BACHELOR THESIS

Hydropower in Nepal

-a literature review

by
201 – David Sundøy Haldorsen
217 – Håkon Nikolai Løhren Heiestad
208 – Nikolai Hoelgaard Weum-Andersen

Renewable Energy

FE403

01-06-2016

SOGN OG FJORDANE UNIVERSITY COLLEGE

Agreement regarding the electronical deposit of scientific publications in HiSF Brage – Institutional archive of Sogn og Fjordane University College

The author(s) hereby give(s) Sogn og Fjordane University College the right to make this thesis available in HiSF Brage provided that the thesis is awarded gr*ade B* or better.

I guarantee that I - together with possible co-authors - have the right of authorship to the material thus have legal rights to allow HiSF to publish the material in Brage.

I guarantee that I have no knowledge or suspicion indicating that this material is illegal according to Norwegian law.

Please fill in your candidate number and name below and tick off the appropriate answer:

201 – David Sundøy Haldorsen

YES _X_ NO___

217 – Håkon Nikolai Løhren Heiestad

YES _X_ NO___

208 – Nikolai Hoelgaard Weum-Andersen

YES _X_ NO___

Foreword

This bachelor thesis has been conducted by three candidates enrolled in the Renewable Energy Bachelor Program organized by the Faculty of Engineering and Natural Sciences at the University College of Sogn og Fjordane, during the final semester of spring 2016.

We would like to express our gratitude and thanks to the following people:

<u>Tyson Weaver,</u>
for supervising our work and providing feedback throughout the writing process
<u>Hege-Beathe Weum-Andersen,</u>
for providing us with tasteful and nutritious dinners
<u>Vilja,</u>
for moral support

Conducted by

David Sundøy Haldorsen – Candidate 1

Håkon Nikolai Løhren Heiestad – Candidate 2

Nikolai Hoelgaard Weum-Andersen – Candidate 3

01.06.2016

Sogndal

Executive summary

With 8 of the 10 world's highest mountains and periods of heavy rain creating over 6000 rivers, Nepal has the potential to be one of the leading hydropower nations in the world. However, the current situation is that Nepal experiences hours of power shortages daily, many people live without access to electricity, and unsustainable use of firewood dominates the energy sector. Nepal currently utilize about 1.8 % of its estimated technical hydropower potential, leaving great possibilities for expanding hydropower and implementing strategies for energy distribution. With an installed capacity of 787 MW, and a peak power demand of 1 291 MW, Nepal is forced to handle their deficit power through importing expensive electricity from India and perform daily load shedding, or power cuts. At the same time, about 1/4th of the population lives without access to electricity or access to the national power grid. This hinders rural development, and in order to stabilize the supply, Nepal is looking at ways to expand both their power grid and capacity. Building micro hydropower plants could provide remote areas and rural communities with the opportunity to elevate their standard of living while receiving much needed benefits of electrification.

Unfortunately, increasing Nepal's capacity will not be enough to supply the population with constant access to electricity, as dry season limits run-of-river-type facilities electricity output. This problem can be minimized by building out storage facilities, but due to dry season lasting several months, it is uncertain if it would have the desired impact, and how much supply would be needed to meet the demand.

Currently, the Government of Nepal together with the Nepal Electricity Authority and Independent Power Producers, are developing numerous projects to increase Nepal's capacity. However, several projects were scheduled for completion before the writing of this thesis, yet nothing has happened. Speculations as to how come these projects have been halted or cancelled are many, such as contractors backing out of projects and natural disasters like the earthquake hitting Nepal in 2015.

Table of Contents

List of Figures

List of Tables

Abbreviations

DOED - Department of Electricity Development

ETFC - Electricity Tariff Fixation Commission

GoN - Government of Nepal

GW - Gigawatt

GWh - Gigawatt hour

HPP - Hydropower plant

IPP - Independent Power Producer

IPPAN - Independent Power Producers Association in Nepal

kV - Kilovolt

kW - Kilowatt

kWh - Kilowatt hour

MHP - Micro hydropower

MW - Megawatt

MWh - Megawatt hour

NEA - Nepal Electricity Authority

PPA - Power Purchase Agreement

RoR - Run-of-River

Rs. - Rupees

T&D - Transmission and distribution

TWh - Terawatt hours

US$ - US Dollar

1.0 Introduction

As the human population grows, the demand for energy increases. At the same time, the standard of living improves, as new household applications, vehicles and devices are being introduced to the public. This development results in increased capability to afford modern day energy services (EIA, 2013). Humans have been emitting large amounts of greenhouse gases for decades through the use of fossil fuels, and are only now starting to see the consequences. The emitted greenhouse gasses have led to a rise in global temperatures. Average temperature change has been projected to cause dangerous climatic changes if raised more than 2 degrees Celsius, compared to pre-industrial levels, by the year 2100 (Nordhaus, 1977). In order to decrease the negative anthropogenic impacts on the planet and secure a sustainable future for the human race, clean and renewable ways of energy extraction and production must be applied. Renewable energy sources can be found in abundance everywhere on the planet in varying forms. One of these highly available resources is hydropower.

Hydropower is a mature technology, offering clean, sustainable energy that is excellent at handling changes in load demand. Currently the world generates approximately 3 500 TWh of hydroelectricity, which amounts to 16.3 % of the world's total electricity needs.

The Federal Democratic Republic of Nepal is a landlocked country located in the south of Asia, stretching along the Himalayan mountain range between India and Tibet, a part of China. The capital and largest city is Kathmandu, with a population of 1.183 million residents. Elevation varies greatly from the flat Tarai river plains in the south, with the Middle Hills in between, and the rugged Himalayan tops in the north, from 70 meters above sea level to the highest point on earth, Mount Everest at 8 848 meters (CIA, 2016). This elevation occurs within 150 kilometers, leading to steep terrain and interesting climatic variations with subtropical conditions in the south and arctic in the north. The country also experiences floods and droughts depending on intensity and duration of seasonal monsoons. Nepal stretches for about 800 kilometers east to west and 150 kilometers north to south. Within its 147,181 square kilometers, 28.8 % of the land is agricultural and 25.4 % is covered in forest. The Nepali population of 31.5 million is spread out with about 48 % living in the Tarai plains and 45 % in the Middle hills, and about 8 % of the population lives in the Himalayan range (California Institute of Technology, 2004).

Nepal is among the poorest countries in the world, with a quarter of the population living below the poverty line. A third of the gross domestic product within Nepal comes from agricultural practices and one third comes from foreign Nepali workers remitting, sending money home to families. The official language spoken is Nepali, though there are over a hundred other languages practiced, and English is commonly spoken within government and business (CIA, 2016).

Nepal, with 8 of the world's 10 highest mountains and periods of heavy rain creating over 6000 rivers, has the potential to be one of the leading hydropower producers in the world. However, the current situation is that Nepal experiences hours of power shortages daily, a third of the country's population lives without electricity, and access to the national electricity grid in rural communities is very limited (Bergner, 2013).

With Nepal's current energy situation, it seems near impossible for them to supply enough power to even keep their lights on for an entire day. As a report from The World Bank summarizes it: "Nepal: Scaling up electricity access through mini and micro hydropower applications" (2015): "Shortage of energy negatively impacts economic development by suppressing agricultural productivity, environmental sustainability, health care, education and job creation" This specifically affects poor and rural households as they spend a large part of their income and time fulfilling their basic energy needs. Households that spend 10 to 30 percent of their income on energy expenses are considered "energy poor". According to this classification, 80 percent of Nepalese households are energy poor (Kumar, et al., 2015).

1.1 Research question

Nepal has a vast untapped hydropower potential, the population faces long blackouts every day and about 25 % of the population lives without access to electricity. In this thesis we wanted to explore this potential, and attempt to find a reason as to why such a small portion of it has been developed. We wanted an overview of their current and future plans of development and the different challenges they face. This has led to the following research question:

What are the key challenges limiting Nepal from achieving universal access and reliable supply of electricity? Based on this question we will provide our recommendations as to how Nepal could achieve this through utilizing a greater part of their hydropower potential.

2.0 Method

In this chapter we will look at the research based method of literature review, get an overview of the sources we have used for accumulating data, what information we have acquired, how we have used the data, the reliability of the data and the limitations surrounding the data.

This bachelor thesis has been conducted using the method of literature review, a purely research based process of studying previously written literature on a specific topic. A literature review starts with a question that is used to assess a body of separately gathered information and data, in order to draw a conclusion and answer the question, presenting it in a comprehensive way to the reader. A literature review question is conducted through a causal relationship, asking if a cause has and effect within a certain topic, e.g. "Does production and use of electric cars contribute to a decrease in total carbon footprint of cars?". A literature review question should be open for flexibility as the gathering of information might shed new light upon the topic, causing you to end up with a more complex, relevant and comprehensive question at the end of the review compared to what question you initially asked. Organizing the body of your gathered data can be done in several ways, such as by chronological order of publication, thematic order, or organizing by what methods were practiced in the sources.

Having a strategy to find relevant information on the research topic is essential. You should search for different aspects within the topic in literature like primary research reports, peer reviewed articles, and even other written literature reviews. Here you can look at what sources have been used, other articles by the same authors, and build a reliable and strong base of sources and data. It is important to stay critical to your sources by considering authors and methods used in the literature, in addition to using the most up to date data according to your studies time frame. You should also analyze your sources for missing information and anomalies that might have an effect on your conclusion, and identify uncertainties. You are supposed to build a body of synthesized information that accurately portrays what your research sources do and do not provide in order to form a reliable result you can use to discuss and conclude your initial question (The University of North Carolina, 2010) (Jill K. Jesson, 2011).

2.1 Data sources

We have chosen to use sources that have a high credible standing within international data gathering, in addition to some local Nepali sources. We have used The World Bank, The International Energy Agency and The Central Intelligence Agency as main sources for most of the data regarding geography, society and energy within Nepal. Official energy related organizations belonging to Nepal have also been used actively, such as the Nepal Energy Authority and its Annual Report 2014/15 which contains a significant amount of updated information on the current and future electricity situation in Nepal. In addition to this, we have used some local newspapers and grey literature as fillers and support to the information from the main sources.

2.2 Gathered data

The physical and technical data we have chosen to use looks at societal energy statistics and environment. Some examples include what percentage of the population have access to electricity in accordance with rural and urban citizens, how much electricity is supplied nationally compared to demand, where the electricity comes from, and what climate Nepal sees through the year. Maps of the power grid and population density have been combined and merged in the photo editing software Adobe Photoshop in order to get an overview of geographical accessibility to power.

2.3 Validity

We have ensured valid results through comparing our main sources with several other sources regarding the same data, which have mostly been showing the same trends. In addition, we have gathered a significant amount of information from the national energy distribution organ in Nepal, the Nepal Electricity Authority (NEA), who assess, gather and work tightly with the quantitative data we are using.

2.4 Reliability

We have attempted to clarify our methods and sources to the best of our ability, in order for the readers to gain the same or similar results if used for further research. The data we have gathered is in our opinion the most credible to date, mostly spanning from 2013 to 2015, together with historical data from the past two and a half decades.

2.5 Limitations

It has been decided to focus on physical and technical data rather than economic data, as much of the economic aspects of the energy situation is too broad to take into consideration given our timeframe. A few economic instances in context, though, have been mentioned to get a slightly broader understanding of the energy situation. Some of the gathered data is old, yet most recent, because we found no conducted research that had been done after that date for that specific data. Real time data has been unavailable, though critically important data comes from 2013 and up, as our sources might not conduct data gathering annually, or their assessment of credible data takes time to finish. Some of the more challenging aspects of writing this thesis, was making sense of all the data. There is a lot of different numbers, all from credible sources, that varies to such an extent that some comparisons have been both difficult and impossible to conduct.

It has been decided to write this literature review in English, as the three thesis candidates written first languages of Norwegian Bokmal, Norwegian Nynorsk and Danish does not match together. We have encountered some instances of linguistic barriers during our research as some information and data has been in Nepalese, and none of the thesis candidates knows this language. The Nepalese calendar is lunar, so the months are staggered compared to the Gregorian calendar. The 1st of Baishakh is the first day of the Nepali New Year, corresponding to the 13th of April, and a fiscal year is from July 16th to July 15th the following year. The current year in the Nepali lunar calendar is 2073, compared to the current year 2016 in the Gregorian calendar (Wikipedia, 2016). As this is a literature review, we have been limited to using previous works of other research conductors rather than our own, as we have not been able to travel to Nepal to do our own research.

2.6 Structure

We have organized the body of this literature review in a thematic way, starting with an explanation of hydropower and the different technologies involved. Then, an overview of the global hydropower potential and capacity, followed by an in-depth look into the different aspects of hydropower in Nepal. After that, we look at Nepal's energy system, in order to identify and explore their challenges, before going into the results, discussion and conclusion.

Economic barriers have been excluded, even though economy has an effect on all the barriers. Even if this has been excluded, we are not suggesting unrealistic economical solutions.

3.0 Hydropower

In this chapter we will briefly summarize the basic functions and history of hydropower, how the energy is produced, what technologies are available and what is most commonly used in Nepal. We will divide the hydropower plants (HPPs) into different categories depending on capacity.

3.1 Hydropower explained

Hydropower is a renewable energy source that has been harvested for centuries. It has been used for grinding grain, breaking ore and in early papermaking, and after the industrialization it has been utilized for producing electricity. After the first modern water turbine was developed in 1849, the construction of HPPs soon began all across the globe. The first plant was opened in Wisconsin, USA in 1882 and many quickly followed. All through the 1900's dams and plants were built in many parts of the world, culminating in the largest plant constructed in 2008, Three Gorges Dam in China, with a capacity of 22 500 MW (International Hydropower Association, 2016).

Elevated, stored water has potential energy, which is converted into kinetic energy when the water starts flowing. The turbine in the HPP converts the kinetic energy from the moving water into mechanical energy, and then to electrical energy in the generator. This energy transformation process is highly efficient in modern HPPs, and can reach over 90 % efficiency. Some energy is lost in the intake and in the tailrace section of the plant, in what can best be described as friction losses, and some is lost as heat in the turbine (Kumar, et al., 2011).

In order to calculate the power (P) delivered by a HPP, there are two important factors to take into consideration, namely flow rate (Q) and effective head (H). Boyle (2012) explains in "Renewable energy – Power for a sustainable future" that "The essential characteristics of a hydro site are the effective head (H), the height in metres through which the water falls, and the flow rate (Q), the number of cubic metres of water passing through the plant per second." (Boyle, 2012). The relationship can be described mathematically by this expression:

$$P\ (kW) = 10\ x\ Q\ x\ H$$

3.2 Hydropower systems

There are three different types of hydropower (Kumar, et al., 2011)

- **Run-of-river hydropower (RoR**):

  The most common type in Nepal. This type of hydropower channels flowing water through a canal or penstock to spin a turbine. RoR systems are very flexible and can provide a good baseload through a continuous supply of electricity. On longer rivers, cascading plants are an option.

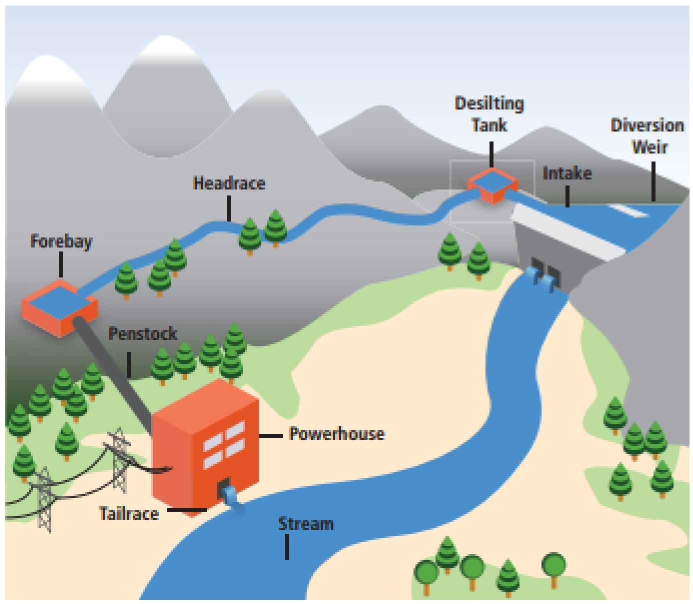

Figure 1 Run-of-river HPP

- **Storage hydropower:**

  Storage-based hydropower is most commonly a large facility that uses a dam to store water. When water is released, electricity is generated. This makes storage hydropower great for peak demand as it can be started up on short notice.

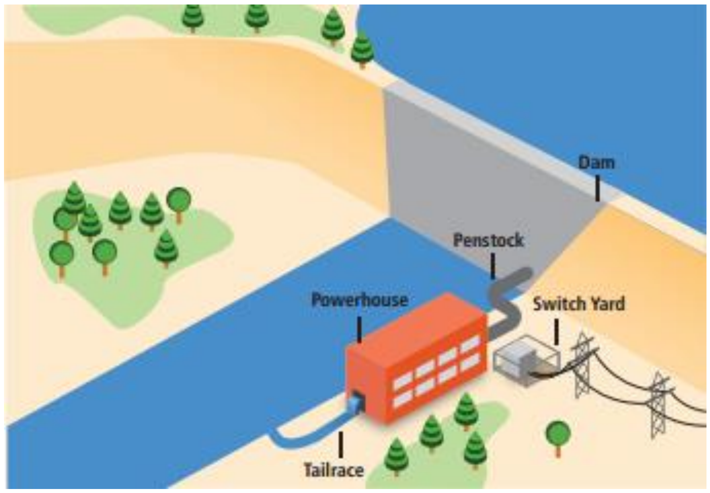

Figure 2 Typical HPP with storage

- **Pumped-storage hydropower:**

  Works in the same way as storage hydropower, but when there is low demand or a surplus of energy generated from other sources, this energy is used to pump water back into the storage dam. It can then be released and turned into electricity when demand goes up again.

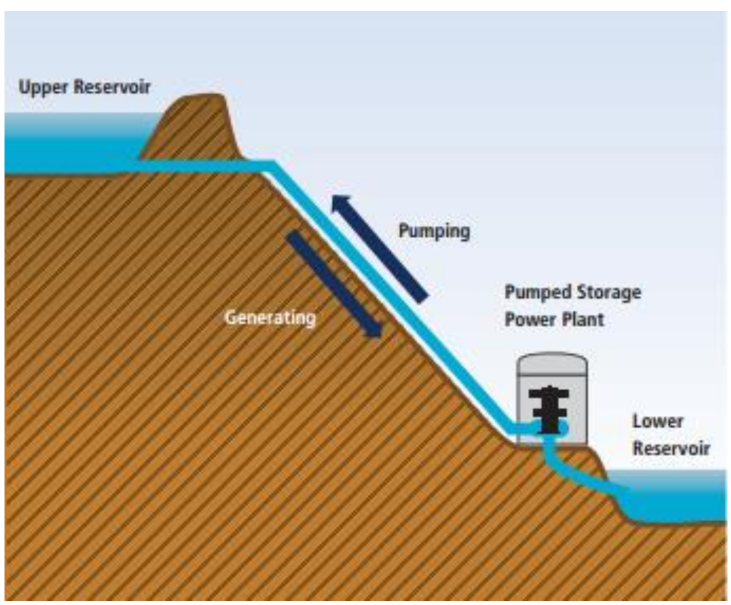

Figure 3 Typical pumped storage project

3.3 Hydropower technologies

There are currently two different types of hydropower turbine technologies, with several different types of runners. These turbines can operate at a high efficiency, upwards of 95 % (World Energy Council, 2013). The different uses for the various types of turbines are shown in figure 4.

- **Impulse turbine:** This turbine is best suited for high head sites and uses the velocity of the water through a concentrated jet to turn the runner. There are three different types of impulse turbines:
    - Pelton (most common in Nepal)
    - Cross-flow
    - Turgo
- **Reaction turbine:** In a reaction turbine, the runner is completely submerged in the water, and uses the combined action of pressure and moving water to turn the runner. There are several types of reaction turbines:
    - Propeller
        - Bulb turbine
        - Straflo
        - Tube turbine
        - Kaplan
    - Francis
    - Kinetic

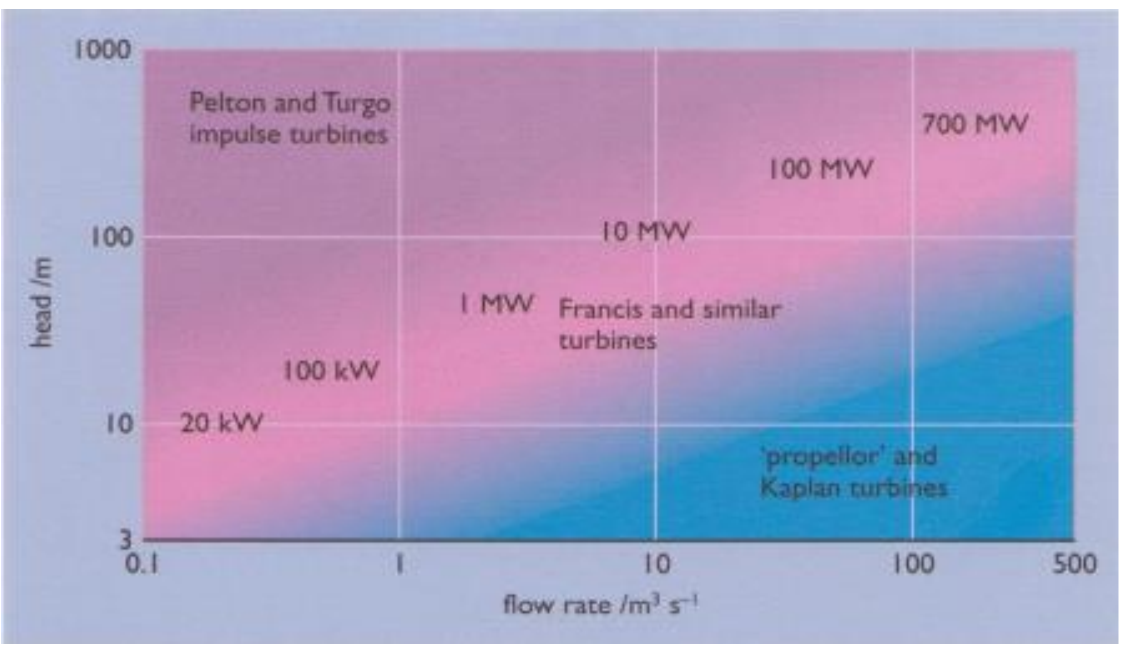

Figure 4 Types and applications of turbines (Boyle, 2012)

3.4 Size classification

There are many different ways to classify the size of a HPP, and there is little agreement on what “small-hydro” is. India classifies everything with a capacity below 25 MW as small-scale, the USA uses 30 MW and China 50 MW.

According to Boyle (2012), most international energy organizations views plants with a capacity below 10 MW as small. Boyle says: “It is generally agreed that world output from small-scale hydro is rising; but it is also generally agreed that it is impossible to estimate either the total output or the installed capacity with any reasonable precision”. Boyle further cites a report from World Energy Council 2010, which estimates the global small-scale capacity (<10 MW) to account for about 60 GW in 2009 or 6 % of the total global hydropower capacity (Boyle, 2012).

We have decided to use the following classification based on information from Nepal’s Ministry of Energy (Government of Nepal, 2016).

- Large scale: > 100 MW
- Medium Scale: 100 – 25 MW
- Small scale: 25 – 1 MW
- Micro scale: < 1 MW

4.0 Global potential and capacity

In this chapter we will offer an overview of the global hydropower potential, installed capacity and generation.

4.1 Potential

All energy potential across the globe, can be split into three generally agreed upon definitions: gross theoretical, technically feasible and economically feasible capability (World Energy Council, 2010).

In a report from 2010 from World Energy Council, the theoretical potential is defined as: “gross theoretical capability is the annual energy potentially available in the country if all natural flows were turbined down to sea level or to the water level of the border of the country (if the watercourse extends into another country) with 100 % efficiency from the machinery and driving water-works.” (World Energy Council, 2010).

The actual theoretical potential can be difficult to estimate. Various countries have different definitions and methods of gathering data, and much data is old and is constantly challenged. This makes obtaining accurate information concerning theoretical potential difficult, so our data might not match other sources.

The technically feasible capability, is the amount of the theoretical potential that can be exploited within the current technical limitations. Constraints such as system performance, topographic limitations, environmental concerns, and land-usage differentiates the theoretical potential from the technical potential.

The economical capability, is the amount of the technical potential that can be exploited under the present local economic situation. This amount can vary from source to source depending upon whether or not environmental and/or social considerations are made (World Energy Council, 2010). Not much data was available on economic potential, so those numbers have been excluded from table 1.

Table 1 Hydropower capability as of 2008 (TWh/y) (World Energy Council, 2010)

	GROSS TECHNICAL CAPABILITY (TWH/Y)	**TECHNICALLY FEASIBLE CAPABILITY** (TWH/Y)
AFRICA	3 909	1 834
ASIA	17 308	5 867
EUROPE	4 919	2 762
NORTH-AMERICA	5 511	2 416
SOUTH-AMERICA	7 541	2 843
OCEANIA	654	233
TOTAL	**39 842**	**15 955**

4.2 Capacity and generation

In a report from 2012, “Technology Roadmaps: Hydropower”, IEA estimates the total global installed hydropower capacity to be (including pumped storage capacities) 1 067 GW. This is following a growth trend in recent years of 24.2 GW/y and is according to this report expected to be doubled by 2050 and reach almost 2 000 GW (International Energy Agency, 2012, p. 19). Below is a graph showing the expected growth in hydroelectricity production by region until year 2050.

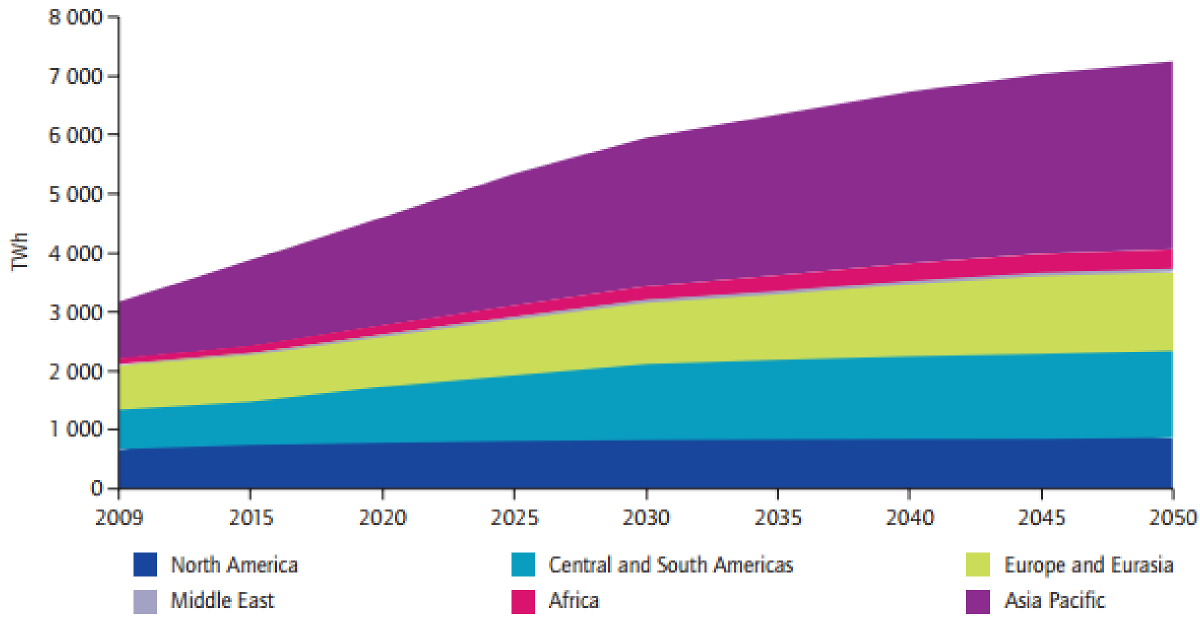

Figure 5 Expected hydroelectricity growth till 2050 (International Energy Agency, 2012)

The same report states that hydropower “…provides 16.3 % of the world’s electricity (about 3 500 TWh in 2010)” (International Energy Agency, 2012, s. 9). International Energy Agency made a BLUE Map scenario in their report, “Energy Technology Perspectives 2010”, which suggests an increase from 3 500 TWh to 5 749 TWh in 2050. This increase in hydroelectricity generation is massive, however, looking at the total production of all energy sources in percentage, it diminishes to 14.1 %. Reason for this is that other sources of power-generation is expected to grow at a faster rate (International Energy Agency, 2010).

5.0 Hydropower in Nepal

In this chapter we will give an overview of the hydropower potential and installed capacity in Nepal. Furthermore, we will provide an overlook of the different sized facilities, the role they play and look at Nepal's hydropower strategy.

5.1 Potential

There is some variation in the estimation on the theoretical potential of Nepal, but even the most conservative at 83 TW shows the huge potential of the country (Sharma & Awal, 2013).

Table 2 Theoretical Hydropower Potential of Nepal (Sharma & Awal, 2013)

RIVER BASIN	SMALL RIVER CAPACITY (GW) (CATCHMENT AREA 300 – 1000 KM^2)	MAJOR RIVER CAPACITY (GW) (CATCHMENT AREA >1000 KM^2)	GROSS TOTAL (GW)
SAPTA KOSHI	3.6	18.75	22.35
SAPTA GANDAKI	2.7	17.95	20.65
KARNALI AND MAHAKALI	3.5	32.68	36.18
SOUTHERN RIVERS	1.04	3.07	4.11
TOTAL	**10.84**	**72.45**	**83.29**

The technically exploitable potential for Nepal is estimated in WEC's survey report from 2010 to be 44 GW (World Energy Council, 2010). A limiting factor on the technical potential could be a lack of reliable and new data. The original report assessing the hydropower resources in Nepal was written in Moscow, USSR, in 1966; a PhD. thesis by HM. Shestra, *Cadastre of hydropower resources*. Many sources still cite this thesis as the basis for calculating capacity, including the source used in table 2.

Economic potential is difficult to estimate, with many foreign investors and developers entering the Nepalese hydropower development scene, causing the economy in this area to shift continuously. More of this potential could be further exploited with a strong focus on electricity export to India with cross-border collaborations. In a report from WEC from 2013 on hydro resources, the economically feasible hydropower potential of Nepal is estimated to be 40 GW (World Energy Council, 2013).

5.2 Capacity

Nepal currently has an installed capacity of 787 MW (not counting MHPs), which is far from its economically feasible capacity of 40 GW. However, there are many projects planned, both short- and long-term. According to the Nepalese Department of Electricity Development (DOED), 105 licenses for construction has been issued with a collective capacity of ≈ 2.5 GW. These projects are at different stages of development. Some are under construction, like the massive Upper Tamakoshi HPP with a capacity of 456 MW, others are still lacking financing (Government of Nepal, 2016).

When planning a new hydropower project, two licenses are needed: a survey license and a generation/construction license. A survey license is required in order to conduct a feasibility study and prepare for an environmental assessment. This license provides the licensee with the exclusive right to investigate a site, and a right-of-first-refusal to develop the project. The survey license is valid for 5 years.

After completing the survey, a generation (or construction) license is needed in order to build and operate the facility. This license is valid for a maximum of 50 years (DOED, 2005).

For transmission and distribution (T&D), similar licenses are required.

Table 3 shows that the total capacity of issued survey licenses is more than double that of the issued generation licenses. Some of the surveys might uncover that a site is not suitable for hydropower, and therefore the capacity currently under exploration might not reflect what will be constructed in the future.

Table 3 Energy-picture Nepal 2016 (Government of Nepal, 2016)

LICENSE	CAPACITY (MW)
ISSUED SURVEY LICENCES	5 440.5
ISSUED CONSTRUCTION LICENCES	2 454.443
OPERATING PROJECTS	765.999
TOTAL	8 660.942

It is worth noting, that during the writing of this thesis, new projects with ≈ 42 MW of capacity have been issued construction licenses. Data in table 3 was gathered from the DOED website on April 22nd, and on May 8th the total capacity on issued construction licenses had changed from 2 454.443 MW to 2 496.063 MW, meaning that one or more plants had a construction license issued and can begin building.

In 2014 Japan International Cooperation Agency on behalf of the Government of Nepal (GoN), published a report called "Nationwide Master Plan Study on Storage-type Hydroelectric Power Development in Nepal Final Report". In this report a plan for expansion on storage-type facilities is laid out, outlining a general plan for NEA to follow. They show a significant focus on storage, with up to 3 154 MW of storage capacity to be added (high case).

Table 4 Proposed expansion of storage-type facilities in Nepal (JICA, 2014)

Project	Capacity (MW)	Commissioning Year (FY)			Remarks
		Base Case	High Case	Low Case	
Kulekhani No. 3	14	2015/16	2015/16	2015/16	Under construction
Tanahu	140	2020/21	2020/21	2020/21	LA has been concluded.
Budhi Gandaki	600	2022/23	2022/23	2022/23	DD is ongoing.
Dudh Koshi	300	2026/27	2026/27	2027/28	
Nalsyau Gad	410	2028/29	2027/28	2029/30	
Andhi Khola	180	2029/30	2029/30	2031/32	
Chera-1	149	2031/32	2029/30	----	
Madi	200	2031/32	2030/31	----	
Naumure	245	----	2030/31	----	
Sun Koshi No. 3	536	----	2031/32	----	
Lower Badigad	380	----	2031/32	----	
Total Capacity	----	1,993 MW	3,154 MW	1,644 MW	

Table 4 shows the proposed plan made by the Japanese study group. In the same report the previous plan made by the NEA, shows many facilities that have been planned, but are several years behind schedule. Table 5 shows NEAs plan for expansion as per FY2005/06. The report says: "According to this table, the projects completed by FY2011/12 are the projects that were scheduled to be completed FY2008/09 or earlier. Construction of some projects with PPA in 2006 has not yet even started in 2012, and PPAs of some projects have been cancelled." (JICA, 2014).

Table 5 NEAs generation expansion plan FY 2005/06 (JICA, 2014)

FY	Project	Installed Capacity (MW)	Type[1)]	Developer	Status[2)] in 2006	Status[2)] as of January 2012
2006/07	Khudi	3.5	ROR	IPP	UC	IO (Dec. 2006)
	Sinsne Khola	0.75	ROR	IPP	UC	IO (Sep. 2007)
	Sali Nadi	0.232	ROR	IPP	Request for PPA	IO (Nov. 2007)
	Baramchi	0.98 [3)]	ROR	IPP	UC	IO (2011)
2007/08	Middle Marsyangdi	70.0	PROR	NEA	UC	IO (Dec. 2008)
	Pheme	0.995	ROR	IPP	UC	IO (2007)
	Tadi Khola	0.97	ROR	IPP	PPA concluded	UC
	Toppal Khola	1.4	ROR	IPP	UC	IO (Oct. 2007)
2008/09	Lower Indrawati	4.5	ROR	IPP	UC	UC
	Lower Nyadi	4.5	ROR	IPP	UC	UC
	Mardi	3.1	ROR	IPP	PPA concluded	IO (Jan. 2010)
2009/10	Kulekhani-III	14	ROR	NEA	UC	Suspended
	Mailung	5.0	ROR	IPP	PPA concluded	
	Upper Mai Khola	3.0	ROR	IPP	PPA concluded	
	Daram Khola	5.0	ROR	IPP	PPA concluded	Canceled
	Upper Mode	14.0	ROR	IPP	UC	
	Madi-I	10.0	ROR	IPP	UC	
2010/11	Chameliya	30.0	PROR	NEA	UC	UC
	Mewa	18.0	ROR	NEA	Planned	
	Hewa	10.0	ROR	NEA	Planned	
	Lower Modi	19.0	ROR	Private		
	Sanjen	–	–	–	–	
2011/12	Upper Trishuli	44.0	ROR	NEA	Planned	
2012/13	Upper Tamakoshi	309.0	ROR	NEA-Private JV		
2013/14	Tamor	83.0	ROR	NEA	Planned	
	Upper Seti	122.0	Storage	NEA	Planned	
	Kankai	60.0	Storage	NEA	Planned	
	Upper Karnali [4)]	75.0	PROR	NEA-Private JV		
2014/15	West Seti [5)]	75.0	Storage	Private		
2015/16	–	–	–	–	–	
2016/17	–	–	–	–	–	
2017/18	–	–	–	–	–	
2018/19	Kebeli-A	30.0	PROR	Private		
	Upper Marsyangdi A	121.0	PROR	NEA	Planned	
	Likha-4	40.0	PROR	NEA	Planned	
	Upper Modi A	42.0	ROR	NEA	Planned	
2019/20	Dudhi Koshi	300.0	Storage	NEA	Planned	

1) ROR: Run-of-river type, PROR: Peaking ROR type.
2) UC: Under construction, IO: In operation.
3) Installed capacity was changed to 4.2 MW.
4) Export project (NEA 75 MW = 25% of installed capacity of 300 MW)
5) Export project (NEA 75 MW = 10% of installed capacity of 750 MW)

IPPs in Nepal currently have 46 plants in operation with a total capacity of 256 MW. 122 new projects are under construction, expected to add another 2 188 MW of capacity by IPPs (NEA, 2015). Data on when the plants are expected to be finished, have not been available to us. Some of the planned capacity has been outsourced as subsidiaries under NEA with a PPA, and therefore we have chosen to identify these as IPPs. Figure 6 shows the distribution between IPPs and NEAs current hydropower facilities in operation (Government of Nepal, 2016).

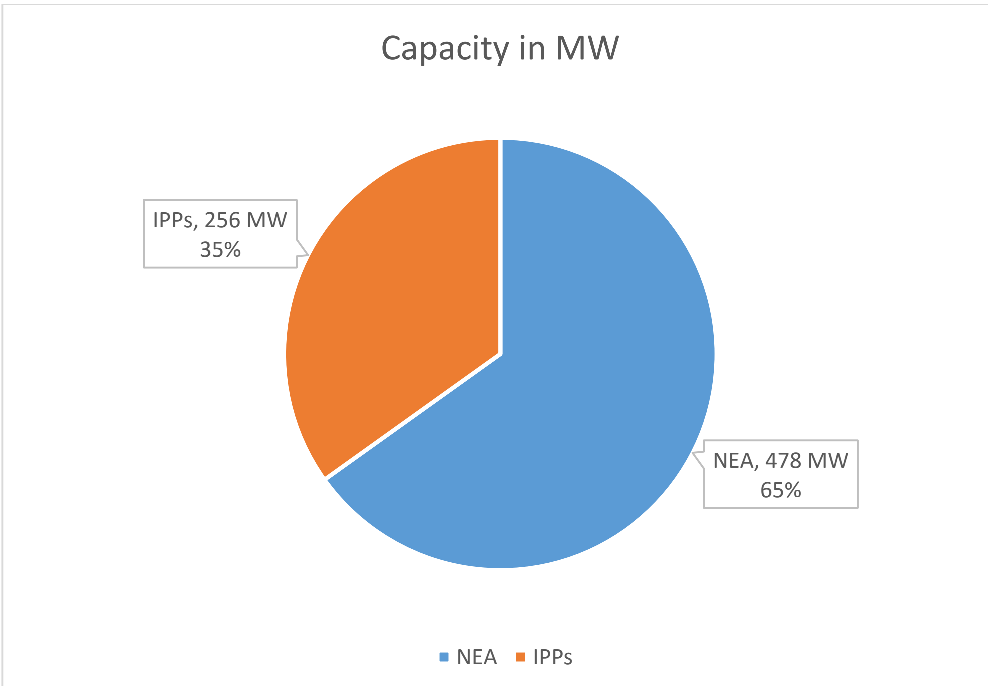

Figure 6 Share of capacity by operator, in operation

The NEA will focus more on building, maintaining and upgrading larger regional storage power projects, but since they will do this as subsidiaries under NEA, we will treat them as IPP projects. They will utilize storage-type hydropower facilities rather than RoR projects and this allows for full control over how much power is produced, using stored water when needed. The private sector IPPs are expected to handle the smaller RoR projects which will provide the bulk of the planned hydropower expansion in the future (NEA, 2015, s. 10).

If we use the numbers from “PPA Status” report and from DOED, we see that if IPPs are to construct 2 188 MW of capacity out of 2 496 MW (newest numbers), NEA stands to provide just 308 MW of added capacity and the share of privately owned and operated plants by IPPs become much larger (NEA, 2015). Figure 7 shows how DOED has issued construction licenses for future facilities between IPP and NEA (Government of Nepal, 2016).

$$NEA = 478\ MW + 308\ MW = 786\ MW$$

$$IPPs = 256\ MW + 2\ 188\ MW = 2\ 444\ MW$$

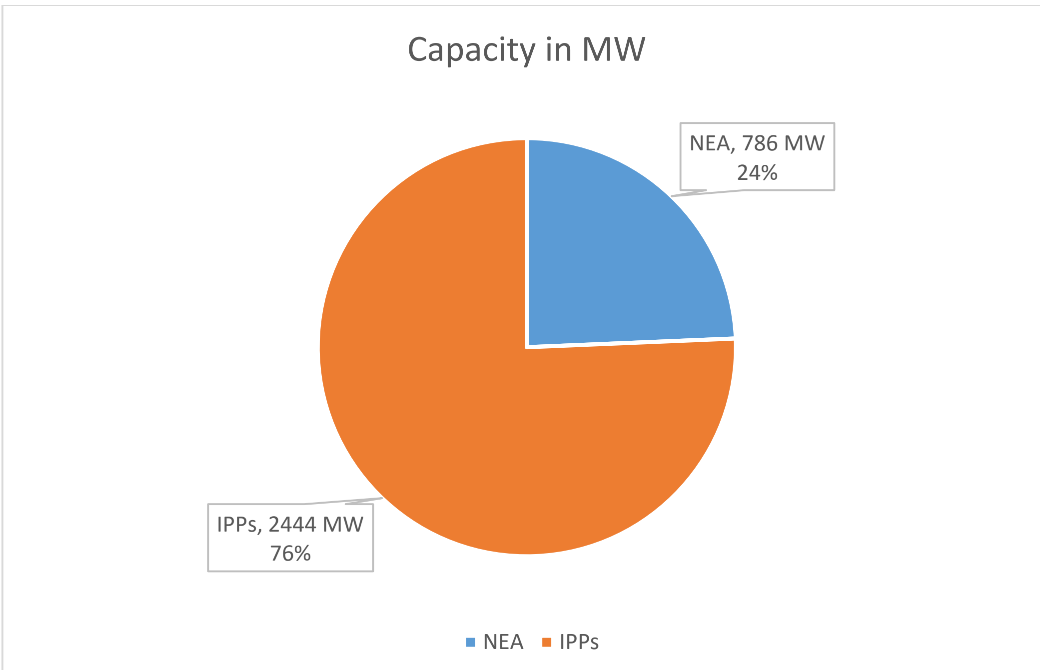

Figure 7 Share of capacity by operator, issued construction licences

The two above figures show a major swing in public versus private ownership of hydropower in Nepal. This is a part of the strategy NEA has implemented to combat the difficulties Nepal faces surrounding shortage of power. Looking at these numbers, we see that IPPs will take on the role as main supplier of energy, while NEA will focus on distributing electricity across the population. As outlined later in chapter 6.4, the GoN has ambitious plans to add close to 38 GW of capacity by 2029, and in order to reach this goal, IPPs will need to play a bigger role.

5.3 Hydropower Plants in Nepal

Small-, medium- and large-scale plants are characterized by all having more than 1 MW capacity. On DOEDs website, no micro hydropower (MHP) plants figure under "Operating Projects" because a license to operate a MHP is not needed. However, a permit is needed, so the plants figure under "Survey License for Generation" and therefore all numbers below include MHP unless specified otherwise.

MHP can be subdivided into three categories (mini-, micro-, pico-), and no applications for licenses are needed for either of these for construction or generation. For plants with an installed capacity below 100 kW, only a permit from the District Water Committee is needed. For plants with an installed capacity of 100 – 1 000 kW some information including maps, electricity distribution area and information regarding other water uses in the area, is required for submittal to the Secretary of Ministry of Water Resources before surveying an area (DOED, 2005). We have chosen to use the term micro-hydropower for all hydropower below 1 MW in this thesis based on this information.

In "Nepal - Scaling up electricity access through mini and micro hydropower applications: a strategic stock-taking and developing a future roadmap" from 2015, it is detailed that there are approximately 1 400 micro-scale plants running off-grid, providing an estimated 25 MW of capacity (Kumar, et al., 2015).

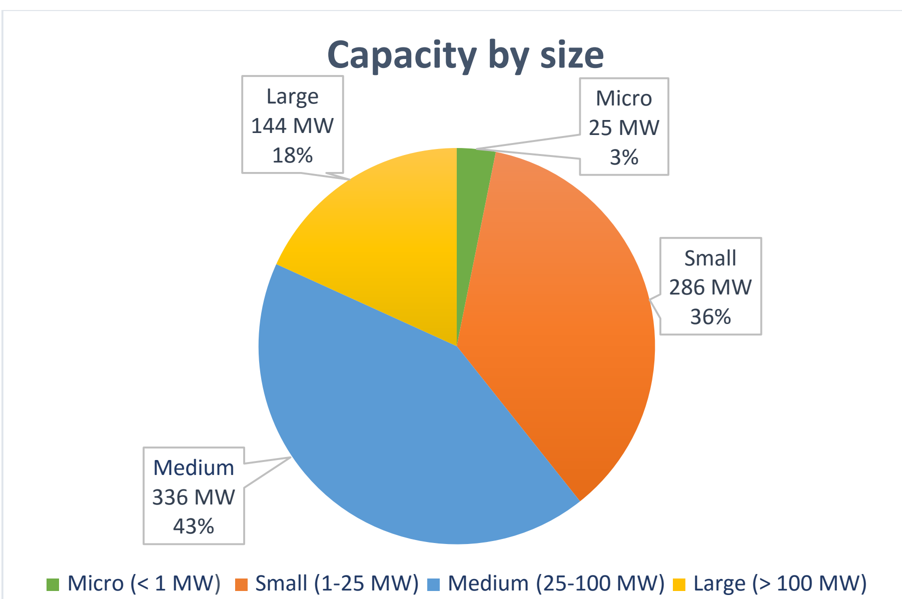

Figure 8 Capacity by size of HPP in operation (Government of Nepal, 2016)

5.3.1 Large-scale Hydropower

In Nepal there is currently one HPP with an installed capacity of more than 100 MW, and that is the Khali Gandaki A plant, built and operated by the NEA. This plant has a capacity of 144 MW and was completed in 2002 (Government of Nepal, 2016).

Many more, large HPPs are being constructed and surveyed. Four plants with a total of 789 MW capacity has been given construction licenses, with the biggest, Upper Tamakoshi HPP with 456 MW capacity, scheduled for completion in 2016 (Government of Nepal, 2016). This has been delayed somewhat due to the earthquake in 2015.

The large plants are designed to fulfil national need, while providing an opportunity to export to neighboring countries.

5.3.2 Medium-scale Hydropower

Medium-scale hydropower generates the largest share of electricity from hydro in Nepal. Total contribution is 336 MW of capacity or 43 % of total current hydropower capacity divided on six plants. Two of these are operating in cascading order, being fed from the Kulekhani reservoir. Only one of them is considered to be a storage plant, the 60 MW Kulekhani-I, while Kulekhani-II (32 MW) is a RoR plant. Kulekhani-III is currently under construction adding 14 MW capacity.

Medium hydropower projects are being used to meet national demand, while the storage projects are excellent for providing power during peak-load, due to a quick start-up time. This goes for any larger-scale storage projects planned for the future as well.

5.3.3 Small-scale Hydropower

Small-scale hydropower contributes about one-third of the hydro capacity in Nepal. This is split on 42 plants and these function in much the same way as the medium sized plants. The major difference is the flexibility of the small-scale HPP, seeing as they can be built on smaller rivers, with a smaller flow and head.

The generally agreed upon criteria of hydropower with a capacity below 10 MW as small-scale, can provide a different picture of the HPP situation.

Small- and micro-scale collectively contributes about 20 % of Nepal's hydropower and shows the importance of these types of hydro plants. This is well above the global share of small-scale at 6 %.

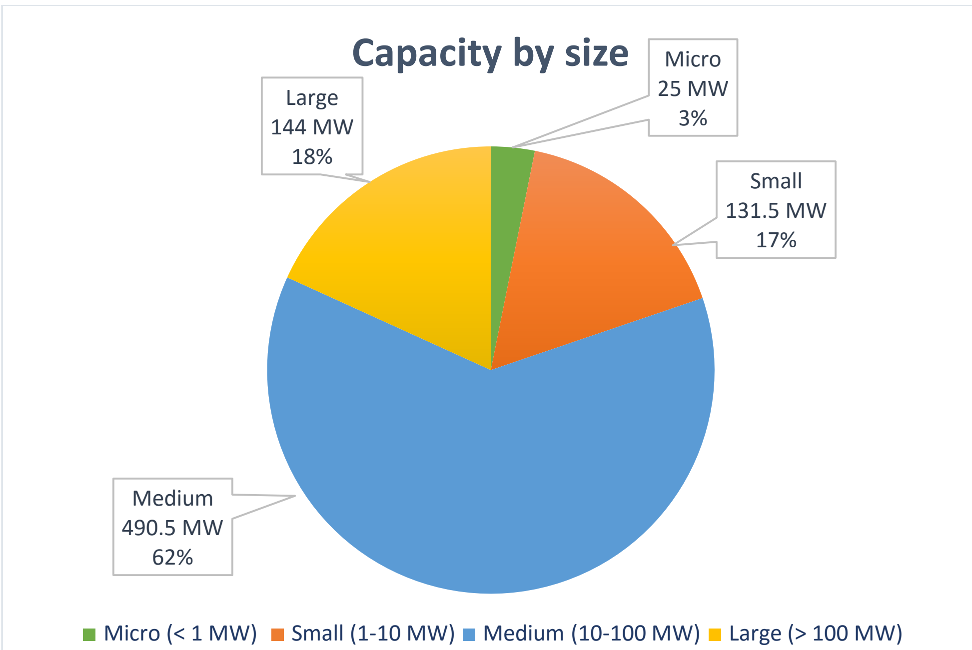

Figure 9 Capacity by size with 10 MW criteria (Government of Nepal, 2016)

5.3.4 Micro-scale Hydropower

MHP is a way for remote communities to gain off-grid access to electricity, or improve their current electrification method. These HPPs can be built and scaled to fit individual demands, based on the access to water flow and head of the resources available. It allows electricity to be generated on-site without the need for connectivity to the national grid. Nepal has built approximately 25 MW worth of MHPs, supplying more than 400 000 rural households with electricity across the country (Kumar, et al., 2015). A UNDP and AECP study from 2010 estimates that the total potential of MHP in Nepal amounts to 150 MW, supplying electricity to about 1.2 million households (Legros, Rijal, & Seyedi, 2011). Figure 10 shows an AECP prediction from 2013 of how the cumulative capacity of MHPs in Nepal will increase until 2020 based on the existing trend of implementation (Kumar, et al., 2015, s. 15). The cumulative capacity is expected to reach 50 MW around 2019.

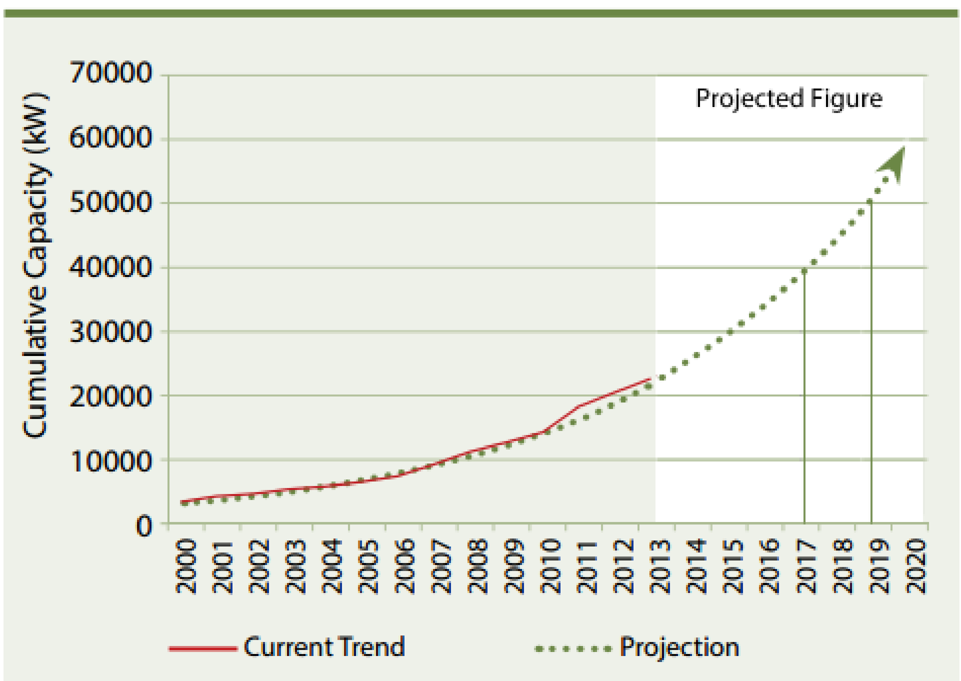

Figure 10 Prediction of MHP capacity (kW) that will be added till 2020 (Kumar, et al., 2015)

MHPs is an efficient way of generating electricity because it does not require a reservoir, while water flow and head available dictates the output of the system. Clean hydropower decreases the need for kerosene and diesel and reduces greenhouse gas emissions. Since MHPs are typically RoR systems, they are dependent on a constant and sufficient stream to generate electricity. Seasonal changes make it hard to benefit with a high efficiency rate throughout the year. Due to MHPs generally being a RoR system, the water needed for electricity generation gets returned to the stream, leaving little impact on the natural ecosystem. System loss due to transportation and distributions limits the possible distance between the generator and consumer.

The introduction of electricity for rural households improves the general way of living compared to rural households that previously did not have access to electricity. The ability to use household appliances to alleviate day-to-day chores frees up time and money that was previously used for covering basic needs, such as providing light and heat. The time otherwise spent on said chores could be used to gain additional household income through e.g. electrified appliances substituting manual labor, improved efficiency of appliances and altogether new enterprises that was impossible before the introduction of electricity. Another monetary benefit for the community is the exempt from paying income tax from generating electricity through MHPs (Kumar, et al., 2015, s. 3).

Studies has shown that electrification of rural communities leads to a number of school-related benefits, ranging from better student to teacher ratio and to a decrease in the percentage of girls dropping out of school. Electrified health care facilities have almost twice as many visitors than those without electricity. At the same time, electrified facilities are more likely to attract health care workers to remote communities. There is about five times as many health care workers in electrified areas than those without (Legros, Rijal, & Seyedi, 2011).

Another aspect to take into account is the simplicity of MHPs. Large scale operations that require large reservoirs takes several years to be built by professionals and has a high price associated. MHPs costs a fraction of what a large scale plant costs, and can be built and maintained by the locals in that specific area (UNDP, 2013). UNDP and AECP, through "Renewable Energy for Rural Livelihood Programme" and "National Rural & Renewable Programme" provides communities with different subsidy options, varying from 33 % to 50 % subsidies for the total investment costs (UNDP, 2012) (Alternative Energy Promotion Center, 2011). There are other options as well, such as Energising Development (EnDev) debt funding, enabling rural communities to fund the initial investment costs and making MHPs attractive for loans from commercial banks (EnDev, 2014). Once the national grid is expanded to include the remote areas that has operational MHPs, it is imperative that the MHPs gets connected to the national grid to increase the total capacity, instead of removing them or rendering them redundant.

5.4 Hydropower strategy

In 1992 a comprehensive set of policies was formulated: Hydropower Development policy 1992, Water Resources Act 1992, Electricity Act 1992 and Foreign Investment and One Window Policy 1992. This was done to promote electricity growth. “The Hydropower Development Act 1992” was aimed to supply urban and rural areas with electricity and to provide new developers with tax benefits and other incentives.

Several measures were implemented to encourage foreign and domestic investors to enter the hydro market in Nepal:

- Generation license for 50 years
- Income tax holiday for 15 years
- 10 % income tax after the first 15 years
- Exemption from VAT
- 1 % customs duty on imported goods for the project
- Energy rate to allow a 25 % rate of invested share capital

“The Hydropower Development Policy 2001” was implemented to allow the positive trend from the previous hydropower policy to continue with the following objectives:

- To generate electricity at low cost
- To provide reliable electricity at reasonable prices
- To link electrification with economic activities
- To extend rural electrification
- To develop hydropower for export

To make sure these measures are taken into account, a concept called BOOT (Build, Operate, Own and Transfer) was implemented. It was applied in order to supply developers of big infrastructure projects with incentives to make the projects more feasible. The developers are given the right to build, operate and own the project for a certain timespan, later to have ownership transferred to the government free of charge when the license expires.

In 2008 the GoN formed a task force to formulate plans and address the ongoing energy crisis. The task force came up with two plans: “Ten Years Hydropower Development Plan 2009” and “Twenty Years Hydropower Development Plan 2009”. The reports have been unavailable to us in English, but in “Investment Prospects and Challenges for Hydropower Development in Nepal” from 2012, the 10-year plan is summarized to “…formulate programs for developing 10,000 MW in 10 years”. This plan runs from 2009 to 2019, and from 2009 to present, approximately 2 500 MW of capacity was issued construction licenses.

The 20-year plan states that 25 000 MW will be added before 2029. In the plan, several projects were identified, including the projects from the 10-year plan, with a total capacity of almost 38 GW as shown in table 6. They present a financial estimate of US$ 33 billion required for this expansion (Dhungel & Rijal, 2012).

Table 6 Proposed added capacity over the next 20 years (Dhungel & Rijal, 2012)

PERIOD	CAPACITY (MW)
2009-2014	2 057
2014-2019	12 423
2020-2024	5 114
2024-2029	18 034
TOTAL	**37 628**

In February 2016 the GoN declared an energy emergency and came up with a plan to end the power crisis, "The National Energy Crisis Reduction and Electricity Development Decade Plan". Through this plan the government will aim to add an additional 839 MW of capacity during the first year, and 1 339 MW during the second year. The plan is to end load shedding in two years, and is based on a combination of hydroelectricity, increased imports from India and new solar and wind projects. In an article from The Kathmandu Post, IPPs welcome the decision made by the government. "We welcome the announcement. But there are doubts whether the announced programmes will be sincerely implemented," said the president of IPPAN, Khadga Bahadur Bista (The Kathmandu Post, 2016).

A new law proposed by the Ministry of Energy targets developers sitting on licenses for an extended period of time. These developers are issued licenses, both survey and construction, without starting the project. Since extending the initial timeframe of five years carries no penalty, the projects can be stalled indefinitely. Poshan Chandra Subedi, joint secretary of the Energy Ministry, says in a newspaper article from April 20th 2016: "We haven't made much progress in hydropower generation despite the issuance of such a huge number of licenses as developers are not making any move to take the project forward,". He continues: "The new law will discourage such tendencies" (Subedi, 2016).

6.0 Existing energy system in Nepal

In this chapter we will provide an overview of the energy sector and how the power establishments are organized. We will talk about the energy segment regarding electricity, and look at supply and demand.

6.1 Energy Sector

The energy situation in Nepal today is quite different from the rest of Asia, let alone the rest of the world. Despite having a large hydro potential, hydropower only accounts for 3 % of Nepal's energy sector, yet it accounts for 99.8 % of domestically generated electricity (World Bank, 2016) (South Asia Regional Initiative for Energy Intergration, 2016). There are no known oil, gas or coal reserves of significance within the country, and the people of Nepal have mostly met their energy needs through fuelwood and other biomasses such as dung and agricultural waste, 97 % of which is predominantly used for cooking, lighting and heating of domestic homes (International Energy Agency, 2016). This has led to an inefficient and unsustainable energy sector contributing to high deforestation and pollution within the country. With an 81 % reliance on biomasses, Nepal's forests see a great stressor from the populations energy needs. From 1990 to 2005, Nepal cut an average of 1.23 % of its forests per year, a total of 24.5 %, 1.2 million hectares. This was the highest deforestation rate in its region followed by Pakistan and Sri Lanka. The annual change in carbon stock in 2005 was a negative of 7 thousand tons, indicating an unsustainable balance caused by overexploitation of the forest (Mongabay, 2005).

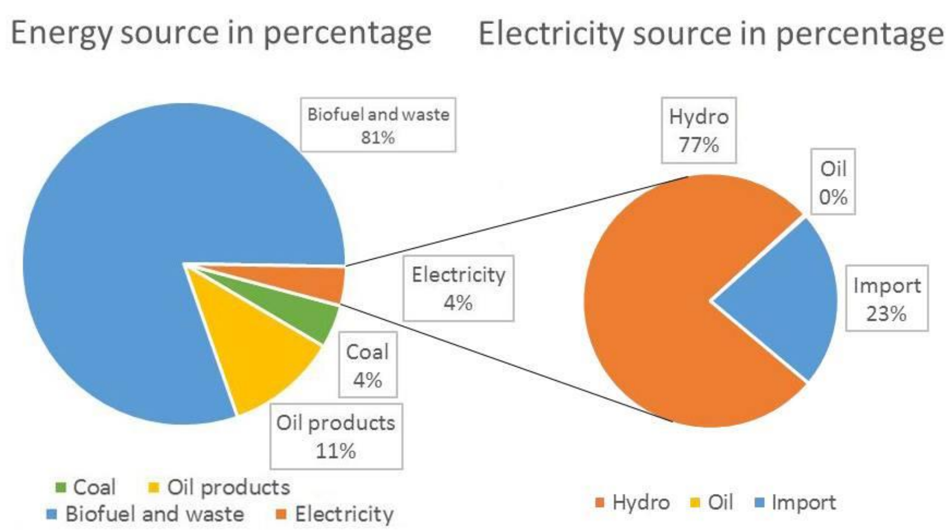

Figure 11 Total primary energy sources (International Energy Agency, 2016)

Nepal imports all of its petroleum products from India, accounting for the second largest energy source in Nepal, with 12 % of the total energy consumption coming from petroleum. India is credited for 59.7 % of Nepal's trade, with 19 990 barrels per day of refined petroleum products imported (CIA, 2016). Kathmandu is currently the third most polluted city in the world, surpassing the WHO pollution guidelines multiple times (Thapa & Adhikari, 2016).

6.2 Power market organization

The electricity market in Nepal is dominated by two entities, the Nepal Energy Authority (NEA) and the Independent Power Producers (IPPs), who represent the government owned and private sectors of the energy production in Nepal, respectively.

The electricity is largely controlled and operated by the NEA, which was formed in 1985 to gather the chaotic and overlapping smaller authorities at that time. They are responsible for generation, T&D of electricity throughout Nepal. They are also responsible for operating and developing the electricity grid, and co-responsible for planning energy distribution and educating professionals in the power field.

The NEAs revenues of about 32.5 billion Rs. have not covered its costs, and the NEA annual report 14/15 shows a net loss of 6.5 billion Rs., accumulating to a total debt of 26.79 billion Rs. "The major cause for attributing this loss is felt to be the higher cost of power purchase and other cost of services as compared to the electricity sales tariff" states the annual report, which means that the electricity imported to Nepal is sold cheaper nationally than what it was bought for. Energy Minister Radha Gyawali acknowledges the unsustainable relation between purchasing and sales tariffs, but also states "from a broader perspective, controlling electricity leakage is the answer" (The Kathmandu Post, 2015).

The private sector within energy production in Nepal was opened for private competition in 1992, which gave form to the Independent Power Producers association, giving everyone an opportunity to invest in power production, to then sell it to the obligated NEA through the Power Purchase Agreement (PPA) (Thakur, 2001). This means that the NEA will buy all of the IPPs produced power and distribute it further across the country if connected to the national grid.

The pricing of electricity in Nepal is decided by the Electricity Tariff Fixation Commission (ETFC), which was formed in 1994. The ETFC states that the tariff shall be decided “on the basis of the rate of depreciation, reasonable profit, mode of the operation of the plant, changes in consumer’s price index, royalty and the policy adopted by GoN in relation to development of electricity, etc.” (Nepal Law Commission, 1994). This means that the ETFC has a basic formula for deciding tariff, but can still modify it and add more factors if they want. The NEA has complained several times that the tariff is too low, as they end up in economic debt every year. The tariff was stagnant after 2001, though the ETFC finally hiked the tariff by 20 % in 2012, and current newspapers report discussions of another 18 % increase in 2016. A mechanism for an annual increase of 5 % in tariff price is also currently being worked on, looking at suitable hikes in accordance with energy sector development. Seasonally varying tariffs will also be considered under this mechanism, as dry and wet season gives varying power supply (GIRI, 2016). A hike in the electricity tariff is essential for the NEA to gain an economic profit and be able to expand, also benefitting IPPs revenues. The tariff needs to be affordable to the public as well.

Another important state owned energy organ is the DOED, under the Ministry of Energy. The DOED was formed in 1993, for the purpose of developing and promoting Nepal’s energy sectors financial effectiveness, through attracting private sector investment. The DOED wants to ensure transparency in the regulatory framework for private sector participation, sharing information and hindering corruption. They accommodate and facilitate processes for private investors through a single-window service and license for power projects. The DOED also assist the Ministry of Energy in implementing energy related policies (Government of Nepal, 2016).

6.3 Electric energy

If we take a closer look at the small portion of the energy sector that refers to electricity, we see the causes of Nepal's heavy biomass reliance. The kWh consumption per capita in Nepal is 128 kWh per annum (2011 - 2015), comparing as 1/3rd of Asia's average and 1/5th of the world's average, respectively, and approximately 1/200th compared to Norway's 23 326 kWh per capita per annum (2011 - 2015) (World Bank, 2016). The current peak demand for electric energy in Nepal, approximately 1 291 MW, is much higher compared to the installed capacity of 787 MW (NEA, 2015) (Government of Nepal, 2016). This mismatch between supply and demand is partly compensated through importing electricity from India. On average, Nepal imports about 23 % of its electric supply. The demand for electricity in Nepal is presently growing by 7-8 % per year according to the NEA annual report 2014-15 and is expected to reach close to 6 000 MW peak load by 2034 as shown in figure 12 (NEA, 2015). Calculating the rise in demand using numbers from the NEA Annual Report (NEA, 2015, s. 109) also used in figure 12, we get a future annual average increase in demand of 17 – 18 %. This means that demand will rise more rapidly in the years to come, as is the case globally.

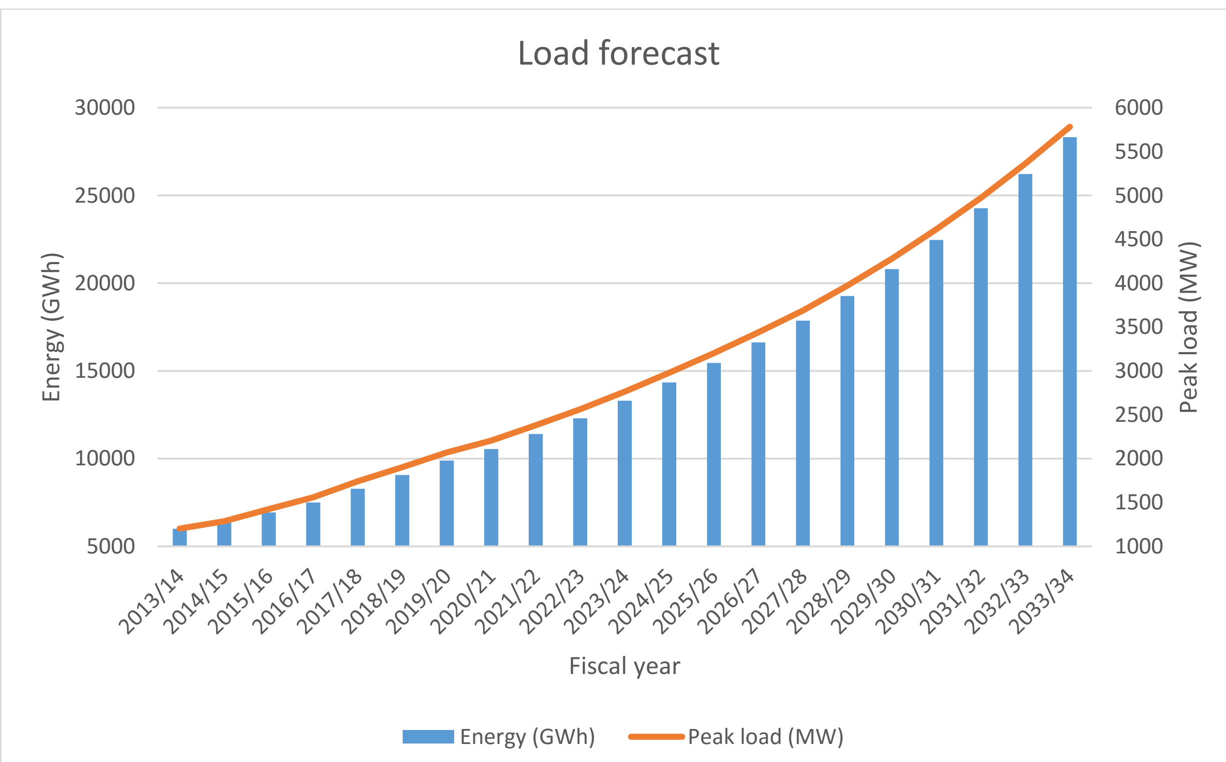

Figure 12 Peak load demand forecast (NEA, 2015)

6.4 Supply and demand

Figure 13 provides a good overview of how the energy situation in Nepal is being handled. The data used can be found in table 7 (JICA, 2014). We can see a steady trend of growth within the demand and supply, but supply has seen a slower growth than demand. This has led to a growing gap over the years, leading to a larger power deficit each year. This deficit, as we can see in the yellow sections of the bars in figure 13, has been compensated by a process called load shedding, which is explained in chapter 7.3.

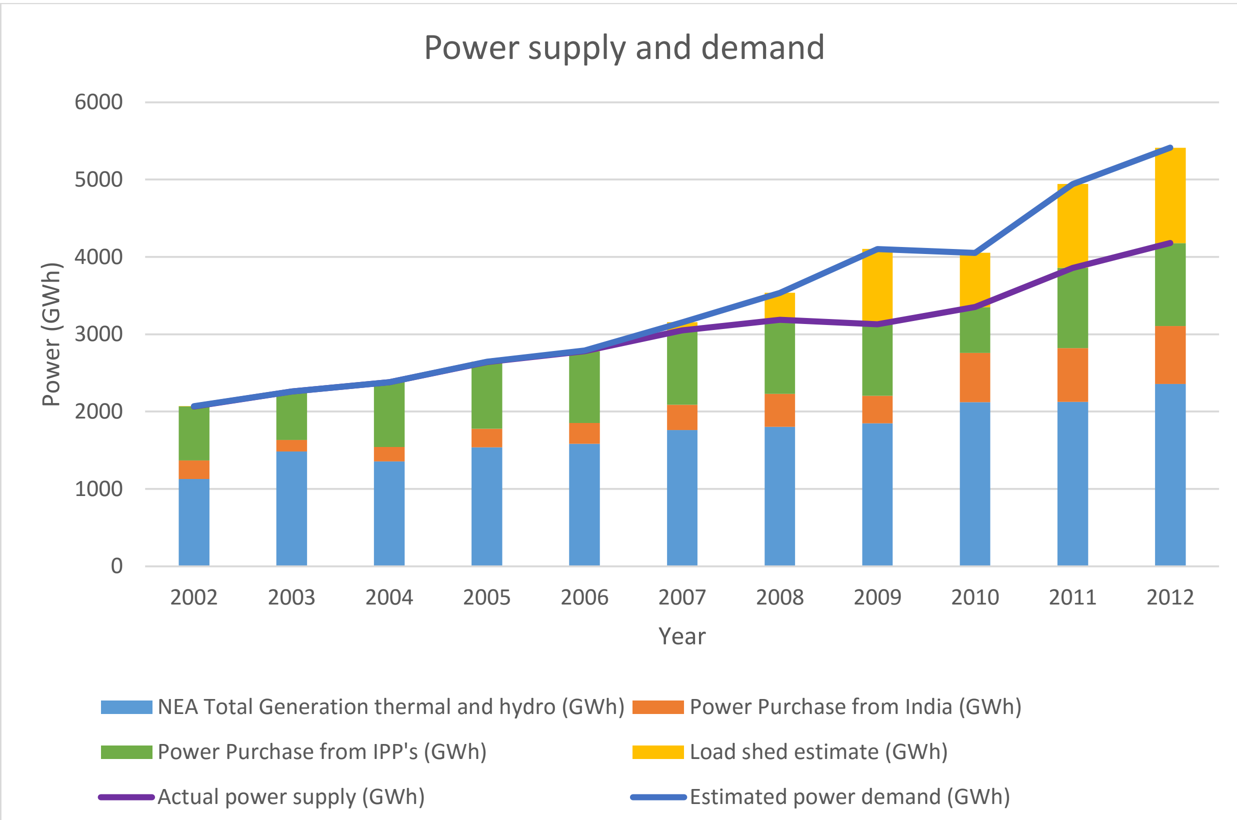

Figure 13 Annual generation, purchase and load shedding compared to the available energy

In the period between 2002 and 2012, power demand has increased by 161.7 %, while power supply has only seen an increase of 102.3 %. The power supply consists of NEA's own generated power, hydro and thermal, combined with power purchased nationally from IPPs and transnationally from India. NEA's thermal electricity generation has been included in total generation due to the fact that in 2012 it only amounted to 0.06 % of NEA's total generation.

The total power purchased from IPPs and India amounted to 1 820 GWh in 2012, a 94.4 % increase from 936 GWh in 2002. On average, annual power purchased from the IPPs has grown by 4.9 %, while annual power purchased from India has grown by 19.4 %. This means that the NEA and the IPPs have not been able to increase their capacity in accordance with demand, causing greater load shedding and larger imports.

Since load shedding started in 2002, Nepal has seen an average increase in load shedding of 5 595.5 % annually. In 2012, the amount of load shedding was almost equal to 25 % of the available energy. As all the energy put into the system is spent, in addition to the fact that load shedding accounts for an additional 25 %, it becomes difficult to estimate their load demand. We could argue that load demand would equal available energy in addition to load shedding, however the population of Nepal has not seen a surplus in supply compared to demand since early 2000's, therefore their actual demand could potentially be much higher than the amount of available energy and load shedding put together.

In 2012 NEAs total generation was 2 359 GWh and load shedding was 1 233 GWh. This means that NEA in collaboration with IPPs will need to supply approximately 50 % more electricity if demand stays the same. It will, however rise as seen in figure 12 above. So total available energy has to be drastically increased in order to meet the growing demand or more energy has to be imported from India. It is doubtful if NEA will have sufficient funds for this, when looking at the financial problems they are already facing as outlined in chapter 6.2.

Nepal experiences a dry season every year, lasting roughly six months, reducing water flow and possible hydroelectric generation. This adds to the need for load shedding.

Supply could be increased if system loss is reduced from the current 31 % of total output. Part of these losses are natural and will always occur, so minimizing system losses as much as possible will only contribute towards reducing load shedding.

Connecting more people to the national grid will cause a greater demand, increasing the need for load shedding, making the current situation worse. Around 25 % of the population is without electricity, mainly living in the rural areas. They will be connected to the grid once it is expanded throughout Nepal, thus increasing need for added capacity.

All of these challenges will be explored in-depth in the next chapter.

Table 7 Data used for figure 13

YEAR	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
NEA TOTAL GENERATION (GWH)	1130	1482	1355	1537	1585	1761	1802	1849	2122	2125	2359
POWER PURCHASE FROM INDIA (GWH)	238	150	187	241	266	329	425	356	639	694	746
POWER PURCHASE FROM IPP (GWH)	698	629	839	865	930	962	958	926	591	1039	1074
TOTAL POWER PURCHASE (GWH)	936	779	1026	1106	1196	1291	1384	1282	1230	1733	1820
ACTUAL POWER SUPPLY (GWH)	2066	2261	2381	2643	2781	3052	3186	3131	3352	3858	4179
LOAD SHED ESTIMATE (GWH)	2	0	1	3	8	103	350	972	701	1084	1233
ESTIMATED POWER DEMAND (GWH)	2068	2261	2382	2646	2789	3155	3536	4103	4053	4942	5412

Table 8 Calculated increases. Data based on table 7

	2002 (GWH)	**2012** (GWH)	**TOTAL INCREASE** (%)	**AVERAGE ANNUAL INCREASE** (%)
TOTAL GENERATION INCREASE	1130	2359	108.8	**9.9**
INDIA INCREASE	238	746	213.4	**19.4**
IPP INCREASE	698	1074	53.9	**4.9**
TOTAL POWER PURCHASE	936	1820	94.4	**8.6**
ESTIMATED POWER SUPPLY INCREASE	2066	4179	102.3	**9.3**
LOAD SHED INCREASE	2	1233	61550.0	**5595.5**
ESTIMATED POWER DEMAND INCREASE	2068	5412	161.7	**14.7**

7.0 Challenges

In this chapter we will identify the main challenges regarding electricity production through hydropower in Nepal. We have chosen four challenges to focus on, that we deem to be the most damaging to the Nepalese electricity sector: Dry season, system loss, load shedding and accessibility.

7.1 Dry Season

The climate in Nepal is important to take into consideration when discussing hydropower projects, as there are large differences in both temperatures and precipitation throughout the year, causing different challenges for planning power production.

Nepal's weather is typically divided into monsoon and dry season. Monsoon happens during summer and starts June, lasting until October in the mountains. In the flat plains in the south, the monsoon starts in July and ends in November. The end of Autumn and winter are considered dry seasons, while spring leads up to the monsoon period (JICA, 2014). The traits of the seasons are also affected by five climatic altitudinal zones, and three longitudinal zones west to east.

During the monsoon, large amounts of water is transported in the air from the ocean in the south-east, and dropped off in Nepal when ascending and cooled by the mountains. The rainy season is slightly cooler than the summer season, yet very humid, and can bring both floods and landslides across the country. The amount of rain that falls depends on the geography of the land. North-western parts of Nepal see very little precipitation because of a "rain shadow", a process where the mountain altitudes deplete the humidity in the air before it reaches the other side of the mountain, leaving a dry climate. In other words, precipitation is abundant in the south-east of Nepal, losing intensity as it moves towards the north-west. The eastern part of Nepal receives 2 500 millimeters precipitation annually, the middle regions around Kathmandu receive about 1 420 millimeters, while the western region receives 1 000 millimeters annually (Nepal Mountain News, 2015).

During the winter months in December through February, the weather is mostly dry and comfortable in the daytime with 15 degrees Celsius in southern parts, yet turns to below freezing when reaching altitudes of 3 000 meters towards the north. Precipitation during winter season is very low, yet westerly winds cause light rain in western Nepal. The seasonal difference in water availability creates difficulties balancing the supply of power, as the monsoon period sees a surplus and the dry period sees a deficit in water flow. The winter season is followed by the spring season between March and the end of May, which brings temperatures exceeding 30 degrees Celsius in the south, sometimes reaching 40 degrees. Sunny, windy and dusty days are what characterizes this season, yet instances of local rain and sleet occurs towards the end of April and May.

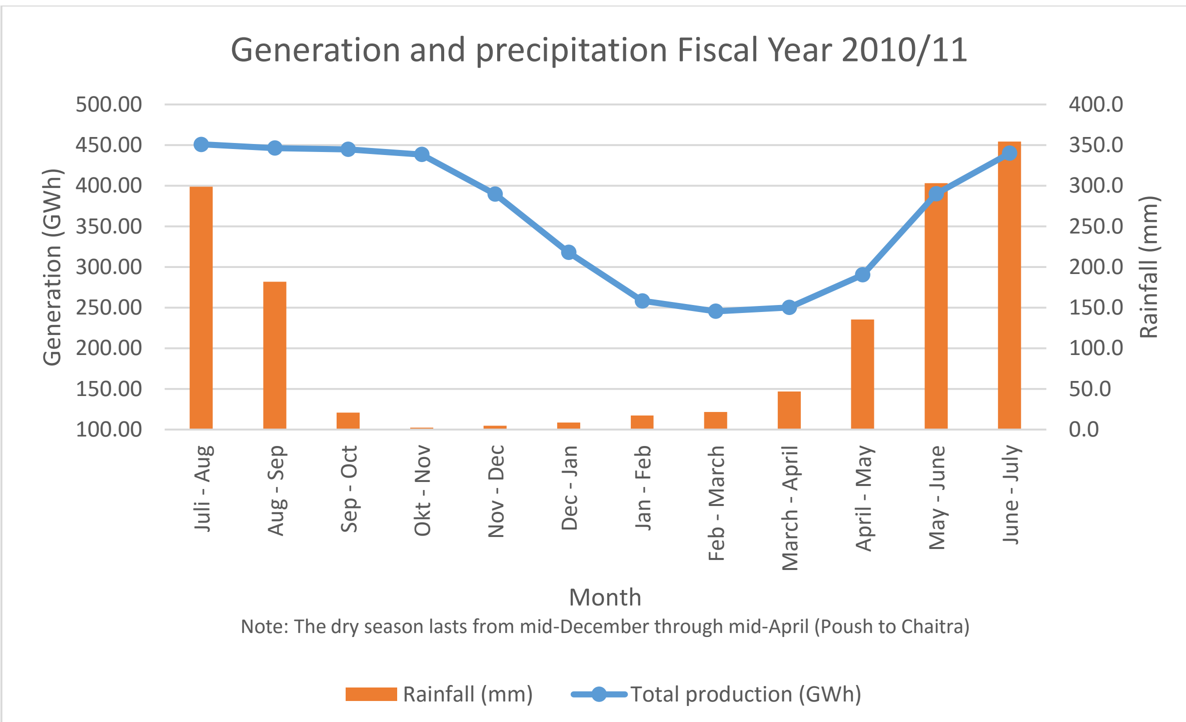

Figure 14 Annual generation and precipitation 2010/11 (World Bank, 2016) (NEA, 2013)

The data for generation used in figure 14 was only available with Nepali dates, while the precipitation data was with Gregorian dates. This makes the graph somewhat inaccurate, but it provides a picture of how the generation goes drastically down during dry season. The same applies for many places that use hydropower, for example Norway. Seasonal changes in water flow cause the possible generation to vary, which is counteracted by having storage facilities or other sources of electricity. Since Nepal only has one storage facility and limited access to other sources, the dry season has a big impact on generation as shown in figure 14.

7.2 System Loss

System loss is also known as transmission and distribution loss. There are two different types of T&D losses and several different reasons why they occur.

Technical losses are mainly due to power dissipation in electrical components. Resistance losses are inevitable, but can be reduced by transferring at high voltages since this decreases the resistance (Ohms Law). Other types of technical losses are corona discharges, inadequate size of conductors and poor workmanship.

Non-technical loses are more variable and hence more difficult to estimate and control. These include theft, meter-tampering, bribing of officials, non-payment of bills and errors in administration (Electrical Engineering Portal, 2013).

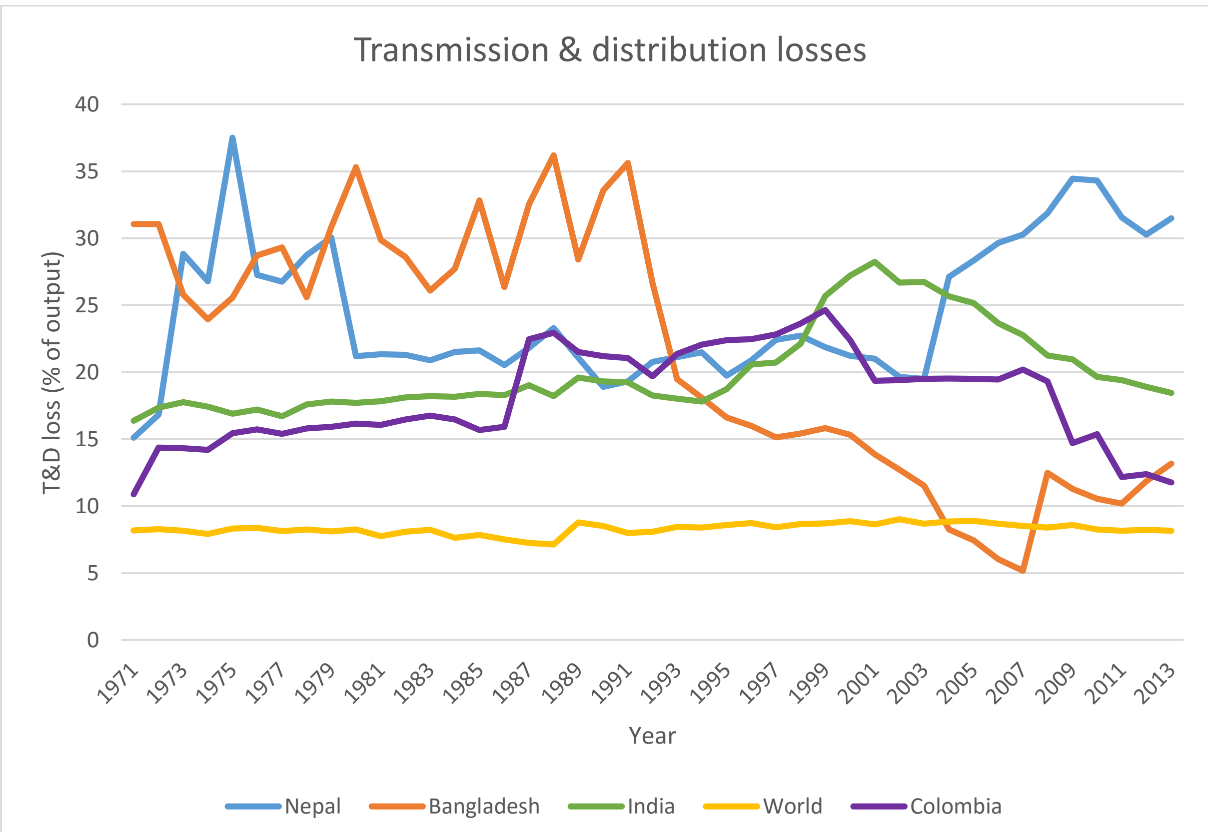

Figure 15 Comparison of system loss (World Bank, 2016)

In a report from 2010 a case is presented from South America, presenting data on a rapid decrease in T&D losses after privatization of distribution companies in Peru, Colombia, Argentina and Chile. In the scenario from Chile, the system losses went down from 21 % to 6 % in seven years. In Colombia a reduction from 22 % to 9 % took just 3 years (Pedro, 2009). The losses described are for the part of the distribution the private companies took over. Data for Colombia can be seen in figure 15 where it is clear that the T&D losses went down in the entire country. We have chosen to include Colombia in order to compare how countries with high T&D losses can minimize this problem in a short period of time.

The spike in system losses in Nepal that started around 2003, can be attributed to many different factors. Lack of metering and maintenance on T&D equipment, has meant that system losses are rising. Due to lack of data, it is impossible to determine whether the losses are technical or non-technical. Therefore, non-technical losses could play a bigger role than anticipated.

In FY2014/15 Distribution and Consumer Services Directorate under NEA initiated special drives to reduce both technical and non-technical losses. One such drive was initiating extra load-shedding hours for areas with high losses. At the same time 1 971 consumers were disconnected from the grid because of theft, and a further 40 577 consumers were also disconnected for unspecified reasons. According to NEA, this saved them approximately 450 million Rs. (ca. US$ 4.2 million) (NEA, 2015, p. 38).

The NEA has also been upgrading cables, meters and transformers resulting in a 17.30 % drop in distribution losses during "this period" (not specified). What the distribution loss was before the drive was initiated, has not been reported either (NEA, 2015, s. 38).

Table 9 The 10 countries with the highest system losses (World Bank, 2016)

COUNTRY NAME	SYSTEM LOSS % OF OUTPUT
TOGO	87
HAITI	54
CONGO, REP.	44
BOTSWANA	39
NIGER	34
NEPAL	31
HONDURAS	31
IRAQ	30
ZIMBABWE	28
CAMBODIA	28

Nepal is currently ranked sixth worldwide with regards to system losses, but many new projects and initiatives are being built and implemented to lower these losses. New transmission- and distribution-lines are being built, many of the old lines are being rehabilitated and continuous information to the public help reduce system losses.

7.3 Load Shedding

The NEA practices a process called load shedding in order to supply power equally across Nepal as the demand for electricity cannot be met at all times with the current installed capacity. Until 2002 there was no load shedding in Nepal, but as the demand exceeded the installed capacity, the need for load shedding arose. This is done through cutting the supply of electricity to certain regions in Nepal between certain hours, following a publicly available schedule to follow, released by the NEA. The duration of the scheduled power cuts depends mostly on the amount of water that is available to produce power according to season, and the amount of electricity imported from India, but can reach up to 16.5 hours daily (2008) (Shrestha, 2010). NEA is attempting to limit the weekly load shedding to a maximum of 77 hours weekly throughout the country (NEA, 2015, p. 27).

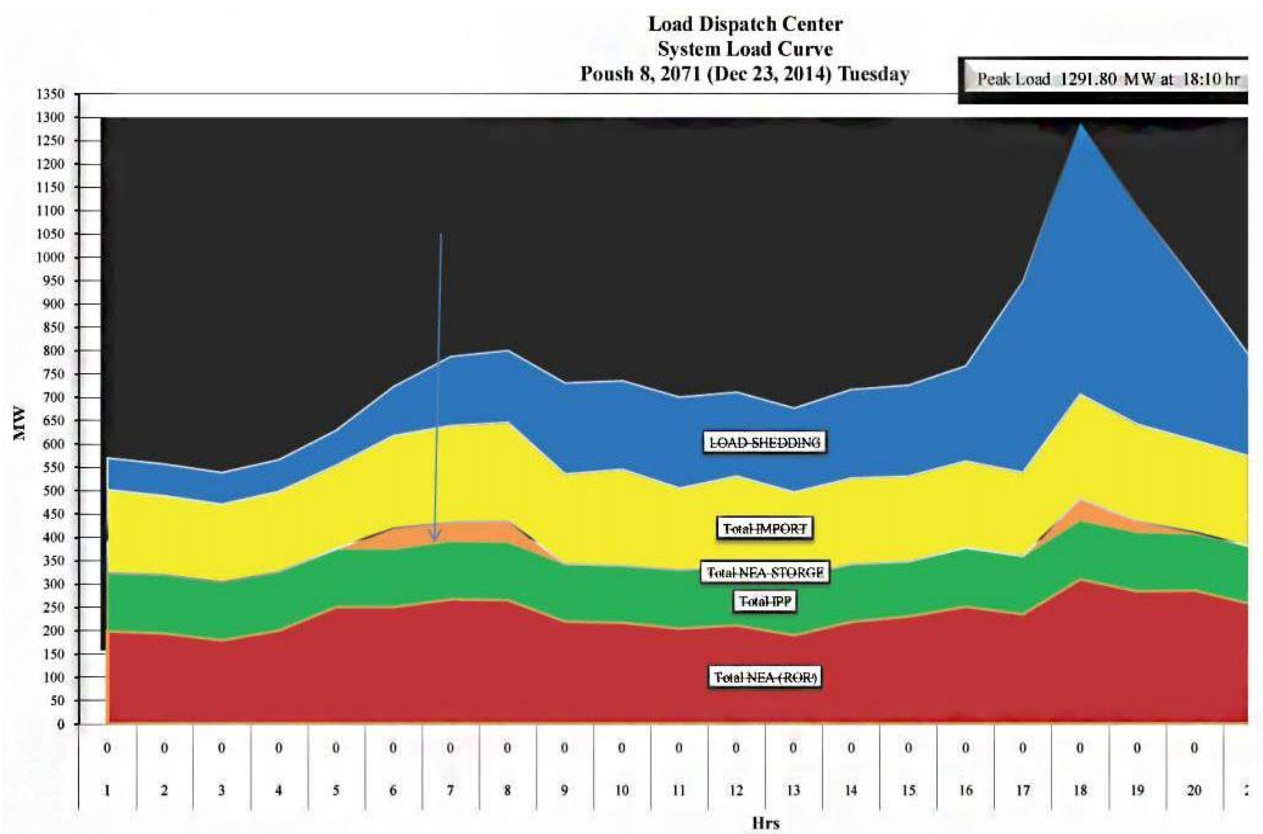

Figure 16 System load curve of peak load day (NEA, 2015, s. 110)

Even during the large surplus of water in the wet season, there is a deficit in electricity production as many hydropower projects does not run at full capacity. The national hydropower capacity in 2008 at 617 MW produced only 530 MW during wet season. "This implies that these plants were not properly maintained and, therefore, not generating at full capacity even during the wet season" states Shrestha. By not being properly maintained, Shrestha means that "In the dry season when a number of power plants are not able to generate to full capacity due to paucity of water, necessary scheduled maintenance should have been undertaken" (Shrestha, 2010). The scheduled load shedding is devastating to the macro economy in Nepal as industries stand stagnant for hours daily, affecting businesses and employment nationwide. The load shedding schedule has become a must-have for all electrified households.

Managing the surplus and deficit power of the dry and wet season is one of the NEAs goals to help eliminate load shedding completely, through exporting power during wet seasons and importing power in combination with storage dams for the dry seasons.

7.4 Accessibility

Many people have recently been able to enjoy the benefits of electricity in the urban areas of Nepal, but according to numbers provided by the World Bank (Figure 17), about 1/3rd of the rural population still does not have access to electricity (World Bank, 2016). This part of the Nepalese people has to rely on kerosene stoves and diesel generators for energy.

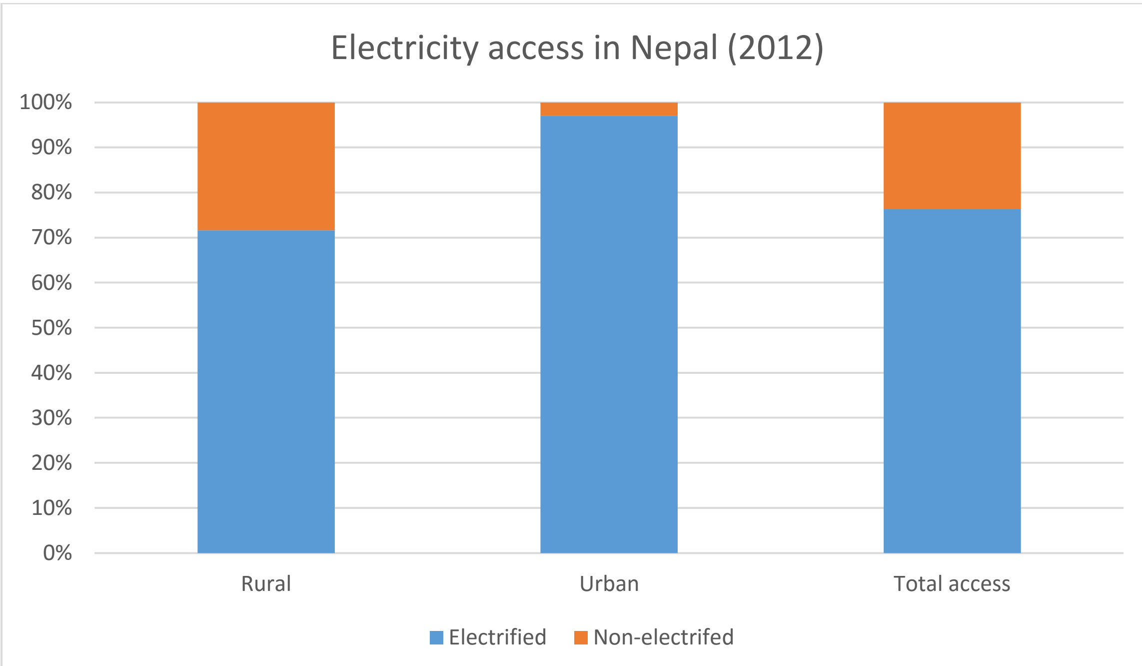

Figure 17 Electricity access in Nepal 2012

The challenging topography of Nepal, the scattered settlement pattern and the economic situation of the Nepalese government, has made the expansion of the transmission grid difficult. Several programs have been initiated to address this issue: South Asia Sub-Regional Economic Cooperation (SASEC) Power Expansion Project funded by the Norwegian Government and the Asian Development Bank, and the United Nations Rural Energy Development Programme in Nepal.

The Power Expansion Project was signed in 2014, and aims to increase basic access to electricity and help overcome load shedding. It will also support the construction of new transmission lines to India, and encourage expansion of off-grid systems (Royal Norwegian Embassy in Kathmandu, 2014).

In 2014, 82 % of the 31 million residents lived in rural areas, of which about 70 % had access to electricity, partly due to the difficulties and high costs that come with building in rugged terrain. In 2004 a program called the Community Rural Electrification Programme (CREP), was launched which aims to extend the NEA electricity grid to smaller communities around Nepal through sharing expenses between government and community. The government covers 90 % of the costs while 10 % is covered by the community. The community also establishes its own distribution unit to deliver power to individual households through training provided by the NEA, which relieves a lot of labor from the NEA (NEA, 2015, s. 42).

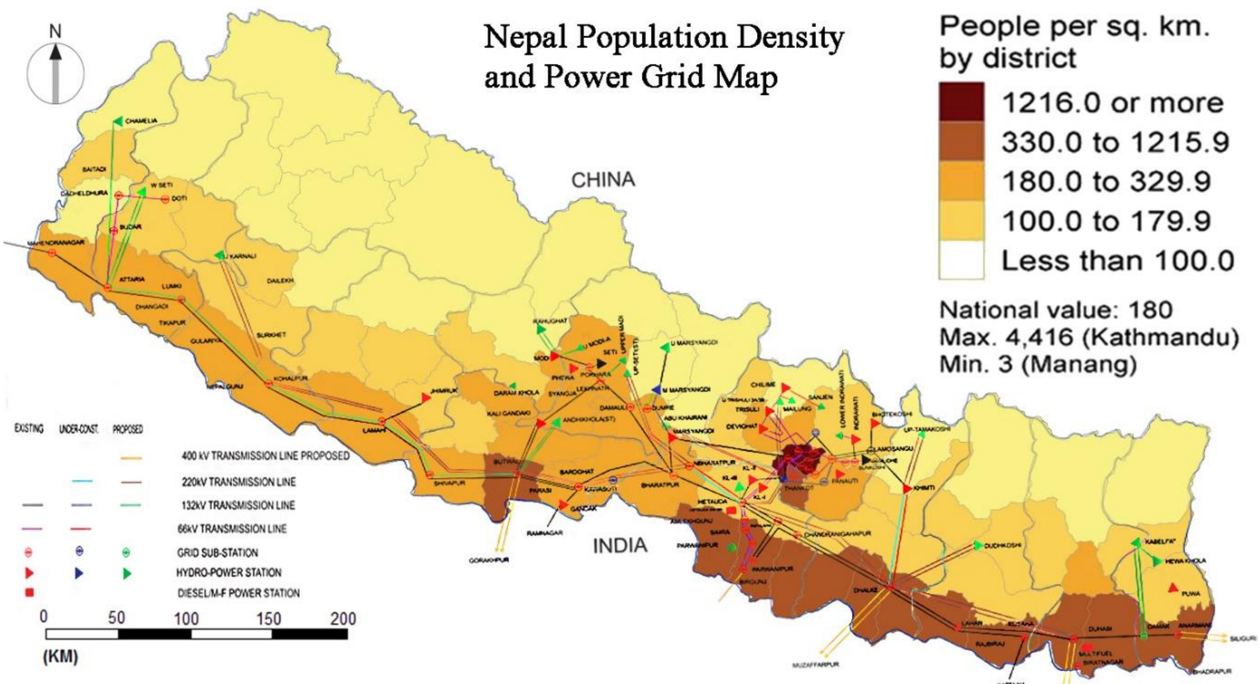

Figure 18 Population density and grid access 2011 (Central Bureau of Statistics, 2011) (Global Energy Network Institute, 2008)

These programs have helped connect a large part of the rural population in the last 10 years, but many still lack access to electricity and it will be a long time before the grid is extended to a degree where everyone has constant access to electricity. In areas with low population-density (less than 100 people per km^2), there is little to no access to the national grid. Around 8 % of the population lives in these areas, and as figure 18 shows, the grid does not extend far into these parts of Nepal.

8.0 Results & discussion

In this chapter we will provide an overview of our key findings as well as discuss and interpret them. We have chosen to write results and discussion in a single chapter, to better shed light on the challenges Nepal is facing.

8.1 Capacity and strategy

Nepal currently utilizes approximately 1 % (787 MW) of their estimated theoretical potential of 83.5 GW, out of which NEA supplies 478 MW while the IPPs capacity is 256 MW. WEC has estimated the technical and economic potential to be 44 GW and 40 GW, respectively.

The DOED has provided us with an excellent overlook of how the interest in hydropower in Nepal is growing. The rise in issued construction licenses over the last decade, shows us there is a constant influx of new plans to exploit the huge hydropower potential in Nepal. It would seem however, that the time-frame NEA operates under, is difficult for them to uphold. Delayed projects, cancelled deals and postponed PPAs, are all to be expected in Nepal. It would seem, however, that more and more private investors and survey teams, are being included to help build up the nations hydropower capacity.

The DOED has issued 105 construction licenses for hydropower projects, amounting to an increase of 2 500 MW capacity, and according to "Nationwide Master Plan Study on Storage-type Hydroelectric Power Development in Nepal: Final Report" 3 154 MW of storage capacity is proposed (JICA, 2014). In the 10- and 20-year plans proposed by the task force in 2009, an increase of up to 38 000 MW of capacity is suggested, but seems unlikely. Financing that much added hydropower is costly (US$ 33 billion), and it is doubtful when and if NEA will be able to afford this. When comparing the goals outlined in the 20-year plan to the plan the Japanese study group proposes, it becomes clear that the 20-year plan is overly ambitious, on the verge to unrealistic. After the 20-year plan was suggested in 2009, only 25 % of the 10 GW has been issued construction licenses, meaning the remaining 75 % have not yet had their feasibility study completed. Financing and constructing 7 500 MW of hydropower capacity in 3 years is difficult to achieve, especially considering how NEA has not been able to fulfil the need for power in the past.

When looking at the issued survey licenses, the amount of added capacity that is being reviewed, should provide Nepal with an opportunity to export electricity to the neighboring countries. It is not clear to us how many of these projects are actually feasible, but new sites could also be found. A clearer and better mapping of hydro resources would be beneficial, and could be necessary to attract more companies to invest. Adding more capacity for the purpose of exporting electricity could become a catalyzer for economic growth and has the potential to increase the standard of living. Meanwhile, Nepal imports energy from India to deal with the difference between supply and demand, and sells it cheaper to its consumers than the initial import price. If NEA were to focus on supporting the further development of micro-hydropower, while letting IPPs play a bigger role in the actual development of hydropower, the economic deficit NEA is currently facing could be turned around.

8.2 Load shedding and dry season

Load shedding is a product of dry season, lack of storage and capacity, and system losses. Figure 16 provides a picture of the challenges with demand/generation on a given day in December 2014. NEA aims to keep load shedding at a maximum of 77 hours per week across the country but certain regions still experience power outages lasting for 16 hours on a daily basis which limits productivity severely. In order to eliminate load shedding, the supply of electricity needs to be higher than the demand, which currently grows by 7 - 8 % annually. Load shedding is at its worst during the dry season and figure 14 shows the monthly changes in generation due to variation in precipitation. It becomes evident that generation is dictated by the amount of precipitation in the previous months, and there is a response time between them as water must accumulate and flow before it is used for power generation.

Dry season begins in December, and is a naturally occurring phenomena that is impossible to avoid. The only way to work around it in terms of hydroelectricity, is to add storage capacity. However, the dry season lasts almost six months, so it is doubtful whether just adding capacity is enough. More energy efficient electronic devices, educating the public on saving power and looking at expanding other sources of renewable energy like solar and wind, are all important parts of eliminating load shedding and overcoming the challenges stemming from the lack of precipitation during dry season.

8.3 System loss

Nepal has one of the highest system losses in the world, amounting to 31 % (2013, table 9) of their total generation. To deal with technical losses, there is a focus on upgrading existing equipment and expanding power lines, however difficult terrain and remote areas makes expansion of the power grid demanding and expensive. Privatizing at least part of the T&D system in Nepal could be an answer to eliminate system loss. As the case from South America showed, it is possible to almost completely remove system losses in a short timeframe. The non-technical losses are more difficult to control under the current energy situation, since theft, meter tampering and bribing of officials, are complex issues with more factors than just high energy prices.

Load shedding, dry season and system loss are all closely related. During dry season there is less available energy, and load shedding becomes a greater issue. This leads to frustrated NEA customers, who might resort to theft of electricity and meter-tampering.

8.4 Micro-hydropower and accessibility

As per 2015, micro-hydropower contributes a total of 25 MW capacity spread across approximately 1 400 HPPs supplying about 400 000 rural households with electricity. An estimate of MHPs capacity in Nepal shows a total potential of 150 MW. Seeing as 82 % of Nepal's population lives in rural areas, of which approximately 70 % has access to electricity, off-grid generation from MHPs could be essential for Nepal to gain universal access to electricity. The benefits involved with electrifying areas without electricity are many. Having access to a single light bulb at night is enough to raise the educational level for a small community, while more energy efficient household applications frees up time and energy, especially for the women living in rural areas. The cost associated with setting up a MHP system is fairly low relative to its capacity and the demand from each site. However, there is a high upfront investment cost for the communities to implement MHPs. This can be alleviated through different subsidy programs and funding to enable the possibility of loans from commercial banks.

9.0 Conclusion

This thesis has provided an overview of hydropower and some of the key challenges linked to hydropower development in Nepal, as well as other factors contributing to their current energy situation.

The two biggest issues that Nepal is facing today seem to be general access to electricity for the population and to maintain equal and full access to electricity for everyone at any given time.

We have identified four main barriers to achieving universal access and reliable supply of electricity:

- Dry season
- System loss
- Load shedding
- Accessibility

During the dry season, hydroelectric production suffers. This can be alleviated to some extent through storage-type facilities to supply the grid, but these projects are big and expensive. Foreign capital is most likely going to be needed in order to expand to a degree that domestic demand can be met as evidenced by increased IPPs over public (NEA) ownership in projects.

Technical losses such as resistance loss through distribution can be reduced by upgrading transmission lines to transfer electricity at higher voltages. The non-technical losses are being identified, but harder to combat. Further research on how to deal with these matters needs to be done in order to find a solution on how to get rid of the non-technical losses.

Load shedding is a result of the challenges that are not being met by the NEA. Meaning that dry season, lack of storage facilities and system losses, all lead to the necessity of load shedding. Load shedding will eventually be eliminated if the growth rate of supplied energy exceeds the growth rate of the demand.

Nepal's rugged terrain creates problematic conditions for the expansion of power grids. A solution to this is to implement MHP projects in the rural communities. MHPs is in our opinion the way forward in regards to provide access to electricity for everyone. It can be implemented anywhere as long as the required head and flow is present, and built in scale to meet most demands that rural, non-electrified communities have.

9.1 Recommendations

Energy management is becoming increasingly important, and having a safe and reliable energy supply is paramount for a nation to grow. To gain an understanding of all components in a matter as complex as an entire nations electricity sector, further research is needed. It has been an important lesson, that there is no easy answer to all the challenges that developing nations face in regards to power production and distribution.

With about 30 % of the population lacking basic access to electricity, it becomes clear that expanding the grid and providing support to off-grid electrification through hydropower, is a matter that needs to be pursued rigorously. Even if expanding the grid into the mountainous areas is difficult, providing the least accessible parts of Nepal with electricity is not an impossible task. It could take many years to provide grid access, so encouraging local communities and district offices to look into the local hydro resources, is key to success in providing equal access to electricity to everyone in Nepal.

Our recommendations are for NEA to focus on expanding storage projects, repair and replace old equipment in the T&D system and continue to promote expansion of micro-scale hydropower. An overhaul of the hydropower strategy and organizations involved with developing hydro, would be beneficial. Too many projects are left stranded, either because of lack of financing or developers sitting on licenses for years. Bring in private investors, both domestic and foreign with the will to expand rapidly. Build up as much capacity as possible to provide the economy with a boost through exporting electricity to India and other neighboring countries, while cutting expenses on import.

Expanding hydropower in order to electrify the communities, will reduce the need for biomass, thus decreasing deforestation and reducing pollution in Nepal. Providing universal access and a reliable supply of electricity, is necessary to raise the standard of living, especially for the rural population, and to raise the national education and equality level.

References

Alternative Energy Promotion Center. (2011). *National Rural & Renewable Energy Programme (NRREP)*. Retrieved from http://www.aepc.gov.np/old/index.php?option=com_content&view=article&id=254:national-rural-a-renewable-energy-programme-nrrep&catid=134:nrrep&Itemid=318

Bergner, M. (2013). *Developing Nepal's Hydroelectric Resources: Policy Alternatives.* University of Virginia. Retrieved from http://www.stimson.org/images/uploads/research-pdfs/Developing_Nepals_Hydroelectric_Resources_-_Policy_Alternatives.pdf

Boyle, G. (2012). *Renewable energy: power for a sustainable future.* Oxford: Oxford University Press/The Open University.

California Institute of Technology. (2004). *Geography*. Retrieved from http://web.gps.caltech.edu/~avouac/nepal_trip/geography.htm

Central Bureau of Statistics. (2011). *Chapterwise Map & Table*. Retrieved from Central Bureau of Statistics: http://cbs.gov.np/atlas/maps.html?chapter=2&map=2.4

CIA. (2016, February 29). *The World Factbook*. Retrieved from Central Intelligence Agency: https://www.cia.gov/library/publications/the-world-factbook/geos/np.html

Dhungel, D. K., & Rijal, P. (2012). *Investment Prospects and Challenges for Hydropower Development in Nepal.* Kathmandu: Samriddhi, The Prosperity Foundation. Retrieved from https://www.academia.edu/7995794/Investment_Prospects_and_Challenges_for_Hydropower_Development_in_Nepal

DOED. (2005, 06). *Procedures for license application for hydropower development in Nepal: A guidebook.* Department of Electricity Development. Department of Electricity Development. Retrieved from Nepal Energy Forum: http://www.nepalenergyforum.com/wp-content/uploads/2013/05/ProceduresForLicenseApplication-English.pdf

EIA. (2013, July 25). *Today in energy*. Retrieved from EIA: https://www.eia.gov/todayinenergy/detail.cfm?id=12251#

Electrical Engineering Portal. (2013). *Total losses in power distribution and transmission lines*. Retrieved from Electrical Engineering Portal: http://electrical-engineering-portal.com/total-losses-in-power-distribution-and-transmission-lines-1

EnDev. (2014). *Nepal*. Retrieved from Energizing Development: http://endev.info/content/Nepal

GIRI, S. (2016). Electricity tariff likely to be hiked by 18pc. *The Kathmandu Post*. Retrieved from http://kathmandupost.ekantipur.com/news/2016-01-07/electricity-tariff-likely-to-be-hiked-by-18pc.html

Global Energy Network Institute. (2008). *Nepal Energy Summary*. Retrieved from Global Energy Network Institute: http://www.geni.org/globalenergy/library/national_energy_grid/nepal/graphics/nepal-grid-2008.pdf

Government of Nepal. (2016). *About us*. Retrieved from Department of Electricity Development: http://www.doed.gov.np/about_us.php

Government of Nepal. (2016, May 08). *Issued Licences*. Retrieved from Government of Nepal, Ministry of Energy, Department of Electricity Development: http://doed.gov.np/issued_licenses.php

Government of Nepal. (2016, May 08). *List of Issued Generation Licenses*. Retrieved from Government of Nepal, Ministry of Energy, Department of Electricity Generartion: http://doed.gov.np/construction_license_for_generation.php

Government of Nepal. (2016, April 22). *Operating Projects*. Retrieved from Government of Nepal, Ministry of Energy, Department of Electricity Development: http://www.doed.gov.np/operating_projects_hydro.php

Government of Nepal. (2016, May 08). *Status of Generation Licences*. Retrieved from Government of Nepal, Ministry of Energy, Department of Electricity Development: http://doed.gov.np/status_generation_licenses.php

International Energy Agency. (2010). *Renewable Energy Essentials:*. International Energy Agency. International Energy Agency. Retrieved from http://www.iea.org/publications/freepublications/publication/hydropower_essentials.pdf

International Energy Agency. (2012). *Technology Roadmaps: Hydropower.* Paris: OECD/IEA. Retrieved from https://www.iea.org/publications/freepublications/publication/2012_Hydropower_Roadmap.pdf

International Energy Agency. (2016). *Nepal*. Retrieved from International Energy Agency: https://www.iea.org/countries/non-membercountries/nepal/

International Hydropower Association. (2016, April 28). *A brief history of hydropower*. Retrieved from iha international hydropower association: http://www.hydropower.org/a-brief-history-of-hydropower

JICA. (2014). *Nationwide Master Plan Study on Storage-type Hydroelectric Power Development in Nepal Final Report.* Japan International Cooperation Agency Electric Power

Development Co., Ltd. Retrieved from http://open_jicareport.jica.go.jp/pdf/12147328_01.pdf

Jill K. Jesson, L. M. (2011). *Doing Your Literature Review, Traditional and Systematic Techniques.* Sage Publications Ltd.

Kumar, A., Schei, T., A. Ahenkorah, R. C., Devernay, J.-M., Freitas, M., Hall, D., & Killingtveit, Å. (2011). *Hydropower. In IPCC Special Report on Renewable Energy Sources and Climate Change.* Cambridge: Cambridge University Press. Retrieved from http://www.ipcc.ch/pdf/special-reports/srren/Chapter%205%20Hydropower.pdf

Kumar, P., Yamashita, T., Karki, A., Rajshekar, S., Shrestha, A., Yadav, A., & Kumar, P. (2015). *Nepal - Scaling up electricity access through mini and micro hydropower applications : a strategic stock-taking and developing a future roadmap.* Washington, DC: World Bank. Retrieved from http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/SAR/2015/09/30/090224b0831133c0/2_0/Rendered/PDF/Nepal000Scalin0ing0a0future0roadmap.pdf

Legros, G., Rijal, K., & Seyedi, B. (2011). *Decentralized Energy Access and the Millennium Development Goals.* Practical Action Publishing.

Mongabay. (2005). *Nepal*. Retrieved from Mongabay: http://rainforests.mongabay.com/deforestation/archive/Nepal.htm

NEA. (2013). *Generation Operation & Maintenance Review, 9th edition.* Nepal Electricity Authority. Nepal Electricity Authority. Retrieved from http://www.nea.org.np/images/supportive_docs/GenerationOM9thIssue.pdf

NEA. (2015). *Annual Report of Nepal Electricity Authority, Year Review 14-15.* Nepal Electricity Authority. Kathmandu: Nepal Electricity Authority. Retrieved from http://www.nea.org.np/images/supportive_docs/year-review-2014-15.pdf

NEA. (2015, December 06). *PPA Status.* Nepal Energy Authority. Kathmandu: Nepal Energy Authority. Retrieved from Nepal Electricity Authority: http://www.nea.org.np/images/supportive_docs/4030PPA_data.pdf

Nepal Law Commission. (1994). *Electricity Tariff Fixation Rules.* Retrieved from Electricity Tariff Fixation Commission: http://www.etfc.gov.np/files/electricity-tariff-fixation-rules-en.pdf

Nepal Mountain News. (2015). *Climate*. Retrieved from Nepal Mountain News: http://www.nepalmountainnews.com/cms/about-nepal/climate/

Nordhaus, W. D. (1977). *Economic Growth and Climate: The Carbon Dioxide Problem.* American Economic Association. Retrieved from http://www.econ.yale.edu/~nordhaus/homepage/carbondixoideproblem.pdf

Pedro. (2009, May). Retrieved from The World Bank: http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2014/11/14/000470435_20141114134154/Rendered/PDF/926390WP0Box3800in0the0power0sector.pdf

Royal Norwegian Embassy in Kathmandu. (2014, November 14). *Increasing energy capacity and network*. Retrieved from Norway: the official site in Nepal: http://www.norway.org.np/Norway_and_Nepal/News_and_events/Increasing-energy-capacity-and-network/

Sharma, R. H., & Awal, R. (2013, May). *Hydropower Development in Nepal.* Retrieved from Renewable and Sustainable Energy Reviews, Volume 21: http://www.sciencedirect.com/science/article/pii/S1364032113000440

Shrestha, R. S. (2010). *Electricity Crisis (Load Shedding) in Nepal, Its Manifestations and Ramifications.* Hydro Nepal. Retrieved from http://www.nepjol.info/index.php/HN/article/view/4187

South Asia Regional Initiative for Energy Intergration. (2016, 03). *Countries*. Retrieved from SARI/EI: http://www.sari-energy.org/pagefiles/countries/nepal_energy_detail.asp#pageTop

Subedi, B. (2016, 04 20). New law to crack down on slow project developers. *The Kathmandu Post*. Retrieved from http://kathmandupost.ekantipur.com/news/2016-04-20/new-law-to-crack-down-on-slow-project-developers.html

Thakur, K. C. (2001). *Nepal Power Sector Reform.* South Asia Regional Initiative for Energy Integration. Retrieved from http://www.sari-energy.org/Publications/NepalPowerSectorReform/NepalPowerSectorReform.pdf

Thapa, G., & Adhikari, A. K. (2016). Kathmandu: The third most polluted city in the world. *Kathmandu Post*. Retrieved from http://kathmandupost.ekantipur.com/news/2016-03-19/kathmandu-the-third-most-polluted-city-in-the-world.html

The Kathmandu Post. (2015). Nepal’s peak hour power consumption up 7.56pc. *The Kathmandu Post*. Retrieved from http://kathmandupost.ekantipur.com/news/2015-08-19/nepals-peak-hour-power-consumption-up-756pc.html

The Kathmandu Post. (2016, 02). Power crisis, by govt lights, to end. Retrieved from http://kathmandupost.ekantipur.com/printedition/news/2016-02-19/power-crisis-by-govt-lights-to-end.html

The University of North Carolina. (2010). *Literature Review*. Retrieved from The Writing Center at UNC-Chapel Hill: http://writingcenter.unc.edu/handouts/literature-reviews/

UNDP. (2012, 07). *Renewable Energy for Rural Livelihood Programme*. Retrieved from UNDP RERL:

http://www.np.undp.org/content/nepal/en/home/operations/projects/environment_and_energy/rerl/home.html

UNDP (Director). (2013). *Nepal Micro-Hydro* [Motion Picture]. Nepal. Retrieved from https://www.youtube.com/watch?v=MXYJYNZpPmo

Wikipedia. (2016). *Vikram Samvat*. Retrieved from Wikipedia: https://en.wikipedia.org/wiki/Vikram_Samvat

World Bank. (2016). *World DataBank*. Retrieved from The World Bank: http://databank.worldbank.org/data/reports.aspx?source=2&country=NPL&series=&period=#

World Energy Council. (2010). *2010 Survey of Energy Resources.* London: World Energy Council. Retrieved from https://www.worldenergy.org/wp-content/uploads/2012/09/ser_2010_report_1.pdf

World Energy Council. (2013). *World Energy Resources 2013 Survey.* London: World Energy Council. Retrieved from https://www.worldenergy.org/wp-content/uploads/2013/09/Complete_WER_2013_Survey.pdf