharing
Cooperation with regional partners

CHAPTER 5: INSTITUTIONAL INVESTOR INVESTMENT LANDSCAPE

Chapter 5 identifies three key catalysts for driving institutional investors into frontier markets like Nepal: low global interest rates; the commercial viability of renewable technologies; and heightened public, shareholder and regulatory opinion in relation to carbon emissions.

The need to attract large amounts of FDI to finance Nepal's power needs is well documented, both the Investment Board of Nepal and National Planning Commission agree that to meet just domestic demand, approximately USD 18 bn is required in capital investment (both debt and equity), or USD 1.5 bn annually.

The Dolma team interviewed some of the world's largest institutional investors, testing the risk and return mandate for Nepal against their current and emerging risk strategies. Interviewees included funds with assets under management from USD 1 bn to 6 tn.

These were our findings:

Some investors suggested that the required return on equity for construction risk could be up to 20%, provided a Nepal project vehicle can demonstrate equivalency to investment grade status after successfully mitigating risks.

Among institutional investors there is a clear negative bias against credit and currency risk, suggesting that FX risk, real or perceived, prevents perhaps trillions of dollars from flowing to the poorest economies.

Dolma's findings also suggested that a country's credit rating is fundamental to getting an investment proposal through the first step of the investment procedure. In some cases, the lack of a sovereign credit rating and international sovereign bonds for Nepal has been too large a barrier to overcome in our discussions with some investors who are often restricted to considering countries that are at least investment grade (BBB-).

Some solutions to perceived risks included adopting Political Risk Insurance (PRI); Currency Hedging Mechanisms; and Bank Guarantees, amongst others.

Investors interviewed fell into two groups –leaders and followers – the former willing to take higher risk in search of greater yield and the latter less so; 2) there is no clear connection between Assets Under Management (AUM) and risk profile when it comes to investing in frontier markets like Nepal.

CHAPTER 6: COMPLEMENTARY INVESTORS

Chapter 6 discusses complementary investors (or blended concessional finance) which provide a new wind of opportunity for institutional investors – previously unable to invest in frontier market because of perceived risk. Blended capital works to de-risk perceived obstacles.

Investment instruments typically involve the deployment of grants, concessional lending, guarantees, and equity. These are deployed using adaptable programme, policy and sector investment loans, debt swaps, PPPs, advanced market commitments, and first loss reserve tranches.

Green bonds have recently also proven to be a potential solution by providing debt financing to eligible climate change projects. As of 2018, green bond issuance reached some USD 250 bn.

Complementary investors have played a key role in attracting investment to Nepal's renewable sector – these include Development Finance Institutions such as FMO, OEEB, DGGF and FINNFUND, as well as Multilateral platforms like IFC and ADB.

As stated in chapter 5, Dolma finds that at least two blended finance instruments are required for institutional investors to consider a renewable energy project in Nepal: political risk insurance and a currency hedge.

Dolma's research finds that countries successful in solving these risks for investors were able to make bold moves within their own domestic economies.

Nepal could follow the path of successful governments in doing so by creating its own government backed instruments and enacting reform.

CHAPTER 7: LEGAL STRUCTURING

Chapter 7 explains the legal structuring backdrop which is an essential component for foreign investors considering large infrastructure in Nepal.

To invest in Nepal through the FDI route, it is important to analyse and decide upon which country to invest from. To date there are 15 jurisdictions which hold a Dual Taxation Agreement (DTA) with Nepal which mitigates the risk of paying double taxation.

Dolma finds that Mauritius is generally viewed as the "gateway" to Nepal because both countries hold a DTA – Mauritius is also known as a transparent jurisdiction that ranks well according to the financial services index. It also has experience fund management and administrative services which manage approximately USD 670 bn in assets.

Despite Mauritius' favourable positioning, the choice of domicile is based on the circumstances and preferences of individual investors.

Dolma views the UK as one of many strong locations to set up a fund manager, and has based the examples in chapter 7 on an English limited partnership or UK company as the fund vehicle.

CHAPTER 8: FINANCIAL STRUCTURING

Chapter 8 explores key regulated and non-regulated institutions that could act as potential sources of financing for energy projects in-country.

Nepal is yet to formulate specific regulatory provisions for private equity funds that invest in private companies.

There are a number of private equity players investing in renewable energy in Nepal, which include IFC, Dolma Impact Fund I and Equicap.

Dolma found that key exit issues for international investors include, but are not limited to the following:
Valuation at exit
Taxation in change of ownership
Repatriation issues

Dolma found that there could be some challenges for investors keen to invest through a project finance model, particularly for debt financing:

A limited tenor and floating interest rates on long term loans.
Generally, a limited capacity for banks to lend.
A limited scope for corporate bonds, which is still a nascent market.

The chapter also explores key financial issues for investors and how to integrate these solutions at the fund level: these include suggestions for currency risk, political risk, and debt risk.

CHAPTER 9: PROJECT DESIGN AND ENGINEERING

Chapter 9 focuses on the practical realities of executing renewables projects in Nepal, acknowledging that besides hydropower – Nepal's most mature energy asset class – other newer technologies such as solar and batteries could play a significant role in servicing growing supply, and providing auxiliary services.

Despite Nepal's installed generation capacity standing at 1,100 MW, there are some 7,000 MW in licenses that have been issued by the government to IPPs. The vast majority of these are for hydro-run-of-river (RoR) projects.

Dolma has identified a priority pipeline of hydro and solar projects that are optimal from a project execution perspective.

The chapter also includes a summary of leading battery technologies and which would be most suited in Nepal's context.

While there are no Nepali contractors that offer Engineer Procurement Construction (EPC) contracts this chapter analyses local firms that have a track record for hydro and solar projects in-country.

As financiers are increasingly aligning their investment mandates to the UN's Sustainable Development Goals, the chapter also outlines high level strategies for climate adaptation and resilience.

LIST OF ACRONYMS

TABLES

FIGURES

ABBREVIATIONS

ADB	ASIAN DEVELOPMENT BANK
CAGR	COMPOUND ANNUAL GROWTH RATE
CAPEX	CAPITAL EXPENDITURE
COD	COMMERCIAL OPERATION DATE
CSP	CONCENTRATED SOLAR POWER
DOED	DEPARTMENT OF ELECTRICITY DEVELOPMENT
EIA	ENERGY INFORMATION ADMINISTRATION
EPC	ENGINEERING PROCUREMENT AND CONSTRUCTION GL
ESIA	ENVIRONMENTAL SOCIAL IMPACT ASSESSMENT
GHI	GLOBAL HORRIZONTAL IRRADIANCE
GON	GOVERNMENT OF NEPAL
IEE	INITIAL ENVIRONMENTAL EXAMINATION
INR	INDIAN RUPEE
IPP	INDEPENDENT POWER PRODUCER
LOI	LETTER OF INTEREST
NEA	NEPAL ELECTRICITY AUTHORITY
NREL	NATIONAL RENEWABLE ENERGY LAB
NPR	NEPALI RUPEE
NRN	NON RESIDENTIAL NEPALI
PPA	PRIVATE POWER AGREEMENT
PV	PHOTOVOLTAICS
RFP	REQUEST FOR APPROVALS
TL	TRANSMISSION LICENSE
UN	UNITED NATIONS
USD	US DOLLAR
VGF	VIABILITY GAP FUNDING

1.1 INTRODUCTION

The majority of our analysis of the institutional investor landscape in this series of reports has not focused on the practical realities of developing renewable energy assets in Nepal. This paper will narrow in on technical details potential developers and investors might want to consider.

Section 1 provides an overview of hydro and solar projects in active development, including analysis from Dolma and Mott MacDonald on a priority hydro run-of-river pipeline. Section 2 analyses market trends in battery technologies and assesses the capacity of local contractors to implement renewable energy projects in Nepal. Section 3 draws on project development risks, focusing particularly on climate change and potential approaches to mitigating its risks.

Findings from this report highlights a recurring theme in this series: the potential of hydro, solar, and batteries (assuming decreasing costs) to grow and stabilise Nepal's electricity grid. Hydro is a mature asset class that is supported through an enabling environment of banks and engineers that understand how to finance, build, and operate its systems. However, those attempting to introduce newer technologies will find the current environment less welcoming and may require more capacity building and planning for their project team.

That said, however, those promoting nascent technologies have reason to be optimistic, as the Government of Nepal has committed to developing ~10-12% of its energy mix through non-hydro renewable technologies.


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1.2 OVERVIEW OF PROJECTS THAT HAVE RECEIVED LICENSES AND ARE NOT UNDER CONSTRUCITON

MARKET OVERVIEW

According to the World Bank, licenses for projects totalling some 7,000 MW have been issued to IPPs (Independent Power Producers), but these projects have not reached sufficient financing to begin construction. As of July 2018, hydro projects totalling 3,000 MW are under construction (including those financed by IPPs and the NEA).

The government has also placed certain licenses that have expired into a basket of projects that may be auctioned in the future.

Table 1 outlines projects in the 100–350 MW range, and Table 5 defines a more specific pipeline that we have refined using a selection criteria developed by the Dolma Foundation and Mott MacDonald.

TABLE 1 LIST OF HYDRO PROJECTS ABOVE 100 MW WITH SURVEY LICENSES

Project	Capacity (MW)	River	Promoter
Dudhkoshi-9 HPP	111	Dudhkoshi	Urja Developers Pvt. Ltd.
Thuli Bheri	121	Thuli Bheri	GAGE Nepal Pvt. Ltd.
Bheri Nadi-8 (BR-8) HEP	125	Bheri	Dugar Brothers and Sons Pvt. Ltd
Tamor Mewa	128	Tamor	Spark Hydroelectric Co. Ltd.
Dadagau Khalanga Bheri Hydropower Project	128	Bheri	Gezhouba Group Power Investment Nepal Pvt. Ltd.
Lower Barun Khola HPP	132	Barun Khola	Ampik Energy Pvt. Ltd.
Super Tamor	155	Tamor	Cristal Power Development Pvt. Ltd.
Ghunsa Khola HPP	155.82	Ghunsa khola	RM Investment Company Pvt. Ltd.
Mugu Karnali HPP	159.62	Mugu Karnali	Butwal Power Company Limited
Kaligandki Gorge	164	Kali Gandaki	NECT-HYM JV
Seti Nadi-3	165	Seti Khola	Chilime Hydropower Company Limited
Upper Budhigandaki HEP	203	Budhi Gandaki	Purnima Developers Group Nepal Pvt. Ltd.
Humla Karnali 1 HPP	235	Humla Karnali	Sichuan Wangping Energy Science and Technology Co. Ltd.
Bheri-2 HEP	256	Bheri	Gezhouba Group Power Investment Nepal Pvt. Ltd.
Budhi Gandaki Kha HEP	260	Budhigandaki	Nilgiri Khola Hydropower Company Limited
Bheri 4	300	Bheri	Bhery Energy Pvt. Ltd.
Jagdulla HEP	307	Bheri	Jagdulla Hydropower Company Limited
Lantang Khola Reservoir Hydropower Project	310	Langtang	Yeti World Investment Pvt. Ltd.
Humla Karnali 2 HPP	335	Humla Karnali	Sichuan Wangping Energy Science and Technology Co. Ltd.
Budhi Gandaki Hydropower Project	341	Budhi Gandaki	Times Enery Pvt. Ltd
Surke Dudhkoshi HEP	350	Dudhkoshi	Yeti World Investment Pvt. Ltd.

Despite the 25 MW PV project funded by the World Bank, there are no commercial, pure PV projects under construction. There are, however, a number of projects that have applied for survey/generation licenses, as can be seen in Table 2.

TABLE 2: LIST OF SOLAR PV PROJECTS WITH SURVEY LICENSES ABOVE 5 MW

Project	Capacity (MW)	Promoter
KTM Energy Solar Hybrid Power Project, Rangeli, Biratnagar	5	KTM Energy Pvt. Ltd.
Bel Chautara Solar Farm Project	5	Solar Farm Pvt. Ltd.
Bhadrapur Solar PV Project	5	Rairang Hydropow-er Development Company Ltd.
Block No 1 Solar Farms Project	5.1	Nepal Electricity Authority
Solar PV Project, Dang	5.3	O.Tech Pvt. Ltd.
Solar PV Project, Dhading	5.49	Otech Pvt. Ltd.
Parkland Solar PV Power Plant	5.9	Parkland Agrotour-ism Pvt. Ltd
Grid-Connect-ed Solar Power Project,Parwanipur, 11kV S/S	8	Api Power Company Ltd.
Grid-Connected Solar Power Project, Duhabi, 33 kV S/S	8	Global Energy & Construction Pvt. Ltd.
Block No 4 Solar Farms Project	8.1	Nepal Electricity Authority
Block No 2 Solar Farms Project	8.3	Nepal Electricity Authority
Grid-Connected Solar Power Project, Butwal , 33 kV S/S	8.5	Ridi Hydropower Development Com-pany Ltd.
Bhrikuti Solar Power Project	9	First Solar Develop-ers Nepal Pvt. Ltd.
KTM Energy Solar Hybrid Power Proj-ect, Rani, Biratnagar	10	KTM Energy Pvt. Ltd.
KTM Energy Solar Hybrid Power Proj-ect, Tankusuwari, Biratnag	10	KTM Energy Pvt. Ltd.
Mithila Solar PV Power Project, Dhanusa	10	Eco Power Develop-ment Pvt. Ltd.
Lamki Solar Energy	10	Api Power Company Pvt. Ltd.
Attariya Solar Energy	10	Api Power Company Pvt. Ltd.
Utility Scale Solar PV	10	G I Solar Pvt. Ltd.
Mithila 2 Solar PV Project,Dhanusa	10	Nabin Kumar Singh
Solar Power Plant, Dang	20	Country Develop-ment Company Pvt. Ltd.

PROJECT PREPARATION PROCESS

Prior to December 2017, the project preparation process for both hydropower and solar followed an identical process from a licensing perspective. Figure 1 outlines this process. But processing the licensing for solar takes less than half the time as it does for hydro.

FIGURE 1: PROJECT PREPARATION PROCESS (HYDRO VS SOLAR)

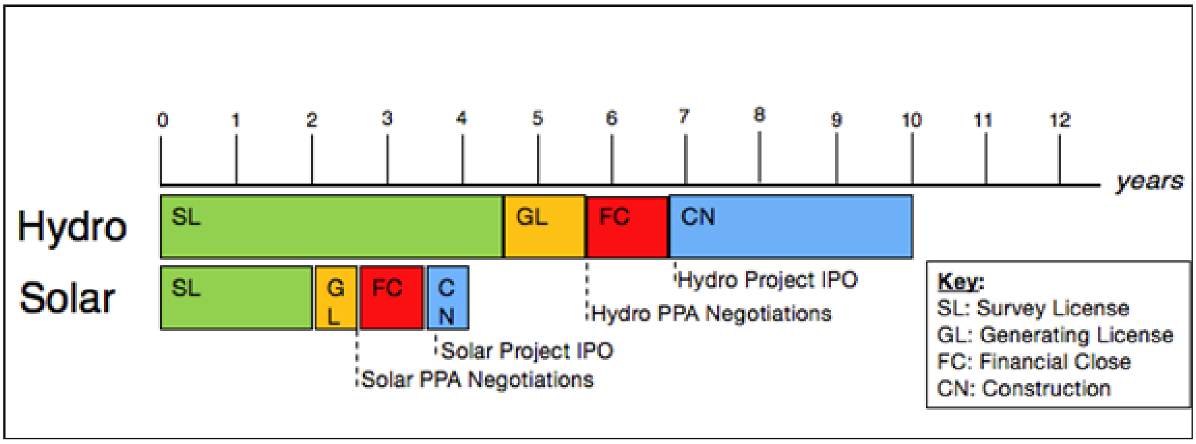


FIGURE 2: TYPICAL TIMELINE OF A SOLAR PV PLANT

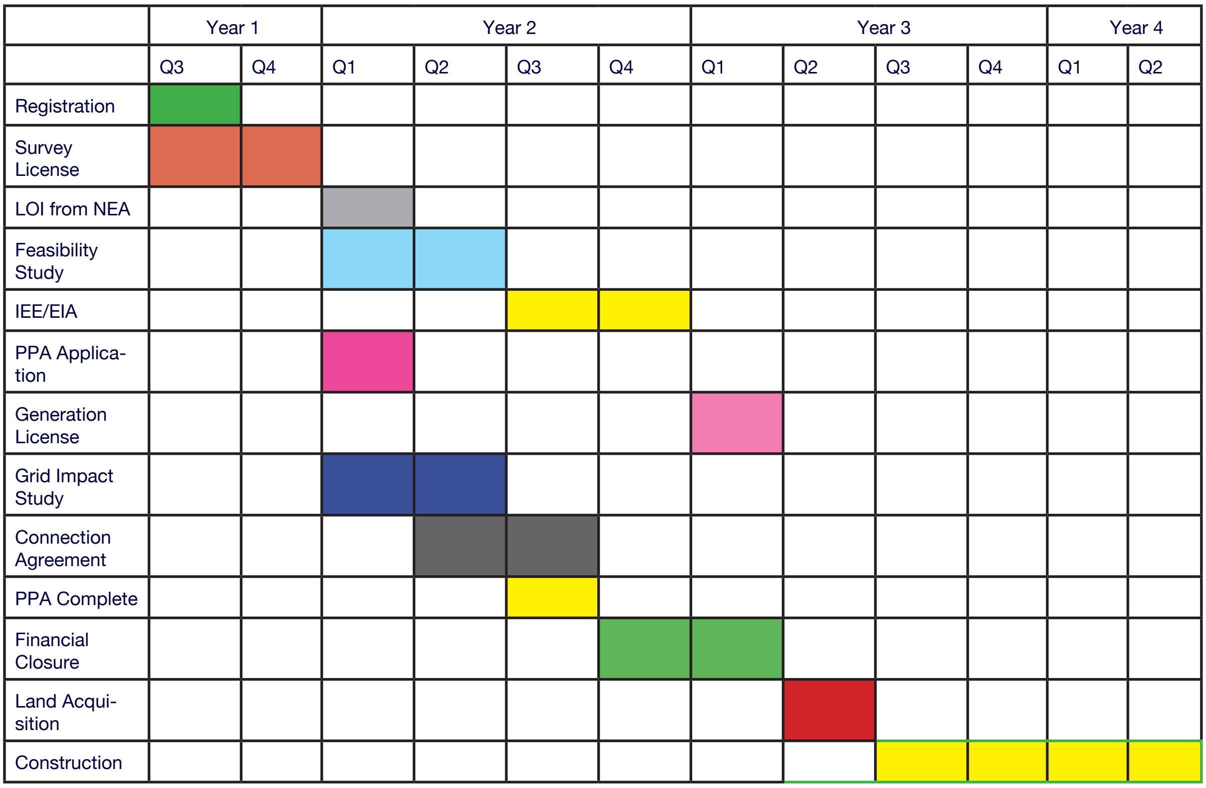
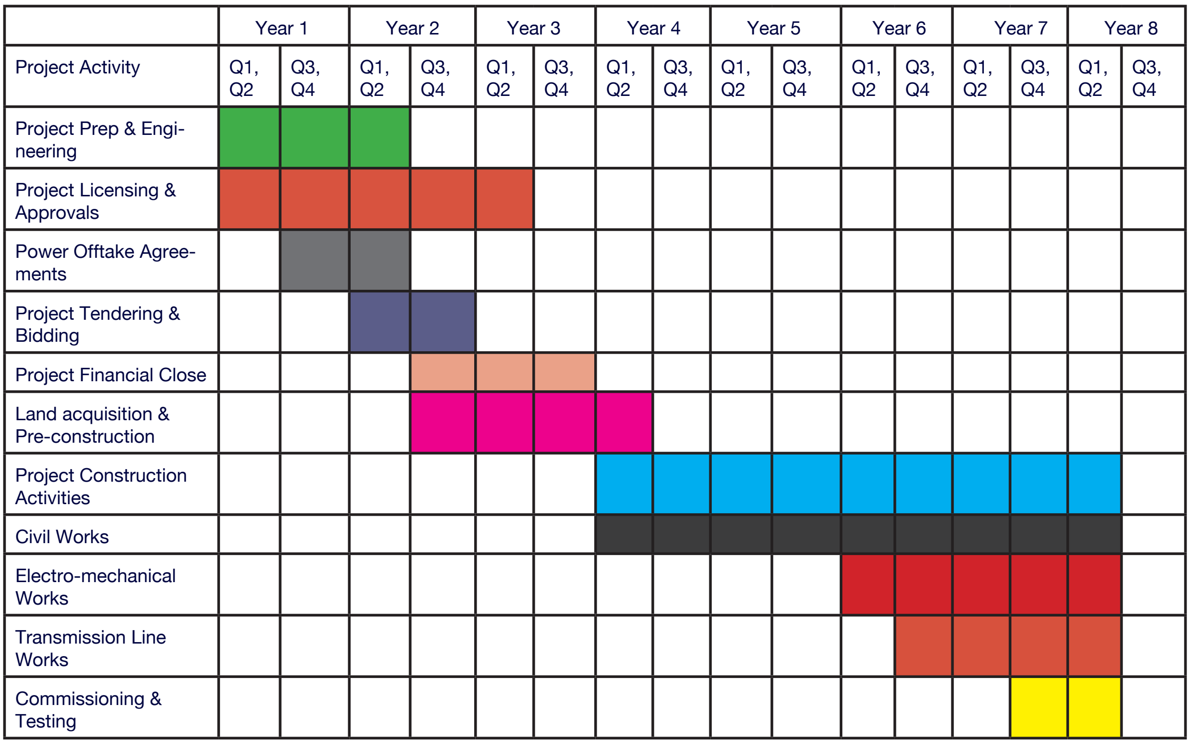


FIGURE 3: TYPICAL TIMELINE OF A HYDRO RUN-OF-RIVER PLANT



Naturally, construction timelines for run-of-river hydro and solar PV are different, with solar PV taking roughly half as long. 3

FILTERING THE PROJECT PIPELINE

Dolma Foundation, in collaboration with Mott MacDonald, created the following criteria to filter potentially attractive projects from Table 1 in the range of 100–300 MW. The set of criteria are an example and will vary depending on the preferences of individual investors and developers.

TABLE 4: PRIORITY PIPELINE CRITERIA

•Peaking feasibility	•Installed capacity 100–300 MW
•CAPEX requirement of USD 200–600 mn	•Applied for Generation License
•Sufficient information available	•Evacuation facility
•Limited environmental issues	•Limited settlement concerns
•Developer capacity	

Filtering by the above criteria results in the following project list:

TABLE 5: PRIORITY PIPELINE

Project	Super Trishuli	Upper Tamor	Budhi Gandaki “Kha”	Budi Gandaki “Ka”	Lower Manang Marsyandgi
Estimated Capex Requirement (USD mn)	200	570	520	260	252
Installed Capacity (MW)	100	285	260	130	140 MW with Q40 (optimized capacity) 210 MW (survey license)
Type	Run-of-river (dam-toe powerhouse scheme)	Run-of-river (peaking possibility)	PRoR (Day Pond)	RoR (cascade of Kha)	RoR
Status	GL applied/PPA negotiations		GL applied; resizing to meet Q40 criteria. Expected COD: 2016. EIA approved	GL applied; resizing to meet Q40 criteria. Expected COD: 2016. EIA approved	GL applied; the applications for PPA & Generation License have been submitted to concern authorities
Catchment Area (km2)	11,659	1,850			
Gross Head (m)	15	490			325
Design Discharge (m3/s)	850 (Q26.5%)	7.8 73 (Q40%)			38
Access Road	Good				Power house site is 90 km away from Dumre
Dam type	Barrage	Crest Elevation: 12 m			
Crest Length: 37 m					
Transmission Lines	New Bharatpu	64 km (Basantapur) 220 kV double circuit			Inter-connection will be made to the Marsyangdi Corridor 220 kV Transmission line planned by NEA at Manang Hub

1.3 SOLAR POTENTIAL, ASSOCIATED TARIFFS, TRANSMISSION AND REGULATIONS

MARKET ANALYSIS

The solar potential of the Himalayan region is immense, according to NREL, a renewable energy research center. The region boasts a raw potential of 648,115 MW. Given its favourable topography, Nepal has an unspecified potential that likely exceeds the estimated potential of commercially viable hydro, which is 43,000 MW. Despite this, the UN, through the Green Environmental Facility, conducted a study in 2008 that placed Nepal's combined Solar PV and CSP potential at 4,000 MW.

ASSOCIATED TARIFFS

Interest in solar in Nepal is beginning to increase and the NEA has responded with new targets to have 2,000 MW of its portfolio made up of renewables. Despite the growing global popularity of wind energy, it is arguably the least developed energy renewable class in Nepal.

To date there have been two notable tenders in the solar space. The first is the World Bank-funded USD 138 mn, 25 MW project that was first approved in December 2014 by the NEA. Risen Energy from China secured the right to build the project after a tender was issued by the NEA in April 2015. The second tender is the recent RFP from the NEA to select IPPs for the construction of solar PV across Nepal. Selected projects will be granted a 25-year PPA, while the NEA (backed by ADB support) will provide incentives in the form of viability gap funding (VGF) of up to USD 20 mn. When it was first conceived of in 2016, the project envisioned installing at least 25 MW of solar power by 2018, but due to delays, this goal is likely to be achieved only by 2020.

NEPAL SOLAR TARIFFS

The posted government tariffs for solar PV in Nepal as of October 2018 is NPR 7.3/USD 0.63 per unit (kWh/m2). However, Dolma expects rates to fall in due course, recent solar PPA's were recorded at NPR 6.35/ USD 0.55 per unit. In India, solar tariffs have plunged to a new low of INR 2.44/USD 0.033 per unit. Table 7 details 200 MW of a 500 MW project in Bhadla Phase II, Solar Park, Rajasthan, highlighting the type of aggressive bidding prevalent in the Indian solar market.

TABLE 7: BIDDING FOR 200 MW SOLAR PLANT IN RAJASTHAN

Date	Entity	Bid (INR/kWh)
November 2015	SunEdison, USA	4.63
January 2016	Fotum Energy, Finland	4.34
April 2017	Solairedirect SA, France	3.15
May 2017	Phelan Energy, South Africa	2.62
May 2017	Softbank Foxconn, Bharti	2.45
May 2017	Acme Solar, India	2.44

TRANSMISSION REGULATION

There are two key steps required to satisfy transmission requirements under the local regulations before a project is commissioned: (1) a transmission line survey license and (2) transmission license.

(1) TRANSMISSION LINE SURVEY LICENSES

Developers are required to submit six monthly progress reports as per Rule 21(2) of Electricity Regulation, 2050. Upon completion of the survey, developers need to submit a Feasibility Study Report, which includes:

- IEE – if transmission voltage level of project is between 33 and 66 kilovolts (kV) or if the project falls under categories mentioned in Schedule 1 of the Environment Protection Rules, 2054
- EIA – if transmission voltage level of the project is greater than 66 kV

(2) TRANSMISSION LICENSE (TL)

A TL is required to construct and operate a transmission facility upon completion of the survey. An application fee is required to be paid equal to one third of the license fee to the DOED, along with the application as prescribed in Schedule 11, Rule 24 of Electricity Regulation, 2050. The TL is issued within 120 days of a complete and adequate application package being received.

GLOBAL MARKET DEVELOPMENTS

Battery storage has been coined by industry commentators such as McKinsey as the next disruptive technology in the global power market. According to IHS Markit, a global energy consultancy firm, "the global grid-connected storage market could reach a total installed capacity of 28 GW by 2022, from just 3 GW in 2016". These developments are made possible due to the falling price of lithium-ion storage: module prices are expected to go below USD 200 per kWh by 2019.

STORAGE BATTERY TECHNOLOGIES

There are various technology options within the battery market that are appealing for use with on-grid solar. The most relevant are below, selected based on their declining capital cost outlook and technical applicability. This subsection draws heavily on findings from Lazard's Levelisted cost of storage analysis 2.0 (2018) and McKinsey's report Battery storage: The next disruptive technology in the power sector (2017).

1. Lead acid
2. Lithium-ion
3. Flow batteries
4. Sodium

LEAD ACID

This technology has been employed in renewable energy projects worldwide since the 19th century and is a first source for off-grid power systems. It is known as a dependable option that has been tried and tested. Until recently it was the only realistic battery technology for storing solar electricity. However, it is rapidly being eclipsed by other technologies with longer warranties and cheaper pricing as solar storage becomes increasingly popular.

Lead acid is low-cost and adaptable (it uses include electric vehicles, off-grid power systems, and uninterruptible power supplies). Advanced lead-acid battery technologies combine a standard lead-acid battery with ultra-capacitors, increasing efficiency and battery life and improving partial state-of-charge. These have a lifespan of about 5–10 years.

TABLE 8: LEAD CAPITAL COST OUTLOOK, LOW TO HIGH

Low	Average	High	
Compound Annual Growth Rate (CAGR)	15%	15%	17%
5-Year	48%	49%	52%

Lead has a high rate of decline based, due to improving lead carbon technology. With an evolving role of carbon, this will be integrated into new and existing products, which will improve lifespan and range of operation.6

LITHIUM-ION

These batteries have come the furthest in recent years in terms of their appeal for energy storage projects. Their popularity has grown with the development of electric cars, and they feature in new devices like the Tesla Powerwall, as well as mobile phones and laptops.

Lithium-ion systems are designed for efficiency and longer life at slower discharges, and faster charging and discharging rates, which requires extra capital equipment.

Lithium-ion batteries have a longer lifespan than lead-acid batteries, providing, on average, around 4,000–6,000 cycles at 80% discharge – a lifespan of up to 18 years. To date, their main drawback is that they are 50% more expensive than lead-acid batteries for the same storage capacity. However, this is expected to change in the next five years, as Figure 5 shows.

TABLE 9: LITHIUM-ION CAPITAL COST OUTLOOK, LOW TO HIGH

Low	Average	High	
Compound Annual Growth Rate (CAGR)	7%	11%	8%
5-Year	26%	38%	29%

In summary, due to the growing econoimes of scale that lithium-ion will witness over the next five years, manufacturing costs will decrease. Moreover, design improvements will lower high cost component input requirements which, along with chemistry improvements, will increase the capability of this battery technology.6

FLOW BATTERIES

Flow batteries are considered a new entrant to the battery storage market, although the technology has been around for some time. They contain a water-based solution of zinc-bromide. Currently, they have limited applications for the residential market and are mainly seen in developed countries.7

Subcategories of flow batteries are defined by the chemical composition of the electrolyte solution; the most common solutions are vanadium and zinc-bromide.

TABLE 10: FLOW BATTERY CAPITAL COST OUTLOOK, LOW TO HIGH6

	Low	Average	High
Compound Annual Growth Rate (CAGR)	4%	7%	10%
5-year	13%	24%	35%

Costs are decreasing because of improved design and manufacturing scale, extending operating range to eight-hour discharge, and integration time for manufacturing.6

SODIUM

“High temperature”/“liquid-electrolyte-flow” sodium batteries have high power and energy density and are designed for large commercial and utility-scale projects. “Low temperature” batteries are designed for residential and small commercial applications.

TABLE 11: SODIUM BATTERY CAPITAL COST OUTLOOK LOW-HIGH

	Low	Average	High
Compound Annual Growth Rate (CAGR)	10%	11%	11%
5-Year	34%	37%	37%

SUMMARY

Table 9 outlines the comparative disadvantages and advantages of these battery technologies.

TABLE 12: SELECTED TECHNOLOGY COMPARATIVE ADVANTAGES/DISADVANTAGES

Technology	Comparative Advantages	Comparative Disadvantages
Lead Acid	• Advanced lead-acid technologies leverage existing technologies Mature technology with established recycling infrastructure	Poor ability to operate in a partially discharged state Relatively poor depth of discharge and short lifespan
Lithium-ion	• Multiple chemistries available Rapidly expanding manufacturing base leading to cost reductions Efficient power and energy density	Remains relatively expensive Safety issues from overheating Requires advanced manufacturing capabilities to achieve high performance
Flow Battery	• Power energy profiles highly and independently scalable (for technologies other than zinc-bromine) Designed in fixed modular blocks for system design (for zinc-bromine technology) No degradation in energy storage capacity	Power and energy rating scaled in a fixed manner for zinc-bromine technology Relatively high balance of system costs Reduced poor depth of discharge and short lifespan
Sodium	• High temperature technology; relatively mature technology (commercially available); high energy capacity and long duration Low temperature technology; smaller scale design; emerging technology and low cost potential; safer	Although mature, inherently higher costs – low temperature batteries currently have a higher cost with lower efficiency Potential flammability issues for high-temperature batteries

ANALYSIS: APPLICABILITY FOR NEPAL

There has been a growth in the number of solar facilities running in conjunction with storage and without subsidies around the world, including in both the UK and India. This subsection will explore which battery technology is most suitable for Nepal's solar market and identify potential obstacles for the expansion of solar storage projects in the Himalayan region.

Table 13 cross-analyses key indicators using Lazard and McKinsey analyses.

TABLE 13: BATTERY TECHNOLOGY CROSS ANALYSIS

Lead acid	Lithium-ion	Flow batteries	Sodium	
Affordability	Arguably the cheapest battery option available in global market due to established recycling infrastructure	Still expensive but costs may fall	Currently economical but no major reductions in capital costs expected over next 15 years	Although a mature technology, inherently high costs
Dependability	Not reliable in partially charged state and has poor depth of discharge	Known to be reliable, despite concerns about flammability	Positive record and limited degradation over time	Potential flammability issues for high temperature batteries used in utility-scale sites
Warranty	No	Yes	Yes	Yes
Applicability for Nepal	Despite economic appeal, not a reliable solution given lack of warranty and remote grid locations for future PV in Nepal	Suitable battery for Nepal's on-grid storage prospects; but high costs for the next five years may be a roadblock	Popular in Western Europe and North America but limited knowledge in the South Asian solar space; but as market proliferates it may be worth consideration	A good solution for lower temperature batteries, but may not be suitable for large-scale utility use

Regulatory changes have been instrumental in the proliferation of storage products in many markets, as McKinsey argues. "The idea of combining solar with storage to enable households to make and consume their own power on-demand, instead of exporting power to the grid, is beginning to be an attractive opportunity for customers."4

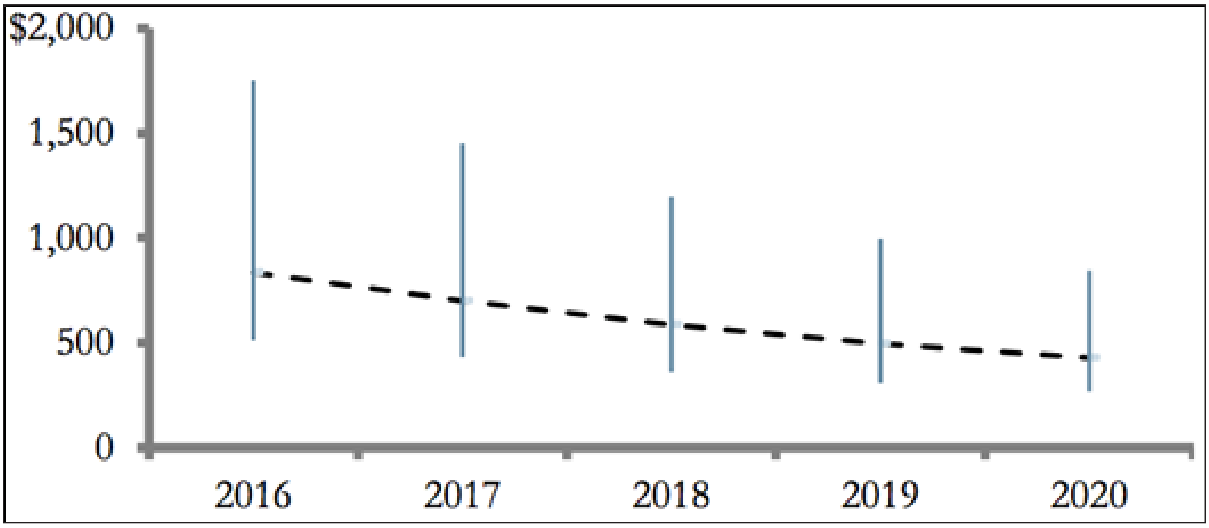
While most energy storage analyses have considered only North America and Europe, policy circles hold that the GoN may introduce net-metering.

Storage could almost certainly serve as a major asset to the NEA as it would help address low generation in the dry months (November–February) and help it operate the grid in markets where loads are expected to be flat or falling.

In order to accommodate this new market, the NEA has begun to explore how low-cost storage might be of use to its grid. Two broad categories of action for Nepal to consider are:

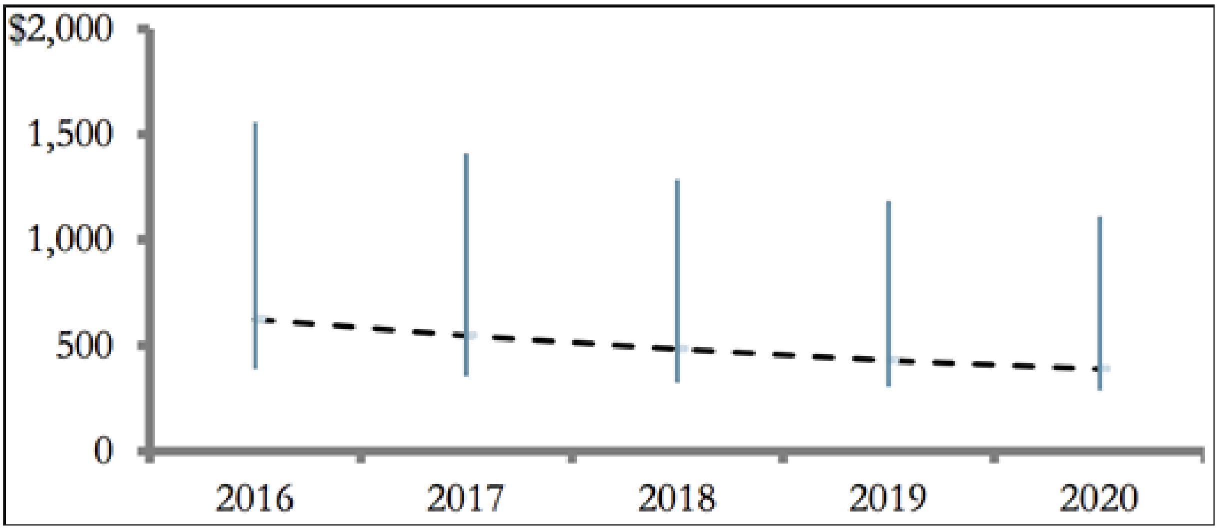
- Redesign compensation structures for solar/storage PPA structures
- Rethink grid system planning

FIGURE 4: LEAD ACID CAPITAL COST OUTLOOK (USD/KWH)6



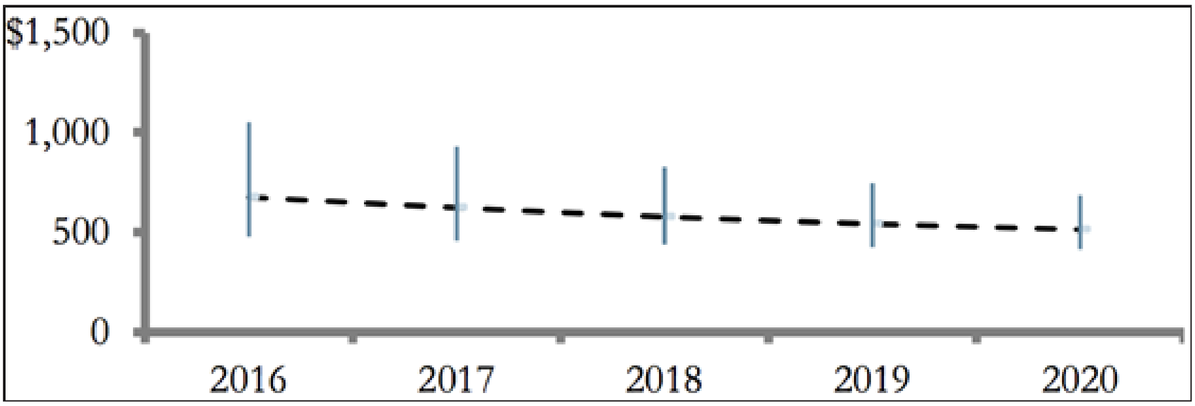
Source: Lazard (2018). Levelized Cost of Storage Analysis 2.0

FIGURE 5: LITHIUM-ION CAPITAL COST OUTLOOK (USD/KWH)6



Source: Lazard (2018). Levelized Cost of Storage Analysis 2.0

FIGURE 6 FLOW BATTERY CAPITAL COST OUTLOOK (USD/KWH)6



Source: Lazard (2018). Levelized Cost of Storage Analysis 2.0

1.4 EPC CONTRACTORS, ENGINEERING CONSULTANTS AND CONTRACTORS IN NEPAL

EPC CONTRACTORS

There are currently no Nepali contractors that offer EPC (Engineering Procurement and Construction). However, contractors in the construction space have a track record for hydro projects in the country, including:

1. Himal Hydro & General Construction
2. High Himal Hydro Construction
3. South Asia Infrastructure

With that said, a number of international contractors are comfortable working in Nepal and able to carry out EPC. Table 4 lists over 20 firms able to provide such services, including transmission construction (which is typically sub-contracted).

TABLE 14 POTENTIAL EPC CONTRACTORS

Ref	Contractor	Origin	Record in Nepal?	Hydro?	Solar?	Transmission?
1	Hindustan Construction Company	India	Yes	Yes	Unsure	Yes
2	CAMC	China	Yes	Unsure	Unsure	Yes
3	Larson & Toubro	India	Yes	Yes	Yes	Yes
4	Nagarjuna Construction Company	India	No	Yes	Unsure	Yes
5	Gammon India	India	No	Yes	Unsure	Yes
6	Özturk Holding Co	Turkey	No	Yes	Unsure	Yes
7	Lanco Infratech	India	Yes	Yes	Unsure	Yes
8	Renaissance Construction	Turkey	Unsure	Yes	Unsure	Yes
9	ENKA Construction & Industry Co.	Turkey	Yes	Yes	Unsure	Yes
10	JP Associates		No	Yes	Unsure	Yes

12	China Overseas Engineering Group Co.	China	Yes (Arun 3)	Yes	Unsure	Yes
13	Patel Engineering	India	Yes (Davighat)	Yes	Unsure	Yes
14	POLIMEKS	Turkey	No	Yes	Unsure	Yes
15	LIMAK	Turkey	No	Yes	Unsure	Yes
16	China Gezhouba General Construction (CGGC)	China	Yes (Bhote Koshi, Chameliya)	Yes	Unsure	Yes
17	Sinohydro	China	Yes (Upper Tamakoshi, Upper Marsyangdi)	Yes	Unsure	Yes
18	China Three Gorges (CTG)	China	No	Yes	Unsure	Yes
19	Hochtief	Germany	No	Yes	Unsure	Yes
20	Impregilo Celini	Italy	Unsure	Yes	Unsure	Yes
21	Skanska	Sweden	No	Yes	Unsure	Yes
22	Kosek	Rep Korea	Yes (Upper Trishuli)	Yes	Unsure	Yes
23	CMC	Italy				Yes

ENGINEERING CONSULTANTS – SOLAR AND HYDRO

Unlike in hydro, the level of expertise in Nepal in large-scale solar projects is limited. There are, however, three solar consultancies and installation companies which work in the off-grid and home installation market. The three largest players are:

- Sun Farmer
- Gham Power
- Saral Urjal

The rest of this section will focus on services in the hydro space. The majority of the consultancy work in this space is carried out by the following six companies (listed in order of market share):

- Hydro Consult Engineering Pvt. Ltd. (HCE)
- Sanima Hydro and Engineering Pvt. Ltd. (SHEPL)
- ERMC P Ltd
- ITECO Pvt. Ltd.
- Jade Consultant
- Shah Consult International

HCE and SHEPL are specialist consulting firms that only provide engineering services (studies, design, and construction management) in the hydro sector. The other firms also take on other engineering work for roads, bridges, irrigation, and water supply.

Hydro Consult Engineering (formally known as BPC Hydroconsult) was involved in the feasibility study, engineering design, and construction supervision of the 60 MW Khimti Project in the 1990s as part of the consortium led by Statkraft Engineering. BPC Hydroconsult was also involved in the design and construction supervision of the 5.1 MW Andhi Khola (recently upgraded to 9.5 MW) and the 12.0 MW Jhimruk hydropower plants. HCE is also the owners' engineer in the construction of the 37 MW Kabeli A (in association with Tata Consulting Engineers) and 30 MW Myagdi Projects in Nepal. They have also collaborated with their Chinese partner to develop approximately 800 MW hydro projects in the Marsyangdi Valley.

Sanima Hydro and Engineering Pvt. Ltd. was formed 12 years ago. Its shareholders include Hydroplan UK and several Non Resident Nepalis (NRNs). They were recently involved in the engineering design and construction supervision of the 22 MW Mai Project, 7 MW Mai Cascade, and the 14.9 MW Hewa Khola "A" Project. Currently, this company is undertaking feasibility studies and detailed engineering design of 10 projects with an aggregate capacity of about 400 MW, including the 28 MW Lower Likhu, 72 MW Middle Tamor, and the 285 MW Upper Tamor projects.

The other consulting firms (ERMC, ITECO, Jade, and Shah Consult) have worked for the Nepal Electricity Authority (NEA) and the GoN hydro works (e.g. studies on behalf of Department of Electricity Development) and as local partners in Joint Ventures (JV) with international firms. These consulting firms have also conducted feasibility studies and Environmental and Social Impact Assessments (ESIA) for various private sector national and international hydropower projects and transmission lines. Jade Consult was associated with Tractebel Engineering for the feasibility study 1,200 MW Budhi Gandaki Storage Hydro Project and Shah Consult recently completed the construction management of the NEA-owned 30 MW peaking run-of-river Chameliya Hydro Project in very difficult ground conditions.

Chinese and Indian consulting firms are also involved in the Nepali hydro sector. For example, Entura Hydro Tasmania India Pvt. Ltd. performed detailed design the 27 MW Dordi Hydropower Project. This company has also been involved in appraisals and independent review of a number of hydropower projects. Shanghai Investigation and Design Institute (SIDRI) of China has an office in Kathmandu and was involved in the investigation of the 750 MW West Seti Hydropower Project, which was intended to be developed by the China Three Gorges Corporation.

Nepali consulting firms are currently able to take on engineering services for projects up to 100 MW, including underground structures. Engineering services in projects larger than 100 MW may require association with international firms. The active Nepali firms together can take on feasibility studies and detailed engineering of about 200–300 MW annually, depending on the number of individual projects.

CIVIL CONTRACTORS

The three most active civil contractors in Nepal are:

- High Himalaya Hydro Construction Pvt. Ltd (3HC)
- Himal Hydro & General Construction Ltd (HH)
- South Asia Infrastructure Pvt. Ltd (SAI)

Among these, HH is the oldest hydro contractor in the country, with over 30 years of experience. HH was involved in the construction of the 60 MW Khimti Hydropower Plant in the late 1990s in association with Statkraft Anlegg. 3HC has been working as a hydro civil contractor since 2009 and has been involved in over 10 projects with a capacity of 3–42 MW. SAI is a relatively new civil contractor (established in 2014) that was involved in hydro tunnel works for projects of 20–30 MW.

These three civil contractors together cover a majority of the private sector market share in Nepal. There are also 5–10 contractors that have experience in civil works of small hydropower plants. There are also new entries in the hydro sector, mainly civil contractors that have experience in roads, irrigation, and construction.

Experienced civil contractors, such as HH, have experience in projects with capacities of 50 MW to 100 MW. Projects larger than 100 MW may require, in general, an international civil contractor. Hydropower plants larger than 100 MW are being built by international contractors (e.g., 456 MW Upper Tama Koshi by Sino Hydro, China).

The current capacity of Nepali civil contractors is limited. Thus, if the hydropower sector of Nepal is to grow, capacity in civil works construction must also increase concurrently, and more international contractors must collaborate with local contractors.

ELECTRO MECHANICAL CONTRACTORS

The installation of electrical works in hydropower plants has two main steps:

1. Design, manufacture, install and commission electro-mechanical equipment
2. Electrical control and protection systems in the powerhouse and switchyard areas

The current practice in the Nepali hydropower sector is to award a “water to wire” contract to the electro-mechanical (EM) equipment supplier. Thus, electrical control and protection systems are part of the “water to wire” contract with the EM supplier. Since EM equipment is not manufactured in Nepal, this has generally been outside the scope of work of Nepali consultants, contractors, or suppliers. However, with recent experience, this is likely to change.

It is estimated that the Nepali and Indian firms (mentioned under Transmission Contractors, below) have over 90% of the market share in transmission line work, including NEA transmission line and substation installation work.

Electro mechanical equipment is generally imported from Europe, India, and China. The main electro-mechanical suppliers are:

- Andritz Hydro
- Alstom Power
- Toshiba
- Boving Foress Ltd (BFL)
- Harbin
- FLovel

HYDRO-MECHANICAL CONTRACTORS

Hydro-mechanical work includes penstock, gates, motors, and general steel work. From Dolma's analysis into past projects, hydro-mechanical costs make up on average around 15% of the total project cost. The major H&M suppliers are:

- NHE – Butwal
- 3M – Pokhara
- CREAM – Butwal
- North – Butwal
- BYS – Kathmandu
- Constructo – Kathmandu
- Mega – Butwal

In addition, other suppliers will come in from India and China as the market in Nepal expands.

Nepal Hydro and Electric Limited (NHE), a company established in 1985 in Butwal, Nepal, is an experienced contractor with large, well-equipped workshop facilities. It is also active in the refurbishment of EM equipment (although NHE does not manufacture EM equipment). NHE also works as a local JV partner with international EM equipment suppliers in installation work.

HYDRO-MECHANICAL DESIGN

Simple steelwork design is undertaken by hydro-mechanical companies. More complicated designs can be carried out by TAC, based in Kathmandu. TAC is a small specialist consultant.

TRANSMISSION CONTRACTORS

Scope: construct substation facilities and transmission lines until the connection point.

1. Transmission line up to the interconnection point

The dedicated transmission line from the powerhouse/switch yard to the NEA interconnection point (substation) is often awarded as a separate contract package (it is outside the scope of work of the EM supplier). There are a number of Nepali and Indian contractors that are active in the hydro/transmission line sector. Generally, these companies will take responsibility for design, fabrication, and installation work. The main contractors are:

NEPALI FIRMS:

- Sigma Con Pvt. Ltd.
- Mudhbhary and Joshi Construction Pvt. Ltd.
- Urja International Pvt. Ltd.
- Cosmic Electricals Pvt. Ltd.

INDIAN FIRMS:

- Aster Pvt. Ltd.
- Jaguar Oversees Limited
- Power Grid Corporation of India
- KEC
- Jyoti
- Tribeni


UMITOMO

1.5 HIGH LEVEL STRATEGIES FOR CLIMATE ADAPTATION

Hydro is the leading energy asset class in Nepal, and given the country's development trajectory it is likely hydro will feature as a central energy source for Nepal moving forward.

If one takes a step back to appreciate the gravity of the issue surrounding the need to implement adaptation strategies in the future, one should appreciate the number of potentially affected individuals in the Himalayan Hindu Kush region.

OPTIMISING THE USE OF WATER THROUGH BETTER PLANNING AND INCENTIVES

Growing populations and rising incomes are increasing demand for water, according to the World Bank. In many parts of the world, the growing demand for water has been unchecked, and some policies have stimulated the overuse of water. Ensuring future water security will therefore require more prudent demand-side management.

REDUCING THE IMPACT OF EXTREMES, VARIABILITY, AND UNCERTAINTY

A major challenge for ensuring a water secure world is reacting to and reducing the impact of extreme weather events expected due to climate change, such as droughts, floods, storm surges, and increased rainfall variability. Reducing freshwater demand relative to supply and increasing the amount of water stored will go a long way towards increasing resilience against highly variable rainfall and the droughts and floods that the variability creates.

Mitigating damage caused by such events will require large investments in technology and infrastructure. Once built, investments are irreversible and much uncertainty surrounds where they should be optimally placed and how large they should be.

Other key investments include upgrading hydro-meteorological and early-warning systems. Increasing the lead time of a storm allows households to evacuate an area and move their belongings to higher ground. Better medium-term and seasonal forecasts can help farmers make cropping and irrigation decisions, which can counteract some of the added uncertainty brought about by climate change.

Another important yet underutilised tool to respond to growing rainfall variability in developing countries is crop insurance. Increasing farmers' access to crop insurance will protect households against falling into poverty or becoming food insecure when the impacts of climate change destroy harvests. Insurance will also incentivise farmers to invest in higher value crops and modern technologies by eliminating the catastrophic risk of losing a large investment if the harvest fails.

Adaptation goals can often be achieved through better management of ecosystems and investments in natural capital at a fraction of the cost of physical and engineering solutions. Natural infrastructure not only provides protection and resilience but is also required for sustainability, to ensure future supply of water. As the residual claimant, ecosystems receive water that is left over from other uses, so the water is often polluted. This, in turn, disrupts river health, the ability to flush pollutants, and a host of other ecosystem services. As the world grows more crowded and thirstier – which is the case in the Himalayas, as shown in Figure 9 – threats to ecosystems will escalate and investments in their production will become more urgent.

FRAMING CLIMATE CHANGE AS A PROJECT RISK

Every hydro development and operation carries a unique set of commercial, economic, and financial risks, as well as complex technical, environmental, and social impacts that must be assessed to determine individual project viability. Changes in future activities in the project area, upstream irrigation, and land or water uses can affect proposed developments, especially during the dry season. In many cases, economic and financial aspects related to the construction cost, schedule and potential delays, discount rate, cost of debt and equity, electricity tariffs, etc., are critical to private and public developers to demonstrate the long-term viability of the project. In all projects, one of the challenges that policymakers, financiers, developers, and designers face is how to assess and quantify specific climate change and climate-induced natural disasters, among a multitude of other risks.

While the impacts of future climate change represent a relatively new threat that may be poorly understood by the hydropower industry, research to date has shown that these impacts are critical to assess but may not be the most important perceived risk for hydropower development. For example, hydrological risks and risks associated with the economic context of hydropower and dam construction, such as assumptions of future electricity prices, or the viability of future export markets and transmission capacity, can be seen as equally or more important.

According to Mott MacDonald's "Hydropower Sector Climate Resilience Guidelines", climate change and natural disaster risks may also be viewed as "threat multipliers", exacerbating risks from other sources when considered a compounding factor. The idea of climate change as a threat multiplier accentuating other project risks is highlighted in Figure 9. Climate change and natural disaster risks present a new dimension of hazards for which best risk management practices have not yet been established for hydropower development and operation.

FIGURE 8 THE WORLD'S LARGEST TRANSBOUNDARY RIVER BASINS AND THE POPULATIONS THEY SUPPORT

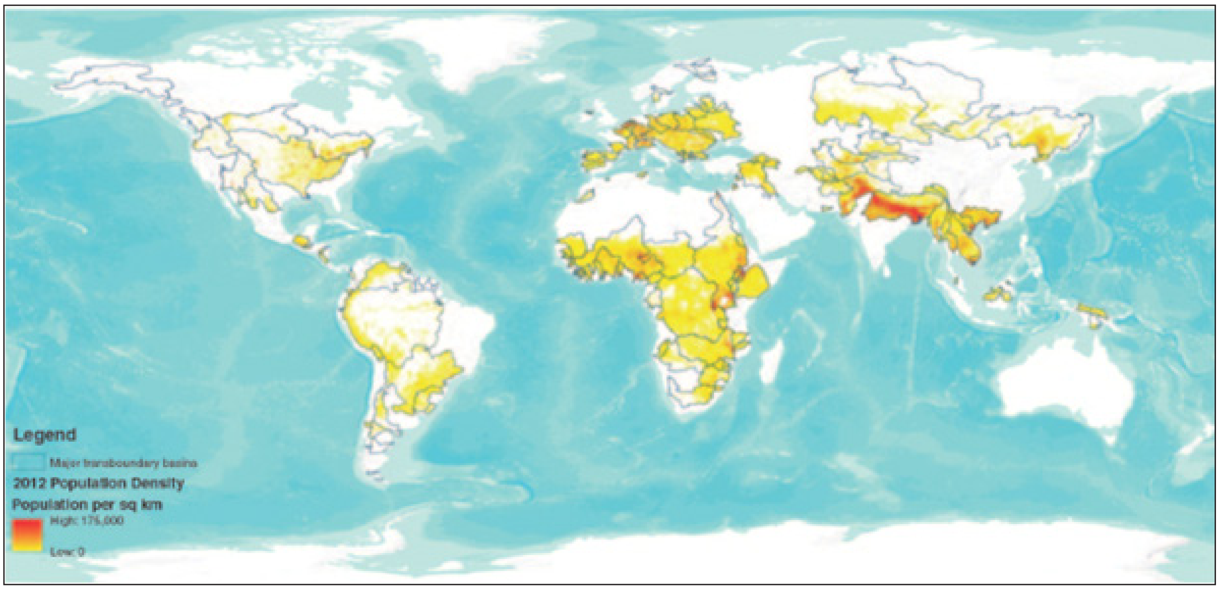


FIGURE 9 RANGE OF HYDROPOWER RISKS SHOWING CLIMATE CHANGE AS A PERVASIVE RISK/ THREAT MULTIPLIER

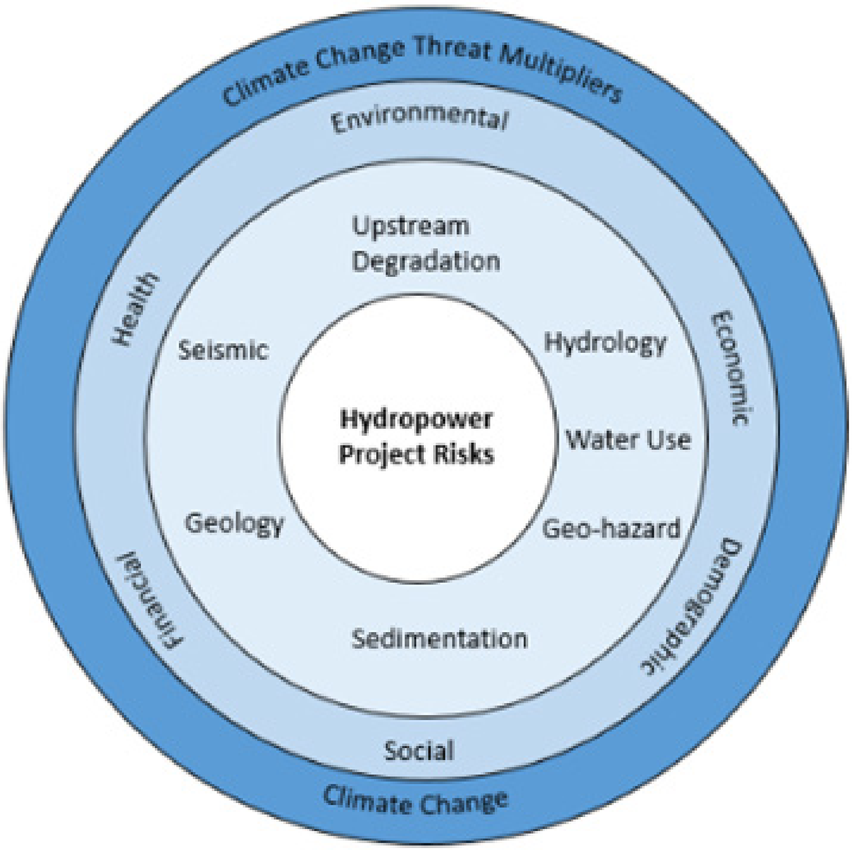
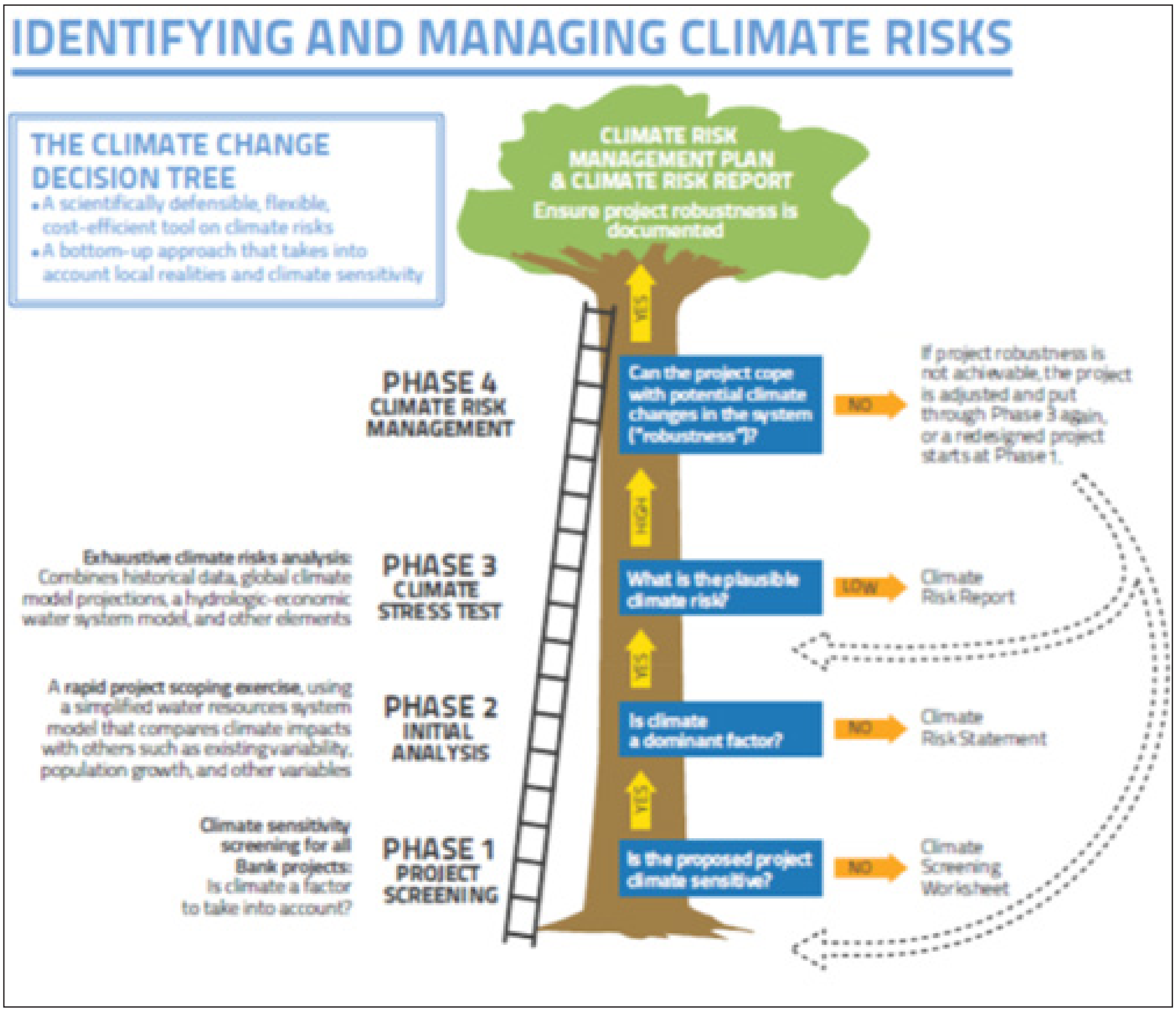


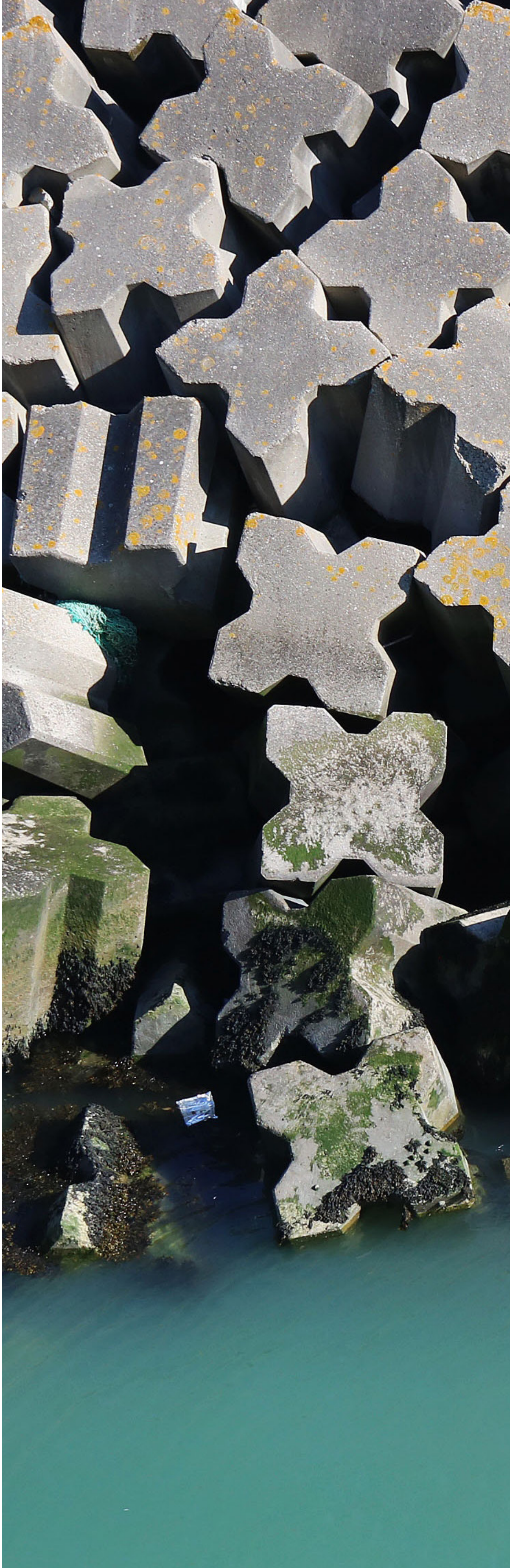
FIGURE 10 IDENTIFYING AND MANAGING CLIMATE RISKS



1.6 HIGH LEVEL STRATEGIES FOR CLIMATE RESILIENCE

A structured approach to climate resilience is required in the interest of cohesion on a global scale. The guidelines below are recommended by Mott MacDonald, broken down into four distinct phases, in line with the World Bank's report "Identifying and Managing Climate Risks"3 and Mott's internal assessment on the risks associated with climate change adaptation.

The World Bank outlines a pragmatic process for risk assessment of water resources projects that can serve as a decision support tool to assist project planning under uncertainty and that would be useful for the WB as well as other practitioners. The approach adopts a robust, bottom-up alternative to previous top-down approaches to climate risk assessment, the quality of which has been contingent on the suitability of future climate projections derived from general circulation models (GCMs).



1.7 RISKS AND DESIGNS SUITABLE TO NEPAL'S TRANSMISSION NETWORK

RISKS

- Terrain
- Ground clearances
- Foundation conditions
- Floods and landslides
- Right of way, including land acquisition and forest clearance
- Environmental and Social (E&S) issues
- Social disturbance during construction

DESIGNS

- Mountain regions
    - Ridge route is preferred, but at times requires major valley crossing
    - Vertical and site ground clearances on slopes
    - Adequate protection (such as retaining walls and drainage) against floods and landslides
    - Good stakeholder management; obtaining permits on time
    - Avoiding national conservation areas and regions with endangered species
    - Good stakeholder consultation

1.8 EXISTING ELECTRICAL AND MECHANICAL EQUIPMENT

Most power plants in Nepal are medium- and high-head, which use Francis and Pelton turbines; however, some low-head plants using tubular turbines are also in operation. Sediment management and refurbishing or replacement of turbines are key issues in the operation and maintenance of hydropower plants in Nepal.

Water conveying system include fully- or partially-lined tunnels and steel penstocks. Electrical equipment includes generators with adequate control and protection systems, transformers, substations, and switchyards.

Transmission to the grid substation is generally at 33 kV and 132 kv.

1.9 TECHNOLOGY OVERVIEW

LARGE SCALE SOLAR

- As mentioned in Section 1.5, grid connected solar is still a relatively new concept in Nepal and suppliers will likely source equipment from India, China, or elsewhere.

ROOFTOP SOLAR/DISTRIBUTED GENERATION

- Monocrystalline PV, a type of crystalline solar technology, was incorporated into the Nepali domestic market over the years, particularly during the years of load shedding years in the Kathmandu valley.

SMART GRIDS AND NET METERING IN NEPAL, ELECTRICAL VEHICLE (EV) CHARGING

- Some progress has been made in net metering and EV development in Nepal. The first net metering project was established in November 2017 after ICIMOD's 92 kWp system was connected to the national grid. Others have followed since. EVs continue to garner support from the NEA and government authorities. A recent announcement from the NEA MD aiming to install EV charging stations across the country underlines this.

HYDRO

- Mature energy asset class with little innovation.
- Automation, software development in the energy management of hydro

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