Energy Resilience in Nepal

Response and Future Directions after the 2015 Earthquake and 2015-2016 Blockade

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Abstract: The resilience of energy systems is not well considered in existing literature. This study seeks to inform this issue by investigating the response to the shocks which the energy systems of Nepal have recently faced. In April and May of 2015, major earthquakes devastated parts of central Nepal, and from September of the same year until February 2016, a trade blockade greatly restricted the import of goods from India, including petroleum fuels. Drawing upon extensive fieldwork amongst a range of stakeholders in Kathmandu, Nepal, this thesis analyses the experiences of different actors in the sector during and after these two key events.

This thesis builds the concept of energy resilience using existing literature. This draws on energy security theory, resilience theory, and cultural theory. Using the concept, this thesis specifically looks at how different actors withstood, adapted and changed energy systems and the energy services they supply while experiencing realised risks to their system vulnerabilities. This approach allows energy resilience to be analysed in the response of Nepal's electricity sector to the 2015 earthquake and the response of Nepal's petroleum sector to the 2015-2016 blockade. To demonstrate the importance of performing this analysis using the energy resilience concept, this thesis brings forward thinking from energy security, energy poverty and energy justice literature to use as analytical tools when assessing the sector responses.

This thesis argues that the impact of the earthquake was most severe for rural users, with the government operated grid users experiencing less persistent damage and a faster recovery process compared to rural uses. This inequality in the electricity sector therefore worsened energy justice issues, while the loss of electricity access for an estimated 600,000 households likely worsened energy poverty issues (NPC, 2015b). In the petroleum sector, the blockade demonstrated the vulnerability to Nepal's energy security associated with relying on India as the sole supplier of petroleum fuels. However, this thesis also argues that the blockade was managed in a way which minimised adverse impacts to energy poverty and energy justice.

Using the results of the sector response analyses alongside further stakeholder interviews, policy documents and existing literature, this thesis then concludes that Nepal's energy future will be formed along three distinct axes of possibilities. In doing so, it is argued that Nepal's energy future could have a distributed electricity sector, which would provide the greatest energy poverty and energy justice benefits. However, this future would be vulnerable to shocks like that which were experienced in the 2015 earthquake. Nepal may also have a regionally integrated energy sector that would provide access to an important electricity market and ensure electricity and petroleum demands will be met, but in doing so a reliance on India would remain. Lastly, Nepal could also reduce its reliance on fossil fuels by generating enough renewable electricity to meet domestic demand and minimising petroleum consumption growth. In this future, Nepal's electricity generation would be vulnerable to climate and seismic related risks, but would provide the greatest benefits for sustainability related principles of energy justice.

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List of Abbreviations

ADB – Asian Development Bank
AEPC – Alternative Energy Promotion Centre
ATF – Aviation Turbine Fuel
BAU – Business as Usual
CREE – Community Rural Electric Entity
GDP – Gross Domestic Product
GoN – Government of Nepal
GW – Gigawatt
HGS – High Growth Scenario
IOC – Indian Oil Corporation
IOC – Indian Oil Corporation
IPP – Independent Power Producers
kW- Kilowatt
LCS – Low Carbon Society
LPG – Liquified Petroleum Gas
MGS – Medium Growth Scenario
MW – Megawatt
NACEUN – The National Association of Community Electricity Users-Nepal
NEA – Nepal Electricity Authority
NOC – Nepal Oil Corporation
NPC – National Planning Commission (Government of Nepal)
NREF – National Renewable Energy Framework
NRREP – National Rural and Renewable Energy Programme Nepal
PDNA – Post Disaster Needs Assessment
PV – Photo-voltaic
SAARC – South Asian Association for Regional Cooperation
SED – Sustainable Economic Development
UN – United Nations
UNDP – United Nations Development Programme
WECS - Water and Energy Commission Secretariat

1 Introduction

Energy systems are intrinsically linked to the functioning of economies by enabling the harvesting of resources, the manufacturing of goods, the transport of products, the provision of services and the consumption of necessities required for sustaining quality living conditions. As a result, the energy services which a person consumes has a direct relationship with the quality of that person's life and livelihood, no matter whether that consumer be a resource rich city dweller or the poorest rural agriculturalist. The systems which act to provide those energy services are therefore tied to economic development and poverty processes, contributing significantly to the circumstances within which one lives. Assuring the challenging task of harnessing energy systems for pro-poor development requires that they must be inclusive and environmentally sustainable. In recent years, it has become widely recognised that energy systems are fundamentally linked to some of the world's most significant issues, with climate change being at its core, an issue of energy systems. Further, it is well recognised that energy services provide a range of social benefits for education, healthcare, socialisation and entertainment (World Bank, 2008b, Barnes et al., 2014).

With energy systems being so deeply bonded to economic, environmental and social outcomes, understanding the way energy systems respond and adapt to external changes is therefore essential for

> The term ***energy system*** is used extensively in this thesis but has multiple meanings in wider literature. In this thesis, ***energy system*** specifically refers to the physical and organisational processes, components and actors involved in delivering an energy service. An example would be a hydropower energy system, which refers to all the processes (e.g. approval process), actors (e.g. project developers) and components (e.g. dam infrastructure) involved in generating hydropower. In this thesis, the term ***sector*** is used to refer to multiple ***systems*** which contribute to a certain energy service.

understanding how those outcomes are achieved. Discourse examining the way other systems respond to external shocks or changes has developed rapidly around the concept of resilience in recent times, with ecological, engineering, social, community and urban resilience all having established bodies of literature (Cretney, 2014). The resilience of energy systems, or energy resilience, however, remains a weakly developed concept in scholarly literature. This is despite the myriad of threats, risks and external changes shown in **Table 1.1** which energy systems must contend with. Given the deep bonds of energy systems to economic, social and environmental outcomes, this lack of discourse around energy resilience presents a dire issue for anyone aiming to achieve outcomes for economic, social or environmental benefit.

The lack of discourse around the resilience of energy systems is the driving aspiration behind this thesis, as it aims to grow the poorly developed concept using one of the best contemporary examples to do so through the country of Nepal. Nepal, as a developing country with recent memories of a decade long civil war and chronic political instability, struggles against significant domestic poverty and inequality issues (ADB, 2018, Shrestha, 2018a, Sharma, 2018). Against a backdrop where these issues need to be urgently addressed, the need to achieve positive energy system outcomes quickly and effectively is critical. In addition, the mountainous nature of Nepal means the country has the potential to generate a surplus of climate-friendly hydropower electricity which can be sold to the rapidly growing Indian and South Asian economies. However, two events in 2015 and 2016 shocked the nation, undoubtedly influencing Nepal's energy systems and the ability of those systems to deliver their desperately needed economic, social and environmental outcomes.

In order to develop an understanding of how energy systems respond to shocks in a context where positive economic, social and environmental outcomes are desperately needed, the way in which Nepal's electricity systems responded to the 2015 Nepal earthquake and the way in which Nepal's petroleum systems responded to the 2015-2016 India-Nepal border blockade are investigated in this thesis. A mixed-methods approach is employed in this investigation, which principally relies on key stakeholder interviews with individuals involved in energy related government, private, NGO and academic institutions in Kathmandu, Nepal. Where appropriate, data provided by stakeholders, reports by media, and data which is otherwise publicly available is used to strengthen the results of this study. The primary research objectives of this study, which reflect the underlying goal to develop the concept of energy resilience, are shown below.

Primary Research Objectives:

a) How did electricity systems in Nepal respond to the 2015 earthquake?

b) How did petroleum systems in Nepal respond to the 2015-2016 India-Nepal blockade?

Table 1.1: Examples of threats facing energy systems globally. Table adapted from Sharifi and Yamagata (2016: pg.1656).

Threat or Event	Cause(s)	Example	Circumstances and Consequences	References
Trade Blockade or Diplomatic Issues	Political	Nepal, 2015	Blockade of India-Nepal border disrupts supply of petroleum fuels and other commodities	(Shakya and Bhattarai, 2016)
Hurricane/Typhoon	Extreme Weather Event	Dominica, 2017	Hurricane Maria caused severe damage to the electricity sector, resulting in at least 75% of the electricity network going down.	(1, 2017)
Earthquake	Geological Event	Japan, 2011	The earthquake and ensuing Tsunami damaged power plants and resulted in a generation loss of 21 GW. Approximately 4.4 million people suffered outages as a result.	(Norio et al., 2011)
Flood or Extreme Precipitation	Extreme Weather Event	China, 1975	Heavy precipitation from Typhoon Nina and the failure for flood waters to be released led to the Shimantan dam holding more than twice its designed capacity and subsequently the dam collapsed, killing 171,000 people and destroying 61 further dams downstream.	(Si, 1998) (Sovacool, 2008)
Extreme Temperatures	Extreme Weather Event	United States and Canada, 2003.	High temperatures caused transmission lines to sag more than normally expected, causing the lines to contact trees and other lines as a result. This resulted in short circuits, which amongst other factors, led to 50 million people experiencing power outages.	(Liscouski and Elliot, 2004, Sharifi and Yamagata, 2016)
Deregulation and privatisation	Governance	New Zealand, 1998	A series of failures in distribution cables led to power outages in central Auckland for five weeks. Poor corporate governance of the company had meant an opportunity to prevent the failures was lost.	(Rennie et al., 1998, Newlove et al., 2003)
Armed conflict, Terrorism and Sabotage	Geopolitical	Pakistan	Terrorist attacks related to the conflict in Afghanistan have targeted energy infrastructures like pipelines and transmission networks.	(Sahir and Qureshi, 2007)
Accident	Governance, Human Error	Ukraine 1986.	Human error led to a meltdown of the reactor at the Chernobyl Nuclear Plant, which resulted in a large amount of radioactive material being deposited into the atmosphere and the displacement of 350,000 people.	(Sovacool, 2008)
International Market Crisis	Political	Worldwide	Geopolitical issues in the 1970's shocked the global petroleum market, resulting in price shocks internationally.	(Ikenberry, 1986)

[1] Government of the Commonwealth of Dominica.

The primary ex post objectives by themselves leave space for an ex ante analysis of resilience in Nepal's future energy systems. As a country needing to achieve positive energy system outcomes for itself and the South Asia region, an analysis of the possible threats against Nepal's energy systems is given in order to suggest considerations for those determining what Nepal's energy future will be. This requires a full examination of the possible energy demands which Nepal will have in the future, alongside an in-depth overview of the possible technologies which will be employed to meet this demand. With this knowledge, the implications for resilience of the possible energy futures is then analysed. Together, the research objectives build on the undeveloped concept of resilience and demonstrate why such a concept of energy resilience is needed in Nepal.

Secondary Research Objective:

What are the resilience implications of Nepal's energy futures?

1.1 Thesis Structure

The concept of energy resilience is largely undeveloped in wider energy discourse, so a conceptual framework is built in this thesis using the existing and developed concepts of energy security, resilience and cultural theory. This provides a conceptual way of understanding how different actors within Nepal's energy systems demonstrated adaptive resilience in their response to the 2015 earthquake and 2015-2016 blockade on a sub-national scale. To demonstrate the importance of using this concept to understand the system responses to these events, three analytical tools are drawn upon using energy security, energy poverty and energy justice literature. The use of this literature to demonstrate the importance of energy resilience shows the impact of the earthquake and blockade on energy systems at a national scale and provides analysis into the impact of those responses on equality and development issues at local scales.

With a conceptual framework developed around energy resilience and three analytical tools presented to demonstrate the importance of the concept, a brief energy overview chapter is then given. The purpose of this chapter is to provide context to the research by explaining what the energy systems of Nepal are and what the relative importance of each system is. Literature examining how Nepal's energy demands will grow in the future is briefly presented here. Using this information, this chapter selects four energy resources to be investigated in this thesis. These are Nepal's hydropower, solar PV, petroleum fuels and energy trading systems, which are chosen due to their importance for providing modern energy sources and their important potential for Nepal's future energy scenarios. A brief overview of the four energy systems is given to conclude this chapter, which lays the foundation for the discussion of the secondary research objective in **Chapter Seven**.

In the following methodology chapter, the conceptual approach to the research is discussed to demonstrate how a mixed-methods approach employing both qualitative and quantitative data is required to meet the research objectives of this study. An explanation of the methods employed is then provided, which indicates that the semi-structured interview method primarily used in this thesis is suitable for providing the information necessary to understand the response of Nepal's energy system responses from an interpretivist and constructivist position. Relying solely on this method meant issues of bias and quantitative knowledge gaps would have been apparent, so further methods of media analysis, policy and literature analysis, and secondary data analysis are used to strengthen and support the results of key stakeholder interviews. The ethical and positionality considerations which were carried through the fieldwork and research process are also explained in this chapter, which focus specifically on the issues of associated with researching in a developing country.

These results are presented across three chapters, corresponding to the three research objectives. In **Chapter Five**, the response of Nepal's electricity systems to the 2015 earthquake is given, followed by the response of the petroleum system to the 2015-2016 blockade in **Chapter Six**. These chapters follow a structure which addresses adaptive reslience in the relevant energy systems (a concept explained in the next chapter), by first examining the impact which the respective shock had, followed by identifying the way energy systems adapted to that shock, and finally by presenting how those systems are changing to prepare for future shocks. In doing this, these chapters demonstrate that using the energy resilience concept identifies how the earthquake and blockade damaged energy security and worsened energy poverty and energy justice issues in Nepal.

To address the secondary research objective the Energy Futures chapter (**Chapter Seven**) employs the resources given in the context chapter, existing work on energy sytems in Nepal, results presented in the earthquake and blockade response chapters, and results collected from key stakeholders. This synthesised approach examines the likely energy demands for Nepal's future electricity and petroleum sectors, explores the benefits and issues associated with the sources which will be used to meet that demand, and suggests what the implications of using those sources will be. In doing so, this chapter argues that the impact of the earthquake and blockade on Nepal's electricity and petroleum sector present risks to Nepal's energy futures. This risk presents implications for energy security, energy poverty and energy justice, but reducing this risk by encouraging certain electricity systems over others also has implications for these issues.

In concluding this thesis, **Chapter Seven** brings together the earlier results of the Energy Futures chapter with the results of **Chapters Five** and **Six**, to suggest that three axes are emerging which will determine how Nepal's energy systems will operate in the future. These axes suggest that Nepal's future energy systems may be organised in a centralised or distributed manner, they may be regionally integrated across South Asia or isolated in Nepal, and they may rely on renewable energy resources or fossil-fuel resources. It is argued that centralised generation seems to be likely in Nepal's energy future, but the other components are less clear and dependent upon the rate at which new generation capacity is built in Nepal and the rate at which domestic demand grows. Through the energy resilience concept, this thesis argues that the energy futures which are possible through these axes will all have implications for energy security, energy poverty and energy justice.

1.2 Development Issues in Nepal

The issues of poverty and inequality in Nepal must be acknowledged throughout this thesis to understand the context from which energy systems and government, business, and community priorities operate. Nepal is a UN-classified least developed country that has been tackling and improving significant issues of income poverty, health and education over the last two decades (NPC, 2017a). Many people in Nepal still do not have access to affordable and reliable modern energy services and the mountainous terrain of much of Nepal's territory means settlements in the northern parts of the country are dispersed and difficult to access with existing infrastructure (Malla, 2013, Chhetry, 2001). Two-thirds of working Nepalis are engaged in the agricultural sector and the country has a low rate of urbanisation (World Bank, 2018i, Ministry of Finance, 2018). These factors contribute to the significant development inequality which exists in the country, and this is especially true between the rural and urban populations (ADB, 2018). **Table 1.2** provides a selection of statistical indicators which demonstrate these development issues.

Table 1.2: Selected development, economic and energy indicators for Nepal.

Indicator		Value	Year	Source
Development Indicators				
Human Development Index		0.574	2017	(UNDP, 2018)
Literacy rate		65.9%	2015/2016	(CBS, 2016)
Under-5 mortality rate (per 1000 live births)		35	2016	(World Bank, 2018h)
Urbanisation rate		19%	2017	(World Bank, 2018i)
Average years of education		12.2	2017	(UNDP, 2018)
Percent of working poor at PPP $3.10 a day		32.6%	2017	(UNDP, 2018)
Economic Indicators				
GDP gross (USD, 000)		$24,472,013	2017	(World Bank, 2018d)
GDP per capita (USD)		$835.1	2017	(World Bank, 2018f)
Grants Received (USD, 000)		$727,100	2016	(World Bank, 2018g)
Income inequality, Gini Coefficient		32.8		(UNDP, 2018)
Energy Indicators				
Electrification:	National	76.3%1;	2015/2016	(CBS, 2016)
		90.1%2	2016	(World Bank, 2018a)
	Urban	93.1%	2015/2016	(CBS, 2016)
	Rural	64.9%		
Energy use (kg oil equivalent per capita)		413	2014	(World Bank, 2018c)
Electric Power Consumption (kWh per capita)		139	2014	(World Bank, 2018b)

1.3 Political Context

Beyond the development context of Nepal, it is necessary to understand the geopolitical environment which Nepal operates within. This is important to Nepal's energy systems because Nepal is a landlocked country with an immense hydropower potential, bordered by the South Asian region where a lack of energy resources has constricted growth (World Bank, 2008a, Chapman, 2009). As a result, energy security has repeatedly been noted as an important benefit of regional cooperation which needs to be considered by South Asian countries (Singh, 2018, Srivastava and Misra, 2007, Dhungel, 2008). This is because there is a mismatch between countries which have potentially large hydropower or hydrocarbon resources far in excess of their energy demand (e.g. Nepal), and countries which have a growing energy demand but limited domestic energy supplies (e.g. India) (World Bank, 2008a). Therefore, there is a great potential for energy trade in the region and Nepal, with its enormous hydropower potential, would thus be well equipped to benefit from this trade (Chapman, 2009).

The South Asian region, however, is infamous for its lack of integration, and the South Asian Association for Regional Cooperation (SAARC), which Nepal is a member of, has achieved little in terms of trade and connectivity (Huda and McDonald, 2016). There are a number of geopolitical reasons for this lack of integration. Deep-seated mistrust, national inhibitions and a fierce desire for states to defend their sovereignty in a region with overlapping ethnicities and cultures has marred the political will of member countries to see SAARC beyond a geopolitical symbol of regional unity (Singh, 2018). Huda and McDonald (2016) note the historical conflict resulting from the partition of the Indian subcontinent, particularly the conflict between India and Pakistan, as a major obstacle to regional cooperation. The influence of China in the region has also weakened regional cohesion, as India is wary of Chinese involvement in South Asia, especially with respect to China's military and economic ties to Pakistan (Huda and McDonald, 2016). Given that Nepal shares a border and a road connection with China, discussion on energy relationships between Nepal and China will need to consider implications on South Asian regionalism.

1.4 The 2015 Earthquake

The earthquake which caused the shock event that the first research objective investigates occurred on the 25th of April 2015 at 11:56 am, with a moment magnitude (M_w) of 7.8 (Hazarika et al., 2016). This earthquake (hereafter 'the earthquake') struck Nepal with an epicentre in the Gorkha District, 77km northwest of Kathmandu (Hazarika et al., 2016). The earthquake began a sequence of aftershocks, with two significant earthquakes occurring on the 26th of April and the 12th May of 2015, with M_w 6.7 and 7.3 respectively (Bhagat et al., 2017). The earthquake damaged residential and government buildings, health and education services, heritage sites, road, water and energy infrastructure, agricultural land and trekking routes (NPC, 2015a). **Figure 1.4** shows the fourteen districts[2] that were declared as severely or crisis hit, including Kathmandu, Bhaktapur and Lalitpur, which are the districts of the Kathmandu Valley (NPC, 2015a). Approximately 9,000 people died as a result of the earthquakes and almost 500,000 homes were destroyed (NPC, 2015b). Heritage monuments were also damaged or destroyed, and UNESCO sites within the Kathmandu Valley suffered significant damage (Bhagat et al., 2017).

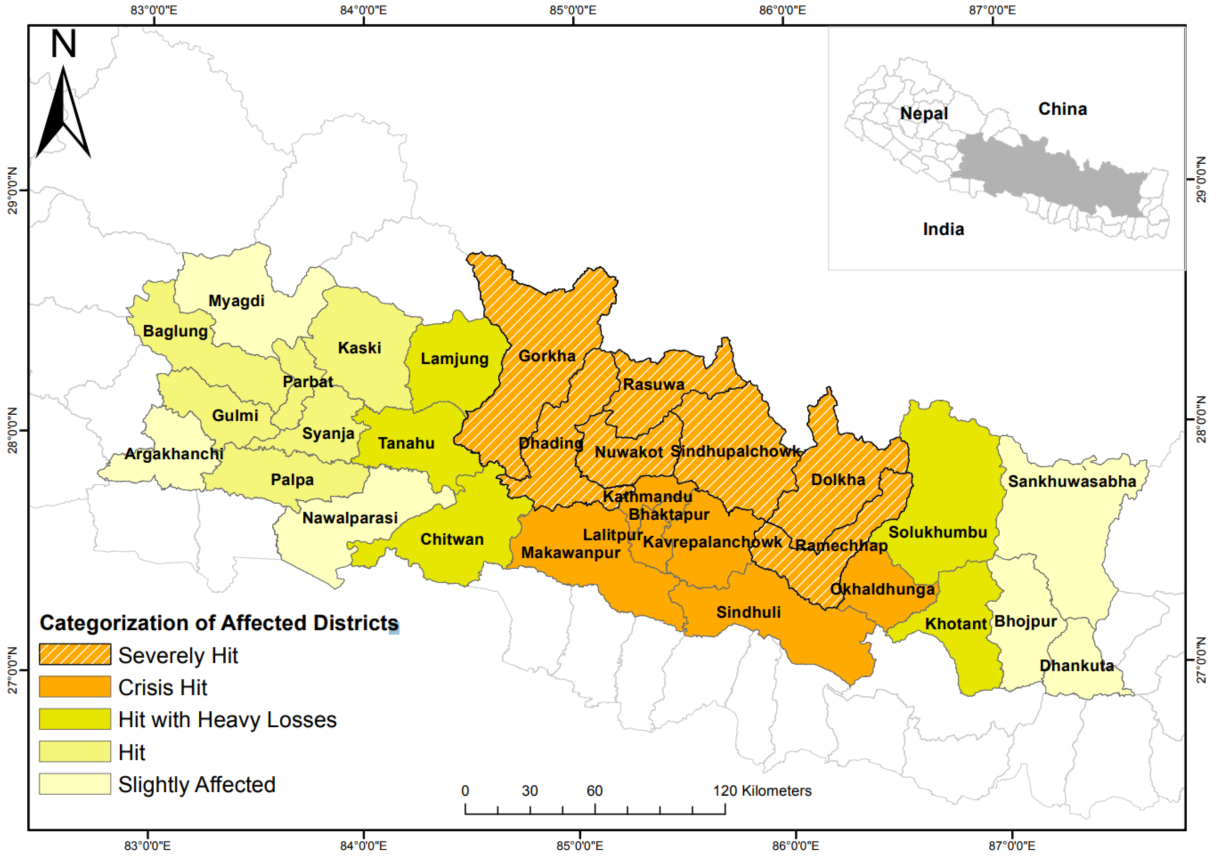

Figure 1.4: *Earthquake Affected Districts. Taken from Nepal Planning Commission (2015a, page XI).*

There is existing work which assesses the damage to the electricity sector in Nepal following the earthquake. The most comprehensive of this work has been published by the Nepal Planning Commission (NPC) alongside the UN and several large donor agencies, in their two volume 2015 Post Disaster Needs Assessment (PDNA) (NPC, 2015b, NPC, 2015a). This document was a preliminary assessment of damage which could be used to identify what recovery actions needed to be taken (NPC, 2015b). This included a comprehensive assessment of damage to the electricity sector, which is summarised here alongside **Table 1.4.** This is done to demonstrate why this thesis specifically investigates the response of Nepal's electricity systems to the earthquake and to allow a comparison against the results of this study, which have been gathered three years after the earthquake. Such a

[2] Administrative districts changed boundaries in 2018, but this study will refer to the boundaries in place at the time of the earthquake to avoid confusion.

comparison means a further form of triangulation and validation can be applied both ways to the results of the PDNA and this study.

The PDNA identified that generation facilities were damaged in the earthquake. Three Nepal Electricity Authority (NEA) owned hydropower stations and 15 Independent Power Producer (IPP) owned power stations were damaged, leading to an outage of 171 MW (NPC, 2015b). At the time the PDNA was published, only one of the three NEA hydropower stations remained out of operation, while only one of the 15 IPP stations had become operational (NPC, 2015b). Several large stations suffered damage but remained in operation, with the 92 MW Kulekhani storage, the 75 MW Upper Marsyangdi, and the 144 MW Kaligandaki A having cracks found in their reservoirs or powerhouses (NPC, 2015b). Damage was also reported in hydropower projects under construction, with construction being stopped in seven projects, in wake of the earthquake and following landslides (NPC, 2015b). In off grid systems, 262 micro hydro projects were damaged, resulting in 3.7 MW of generation lost across 81,000 households (NPC, 2015b). There was also widespread damage to solar PV systems (NPC, 2015b).

Damage also occurred to the transmission and distribution systems. Due to the transmission system being 1,948 km in length with 6,093 towers, it was not clear at the time of the PDNA being published what damage had occurred (NPC, 2015b). All transmission lines remained in service however despite three 132 kV lines and two 66 kV lines reportedly being damaged (NPC, 2015b). Six 66 kV substations and one 132 kV substation, where the transmission and distribution systems are connected, were also reported to be damaged (NPC, 2015b). Four of these major substations were inside the Kathmandu Valley, but these substations were repaired and supply was restored within four days of the earthquake (NPC, 2015b). In the 14 badly affected districts, which includes the three districts of Kathmandu, the distribution system was providing between 37% and 100% of pre-earthquake supply when the PDNA was published (NPC, 2015b). Further information on the infrastructure damaged in the distribution system is given in **Table 1.4.**

1.5 The 2015-2016 Blockade

The shock event which the second primary research objective of this thesis investigates is the 2015-2016 blockade (hereafter 'the blockade'), which began in September of 2015 and continued for five months until January 2016 (Kumar, 2017). During this time, supplies of petroleum fuels, medicines and food products coming across the India-Nepal border were disrupted (Kumar, 2017, Sharma et al., 2017). This hindered earthquake recovery and reconstruction efforts and threatened ambulance services, education services and local transportation (Herington and Malakar, 2016). The blockade affected multiple India-Nepal border crossings, including the Birgunj-Raxual border (see **Figure 1.5**), which is the crossing point for the main fuel supply route into Kathmandu (Shakya and Bhattarai, 2016). The reason for this blockade

Table 1.4: Damage Reported in the electricity sector in the Post Disaster Needs Assessment (NPC, 2015)

Sector / System	**PDNA Damage Report (2015)**
Grid Generation (Hydropower)	- 3 NEA stations damaged (48 MW) - 15 IPP stations damaged (123 MW) - Other stations damaged but still in operation with damage status unavailable.
Off-Grid Generation	- 262 micro hydro projects damaged. - 115,438 solar home systems damaged. - 156 institution solar systems damaged. - 3.7 MW of generation lost across 81,000 households.
Transmission	- 7 substations damaged - 5 transmission lines damaged but remained in service; extensive length of the transmission line system meant damage assessment is timely.
Distribution	- Electricity supply in Kathmandu restored within four days; Some distribution systems in the 14 affected districts still not restored at time of publication. - 1,577 km of lines of different voltages requiring restoration or reconstruction. - 723 transformers requiring restoration or reconstruction. - 143,519 energy meters requiring restoration or reconstruction. - 49,670 distribution poles requiring restoration or reconstruction.
Sector wide	- 600,000 households directly lost electricity services. - 17,807 million NPR (approximately $175 million USD in 2015) of damages to the electricity sector in total.

Figure 1.5: *Map of Indian and Nepali fuel depots relevant to Nepal's petroleum sector. The main border crossing for fuel entering Kathmandu, the Birgunj-Raxaul border, is shown on the map. This point was affected by the blockade. Map adapted from NOC (2018).*

was never satisfactorily explained, however sources point to both strikes from the Madhesi group in Nepal alongside the border with India and the exercising of discontent from India following the adoption of a new constitution in Nepal (Budhathoki and Gelband, 2016, Kumar, 2017). The blockade was not the first India-Nepal blockade to occur, as India had previously placed a 13-month blockade on Nepal in 1989 (Budhathoki and Gelband, 2016). Sharma et al. (2017), Budhathoki and Gelband (2016) and Lamichhane (2015) have written on the health impacts of the blockade, particularly as a result of the restriction of medicine supplies being allowed through into Nepal. Despite there being many reports in media, however, there is limited published literature detailing the impact of the blockade on Nepal's energy sectors, aside from the work on energy poverty and security by Herington and Malakar (2016) and the economic impact assessment of the blockade by Shakya and Bhattarai (2016).The absence of literature regarding the impact of the blockade presents an opportunity for this thesis to fill, although in a capacity limited to energy system responses.

2 Literature Review

This chapter builds a conceptual framework to understand the idea of 'energy resilience' through. This framework guides the research and employs the concepts of energy security, resilience, cultural theory, energy justice and energy poverty.

The concept of energy resilience is not well developed in academic literature and has only been applied in isolated studies with little relationship to one another. Ghasemieh et al. (2015) for example, use the idea of energy resilience within research on household scale energy systems, while Blum and Legey (2012) use the term in discussion around energy security and economic development. Sharifi and Yamagata (2016, 2015) have begun using energy resilience on a conceptual level to examine urban energy resilience through a framework shown in **Figure 2.1.0a**. However, this framework has a key focus on urban themes like infrastructure, land use, urban geometry and governance (Sharifi and Yamagata, 2016). The lack of a developed energy resilience concept requires that this chapter develop a conceptual understanding of energy resilience before demonstrating how the concept can be applied to the research objectives of this thesis.

2.1 Conceptual Framework

To develop a conceptual framework for energy resilience amidst a narrow and poorly established body of literature on the term, this study draws on the wider and well-developed bodies of literature on energy security and resilience. This approach is similar to that of Sharifi and Yamagata's (2016) work, who demonstrate that concepts of energy availability, accessibility, affordability and acceptability from energy security literature can be used in conjuction with concepts of adaption and recovery from resilience literature to develop a framework relevant to energy system resilience (Sharifi and Yamagata, 2016, Kruyt et al., 2009).

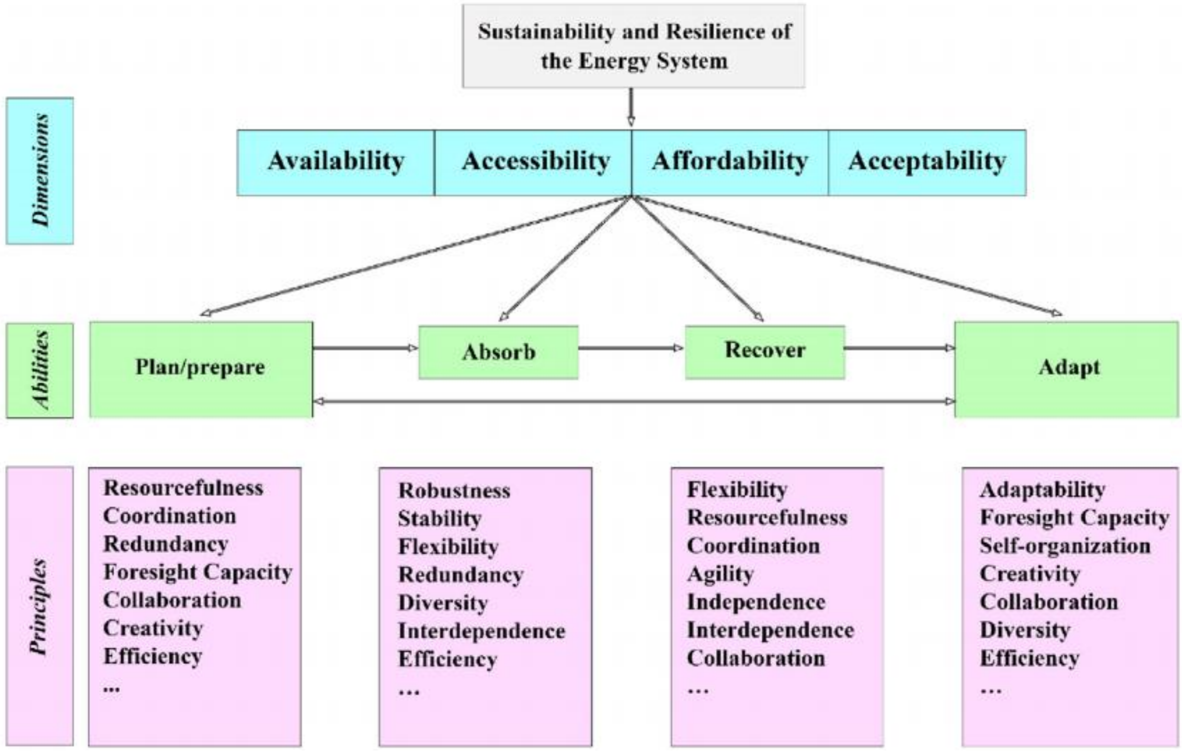

Figure 2.1.0a: *Sharifi and Yamagata's (2016) major components of their conceptual framework for assessing energy resilience (pg. 1666).*

Energy security, as this framework will explain, allows a conceptual understanding of the components within energy systems that ensure a secure supply of energy resources. However, arguably much of the energy security literature is operated at a scale which is too large, both geopolitically and temporally, to understand the impact of the specific earthquake and blockade events within Nepal. Resilience literature is used to engage this research at a smaller scale, as the concept of resilience is used in disaster, community and urban applications to understand how systems respond to shocks. To complete the framework, cultural theory is used to allow an analysis of how different actors in a developing country context operate within energy systems responding to shock.

Literature that has utilised energy security, resilience and cultural theory concepts in research related to Nepal are reviewed throughout this chapter in **Boxes 2.1.1-3** to provide examples of how the three concepts can be applied in practice. Together, the concepts of energy security, resilience and cultural theory are applied together in this framework to direct the research in a manner which investigates how different actors within Nepal's energy systems responded to the earthquake and blockade. This provides the conceptual framework that guides this research as shown diagrammatically in **Figure 2.1.0b**.

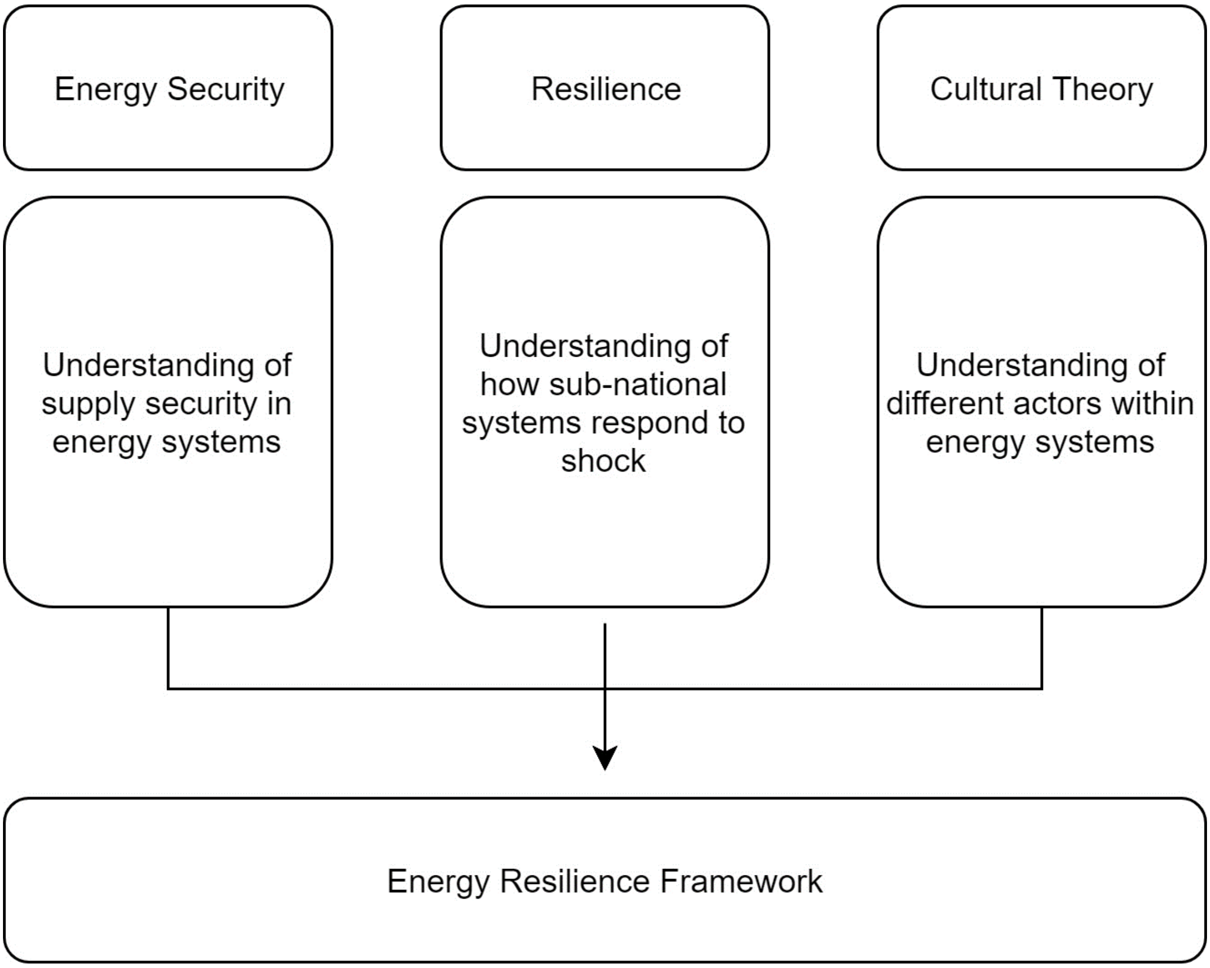

Figure 2.1.0b: *The Energy Systems Resilience Conceptual Framework.*

2.1.1 Energy Security

Thinking from energy security literature has previously been used by Sharifi and Yamagata (2016) to understand the supply of energy in their conceptual framework for energy resilience in an urban context. This framework follows their approach. The idea of energy security is drawn from a national or supra-national level of conceptual energy policy thinking. At this level, the idea of the 'energy trilemma' has emerged in the literature as a way of recognising that energy policy must address three competing goals of energy security, environmental sustainability and social equity to ensure a broader goal of energy sustainability (WEC, 2011, WEC, 2012). Energy security aims to ensure the physical availability of a diverse range of energy sources, environmental sustainability aims to ensure an acceptable level of environmental impact from energy systems, and social equity aims to ensure that energy supplies are affordable and accessible (WEC, 2011, WEC, 2012). Within this trilemma, the term energy security is an established but still emerging concept used in energy policy and public discourse. The longer form of the term, 'security of energy supply' represents the policy goal given as part of the energy trilemma.

Any definition beyond this longer form of the term is contested, however, and as such there is an expansive range of definitions and indices for the concept.

Multiple authors have discussed how the security of energy supplies may be attained, and this differs depending on how energy security is classified beyond a simple definition of the security of energy supply. A common classification of energy security is given through the four A's, which are four characteristics which must be met to ensure energy security exploitation (Kruyt et al., 2009, APERC, 2007). These are: *availability*, which is the availability of energy resources; *accessibility*, which is the geopolitical relationships which allow for energy access; *affordability*, which is the price of energy; and *acceptability*, which are the environmental and social effects that are tied to energy resources and their exploitation (Kruyt et al., 2009, APERC, 2007). Sovacool and Mukherjee (2011) expand from this classification and identify five dimensions of energy security: availability, affordability, technology development and efficiency, environmental and social sustainability, and regulation and governance. Their table explaining these dimensions is shown in **Table 2.1.1.**

Table 2.1.1: *Energy Security Dimensions and Values. Adapted from Sovacool and Mukherjee (2011: pg.5345).*

Dimension	Explanation	Underlying Values
Availability	Having sufficient supplies of energy. Being energy independent. Promoting a diversified collection of different energy technologies. Harnessing domestically available fuels and energy resources. Ensuring prudent reserve to production ratios	Self-sufficiency, resource availability, security of supply, independence, imports, variety, balance, disparity
Affordability	Producing energy services at the lowest cost, having predictable prices for energy fuels and services, and enabling equitable access to energy services.	Cost, stability, predictability, equity, justice, reducing energy poverty
Technology Development and Efficiency	Capacity to adapt and respond to the challenges from disruptions, researching and developing new and innovative energy technologies, making proper investments in infrastructure and maintenance. Delivering high quality and reliable energy services.	Investment, employment, technology development and diffusion, energy efficiency, stockholding, safety and quality
Environmental and Social Sustainability	Minimizing deforestation and land degradation, possessing sufficient quantity and suitable quality of water, minimizing ambient and indoor pollution, mitigating GHG emissions associated with climate change, adapting to climate change.	Stewardship, aesthetics, natural habitat conservation, water quality and availability, human health, climate change mitigation, climate change adaptation.
Regulation and Governance	Having stable, transparent, and participatory modes of energy policymaking, competitive markets, promoting trade of energy technology and fuels, enhancing social and community knowledge about education and energy issues	Transparency, accountability, legitimacy, integrity, stability, resource curse, geopolitics, free trade, competition, profitability, interconnectedness, security of demand, exports

There are different perspectives on how energy security can be attained, which Kruyt et al. (2009) present as a result of two dichotomies. The first is the tension between attaining energy security through multilateralism, market trust and international co-operation versus attaining energy security through increased energy independence (Kruyt et al., 2009). In the former option the focus for energy policy will be on production capacity, costs and physical availability, whereas in the latter the focus will be on accessibility to resources and geopolitical factors (Kruyt et al., 2009). The second dichotomy is the tension between achieving environmental targets and ensuring low energy costs, as energy costs generally rise when responding to environmental challenges (Kruyt et al., 2009). The four A's of energy security are tied to different energy perspectives in this model, with each term occupying a branch of the axes shown in **Figure 2.1.1a** (Kruyt et al., 2009).

To contrast the dimensions approach to energy security given by the four A's and Sovacool and Mukherjee (2011), a risk focused approach can be taken. Winzer (2012) have developed a framework for energy security, given in **Figure 2.2.1b,** which does this. There are two parts to this framework, the first indicating sources of risk and the second outlining ways in which this risk should be examined. In using this framework, energy security is considered as a result of technical, human and natural risks which can have multiple aspects of impact with differing scales of severity (Winzer, 2012). This focus on risk is important as Winzer (2012) argues that there is at least an agreement in the literature that the concept of energy security is concerned with risk. Cherp and Jewell (2011) also take a risk approach to considering energy security, arguing that energy security is "*protection from disruptions of energy systems that can jeopardize nationally vital energy services"* (pg. 329). This focus on risk is centred on threats, such as blockades or sabotage, predictable and controllable threats, like resource depletion or infrastructure failure, and unpredictable threats, such as market volatility and technology changes.

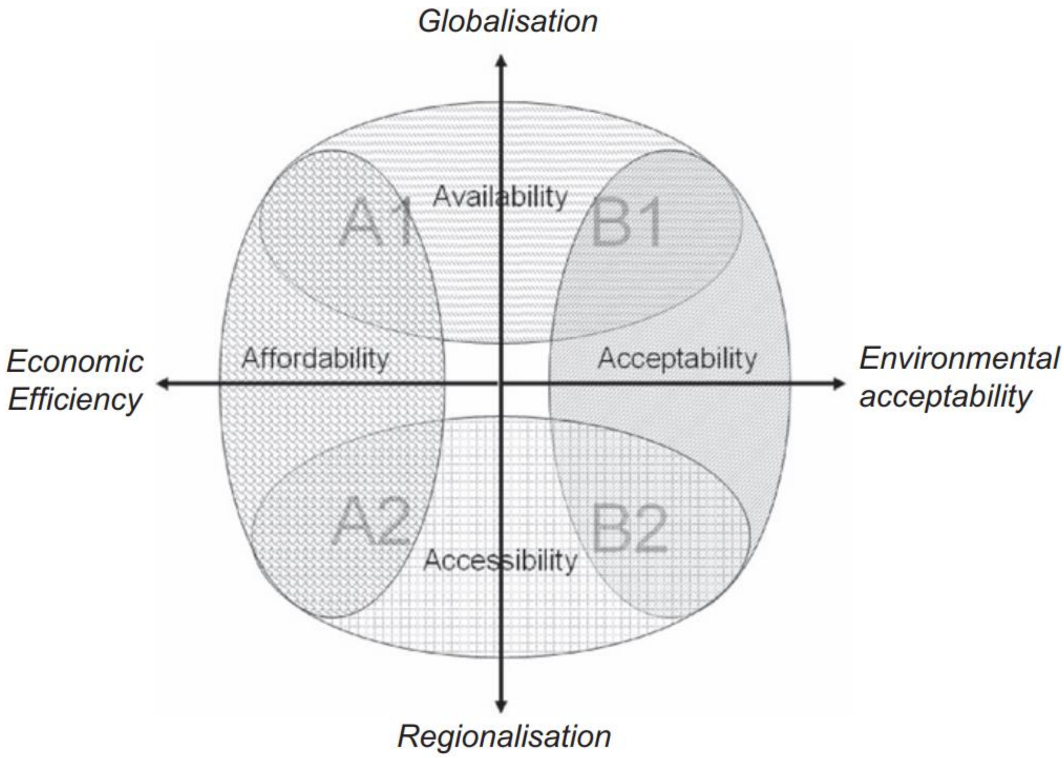

Figure 2.1.1a: *The two dichotomies of Energy Security. From Kruyt et al. (2009: pg.2168).*

The risk focused approach to energy security used by Winzer (2012) and Cherp and Jewell (2011) is useful as it limits consideration of energy security specifically to the risks which a given energy system faces, opposed to the four A's and dimensions approach which considers climate change, energy access and energy affordability (Cherp et al., 2012).

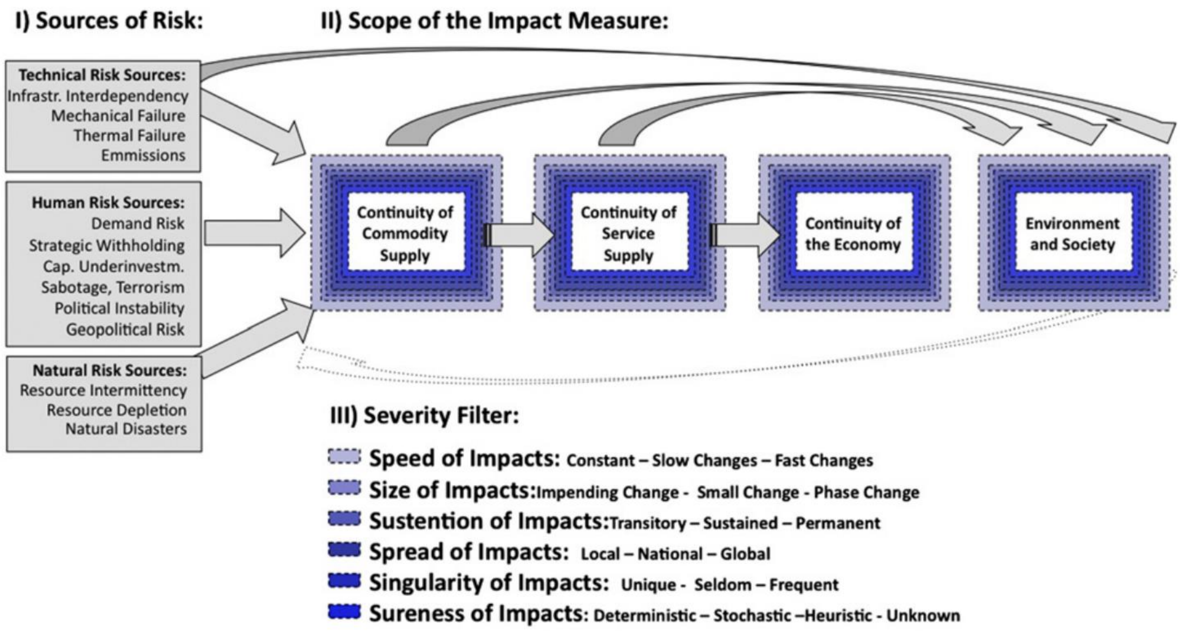

Figure 2.1.1b: *Dimensions of Energy Security. Taken from, Winzer (2012: pg.10).*

For the purposes of this study, the literature reviewed here provides an understanding of energy security as a concept which aims to ensure a secure energy supply is achieved through multiple dimensions, by ensuring minimal risk. This analysis employs the use of the well-known 'four A's', or an expanded version of those dimensions, while also drawing on the idea of energy security as a goal to reduce risk in energy. Using both approaches allows discussion to be focused on specific risks where appropriate, such as damage caused to infrastructure by the earthquake, and broader discussion when considering issues of energy affordability and access. However, both the dimensions and risk based approaches to energy security are often engaged for national and geopolitical scale analysis (Cherp et al., 2012, Laldjebaev et al., 2015). This means geopolitical, technical and economic considerations can overshadow issues on a smaller scale (Laldjebaev et al., 2015). This is an immediate problem for this study as the research aims require that sub-national impacts on organisations from specific events be examined. This limitation to energy security literature, as is demonstrated in **Box 2.1.1**, requires that the conceptual framework for this study be synthesised with another body of literature that allows energy systems to be examined at a smaller organisational and temporal scale.

Box 2.1.1: Energy Security Studies in Nepal

Although there are only a limited number of studies, it is useful to consider research related to energy security in Nepal to provide foresight into energy system vulnerabilities and energy security possibilities. Ebinger (2011a) analysed energy security in Nepal by examining the history, state and issues associated with the electricity and oil sectors in the country. In doing this, Ebinger (2011a) concludes that

> *"Nepal's energy security suffers from a number of impediments: overburdened or deteriorating infrastructure; lack of sufficient private investment; inadequate taxation policies; endemic power theft; ineffective institutions; and lack of an independent, competent regulator"* *(pg.118).*

Ebinger's conclusion highlights vulnerabilities in Nepal's energy systems, particularly those associated with the country's inability to provide adequate energy supplies for itself.

Sah (2018) also analyses Nepal's energy security in a similar manner to Ebinger (2011a), although only by looking at the hydropower sector. This leads Sah (2018) to draw similar conclusions to Ebinger (2011a), who argues that issues in providing adequate energy supplies through hydropower are a challenge for Nepal's energy security. When considering energy security across the South Asian region, Ebinger (2011b) discusses the potential for Nepal electricity trade with India and Bangladesh. Such trade would require Indian cooperation and hydropower development in Nepal, but would significantly improve the regions energy security by increasing sustainable electricity access for the region (Ebinger, 2011b).

The Asian Development Bank (ADB) undertook an energy sector assessment for Nepal which informs energy security (ADB, 2017a). Through its sector overview, it identified issues related to energy security of acute shortages for electricity and petroleum supplies, seasonal generation difficulties, and poor financial performance of the Nepal Electricity Authority (ADB, 2017a). The ADB (2017) report is a broad document which provides a comprehensive strategy for the sector. Included in this is a recommendation that Nepal develops a National Energy security policy, which would increase the storage capacity for petroleum fuels and see accelerated sustainable development of hydropower.

The energy security approach used by these studies allows national energy issues and opportunities to be presented. However, this approach does not discuss organisation level processes or threats imposed by specific events, which demonstrates that energy security literature fails to provide a scale which can address the way sub-national organisations within Nepal's energy systems may respond to specific events.

2.1.2 Resilience Theory

The inadequacies of energy security literature to allow an assessment of energy system responses to events on smaller scales requires that a different concept be drawn upon, namely one which allows the investigation of the way sub-national systems respond to specific shocks, and particularly disaster shocks. The concept of resilience enables this scale to be engaged alongside energy security literature because resilience literature has become the de facto framework for studies aiming to enhance community level disaster response and recovery capacity (Khazai et al., 2018, Cutter et al., 2014). Originally a concept used in ecology for understanding shifts in systems, the term resilience has found widespread use in the plans and policy of governments, NGOs and international organisations (Holling, 1973, Cretney, 2014). As a result, the concept of resilience is highly contested in the literature and presented in many branches; including ecological resilience, engineering resilience, social resilience, socio-ecological resilience, community resilience, urban resilience and disaster resilience (Cretney, 2014, Paton and Johnston, 2006). The wider field of resilience literature is too broad to include in this review, so the three conceptualisations most relevant to this study; community resilience, urban resilience and disaster resilience, have their definitions and core theory briefly reviewed here in.

Disaster resilience is the immediately obvious branch of resilience to draw from in this study, given that the earthquake and the blockade form the basis of the research objectives. Paton and Johnston (2006) provide four components which define resilience from a disaster perspective. The first component relates specifically to the resources which are held by people within communities, businesses and societal institutions, which allows those people to ensure their safety and continue their organisation's core functions during a disaster or its aftermath. The people within communities, businesses and societal organisations can all be considered as agencies when considering disaster resilience, as they all have an ability to influence how a disaster is responded to. The last three components extend beyond resources to encompass the competencies, mechanisms, and strategies used by those agencies in the event of a disaster. These competencies allow those agencies to respond in a manner which confronts and adapts to problems caused by the disaster, while those mechanisms allow for the integration and organisation of resources across agencies and levels in order to ensure coherent societal capacity and the opportunity for change and growth. Lastly, the strategies employed by agencies ensure that the resources necessary for the first component have a sustained availability during periods of hazard quiescence and changing community needs. This perspective of resilience demonstrates the necessity for a physical or financial element, here being the resources necessary to respond to the disaster, and a process and knowledge element, held in the people who form the agencies affected by the disaster. Implicit within Paton and Johnston's (2006) components is the notion of adaptive capacity, which ensures that their perception of resilience is one in which a disaster can be the catalyst for adaptation and development.

Norris et al. (2008) approach the concept from a community perspective, defining resilience as *"A process linking a set of adaptive capacities to a positive trajectory of functioning and adaptation after a disturbance"* (pg.30). The focus in this definition is carefully placed on the process which links resources, as opposed to an outcome (Norris et al., 2008). Norris et al. (2008) develop a model to explain resilience, which has been included here as **Figure 2.1.2.** In this model are stressors, which are the *"aversive circumstances that threaten the well-being or functioning of the individual, organization,* *neighborhood, community, or society"* (pg.131) and stress resistance, which are the resources that would effectively block that stressor. An example of the two concepts would be an earthquake (the stressor), and redundant electricity generation sources able to match generation sources damaged in that earthquake (Norris et al., 2008). This model makes a useful contribution to this study's understanding of resilience as it demonstrates that a period of transient dysfunction and adaptation may occur following a stressor event if stress resistance is not adequate.

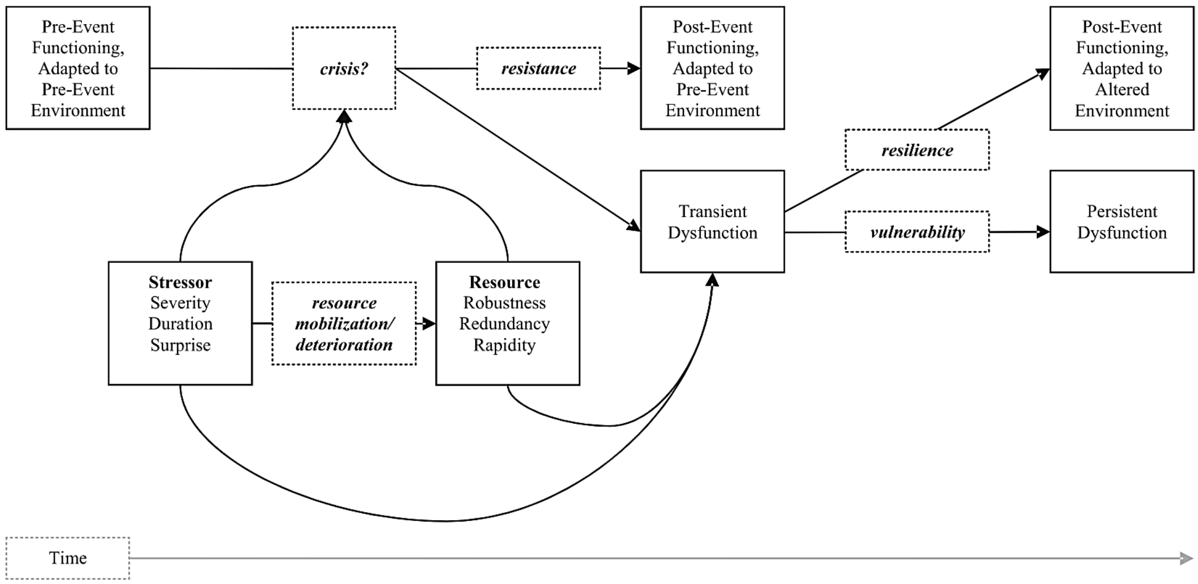

Figure 2.1.2: *A model of resilience and stress resistance over time. From Norris et al. (2008), page 130.*

Urban resilience is another branch of resilience discourse which has emerged to reflect the tensions and processes inherent in cities which faced disturbance. Meerow et al. (2016) have performed an extensive review of urban resilience literature to propose the following definition:

> *"Urban resilience refers to the ability of an urban system-and all its constituent socio-ecological and socio-technical networks across temporal and spatial scales-to maintain or rapidly return to desired functions in the face of a disturbance, to adapt to change, and to quickly transform systems that limit current or future adaptive capacity."* *(pg. 39).*

This definition allows for five conceptual tensions which Meerow et al. (2016) believe are unresolved in the broader resilience literature. The benefit of using the understanding of resilience given by Meerow et al. (2016) does not strictly come from the urban perspective of resilience, but from the way Meerow et al. (2016) explain these five tensions. The first has already been touched on and is an argument about whether systems revert back to a stable state, or whether systems are always in a state of change. The second is a tension around whether resilience is necessarily a positive concept, as the original state may be resilient but also undesirable. An obvious example where this might be the case in energy systems is where the original state is a strongly fossil fuel dependent system causing environmental harm. A further tension surrounds the different pathways to achieving a resilient state, as Meerow et al. (2016) note that some studies use resilience as an ability to resist disturbance, while others use resilience as an ability to transition or transform. The arguments over whether general resilience, or resilience specific to certain adaptation, should be encouraged is also a tension within resilience discourse. Finally, the timescale of response action is a tension within resilience discourse, which particularly questions what the speed of 'rapid' is. The tensions presented by Meerow et al. (2016) demonstrate multiple ways of considering resilience, which this framework must navigate.

The conceptions of resilience given above provide valuable insight into the way resilience can be understood. However, they fail to provide a clear framework which can be used in later discussion to analyse the way Nepal's energy systems responded to the earthquake and blockade. Fortunately, the concept of adaptive capacity has been used in all three branches of resilience discourse given above, thus linking the community, disaster and urban conceptions of resilience. Adaptive capacity in its simplest form is the ability to adapt, and is a term which has longstanding use in scholarly literature (Engle, 2011). It has been used in biology to describe an organism's response to its environment and is used in anthropology when showing that humans, when faced with adversity, will adapt to survive (Engle, 2011). This term has also been used with climate change discourse after adaptive capacity was used in the third assessment report of the IPCC to describe *the "potential or ability of a system, region, or community to adapt to the effects or impacts of climate change."* (Smit et al., 2001: pg.881, Smit and Wandel, 2006).

This idea of adaptive capacity gives way to its own conceptualisation of resilience as *adaptive resilience*. Adaptive resilience has been used by Sharifi and Yamagata (2016), who describe it in the following manner:

> *"Adaptive resilience seeks to embed the following characteristics in a socio-ecological system: (1) system integrity that enables the system to undergo shock, withstand and absorb it, and maintain the same character, function, and architecture; (2) capability of "self-(re)organization to accommodate external changes"; and (3) ability to learn from the disaster and seize it as an opportunity for self-improvement and enhancement of the coping capacity"*
>
> *(pg. 1660).*

Although Sharifi and Yamagata (2016) use adaptive resilience in a context focused on urban environments, their conceptualisation recognises the complexity and dynamicity of socio-ecological systems. Importantly, the concept allows for an idea of resilience which identifies the need to return the functions of a system after a disaster in the short-term and allows the system to learn from the disaster in a way which results in an improved system in the longer-term.

Adaptive resilience reflects Paton and Johnston's (2006) view of resilience as the importance of physical resources is acknowledged as an element critical for allowing a system to "*undergo shock, withstand and absorb it"*, while the importance of process and knowledge resources which enable a system to adapt and improve following a disaster is acknowledged through the second and third components (Sharifi and Yamagata, 2016). Adaptive resilience also supports the idea from Norris et al. (2008) who recognise that systems may have a period of transient dysfunction and adaptation after a shock. Considering the tensions brought forward by Meerow et al. (2016), adaptive resilience provides a view of resilience which suggests that resilience is neither a good thing or a bad thing, but an ability to revert back to a state where the core functions of a system remain, while also adapting and changing to increase coping capacity against future shocks.

The use of the adaptive resilience alongside energy security in this conceptual framework suggests that the concept of energy resilience is an idea which represents the ability of energy systems to withstand a shock; to adapt to that shock in order to provide an available, accessible, affordable, and acceptable energy supply; and to learn from that shock to increase coping capacity. This idea guides how this thesis can investigate the response of Nepal's energy systems to the earthquake and the blockade.

Just as energy security literature could not provide for the smaller scale analysis necessary to make this investigation however, the concept of resilience has been critiqued for failing to account for the range of social actors involved in social-ecological systems (Meerow and Newell, 2016). Inequalities, power and social justice issues within those systems can also be obscured as a result of heavily focusing on system responses through the concept of resilience (Cretney, 2014, Cretney and Bond, 2014). The nature of energy systems often requires that a range of social actors are involved producing and delivering energy systems and the next chapter will confirm that this is especially true for the electricity sector in Nepal. The earlier **Section 1.2** also recognised that issues of inequality persist in Nepal (ADB, 2018), so these concerns about the concept of resilience must be addressed through this conceptual framework to provide meaningful and contextually sensitive results.

Box 2.1.2: Resilience Studies in Nepal

There are ample studies of resilience in Nepal which discuss a broad range of topics, with research including adaptation to climate change (Khadka et al., 2018), infrastructure resilience (Didier et al., 2018, Aydin et al., 2018), and health related resilience (Ali-Abadi et al., 2018). Amongst these are several studies which are more closely related the aims of this research, which are worth exploring here.

Khazai et al. (2018) investigated urban resilience in Lalitpur, a city in the Kathmandu Valley, using a resilience performance scorecard. This scorecard had been designed for the Lalitpur stakeholders through a series of interviews, which allowed the scorecard to evaluate urban resilience in a manner fitting to the context of the city (Khazai et al., 2018). The scorecard was then used by having stakeholders vote for the level of attainment they believed had been attained for six key themes which represented urban resilience (Khazai et al., 2018). These themes were; advocacy and awareness, social capacity, legal and institutional arrangements, planning regulation, critical services, and emergency response (Khazai et al., 2018). The scorecard was used with Lalitpur stakeholders one year before and one month after the 2015 earthquakes, and in doing so was able to identify the status, gaps and achievements in urban resilience activities (Khazai et al., 2018).

Baharmand et al. (2016) investigated community disaster resilience in Nepal following the 2015 earthquakes. Using open and semi-structured interviews with key informants from NGOs, government, and international organisations, Baharmand et al. (2016) were able to identify key issues and ideas on community resilience from the stakeholders. This allowed the authors to analyse persistence, adaptability and transformability as aspects of community resilience (Baharmand et al., 2016). Baharmand et al. (2016) found that efforts made to strengthen resilience in communities was mainly top-down and one directional, with little work being done to enable communities to build resilience themselves.

Jones et al. (2013), working before the 2015 earthquakes, engaged in 'action research', where they developed a trial program to improved resilience and risk reduction in community level governance. Their study did not look at a particular shock event, but instead evaluated whether there was interest in the trial programme and how effective the programme was (Jones et al., 2013). The methods Jones et al. (2013) used for their evaluation of the programme were structured interviews with community members and semi-structured interviews with stakeholders in the program. The study concluded that there was potential for the program, and identified that institutional embedding of the programme in local government increased one branch of the programme's effectiveness (Jones et al., 2013).

Although the research objectives of the studies from Khazai et al. (2018), Baharmand et al. (2016) and Jones et al. (2013) were significantly different, they all employed qualitative stakeholder research methods to evaluate multiple aspects in their relevant field of resilience. This allowed the studies to provide information at a scale which allows for evaluation of organisational and community level responses to a select range of issues relevant to the topic of study. Energy security studies in Nepal were unable to do this and for this reason the use of resilience literature concepts alongside energy security concepts enables this study to address resilience in sub-national energy systems.

2.1.3 Cultural Theory

The framework thus far has drawn on energy security and resilience thinking to provide a conceptual way of understanding the response of Nepal's energy systems to the earthquake and the blockade. This framework however, does not allow for an understanding of the role which the actors within Nepal's energy systems, be they government, private, community or NGO organisations, had in the response, nor does it allow for an understanding of inequalities, social justice and power issues which may have been present in the response. The concept of cultural theory (also known as plural rationality theory) is used to gain this understanding, which is theory that has previously been used, respectively, by Gyawali et al. (2018) to investigate aid, technology and development in Nepal, and by Islar et al. (2017) to evaluate national and local energy development in Nepal. Verweij (2018), who uses the theory to apply to actors in political and economic development in Nepal, provides a clear explanation of cultural theory and its classification of the four ways in which social relations can be organised, perceived and justified. These classifications are as follows.

The first classification, *egalitarianism*, refers to a classification in which individuals are essentially caring until corrupted by markets or bureaucracies. In this classification individuals must respect the environment as nature is fragile and not only begin life as equals but end up as equals in a just society. International bureaucracies should be dismantled, and economic localisation and grass-roots democracy should be encouraged. While global solidarity is encouraged, official development aid and the charity of the rich should be treated with suspicion in this classification (Verweij, 2018).

In the *hierarchical* classification, actors perceive the world as controllable as individuals are flawed unless redeemed by firm institutions. The environment has limits which can be determined by experts, and exploitation of the environment should be restrained to these limits by statutory regulation. The economy in this classification should be planned by technocratic elites, who plan for the interests of all social-strata as well as the principles of sustainability. Verweij (2018) notes that this classification is tied to a perception that poor countries often lack the expertise and finance to kick-start development, and therefore require advanced nations to provide this for them. Verweij (2018) also notes that this perspective has often prevailed amongst aid agencies and can be seen within the Millennium and Sustainable Development Goals.

In the *individualistic* classification, actors perceive individuals as self-interested and the environment as resilient and able to recover from exploitation. The economy should be left to self-organise into unfettered markets, and risks and opportunities should be seized by individuals. International bureaucracy should be restricted while pluralist democracy and global markets should be encouraged, and development should be enabled not by aid but by the opening of domestic markets to foreign finance and labour (Verweij, 2018).

Lastly, the *fatalistic* classification refers to a perception in which man is untrustworthy, life is unfair and there is no possibility of ever improving society. Environmental management is not possible because the state of nature is unknowable, while economic gain in this view can only be done at the expense of others. Official development efforts are done only to increase the wealth and power of the powerful and wealthy, while justice demands only that one must do what is necessary for survival (Verweij, 2018).

Considering the different actors within Nepal's energy systems through the four classifications of cultural theory allows for a more detailed examination of the roles and results of these actors during and after the earthquake and blockade. Energy resilience can now be considered as an idea which recognises the ability of hierarchal, egalitarian, individualistic and fatalistic actors which play a role in energy systems to withstand a shock; to adapt to that shock in order to provide an available, accessible, affordable, and acceptable energy supply; and to learn from that shock to increase coping capacity. Examples of how cultural theory can be used to examine development issues is demonstrated through examples from Nepal in **Box 2.1.3**.

Box 2.1.3: Cultural Theory in Nepal

Gyawali and Dixit (2010) use a case study of drinking water in Kathmandu which can demonstrate how these classifications may apply in practice. Kathmandu has a shortage of water, and different solutions are offered by the actors in each classification. For hierarchical actors, which are the government and government-led organisations, the solution to the water shortage is an expensive infrastructure project which would provide Kathmandu water through a 26.5km tunnel (Gyawali and Dixit, 2010). This option would enhance the governments sense of control because the leadership and development of the project is limited to an expert-based bureaucracy (Gyawali and Dixit, 2010). The individualistic solution is provided by the vendors who have developed businesses in the interim while the tunnel project is being developed, which sell bottled water and water trucked from nearby springs to the Kathmandu market (Gyawali and Dixit, 2010). These actors demonstrate a belief that the environment is abundant and market economics free of intervention allow for a good to be supplied if the price is paid (Gyawali and Dixit, 2010). The egalitarian solution, advocated for by activist NGOs and consumer forums, would be alternative means of supply like traditional ponds and rainwater harvesting (Gyawali and Dixit, 2010). The egalitarians see that the hierarchical solution is expensive and slow, while the individualistic solution creates pollution and groundwater mismanagement (Gyawali and Dixit, 2010). The fatalistic actors, while not mentioned by Gyawali and Dixit (2010) in their case study, would likely accept whichever option is available without concern as to where or how it is supplied.

In another example, both Gyawali and Dixit (2010) and Upadhya (2018) provide a critique of the politics of development by drawing on the case study of the Bhattendanda Milkway. This Milkway is a cable car system which transports fresh milk from an area outside Kathmandu across a deep ravine, transforming a five-hour journey by foot to a 20 minute journey (Upadhya, 2018). This allows the milk to be sold as fresh produce to the market in Kathmandu, where it would otherwise be sold for less as a dehydrated milk paste, requiring extensive labour and firewood (Gyawali and Dixit, 2010). Gyawali and Dixit (2010) and Upadhya (2018) use the case of the Milkway as an example of an effective means of transport across Nepal's rugged and mountainous terrain. Indeed, when considering energy the Milkway system has the benefit of being able to run on hydropower generated electricity instead of the petroleum fuels which road vehicles consume (Gyawali and Dixit, 2010). Yet, Gyawali and Dixit (2010) argue that international donor agencies and the government of Nepal have encouraged roads as a mechanism of development, over the cheaper and more suited technology of cable car systems. The reason for this Gyawali and Dixit (2010) argue, is that roading allows the development of infrastructure to be restricted to the expert-based bureaucracy, in place of the cable car system option. Promoting the cable car system in place of roading as a mechanism of development, Gyawali and Dixit (2010) argue, would therefore allow communities to address the issue of transportation themselves. While this study will not look at transport, this case study demonstrates how cultural theory shows that hierarchal solutions may have more egalitarian alternatives when considering infrastructure development. This suggests that a cultural theory critique of energy system response and energy policy may therefore be useful for this study.

2.1.4 Synthesising the Framework

The concepts of energy security, resilience theory and cultural theory have been synthesised in this conceptual framework to provide a way of thinking about energy resilience. Energy security suggests that risks to, and vulnerabilities within, energy systems can threaten the availability, affordability, accessibility and acceptability of energy supplies (Sovacool and Mukherjee, 2011, Winzer, 2012, Cherp and Jewell, 2011). Resilience theory provides the concept of adaptive resilience, which guides this research to investigate the way systems withstand a shock, the way they adapt to that shock, and the way they change to increase their capacity to cope with future shocks (Sharifi and Yamagata, 2016). Finally, cultural theory recognises that different actors which can broadly be classified as hierarchical, egalitarian, individualistic and fatalistic have a role to play within energy systems (Verweij, 2018). To investigate energy resilience, this thesis will take an approach which looks specifically at how different actors withstood, adapted and changed energy systems and the energy services they supply while experiencing realised risks to their system vulnerabilities.

2.2 Analytical Tools

The concept of energy resilience has developed in the above framework to provide a way of investigating the response of Nepal's energy systems to the earthquake and the blockade. To provide a useful contribution to wider energy studies literature, this thesis demonstrates that using the concept of energy resilience has useful outcomes. This must be done by demonstrating how the ability of systems to exhibit energy resilience results in meaningful energy supply outcomes. To do this, the chapter employs thinking from energy security, energy poverty and energy justice literature as analytical tools. These bodies of literature allow this thesis to recognise that the services which modern energy systems provide are important to larger scale economies and smaller scale human development, while simultaneously recognising that energy systems may perpetuate issues of inequality and unfairness. Given that issues of underdevelopment, poverty and inequality persist in Nepal, the use of energy security, energy poverty and energy justice literature as analytical tools provide a suitable way of demonstrating the importance of energy resilience to these issues. The literature from which these analytical tools are derived from is given in the second part to this chapter.

2.2.1 Energy Security

The first analytical tool is taken from energy security literature. Referring back to **Section 2.1.1**, the dimensions approach by Sovacool and Mukherjee (2011), Kruyt et al. (2009), and APERC (2007) provides a way of thinking about energy security through different dimensions. This has provided a platform to understand energy resilience from, but these dimensions also provide an analytical tool if they are approached by asking whether those dimensions of energy security were affected by the earthquake and the blockade. Given that secure supplies of energy are paramount to human security and the operation of economies, any impact of the earthquake and blockade on Nepal's energy security will have meaningful impacts on the country (Sovacool and Mukherjee, 2011). For further information on energy security, see **Section 2.1.1.**

2.2.2 Energy Poverty

The second analytical tool uses the literature of energy poverty to ask whether the response of Nepal's energy systems to the earthquake and the blockade had impacts upon human development in Nepal. This is a particularly useful complement to the energy security literature as it allows an understanding of human and economic development issues on a smaller scale which energy security literature cannot address. Energy poverty is relatively recent term used in wider development discourse to acknowledge the importance of energy access when considering poverty (Sovacool, 2014a). This stems from the issues associated with a quarter of the world's population not having access to electricity or modern forms of energy, while a third of the world's population remains reliant in part on solid fuel like firewood and cow dung (Sovacool, 2014a). Despite its recent recognition, a global understanding of the issue is now established with the term being used by the UNDP, ADB and other international organisations (Sovacool, 2014a, Bouzarovski et al., 2017).

There are many reasons why access to energy is important when considering poverty, human development and economic development. There is evidence that access to electricity increases income and economic development under the right conditions, and access to electricity for farming households allows for productivity increases as irrigation, tools and processing appliances can be used (Barnes et al., 2014, Dinkelman, 2011, Khandker et al., 2014). Access to electricity also provides social benefits, with lighting providing more time to study, socialise and operate businesses, while appliance use can provide entertainment and services (World Bank, 2008b, Barnes et al., 2014).

Meanwhile, relying on traditional solid biomass (including firewood, plant residues and animal dung) as fuel to burn for cooking results in smoke being emitted within homes (Barnes et al., 2014). This smoke causes household air pollution which was associated with 3-4 million deaths annually in 2010, making indoor air pollution one of the worst risk factors to health worldwide (Smith et al., 2014). Beyond health benefits, relying on solid biomass as a fuel source requires that consumers spend long periods of time collecting fuel, which is a task that often falls upon women to do (Barnes and Sen, 2004). Access to modern energy services from improved cooking stoves or liquid fuels like biogas and LPG can reduce these negative implications of traditional solid fuel use (Sovacool, 2014a, Sovacool, 2012). Considering issues of energy poverty across multiple scales will prove that the concept of energy resilience is important as the ability of energy systems to provide access to modern forms of energy will have impacts for human, economic and social development.

There are different ways to consider energy poverty and how it can be addressed. One approach is through the energy ladder concept, shown in **Figure 2.2.2**, which assumes that households will move their energy use habits uniformly towards more advanced energy sources as their income increases (van der Kroon et al., 2013). The energy ladder model has been criticised as evidence has shown that households do not always move uniformly towards more advanced fuels with increasing incomes, with cases observed where traditional biomass is chosen by households across a wide spectrum of consumers because of its low cost and availability (Sovacool, 2012, Hiemstra-van der Horst and Hovorka, 2008). The energy stack model is perhaps a better conception, as it indicates that as household income increases, more energy services become available and multiple energy services may be used (van der Kroon et al., 2013). The energy stack model, also shown in **Figure 2.2.2** is useful to this study as it demonstrates that multiple energy services may be available to a household and if one or more of those services are affected, other energy sources may be drawn upon.

Beyond the conceptual level of energy poverty, Pachauri and Spreng (2011) demonstrate that influences of energy poverty exist on multiple scales and therefore the measurement and monitoring of energy poverty must be done across appropriate scales also. Factors such as distance to markets, energy subsidies and energy imports, for example, operate on larger scales to that of which the factors of income, family size and type of stove which a single household has operate; yet these factors all influence energy poverty (Pachauri and Spreng, 2011). Given that the need to consider multiple scales when considering energy systems has previously been expressed as a critical flaw of energy security literature, it is unsurprising that this argument will follow for energy poverty.

Energy poverty can clearly be used as an analytical tool to demonstrate the importance of energy resilience in this thesis. To do this, the thesis must analyse how the ability of Nepal's energy systems to respond to the earthquake and the blockade affected users' access to modern energy resources from consumers. If the disasters did cause access to an energy resource to be lost, then energy poverty literature suggests that loss of access would mean a loss of all the human and economic development benefits which that energy resource provides (Barnes et al., 2014). The use of energy poverty literature is suitable for this study as it is sensitive to the least developed country context of Nepal and it can address impacts on multiple scales, unlike energy security (Pachauri and Spreng, 2011). **Box 2.2.2** demonstrates the development benefits of energy access in Nepal and shows how energy poverty can be considered across those different scales.

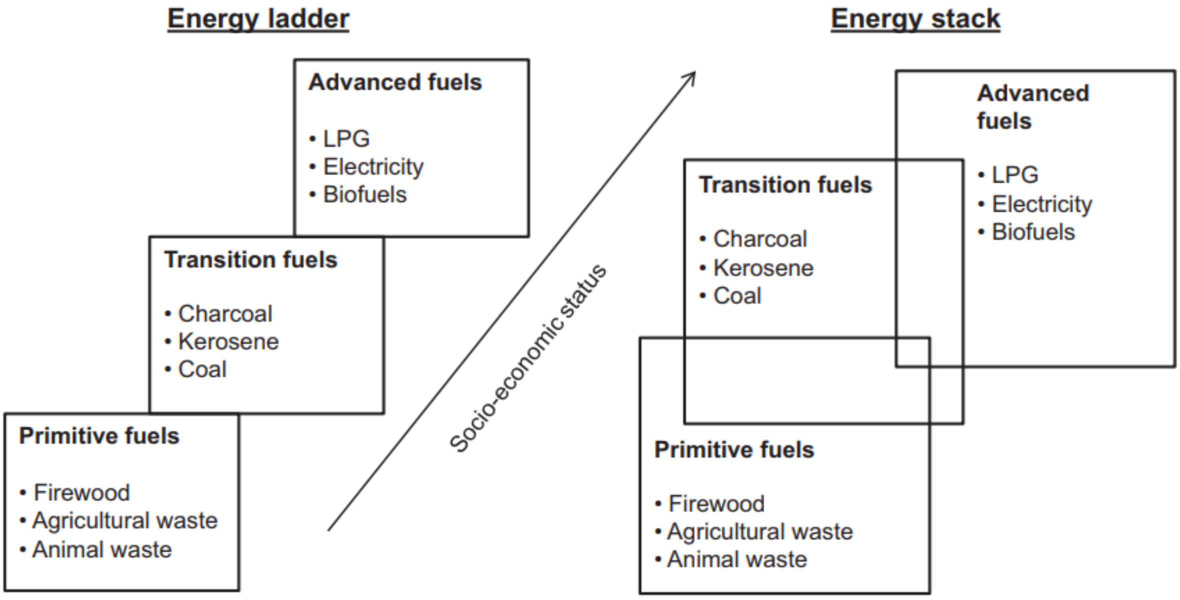

Figure 2.2.2: *The Energy Ladder and Energy Stack models. From van der Kroon et al. (2013: pg.505).*

Box 2.2.2: Energy and Development in Nepal

There is an established body of literature broadly related to the relationship between energy and development in Nepal, which is presented here as the benefits of energy access will be dependent on the ability of an energy system to provide that energy access through shock events. The relationship between energy and development is often focused on rural energy access, and both Gurung et al. (2012) and Sapkota et al. (2014) have produced reviews of the benefits which renewable energy technologies can have for rural areas in Nepal. In these reviews, Gurung et al. (2012) and Sapkota et al. (2014) acknowledge that health, social, economic, education and agricultural benefits can come from improved access to energy, particularly from the renewable energy technologies of micro hydro, solar and biogas systems. Indeed, evidence from studies in Nepal confirm the negative health consequences from the burning of traditional fuels indoors (Shrestha and Shrestha, 2005). The demand for firewood to provide a source of energy has also been part of the cause of pressure on Nepal's forestry resources (Nepal et al., 2011).

These benefits have been discussed in further detail by other authors. Often for women, access to energy can reduce the time spent on tasks such as collecting firewood and water, or manual agricultural processing (Gyawali, 2014, Sapkota et al., 2014). With basic solar PV systems which provide lighting, evidence from Zahnd and Kimber (2009) shows that health conditions are improved because biomass no longer needs to be burnt indoors to provide lighting. Children's education and community social gatherings are also improved from lighting as it allows children to study at home during night time and allows people to socialise later in the evening (Zahnd and Kimber, 2009). Micro hydro systems in rural areas have been shown to create employment opportunities and income generation, by directly employing people to develop, operate and maintain systems, and to manage system finances (Gippner et al., 2013). Indirectly, micro hydro systems can power agricultural processing systems while businesses can use power for applications such as light manufacturing or food related services, creating additional income (Gippner et al., 2013).

Bridge et al. (2016a, 2016b) identified a very large and significant relationship between household income and electricity access which runs both ways, meaning that electricity access has the effect of increasing household income, while higher household incomes also have the effect of increasing electricity access likelihood. Access to electricity also has a strong relationship with schooling in a family, and on average members of a household with access to electricity will have a 56% increase, or 3.3 more years, of education compared to members of a household without electricity (Bridge et al., 2016a). Factors linked to a reduced level of electricity consumption per capita in Nepal include longer distances to paved roads or market centres, households being of a lower caste, and lower education attainment of the household head (Bridge et al., 2016b).

2.2.3 Energy Justice

The last analytical tool used to demonstrate the importance of considering energy resilience uses the literature of energy justice to explore fairness in the response of Nepal’s energy systems to the earthquake and the blockade. Energy justice is used because a criticism of the resilience concept used earlier in this framework was a failure for social justice and inequality issues to be incorporated into resilience discourse (Cretney, 2014, Cretney and Bond, 2014). A failure to address inequality issues associated with energy system responses to the two disasters would be a serious concern for this thesis, as major inequality issues persist in Nepal (ADB, 2018). While cultural theory is helpful for understanding the different actors in Nepal’s energy systems and energy poverty is helpful for understanding poverty and development issues, social justice, power and inequality issues have not been addressed through this review thus far. This is an issue which has been recognised for energy studies in general, with Sovacool (2014b, 2014c) arguing that energy studies must become more socially orientated.

Energy justice can be summarised briefly through two perspectives. Sovacool and Dworkin (2015) developed principles of energy justice to assess availability, affordability, due process, good governance, sustainability, intragenerational equity, intergenerational equity, and responsibility. In assessing these principles, questions about the distribution of energy systems across society, the transparency of governance processes and the long term sustainability of energy systems can be asked (Sovacool and Dworkin, 2015). To develop these principles, Sovacool and Dworkin (2015) draw on philosophical concepts of virtue, utility, human rights, procedural justice, welfare and happiness, freedom, posterity, and fairness, responsibility and capacity. By drawing on these concepts the issues relevant to energy systems, including energy poverty amongst a number of others, are addressed through the principles (Sovacool and Dworkin, 2015).

McCauley (2017), recognising that "*fairness must be at the heart of our response to growing energy*" (pg. 5) provides an alternative way to approach energy justice. In this approach, the core need to address fairness in energy studies means that energy justice must be a key element within the global energy trilemma discussed earlier (see **Section 2.1.1**). The reason why energy justice must take this position, McCauley (2017) argues, is the inherent inequality in the distribution of energy system technologies and outputs, a need to recognise where these inequalities emerge, and a need to ensure decision making procedures are operated in a way which achieves the recognition of energy service distribution inequalities. This approach to energy justice has also been supported by Jenkins et al. (2016), who consolidate existing work on energy justice through a conceptual review to identify the three dimensions of distribution, recognition and procedure. In this approach, energy justice can be considered as an analytical tool which delves into the questions given in **Figure 2.2.3**.

Energy justice can be employed by analysing whether energy system responses to the earthquake and blockade had implications for Sovacool and Dworkin's (2015) principles or whether they had implications against the framework by McCauley (2017) in **Figure 2.2.3**. In doing so, the importance of resilience in Nepal's energy systems will be demonstrated if energy justice issues arose because of different energy system responses to the earthquake and blockade. This may occur for example, if certain parts of Nepal's society received different energy services in wake of the earthquake or blockade. Using the concept of energy justice in this way also improves the contextual sensitivity of this thesis. **Box 2.2.3.** provides an example as to how energy justice thinking has been applied to previous energy research in Nepal.

Figure 2.2.3: *Analytical Energy Justice Framework. Taken from McCauley (2017*: *pg.17).*

	Availability	*Accessibility*	*Sustainability*
Distribution	Where are the resources located?	Where does consumption take place?	Where emits carbon dioxide emissions?
Recognition	Who does not benefit from the resources?	Who cannot access?	Who does not emit?
Procedures	How are production decisions made?	How are consumption decisions made?	How long term are the policy structures?

Box 2.2.3: Energy Justice in Nepal

Islar et al. (2017) adopt the principles by Sovacool and Dworkin (2015) to recognise that energy in Nepal must be understood as part of social systems. To do so, they use an energy-justice framework which tests the following principles; (1) the availability of energy in a landlocked country, (2) the affordability of energy through organised collective action, (3) the good governance of energy policy for intra-generational equity, and (4) the sustainability and intergenerational equity of energy systems (Islar et al., 2017). Using this framework, Islar et al. (2017) are able to discuss issues of how Nepalese policy-makers may decide to strengthen local technological capacity through grid-extension actions with community cooperative systems, or how these policy makers may decide to build geopolitical relationships with China and India by engaging technological transfers through aid or trade. The energy justice framework which they use drives them to ask questions about who has the agency to develop and put into action energy policy, and how might certain ambitions be attained in place of others (Islar et al., 2017). Given that this study will investigate energy futures, the use of the energy justice framework (originally developed by Sovacool and Dworkin (2015)) will have value for this study if the results yield questions that have implications for the principles employed by Islar et al. (2017).

2.3 Conclusion

This chapter has provided a conceptual approach for considering energy resilience across multiple scales and has given analytical tools which will demonstrate the importance of doing so to wider energy studies literature. The conceptual approach, which was developed through a framework using energy security, resilience and cultural theory, requires that this thesis investigate how different actors withstood, adapted and changed energy systems and the energy services they supply while experiencing realised risks to their system vulnerabilities. **Chapter Five** and **Chapter Six** will use this approach to address the primary research objectives of this thesis by analysing how Nepal's electricity sector responded to the earthquake and how Nepal's petroleum sector responded to the blockade. **Chapter Seven** will then follow by using the results of **Chapter Five** and **Chapter Six** to build upon the energy sector overview given in the next chapter (**Chapter Three**). This allows **Chapter Seven** to address the secondary objective of this study by investigating resilience in Nepal's energy futures. Throughout all three of the results chapters, the analytical tools brought forward from energy security, energy poverty and energy justice literature in this literature review will be used to demonstrate how the resilience of Nepal's energy systems has meaningful impacts on national scale energy security and smaller scale development and inequality issues. In doing this, the importance of the resilience concept will be shown.

3 Energy Sector Overview

This chapter provides context to the research through an overview of the energy sector of Nepal. Using existing literature and data, this chapter provides a base to build an understanding of Nepal's energy futures from.

Establishing an energy sector overview is a commonly used approach in broad scale energy research. In studies on Nepal's energy sector by Ebinger (2011a) and ADB (2017a) for example, a sector overview was given to present the status and potential for different energy resources. This breaks down the energy sector into different components, allowing a wider energy sector to be considered through its constituent parts. The understanding of the status and potential of components with an energy sector overview therefore builds a platform from which the possible futures an energy sector may considered from. For this reason, this energy sector overview is critical to building the later energy futures analysis in **Chapter Seven**. Additionally, an energy sector overview provides context of the relative importance of systems in Nepal's electricity and petroleum sectors, which are investigated in **Chapter Five** and **Chapter Six**.

This chapter builds an energy sector overview of Nepal by first explaining the energy systems of Nepal. The relative share of production and consumption these energy systems have within Nepal's energy sector is then given, which is followed by a review of literature that has projected how these shares may change in the future. These forecasts demonstrate that both Nepal's domestic electricity and petroleum demand will grow in the future. To conclude the energy sector overview, the status of four key energy resources in Nepal are explained. Traditional biomass or non-commercial fuels have not been included in this energy overview because these fuels are often directly sourced by households and thus don't require a larger energy system to supply that fuel. This places traditional biomass fuels outside the scope of this thesis, which specifically aims to investigate energy system responses to the earthquake and blockade. Biogas, which is gas made from latrine waste and manure, is also outside the scope of this thesis as the inputs, processing, output and by-products can all be provided, operated and consumed by a typical agricultural household without the need for a wider energy system (Rai, 2018, K.C et al., 2011)

3.1 Energy Systems of Nepal

The energy systems of Nepal are central to this research, but the roles which different actors play within these systems are not straightforward. **Figure 3.1** shows the energy systems of the petroleum and electricity sectors in Nepal. As shown in this diagram, there are three methods by which a consumer may access electricity services. The grid system delivers electricity either generated by the Nepal Electricity Authority (NEA), generated by Independent Power Producers (IPPs), or imported from the Indian grid (NEA, 2018). This electricity must travel through the NEA operated national transmission system, before being distributed either through the NEA operated distribution system, or a Community Rural Electrification Entity (CREE) grid extension distribution system (NEA, 2018). Electricity from the grid may also be exported to the Indian grid (NEA, 2018). The remote nature of many communities in Nepal means that off-grid systems are common and include both generation and distribution systems. These systems are supported by the government's Alternative Energy Promotion Centre (AEPC) (AEPC, 2013). The petroleum sector is dominated by the Nepal Oil Corporation (NOC), who manage the import, storage and distribution of petroleum fuels (NOC, 2018a). There are no significant reserves of fossil fuels in Nepal, so the NOC purchases fuel supplies on the global market and relies on the Indian Oil Corporation (IOC) to supply that fuel to depots close to the India-Nepal border (Ebinger, 2011a, Malla, 2013). There is an exception for LPG however, which the NOC sources from independent suppliers within India (NOC, 2018a). The NOC then coordinates the import of all petroleum fuels from India and distributes that fuel to retailers within Nepal (NOC, 2018a). For aviation fuel consumers, the fuel is directly distributed and sold by the NOC (NOC, 2018b).

3.2 Sector Share

Sector share analysis is a key element of an energy sector overview as it provides a baseline to understand energy demand projections from and puts energy resources in context of the national energy system. The majority of this data presented here comes from two recent reports, being the Nepal Electricity Authority's (NEA) 2017/2018 annual report (2018), and the Government of Nepal's Water and Energy Commission Secretariat's (WECS) Electricity Demand Forecast Report 2015-2040 (2017). The statistics indicating the sector shares for gross energy, electricity and fuels are given in **Table 3.2**.

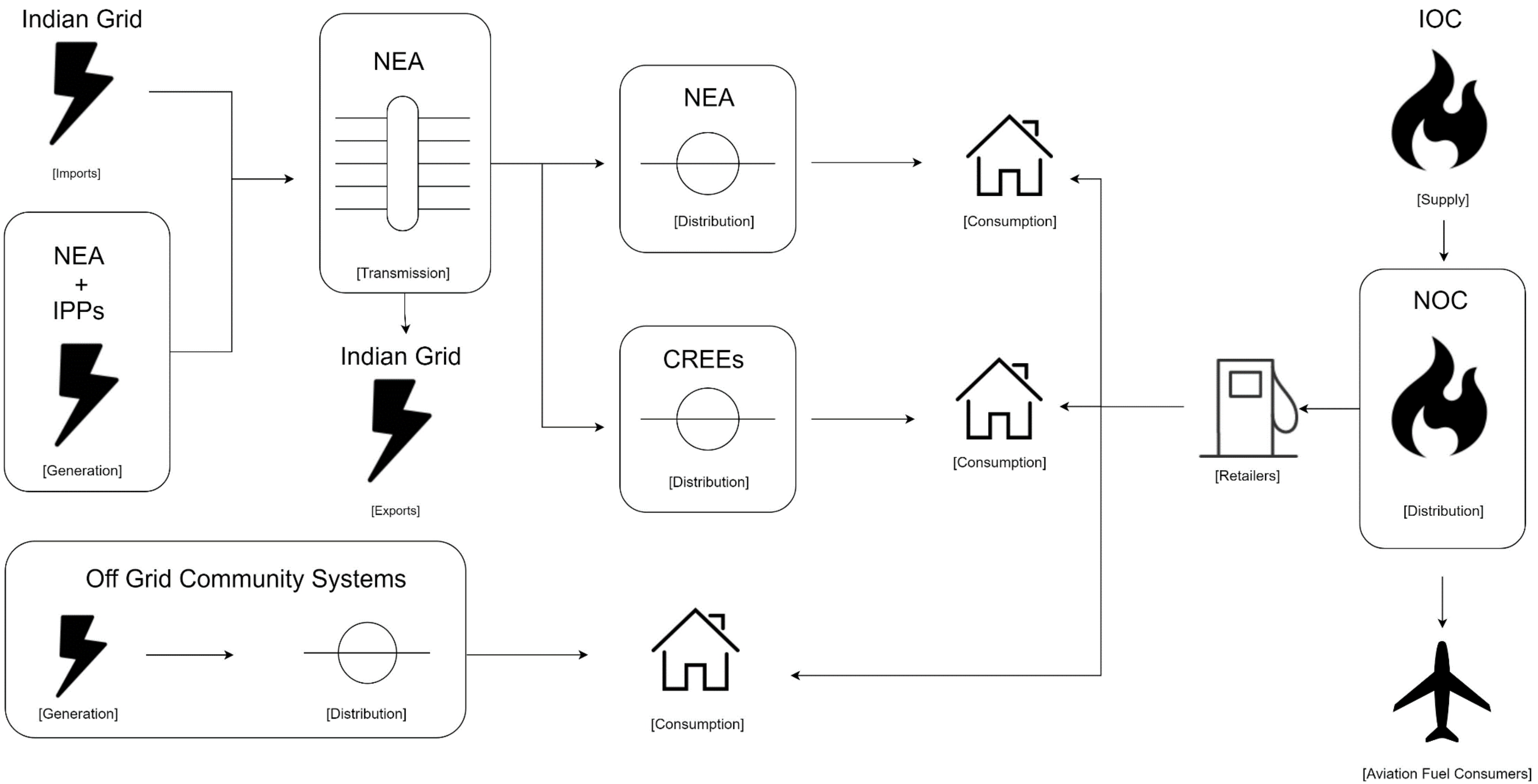

Figure 3.1: *Energy systems within Nepal's electricity sector (left) and petroleum sector (right) of Nepal.*

NEA: Nepal Electricity Authority
CREE: Community Rural Electricity Entity
NOC: Nepal Oil Corporation
IOC: Indian Oil Corporation
IPP: Independent Power Producer

*Consumption indicates household, manufacturing, primary, industry, service and transport consumption.

**Outlines indicate systems investigated in this thesis.

Table 3.2: Energy Sector Share Statistics

Table 3.2a: Gross Energy Consumption by Source (2014/2015). Data from WECS (2017: pg.4)

Energy Source	Amount (TJ)	Percentage share (%)
Fuel Wood	352 229.10	70.5
Agricultural-Residue	17 408.43	3.5
Animal Dung	18 401.96	3.7
Coal	19 819.09	4.0
Petroleum	62 618.27	12.5
Electricity	16 932.75	3.4
Renewable	12 430.26	2.5
Total	499 839.86	-

Table 3.2b: Gross Energy Consumption by Sector (2015). Data from WECS (2017: pg.11)

Energy Source	Amount (TJ)	Percentage share (%)
Agriculture	5 828.03	1.2
Manufacturing	39 849.96	8.2
Transportation	35 671.54	7.3
Household	38 9619.4	79.9
Services	16 893.74	3.5
Total	487 866.87	-

Table 3.2c: Electricity Generation by Source (2018, provisional). Data from (NEA, 2018: pg.171)

Energy Source	Amount GWh	Percentage share (%)
NEA Hydro Power	2 308.24	32.7
NEA Thermal	0.13	0.0
IPP Hydro Power	2 167.76	30.7
Import from India	2 581.80	36.6
Total	7 057.93	-

Table 3.2d: Electricity Consumption by Sector (2018, provisional). Data from (NEA, 2018: pg.172)

Energy Source	Amount GWh	Percentage share (%)
Domestic	2 509.29	45.1
Industrial	2 010.09	36.2
Commercial	413.07	7.4
Water Supply/Irrigation	126.20	2.3
Community Sales	129.08	2.3
Export to India	2.94	0.1
Total	5 560.24	-

Table 3.2e: Fuel Consumption by Sector. Data from WECS (2017: pg.11)

Energy Source (kToe)	LPG	Diesel	Petrol	Aviation Fuel	Traditional Fuels	Total
Agriculture	-	130.1	2.1	-	-	132.2
Manufacturing	-	141.5	2.9	-	219.0	363.4
Transportation	7.4	508.1	214.4	121.4	-	851.3
Domestic	191.4	-	-	-	8 664.1	191.4
Services	33.7	0.4	0.4	-	221.5	256
Total	300.0	780.2	219.8	121.4	9 104.6	1421.4

In terms of gross energy consumption, traditional biomass dominates with fuel wood comprising 70.5% of all energy consumption. The amount of energy consumed as electricity in comparison, is less than the energy consumed through burning animal dung, at a total of 3.4%. For electricity consumption, the domestic sector has the largest share with 45.1% of consumption, followed by the industrial sector at 36.2%. This electricity is supplied almost evenly three-ways between NEA generated hydro power, IPP generated hydro power, and electricity imports from India. The amount of electricity exported to India is orders of magnitude smaller than the amount of electricity imported into Nepal, with electricity exports making up just 0.1% of the consumed electricity in Nepal during 2018. It is also worth noting that the large difference in the reported values of electricity supplied and electricity consumed in 2018 reported by the NEA is likely due to electricity losses within the transmission and distribution systems. The energy consumed through burning petroleum fuels is significantly higher than that consumed as electricity, with petroleum providing 12.5% of Nepal's energy needs in 2018. For petroleum fuels, 60% of fuels (by kToe) were used for transportation, while 25% was used for manufacturing and 18% was used for services. There are notable differences in the type of fuel used in each sector, with LPG mostly being used for domestic purposes.

3.3 Energy Demand Projections

Energy demand projections provide forecasts which are important to this study because they provide a platform for understanding what Nepal's energy futures will be. This is a critical part of the secondary research objective and the subject of **Chapter Seven**. Several studies have projected energy demands for Nepal across different scenarios. The results of these projections are shown in **Tables 3.3.1-3**. Parajuli et al. (2014) have developed energy consumption projections for Nepal using models which use GDP, shares of GDP and population data to form business as usual (BAU), medium growth (MGS) and high growth (HGS) scenarios. Their projections are made to 2030 and forecast increasing demand for fuel wood, biogas, LPG and petrol (Parajuli et al., 2014). Total electricity consumption was modelled to increase between 3.5-10.1 times by 2030, which would require an installed grid generation capacity of 2235 MW under BAU and 6600 MW under HGS (Parajuli et al., 2014). In the BAU, MGS and HGS, the required capacity for off-grid systems remains the same at around 82 MW (Parajuli et al., 2014).

Malla (2013) uses a Long-range Energy Alternatives Planning System to analyse and project Nepal's household energy demand through to 2040. This demand is analysed for thirteen regions and uses four scenarios; high economic growth (HIG), business as usual (BAU), sustainable energy development (SED) and low carbon society (LCS) (Malla, 2013). The HIG and BAU scenarios are conceptually similar to the HGS and BAU scenarios in the study by Parajuli et al. (2014), while the SED represents a future which has a greater share of renewable energy and greater efficiencies, and LCS represents low economic growth and low fossil-fuel use (Malla, 2013). The forecasts made by

Table 3.3.1: Total Primary Energy Consumption Projections adapted from Parajuli et al. (2014: pg. 440).

Source	Unit	2009	2015			2025			2030		
			BAU	MGS	HGS	BAU	MGS	HGS	BAU	MGS	HGS
Fuel Wood	%	77.7	81.5	78.5	78.4	84.8	76.7	76.4	86.46	75.8	75.46
	PJ	311	355	360	380	431	445	515	474	495	600
Agri-residues	%	3.7	3.7	3.6	3.4	3.8	3.3	2.83	3.75	3.15	2.59
	PJ	15	16			19			21		
LPG	%	1.4	2.4	2.9	3.2	5.2	9.0	11.4	7.68	15.91	21.47
	PJ	6	10	13	15	26	52	77	42	104	171
Petrol	%	1.0	1.3	1.3	1.2	2.4	2.1	1.8	3.18	2.67	2.19
	PJ	4	5.83	5.83	5.83	12.11	12.11	12.11	17.45	17.45	17.45
Biogas	%	0.7	1.0	1.3	1.7	1.9	3.6	8.2	2.55	6.13	17.85
	PJ	3	4.28	5.77	8.29	9.43	20.99	55.09	14.01	40.03	142.01
Electricity	%	2.1	2.9	3.2	3.6	4.3	5.5	7.3	5.23	7.24	10.53
	PJ	8	13	14.62	17	22	32	49	29	47	84
	GWh	2222	3611	4061	4722	6111	8889	13611	8056	13056	23333
Total Primary Energy	PJ	401	436	458	485	508	580	674	549	653	796

Table 3.3.2: *Household Energy Consumption Projections adapted from Malla (2013: pg. 996).*

Source	Unit	2010	2025				2040			
			BAU	HIG	SED	LCS	BAU	HIG	SED	LCS
Biomass	%	96.1	92.5	90.7	91.1	91.6	86.6	82.5	81.9	84.4
	PJ	352.6	403.3	347.0	354.5	388.5	429.9	318.9	327.7	402.5
LPG	%	1.1	2.3	3.0	2.5	2.2	4.1	5.8	4.7	3.8
	PJ	4.1	10.0	11.6	9.8	9.2	20.6	22.3	19.0	18.3
Electricity	%	1.2	2.4	3.1	3.1	1.9	4.7	6.4	6.4	3.6
	PJ	4.3	10.4	11.9	12.2	8.2	23.2	24.6	25.7	17.2
Biogas	%	0.7	2.3	2.6	3.0	3.8	4.3	5.0	6.9	8.0
	PJ	2.7	10.0	9.8	11.8	16.2	21.2	19.3	27.7	38.3
Total Household Energy	PJ	367.0	436.1	382.7	389.0	424.0	496.2	386.3	400.2	476.9

Table 3.3.3: Electricity Demand Projections from WECS (2017)(Pgs. 11-17, adapted)

Sector	Unit	2015	2015-2025			2025-2030			2035-2040		
			BAU: 4.5	**Ref: 7.2**	**High: 9.2**	**BAU: 4.5**	**Ref: 7.2**	**High: 9.2**	**BAU: 4.5**	**Ref: 7.2**	**High: 9.2**
Industry	%	36.7	45.1	46.3	44.4	47.5	50.5	47.2	57.1	62.7	56.0
	GWh	1423.62	3309.7	3759.9	3782.9	5820.8	7512.1	7819.6	15320.8	25518.3	29653.7
Transportation	%	0.2	0.6	0.6	0.6	4.6	3.9	3.5	5.3	3.8	3.1
	GWh	8.1	45.5	46.3	46.9	567.6	575.7	582.9	1414.1	1528.7	1656.9
Domestic	%	47.9	49.1	44.4	42.2	47.2	38.8	34.9	43.4	28.6	21.9
	GWh	1857.3	3601.9	3601.9	3601.9	5775.4	5775.4	5775.4	11632.2	11632.2	11632.2
Service	%	13.0	8.9	8.7	8.8	7.0	6.8	7.0	5.5	5.0	5.2
	GWh	503.6	655.1	704.8	752.6	862.8	1004.6	1154.8	1471.6	2042.1	2776.6
Total Electricity Demand	GWh	3874.0	7338.4	8112.9	8525.4	12242.2	1487.8	16550.5	26819.2	40721.2	52998.0
Total Required Capacity	MW	1721	5787	6617	7366	8937	11111	13296	19151	29427	42228

Notes: Unit PJ are Petajoules.

BAU, MGS and HGS are Business as Usual, Medium Growth Scenario, and High Growth Scenario under the methodology from Parajuli et al. (2014). Total Primary Energy projections in this study are not an aggregate of fuel projections because some fuels, such as diesel, could not be correlated for projections in the study.

BAU, HIG, SED and LCS are Business as Usual, High Economic Growth, Sustainable Energy Development, and Low Carbon Society scenarios under the methodology from Malla (2013).

BAU 4.5, Ref 7.2 and High 9.2 refer to scenarios of 4.5%, 7.2% and 9.2% annual economic growth under the methodology from WECS (2017).

Malla (2013) are shown in **Table 3.3.2.** Interestingly, Malla (2013) provide a regional analysis which shows that the Kathmandu Valley is expected to dominate current and future commercial fuel and electricity consumption. Similarly, the disparity between urban and rural energy consumption is expected to be significant at around 4-14 times greater in urban areas compared to rural areas (Malla, 2013).

WECS (2017) use the International Atomic Energy Associations Model for Analysis of Energy Demand to forecast electricity demand under different economic growth scenarios; with BAU (4.5%), a reference scenario (7.2%), and a high growth scenario (9.2%). Forecasting to 2040, WECS (2017) predict a total electricity demand of 26,819 GWh in the BAU scenario, which stretches up to 52,998 GWh in the high economic growth scenario. This growth would require a generation capacity between 19,151 MW to 42,228 MW, for the BAU and high scenarios respectively. Considering that WECS (2017) report a total electricity demand of 3784 GWh and a required 1721 MW of generation capacity in 2015, these increases are significant and would require an 11-25 times increase in the generation system by 2040.

3.4 Energy Resource Overview

To complete this energy sector overview, an understanding of the status of energy resources relevant to this study's research objectives is needed. This provides context as to the relative importance of certain energy systems which experienced the earthquake and blockade and provides a base to build discussion on the implications of Nepal's future energy scenarios upon. Four key energy resources for Nepal are described below, which include hydropower, solar and alternatives, energy trading and petroleum. These four energy resources have been chosen because they all require an energy system to be delivered to the consumer and they have a significant share within Nepal's electricity or energy sectors. The exception to this is solar, which has been included because of its established use in Nepal. According to the energy stack by van der Kroon et al. (2013) these resources also provide advanced fuels, which provide the greatest economic and social benefits.

3.4.1 Hydro

Nepal, as a mountainous country which occupies part of the highest mountain range in the wold, has an extraordinary possibility for hydropower with somewhere between 83,000 MW and 42,000 MW of hydro power potential (ADB, 2017a, Jha, 2011,[3], 1997). Hydropower is incredibly important for Nepal as it is available in "*virtually every Nepali village*" (Sovacool et al., 2011b: pg.3470). The technology also works against issues associated with other energy resources in Nepal as hydropower contributes little to air pollution, doesn't require biomass which causes deforestation, works at night and when it is

[3] Government of Nepal, Ministry of Water Resources and Ministry of Population and Environment.

cloudy, and can be established independent of the national grid negating the need for expensive transmission lines (Sovacool et al., 2011b).

Hydropower can be generated through two methods, by either using the flow of a river as it runs to generate electricity (called run-of-river), or by using a dam to build up a reservoir of water before it flows through a turbine (reservoir hydro) (Ramage, 2012). The major difference between the two forms is the ability of reservoir hydro to store water, while run-of-river hydro is reliant on the steady water flow of a river (Ramage, 2012). The size of hydropower facilities ranges significantly, so the discussion of hydropower in this thesis is separated into smaller hydro and larger hydro. Smaller hydro implies a discussion of hydro power facilities which have small generating capacities and are generally for serving smaller communities which may be off-grid or grid-connected. Larger hydro on the other hand describes hydropower facilities with large generating capacities which are operated to provide commercial grade electricity for the national grid.

Smaller hydro has had a significant history in Nepal since electrification efforts started in the 1960's with the development of donor-assisted micro hydroelectric projects (Sovacool et al., 2011b). These replaced diesel engines that were being used in rural areas for agro-processing (Karki, 2018). By the 1980's, micro hydro projects were able to provide lighting in addition to their agro-processing functions, and government subsidies from the Agricultural Development Bank meant village communities quickly adopted the technology and the projects flourished (Karki, 2018). Karki (2018) points to the adoption of micro hydro in village communities as a success driven by the private-sector but enabled by the government and the social capital of the communities themselves. In 2004 the World Bank, alongside local banks and the Government of Nepal, started the Nepal Power Development Program, which aimed to develop grid connected hydropower, develop off-grid hydropower, and promote private participation in the power sector (Sovacool et al., 2011a). The program achieved the expansion of micro hydro service coverage to an additional 30,000 households and constructed a 220 kV transmission line, but it failed in its other goals (Sovacool et al., 2011a).

Larger hydro has a more recent history in Nepal, as the first hydro project which was constructed to provide electricity to the general public was the 2.4 MW Panauiti project completed in 1965 (Sharma and Awal, 2013). From there, the first project larger than 20 MW was constructed in 1967, the first larger than 50 MW in 1982 and the first project larger than 100 MW in 2002 (Sharma and Awal, 2013). During the 1980's and 1990's the proposed donor financed 404 MW Arun III project was the cause of a significant amount of controversy because of concerns about cost, the impact on indigenous peoples and environmental issues (Udall, 1995). Ultimately, these concerns lead to the project being cancelled at the last minute in by donors in 1995 (Shrestha, 2018b). Prior to 1990, private investment in hydropower was closed as the government's NEA and its precursors had been the sole owners and developers of hydropower projects. Independent power producers (IPPs) have since become established in Nepal's domestic electricity market, supplying 30.7% of electricity generated in 2018 to the NEA, the country's sole grid electricity purchaser (NEA, 2018). To date, the largest hydropower project remains the 144 MW Kaligandaki A station constructed in 2002. However, over one million MW of generation capacity is currently under construction while almost three million MW of generation capacity is planned or proposed (NEA, 2018).

3.4.2 Solar

Solar PV in this thesis refers to the use of solar photo-voltaic (PV) panels to generate electricity (not to produce thermal heat). Solar PV has a relatively short history of use in Nepal, with the first implementation of solar PV being in 1988, and the initial subsidies being given in the 1990's (Gurung et al., 2012). However, solar PV technologies are now established in Nepal with K.C et al. (2011) reporting that there are 363,000 solar systems in Nepal with a total generating capacity 8.3 MW. This does not represent a significant amount of generation compared to the generating capacity of hydropower stations, but the number of systems which were reportedly in use in 2011 indicates that there are many solar technology users. The latitude and climate of Nepal provides an abundant solar resource for the country, with about 300 sunny days a year providing 3.6-6.2 kWh /m^2 per day (Nepal, 2012). As a result, K.C et al. (2011) believe the estimated market potential for solar PV systems to be huge, but there are issues with affordability as the per kW cost of solar can be too expensive for rural communities at around $14,286 (K.C et al., 2011). The technology of solar PV also has inherent issues of being unable to generate electricity at night or during cloudy weather, which means the generation of solar PV electricity is often mismatched with demand patterns (Boyle and Everett, 2012).

Gurung et al. (2012) have reviewed literature and policy on renewable energy technologies in Nepal, and categorise solar PV systems in Nepal into four types: solar home systems, which have a capacity of 10-40 Watt peak capacity (Wp); community solar PV systems, which may use solar panels that have capacities varying between 130 Wp and 40 kWp; institutional solar PV systems, which may use solar panels that have capacities between 34 Wp and 6.45 kWp, and solar lanterns, which are white LED lanterns that have a module size of 2.5 or 10 Wp. Of these applications, solar home systems (SHS) are the most widespread in Nepal and in 2010 approximately 225,000 of the systems had been installed with an approximate output of 5.36 MWp (Gurung et al., 2012). Solar home systems are generally used to supply household electricity and one study reported the average cost of installation ranged between US $244-$880, depending on the size of the system (Nepal, 2012). Community solar PV systems in Nepal are commonly used for pumping drinking and irrigation water, and in 2010 there were about 100 systems in the country (Gurung et al., 2012). Institutional solar PV systems are used on public intuitions such as schools or government buildings, and in 2010 there were 259 of these systems in Nepal. There were about 9000 installed solar lanterns in Nepal in 2010 (Gurung et al., 2012).

3.4.3 Petroleum Fuels

Nepal has no significant reserves of fossil fuels and all petroleum products are currently imported from India (Malla, 2014). In the transport sector petrol, diesel and aviation turbine fuel (ATF) comprised 98% of the energy used for transport in 2013, with electricity and LPG making up the very small remaining share (Malla, 2014). The transport sector was the largest petroleum consuming sector, using 63% of national petroleum consumption (WECS, 2017). The domestic sector consumes the second highest amount of petroleum fuels. Within this sector, LPG gas is used by about a quarter of households in Nepal for cooking purposes (CBS, 2016). Petroleum fuel is mostly used by urban consumers with almost half of the petrol imported in Nepal being consumed in Kathmandu (Malla, 2014, Karki et al., 2010). With this being said, Karki et al. (2010) believe the consumption of petroleum fuels in rural areas was a threat to rural energy security because of price volatility and the inconsistent supply of fuel to rural areas. Writing before the blockade occurred, Malla (2014) claimed that one of the three major challenges facing the transport system in Nepal was the ability to "*sustain the supply of fuel and security to meet growing demand for motorized mobility*" (p.486). Because Nepal's transport petroleum products are all imported from India, Nepal's transport system is almost totally reliant India for this supply and security of fuel.

3.4.4 India-Nepal Energy Trade

Nepal's energy relationship with India, as Nepal's only South Asian neighbour, is not only critically important for Nepal-India energy trading, but for potential regional energy trade also. Currently, the relationship is mostly one sided as Nepal imports petroleum and electricity from India without exporting significant quantities of energy (NEA, 2018, Malla, 2014). This situation has been developing recently as Nepal has increased electricity imports from India to reduce the country's generation/demand gap (ADB, 2017a). For petroleum products, The Nepal Oil Corporation (NOC) and Indian Oil Corporation (IOC) recently renewed a Memorandum of Understanding in 2017 which ensures that the IOC will supply the NOC with its full petroleum product needs (IOC, 2017). For electricity, the most recent power trade agreement between India and Nepal was signed in 2014, which seeks to *"enable cooperation in the power sector, including developing transmission interconnections, grid connectivity, power exchange and trading through the governmental, public and private enterprises of the two countries on mutually acceptable terms*" (Ministry of Energy, Government of Nepal; Article-I). It is worth noting that India has not traded electricity with Nepal for a fair price in the past, as Nepal was charged 11-12 rupees per kWh for imports during the dry season while only getting paid about half of this amount when Nepal exports electricity to India during the wet season (Sovacool et al., 2011a).

3.5 Conclusion.

This energy sector overview has explained the energy systems of Nepal and provided a review of data pertaining to energy sector share and energy demand projections of Nepal. This demonstrates that, although the electricity and petroleum sectors currently have small overall shares of total energy consumption, demand in both sectors looks to grow significantly. Meeting this demand will be a key challenge for Nepal's energy systems which **Chapter Seven** will need to address when considering resilience in Nepal's energy futures. This chapter has demonstrated that smaller and larger hydropower, solar PV, petroleum fuels and energy trading are important energy resources to Nepal, and this allows **Chapter Seven** to examine the benefits, issues and potential of those energy resources with the results of this thesis.

4 Methodology

This chapter explains the conceptual methodological approach to the research and justifies the methods used. Ethical and positionality considerations are also discussed.

4.1 Conceptual Approach

The objectives of this study as identified through **Chapter One** and developed in the preceding literature review (**Chapter Two**) requires that a mixed-methods approach be used in this thesis as a mixed-method approach allows for both qualitative and quantitative knowledge to be used together (Lewis-Beck et al., 2004). Researching energy systems, which have earlier been described as the physical and organisational processes, components and actors involved in delivering an energy service, is a task which is well suited to using both qualitative and quantitative knowledge because of their inherent combination of physical and social-organisational components. Further, a mixed-methods approach employs and compares results from multiple methods to minimise incorrect inferences through triangulation (Lewis-Beck et al., 2004).

Considering the physical elements to energy systems, particularly the quantities of energy services delivered and the capacities of energy infrastructures, is a strictly quantitative task. This knowledge is positivist or post-positivist in nature as it takes a rational and objective understanding of facts, although acknowledges that uncertainty and error will be inherent (Bryman, 2016, Creswell, 2014). A quantitative understanding of the energy systems of Nepal provides information which is useful for understanding the magnitude of the disasters' impact; for example, a decrease in generating capacity following the earthquake or a reduction in fuel supply during the blockade clearly shows an impact to energy service provision and Nepal's energy security.

Relying on quantitative knowledge however, would leave deep gaps in this research as the conceptual framework indicates that understanding sub-national responses to the earthquake and blockade events are required for understanding energy resilience across different scales. The sub-national and institutional responses to these events across different scales is an organisational process which requires actions and decisions made by people within certain roles in those organisations.

While these actions and decisions are in response to the physical impacts which can be measured quantitatively, the understanding of the reasons why certain actors made decisions is constructed knowledge held by individuals. This knowledge can be understood through an interpretivist-constructivist research approach, which asserts that such knowledge is subjective and constructed by individuals who create meaning based on their own experiences and values (Bryman, 2016, Creswell, 2014). This approach allows for multiple understandings of phenomena, which is critical for this study as the investigation of how different actors understood the response to two disasters is necessary for employing the concept of cultural theory given in the conceptual framework (Bryman, 2016). Researching this form of knowledge requires that a qualitative approach be used, so such an approach is combined with the quantitative strategy in a mixed-method, pragmatic manner (Bryman, 2016, Creswell, 2014).

4.2 Methods Used

As a mixed-method approach is used to engage both quantitative and qualitative understandings of knowledge in this study, it follows that a mixed selection of methods are employed to collect this knowledge. Semi-structured interviews with key stakeholders are the principal method used to gather primary data, and these are supported with data analysis, media analysis and literature and policy analysis from secondary sources.

4.2.1 Primary Method

Semi-structured interviews are an established and recognised method which refers loosely to an approach of interviewing informants with a flexible and fluid structure (Lewis-Beck et al., 2004). These interviews have proven useful to resilience research by Khazai et al. (2018)**,** Baharmand et al. (2016) and Jones et al. (2013), as shown in **Box 2.1.2,** as they provided information at a scale which allowed evaluation of organisational and community level responses to certain issues. Semi-structured interviews are able to provide information useful for this smaller scale as the method is well suited to interpretivist and constructivist positions (Lewis-Beck et al., 2004). This enables respondents to generate their own accounts of experiences, perspectives and understandings related to the subject matter of the research (Lewis-Beck et al., 2004). For this reason, semi-structured interviews were used in this thesis to provide the qualitative knowledge required to make an analysis of how actors within energy systems responded to the earthquake and the blockade.

Using semi-structured interviews requires that certain participants who have knowledge on the subject of the research are sought purposively (Magnusson and Marecek, 2015). Thompson et al. (2018) suggests the public, private and NGO sectors may be involved in Nepal's energy systems as actors of development. This is true for Nepal, as the energy overview chapter (**Chapter Three**) indicated that the government is heavily involved in Nepal's electricity sector by making national policy and owning the NEA, NOC and AEPC organisations. The private sector is involved in the electricity sector through IPPs, while egalitarian CREEs provide distribution services and NGO's provide support and advocacy across the wider electricity sector. Stakeholders within these sectors, alongside academics who had knowledge of these sectors, were therefore sought to be participants in semi-stakeholder interviews as they possessed the knowledge which could explain energy system responses to the earthquake and blockade.

These interviews were undertaken in the Kathmandu Valley, which is an urban conglomeration of three cities including Kathmandu, which is the political and administrative capital of Nepal. I spent four weeks between February and March of 2018 undertaking fieldwork there. During this time, I employed Sabin Lamichhane as a research assistant to help with my fieldwork in Kathmandu. Sabin is the head of the social work department at a local college who had experience researching alongside foreign researchers in Nepal. Sabin spoke Nepali, which allowed stakeholder interviews to be undertaken in Nepali if the stakeholder desired. Sabin also helped me to understand local customs and provided a critically valuable source of information which helped me understand how the effects of the earthquake and blockade were felt in Kathmandu.

Through the process of the research, the relationship between Sabin and I became one of friendship in nature. I believe this influenced the research process because it allowed Sabin and I to approach the research task in a more collaborative way, opposed to me instructing Sabin as my assistant. Using Sabin's knowledge of local issues and processes, Sabin's input into the goals of the stakeholder interviews and his input within interviews provided clearer and more insightful results then I would have been able to get on my own. It must be acknowledged however that by relying on Sabin for translating the two interviews which were undertaken in Nepali and by encouraging Sabin to contribute to stakeholder interviews, Sabin's own bias was inevitably introduced to the research process. I cannot tell what was actually said in the translated interviews compared to what is given in the transcription, and I must rely on Sabin for being truthful and honest in those transcriptions.

Recruitment of participants was performed using targeted nominations, direct targeting and chain referral methods (Magnusson and Marecek, 2015). The targeted nomination method was used first, which was performed by organising meetings via email with contacts my supervisor had in Kathmandu. Once I arrived in Kathmandu, I met with these contacts who then coordinated interviews for me with stakeholders they knew of working in the government, NGO and academic sectors. Sabin also coordinated interviews for me using his existing contacts. In addition, I directly contacted stakeholders who had websites publicly advertising their contact information, which was common for NGO and private sector stakeholders. Most of the stakeholders were contacted through phone calls by Sabin, as it was difficult for me and most stakeholders to communicate effectively through phone calls due to language and accent issues. Once we had met with key stakeholders, we then employed the chain referral method (also known as snowball sampling) by asking stakeholders for further contacts (Magnusson and Marecek, 2015). The chain referral method proved most successful as introductions to potential participants made by recruited stakeholders helped establish a relationship between Sabin Lamichhane and I as the researchers and the potential participants.

A total of 19 stakeholder interviews were performed; with two stakeholder interviews in the academic sector, seven in the government sector, five in the NGO sector, three in the private sector, one in the government petroleum sector, and one being with a stakeholder in both the NGO and government sectors. This is show displayed in **Table 4.2.1**.

Table 4.2.1: *Key Stakeholder Interviews Taken*

Sector	Code
Petroleum Fuels Sector (Government)	1
Government Stakeholder	7 (8)
NGO	5 (6)
Private Sector	3
Academic	2

Analysis of the results gathered through the semi-structured interviews was performed through a simple process. Interviews, which were recorded with an audio recorder in the field, were transcribed both in the field and in New Zealand after the field work had concluded. Initially, transcriptions performed whilst field work was ongoing were done so as ‘full transcriptions’, being almost word for word versions of interviews to ensure information discussed in these interviews were not lost (Bazeley, 2013). Transcriptions performed some time after the conclusion of field work were not done to such a comprehensive level. I kept a notebook of notes reflecting on interviews taken in the field, and shortly after the conclusion of the field work I used this notebook to revise the research objectives and map the subjects discussed in interviews. This allowed later transcriptions to focus on indicating the beliefs and positions of stakeholders on these subjects, with only key quotes being kept as word for word transcriptions. The earlier word for word transcriptions were adapted to the later version, and together this formed a collection of notes for each of the 19 interviews. Together, these collection of notes were organised around loose subject codes through an organising method similar to that described by Bazeley (2013: pg.135).

Originally, this study aimed to take site observations of damaged infrastructure, but due to timing and organisational constraints, only one site observation was taken. This site observation is treated as if it was an interview when presented in the results, as the key stakeholder (G1) provided a tour of the facility being observed.

4.2.2 Secondary Methods

The results gathered from key stakeholder interviews had significant limitations as interviews with key stakeholders assumes those stakeholders will be representative of a wider group they are affiliated with (Willis, 2006). Issues of positionality also arise (see **section 4.4**), which can skew data as interview participants discussing topics which directly reflect on the performance of their organisation, or their role within that organisation may answer in a way which shows them positively (Willis, 2006). Conversely, an interview participant may answer in a more negative manner if discussing an organisation which their own organisation competes against.

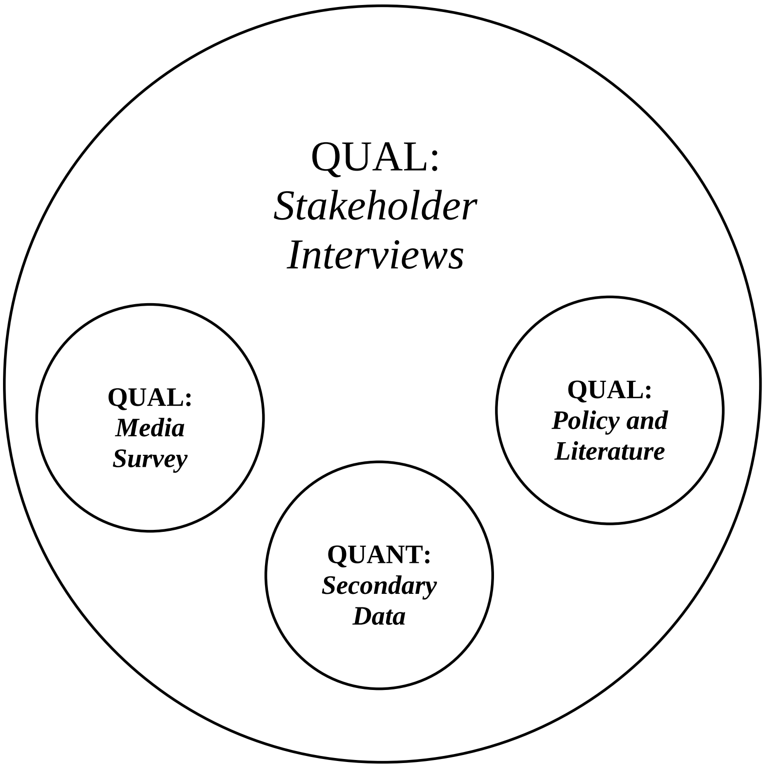

Figure 4.2: *Qualitative stakeholder interviews are used as the primary method in this study, with a media survey and analysis of policy, literature and data being the supporting secondary methods. The smaller circles being nested within the larger circle demonstrates the nested mixed-methods research design from (Leavy, 2017).*

To address this potential bias in stakeholder interview responses, secondary sources from media, policy documents and academic literature were drawn upon to enhance confidence in the results through triangulation (Lewis-Beck et al., 2004). Key stakeholder interviews are also unable to provide the quantitative data required to form an understanding of the physical impact of the earthquake and the blockade, so secondary data collection and analysis was used to gather this information. This methodology was therefore designed to be supported by three secondary methods in a nested research design, as shown in **Figure 4.2** (Leavy, 2017).

Secondary analysis of quantitative data is the supporting method used in this study to access information detailing the physical nature of the electricity and petroleum sector (Dale et al., 2008). Such secondary analysis is a suitable method as the quantitative knowledge of Nepal's electricity and petroleum sectors can only be known to the organisations which manage those respective energy systems. Thus, it would be inappropriate for this study to gather this quantitative knowledge in a primary fashion as it is outside the scope of the study to engage with managing organisations to do so. Instead, I asked contacts within the NEA and NOC for data pertaining to the earthquake and blockade events (respectively), which they kindly provided. This data is referenced without a date in the results chapters of this thesis. Some very basic analysis was performed on this data to be able to present the data through graphs, but it was otherwise unaltered.

To address the issue of bias within stakeholder responses, a media analysis was also used as a supporting method. Media analysis draws from the well-established method of content analysis and can be both qualitative and quantitative (Macnamara, 2005). In this study, the media analysis is limited to being qualitative in nature as its purpose here is to provide results which can be compared against those gathered from the key stakeholder interviews. The researcher interpreted meanings of media articles gathered through a qualitative media analysis enables those comparisons to be made (Macnamara, 2005). Basic keyword searches in the Factiva database was used to access these media articles, and PDF copies of the media articles used have been retained by the author. To clearly indicate where media reports are used, the citation is given with the authors name if available, followed by the full date (dd/mm/yyyy). Providing the full date also provides context as to when the information was published relative to certain events. A separate bibliography is given for the articles used in the media analysis, given in the Appendix of this thesis.

Analysis of literature and policy is the second supporting qualitative method used to triangulate key stakeholder interview results with. This method can be considered document analysis, which draws from the methods of content analysis and thematic analysis to establish the meaning of documents to the topic being explored (Bowen, 2009). The use of academic and grey literature was necessary to construct the energy sector overview in the Energy Futures chapter (**Chapter Seven**) This is because there is established knowledge on components of Nepal's energy systems within this literature which is useful for considering Nepal's energy futures. The analysis of policy documents which suggest how certain organisations envision Nepal's energy futures is also necessary when considering Nepal's energy futures in this later chapter. Because the results gathered from primary stakeholder interviews were vulnerable to bias, the literature and policy analysed through this method provides an independent source of information which can be compared to the primary results. This provides confidence to the study's results. It should be noted that a significant limitation of the literature and policy analysis was my inability to read Nepali, which meant potentially useful documents were omitted.

Policy and grey literature documents available in English were sought from key agencies representing a component of Nepal's energy systems. Suggestions from stakeholders (special thanks to G7) as to what policy documents would be worth investigating proved greatly helpful in doing this. **Table 4.2.2** indicates the policy documents surveyed in the policy analysis, alongside their authoring organisation and relevant energy system component. An analysis of the key goals from these policy documents is included in the Appendix.

Table 4.2.2: Policy Surveyed in Policy Analysis.

Policy Title	Authoring Organisation	Year	Energy System Component
The Hydropower Development Policy	Ministry of Water Resources	2001	Hydropower
SAARC Framework Agreement for Energy Cooperation (Electricity)	SAARC	2014	Energy Trading
Agreement Between the Government of Nepal and the Government of the Republic of India on Electric Power Trade, Cross-Border Transmission Interconnection and Grid Connectivity	Government of Nepal, Government of India.	2014	Energy Trading
Memorandum of Under Standing (MOU) between the Government of Nepal And the Government of the People's Republic of Bangladesh on Cooperation in The Field of Power Sector	Government of Nepal, Government of Bangladesh.	2018	Energy Trading
Intended Nationally Determined Contributions (INDC)	Ministry of Population and Environment	2016	Sector Wide
Universalizing Clean Energy in Nepal: A Plan for Sustainable Distributed Generation and Grid Access to All by 2022	National Planning Commission	2018	Sector Wide
Nepal Sustainable Development Goals: Status and Roadmap 2016-2030:	National Planning Commission	2017	Sector Wide
National Rural and Renewable Energy Programme Nepal (NRREP) Programme Document	Alternative Energy Promotion Centre	2012	Rural Energy
National Renewable Energy Framework (NREF)	Alternative Energy Promotion Centre	2017	Rural Energy
Biomass Energy Strategy	Ministry of Population and Environment	2017	Rural Energy
Renewable Energy Subsidy Policy	Ministry of Population and Environment	2016	Rural Energy
National Sustainable Transport Strategy (NSTS) for Nepal (2015-2040)	Ministry of Physical Infrastructure and Transport	2015	Transport Energy

4.3 Ethical Considerations

Research conducted by western academics in developing countries has been criticised in the past for constructing development discourse in way which legitimises western ‘experts’ through undermining the voice of local people (Escobar, 1995). In doing this, colonial patterns of domination against the researched ‘others’ can be reinforced, creating clear ethical issues (England, 1994, Scheyvens and Storey, 2003). There is no easy solution to these critiques and this study does not have an approach which is employed as a ‘cure-all’ to the issue. Instead, considerations about the way this study gathered, analysed and presents results were made throughout the entire research process. To avoid constructing discourse in a way in which undermines the local voices, Sabin Lamichhane and I approached most interviews together from an equal position, and Sabin’s input into the research process was highly valued. Stringent care was taken in stakeholder interviews to ensure that the information which was discussed was not directed in a way that I believed to be the right way or best way. I have also deliberately chosen not to present policy recommendations in this thesis to further reduce any construction of the knowledge presented in this thesis as ‘expert’ knowledge which dominates local knowledge. To the best of my ability, I treated the opportunity to undertake this research and visit Nepal as a tremendous privilege provided to me by the country of Nepal, not a right.

Ethical considerations were also managed through the process governed by the University of Otago Human Ethics Committee, which required than ‘ethics A’ approval be given. This process ensured the process in which participants were recruited, the methods in which results were gathered, and the way in which results are published would not cause serious ethical issues. The information sheet provided to respondents is provided in the Appendix of this thesis.

The ethics approval requires that each participant had prior and informed consent before participating in an interview, and as such, asked that respondents sign a consent form ensuring they understood what their response would be used for and how their results would be published. Sabin Lamichhane translated the consent and information documents into Nepali, so that stakeholders more comfortable with reading Nepali would understand what the study was about and how their responses would be handled. In some cases, the formal nature of this consent process was received awkwardly as the preferred local practice when meeting with someone for the first time is to establish an understanding of each other first, and often share tea, before moving into the subject of the meeting. This was realised quickly and the approach to gaining consent from respondents was altered accordingly. In the altered approach, Sabin or I would verbally explain what the research was for and how the stakeholders’ responses would be used at the start of the meeting, before verbally asking for consent. If this was given, we would begin asking about the research and at the conclusion of the meeting ask for written consent.

Full anonymity of stakeholders was a condition required for ethical approval. For this reason, stakeholders in this thesis are referred to only by a coding which corresponds to their sector. These codes represent the following:

Table 4.3: Codes used for stakeholders.

Code	Sector
O	Petroleum Fuels Sector (Government)
G	Government Stakeholder
N	NGO
P	Private Sector
A	Academic

4.4 Positionality

As with any research undertaken by researchers in a foreign environment, my own positionality as a New Zealand researcher in Nepal requires full acknowledgement. I am a New Zealand born male of European descent with a bachelor's degree from the University of Otago. At the time of researching I was 22 years old. I have lived my entire life in New Zealand and had never travelled to Nepal before. Although I read widely and tried to follow domestic affairs before arriving in Nepal, my understanding of local values, customs, issues and politics, along with my understanding of Nepal's physical environment and economic processes, could only ever be a skewed and miniscule fraction of the understanding which local Nepali people have. Further, I have never experienced a disaster which caused as much devastation as the 2015 Nepal earthquake caused, nor have I ever experienced a political dispute which resulted in shortages of key goods which I rely on access to in my own everyday life. This inherent difference in the experiences and knowledge which I have compared to those of local Nepali's presents strengths and weaknesses which need to be considered.

On one side, my position as an outsider means I did not carry bias towards certain agencies, nor did I carry preconceived ideas about policy objectives or ongoing issues within Nepal. This meant key stakeholders could share their beliefs with me without any fear of me disagreeing with them or judging them for their position. From this perspective, my positionality enabled me to view the issues discussed in this thesis from a neutral, outsider view who could take an objective approach to the subject matter at hand. It was also suggested to me at one point by a non-participant contact in the field that my positionality enabled me to contact stakeholders which local researchers may have struggled to have access to, because of an existing desire of stakeholders to leave a good impression of Nepal to foreigners. On the other side, my very limited knowledge of local values and issues meant it was difficult for me to discern bias within stakeholder responses. In many cases, stakeholders responded to questions about the response which directly reflected on the responsibilities of their organisations and their roles within that organisation, so it is reasonable to expect that those stakeholders would present a biased view of their role in the disaster response. My limited knowledge also meant that it was difficult for me to understand the specific nature of the roles in which certain stakeholders played in the response, because my understanding was necessarily translated upon my understanding of the energy systems of New Zealand.

4.5 Conclusion

This chapter has explained why a mixed-methods approach is required for this thesis, which employs both qualitative and quantitative methods. The process by which the 19 key-stakeholder interviews from government, private, NGO and academic sectors were taken and analysed has also been described. Issues of positionality and ethics have also been addressed, which were of paramount importance to this research. The results of the methods described in this thesis are presented in the following three chapters.

5 Earthquake Response

This chapter examines the response of Nepal's electricity sector to the 2015 earthquake. This response had implications for Nepal's energy security, energy justice and energy poverty.

5.1 Introduction

This chapter explores the responses of Nepal's electricity systems to the 2015 earthquake. The results of stakeholder interviews are used to do this, alongside media, data and reports given by stakeholders through the research process. The structure of this chapter follows the conceptual approach outlined in **Section 2.1.4**. The impact or damage brought upon the electricity sector by the earthquake is first presented, which is followed by explanations from stakeholders describing how energy sector actors managed this damage. Actions which stakeholders believed would increase resilience in the electricity sector are also given. This chapter then moves to critically analyse how the response of Nepal's energy systems affected energy security, energy poverty and energy justice in Nepal. In doing this, this chapter demonstrates the importance and usefulness of considering resilience in energy systems.

5.2 Earthquake Damage

Electricity generation, transmission, distribution and management infrastructure all experienced the earthquake. Across all systems, the damages to infrastructure were equivalent to approximately USD $212 million, with USD $58 million being damages in the private sector (G7). This damage experienced by the electricity sector can be analysed for each system.

5.2.1 Generation Systems

The largest generation facility damaged by the earthquake was the 45 MW Bhotekoshi dam, which was struck by boulders that had fallen from overlying cliffs (A1, NEA, Fairley, 11/05/2015). Thirteen grid connected hydropower facilities were also damaged at the time put out of operation, causing 150 MW of generation to be lost (G7, NEA, Fairley, 11/05/2015). G7 believed this represented about one-fifth of the country's total power supply. Despite this damage, Fairley (11/06/2015) reported statements from the managing director of the NEA that other damaged hydro projects could keep operating, while some damaged projects could be fixed "*within weeks*". By May 2015, 96 MW still remained out of operation (NEA). G7 believed this loss had a significant impact as much of Nepal at that time was already facing load shedding for up to 16 hours a day because of a shortage of electricity supply. It has been reported that about 1000 MW of generation capacity under construction was also partially damaged because of the earthquake (Adhikari, 4/02/2016).

G7 and G2 reported that 239 or 267 micro hydro projects (respectively) were affected by the earthquake, and at the time of the fieldwork, some of these projects had still not been rehabilitated. G7 indicated that this damage corresponded to a loss of electricity for approximately 60,000 households and suggested the districts of Dhading, Gorkha, and Okhaldhunga suffered the worst damage to micro hydro facilities (see **Figure 1.3** for map). NG5, referring to an upcoming study, believed that damages to the civil structures in micro hydro systems were the most severe, while damages to the mechanical parts were less so.

This significant amount of generating capacity which was lost in both the grid and off-grid systems suggest that generation systems did not perform well in Sharifi and Yamagata's (2016) first criterion. The arrangement of the generation systems in Nepal provide for a hierarchal government actor through the NEA owned generation facilities, individualistic actors through the IPP owned stations, and egalitarian actors through community micro hydro systems. All three actors suffered damage to their generation capacity, although the NEA owned facilities appeared to suffer the least damage with only one facility out of operation when the PDNA was published (NPC, 2015b). This may be a result of G1's view that the government sector adheres to international building standards while independent providers did not. However, the relatively light damage to NEA facilities may be also be due P1's view that the earthquake damage was very site specific. It is not clear which view is more accurate, although the PDNA did recommend *the "standardization of parameters for seismic-safety features in the design of electricity infrastructure"* (2015b: pg.152). The ability for the private sector to adhere to seismic-safety building standards in the future may therefore influence the generation systems' ability to meet Sharifi and Yamagata's (2016) first criterion of adaptive resilience.

5.2.2 Transmission System and Management Infrastructure

The transmission system remained operational after the earthquake, and stakeholders G1, N2, and G6 believed that the damage to the system was not severe (NPC, 2015b). Stakeholders did not allude to the reason why this system performed well after the earthquake, but it was suggested that a major cause of damage in the distribution system was the collapse of buildings causing stress on lines (N2, G6). As the transmission system is likely to be physically operated independent of supporting structures external to the transmission system, the controlling body has complete control over the transmission system. The NEA, as the hierarchical government actor, will have this control vested in a bureaucracy of managers with technical expertise, and it appears that this worked well for the transmission system during the earthquake. As no other actors appear to be involved in the transmission system it is difficult to suggest whether they would have performed better.

Electricity sector management infrastructure was damaged, although no evidence was found to suggest management operations were severely affected. G1 discussed the experience of the NEA's load dispatch centre after the earthquake, explaining how the control room was damaged. As a result, the system collapsed and electricity supply was shut off. However, G1 noted that this damage was repaired to a point where the system could be operated again quickly, and supply was restored within 8 hours. In Kathmandu, G6 believed three service stations were also damaged.

5.2.3 Distribution Systems

Both N2 and A1 expressed that the main earthquake damage occurred in electricity distribution systems, where it has been reported that some 800km of lines of different voltages were affected (Adhikari, 4/02/2016). In both urban and rural affected areas, N2 and G6 acknowledged the collapse of buildings seemed to be a major cause of damage as the attached lines would become stressed, cracking poles, cables and wires in the system. N2 noted that damage was most severe in affected rural areas as almost all households collapsed, and this created follow on impacts as damaged lines created fires and electric shocks. N2 believed that damage in rural areas had impacts beyond households as electricity access was lost to health and communication services. This created challenges for the government's recovery operations as they could not communicate effectively (N2). In the affected rural cooperative systems almost 7,000 wooden poles were completely destroyed, and between 50-90% of all electrical infrastructure in these cooperatives was also destroyed or damaged (Sanjel and Nepal, unpublished). **Table 5.2.3** further details the damage to infrastructure in these cooperatives.

Table 5.2.3: *Damaged distribution infrastructure in affected electricity cooperatives. From Sanjel and Nepal (unpublished: pg.6).*

Component	Dhading	Gorkha	Kavre	Lalitpur	Lamjung	Ramechhap	Sindhupalchowk	Dolakha
Wooden Poles	1014	3226	3564	275	1889	150	125	10243
Conductor (km)	7.17	24.2	21.3	14.5	1	3	2.5	6.5
Energy Meters	302	1010	521	658	1186	54	495	550
Service Cable (km)	6.82	23.65	30.12	2.5	2.4	1	1	1
Consumers in District	4216	7262	1058	4587	3150	1750	751	8700

Various stakeholders had further comments on the earthquake's impact to distribution systems. G1 believed insulation within substation transformers, where transmission lines are connected to the distribution system, were vulnerable to earthquake damage. In Kathmandu, G6 described how the distribution system was shut off and isolated immediately after the earthquake, preventing fires. N2 noted that in urban areas, the damage to houses was not so extensive, so there were some alternatives for lighting if neighbouring buildings remained intact. However, in rural areas most houses collapsed which meant there was no access to lighting or energy supplies for people in those areas (N2). G6 believed a second earthquake, which occurred on the 12th of May, caused the most damage for distribution systems as it damaged already weakened infrastructure.

This evidence indicates that the performance of distribution systems against Sharifi and Yamagata's (2016) first criterion was unequal for the hierarchical NEA managed grid system and the egalitarian CREE and off-grid distribution systems. In both systems, the collapse of buildings led to the stressing and breaking of lines (N2). The stakeholders' responses however, suggest that this damage was worse in the affected rural areas compared to urban areas because of the less extensive damage in urban areas and the quick isolation of the distribution system there. The indirect impact was also worse in rural areas because the lack of electricity impaired recovery operations and meant there was no access to lighting (N2). It is difficult to assign full responsibility of this damage to either of the actors managing these systems as the nature of distribution systems require that consumers' households be physically connected to the system through lines. The ability of households to withstand earthquake damage is external to both the NEA's distribution and CREE and off-grid distribution systems roles, so the difference in system responses is partially a result of rural households being more vulnerable to earthquake damage than urban households.

5.2.4 PDNA Report Comparison

Section 1.4 summarised a preliminary evaluation of damage in the Nepal electricity sector following the earthquake. This evaluation, called the Post Disaster Needs Assessment (PDNA), was published by the Government of Nepal's planning commission, alongside the UN and several large donor agencies (NPC, 2015a, NPC, 2015b). Given that almost three years had passed since the earthquakes at the time which the results of this study were gathered, the above results make a useful comparison against those of the PDNA. This comparison is summarised in **Table 5.2.4.**

There is some disagreement between the results of this study and the damage reported by the PDNA. Generally, the PDNA reported more damage than was indicated by this study's results, with less hydropower generation damage, less off-grid households losing electricity access, and less substations damaged being reported by stakeholders. It is difficult to know which source is valid, however, the disagreement between the PDNA results and this study's results is not significant enough to warrant serious concern over the validity of either source. Together, the damage in the electricity sector, as given in **Table 5.2.4** from both sources, provides an assessment of damage from which is suitable to draw the following discussion.

5.3 Response to Earthquake Damage

Section 5.2 demonstrates that the major impact of the earthquake fell upon distribution systems and off-grid generation systems. This provided for very different experiences between urban and rural communities. The response to the earthquake by distribution and off-grid generation systems can therefore be considered separately for grid connected urban distribution, cooperative grid-extension and rural off-grid systems.

5.3.1 Urban Systems

In urban grid-connected areas the damage caused problems in the distribution system. This damage was generally repaired within a month, except in residential areas with severe damage where repair work is ongoing (G3). G6 claimed that the repair of the distribution system in Kathmandu was not uniform, with one distribution centre being able to restore their parts of the grid within four days, while some others took one to three months for the system to be restored (G6). Media support this claim, with one article reporting statements from the NEA's chief of distribution; which said that power supply had been restored to 75% of consumers in the Kathmandu valley within four days (Republica, 29/04/2015). It was also reported that electricity supply had been restored to essential services, such as hospitals and Kathmandu's international airport, by the evening after the earthquake (Republica, 29/04/2015).

Table 5.2.4: Comparison of Electricity Sector Damage Reported by PDNA and Results

Sector / System	PDNA Damage Report (2015)	Results (February/March 2018)
Grid Generation (Hydropower)	- 3 NEA stations damaged (48 MW) - 15 IPP stations damaged (123 MW) - Other stations damaged but still in operation with damage status unavailable.	- 13 grid connected hydropower facilities damaged at the time causing 150 MW of generation to be lost (G7, NEA). - By May 2015, 96 MW remained out of operation (NEA).
Off-Grid Generation	- 262 micro hydro projects damaged. - 115,438 solar home systems damaged. - 156 institution solar systems damaged. - 3.7 MW of generation lost across 81,000 households	- 239 (G7) or 267 (G2) micro hydro projects damaged. - Approximately 60,000 off-grid households lost electricity access (G7)
Transmission	- 7 substations damaged - 5 transmission lines damaged but remained in service; extensive length of the transmission line system meant damage assessment is timely.	- Transmission sector infrastructure not as badly damaged as other sectors (G1, N2, G6). - Substations vulnerable to insulation damage (G1). - Three substations damaged within Kathmandu (G6).
Distribution	- Electricity supply in Kathmandu restored within four days; Some distribution systems in the 14 affected districts still not restored at time of publication. - 1,577 km of lines of different voltages requiring restoration or reconstruction - 723 transformers requiring restoration or reconstruction - 143,519 energy meters requiring restoration or reconstruction - 49,670 distribution poles requiring restoration or reconstruction	- Main damage occurred in distribution system, with poles, cables and wires being damaged with the collapse of buildings. (N2, G6). - 7,000 wooden poles destroyed, and 50-90% of electricity infrastructure destroyed or damaged in affected CREEs. - Three service stations in Kathmandu damaged (G6) - System damage caused risk of electric shock, fires and challenges for recovery operations in rural areas (N2).
Sector wide	- 600,000 households directly lost electricity services. - 17,807 million NPR (approximately $175 million USD in 2015) of damages to the electricity sector in total.	- Sector wide damages approximately USD $212 million, with USD $58 million of damages in the private sector (G7). - Load dispatch centre damaged but operation restored within 8 hours (G1).

G6 described the systematic approach taken to repair the distribution systems which prevented fires from igniting from short circuits in Kathmandu. This approach saw isolated areas of the shut off distribution system being inspected and approved before being charged again (G6). These inspections were visual at first, with an electrical inspection then being given if needed (G6). This approach was not planned for but was effective in ensuring repair work could be undertaken safely without the risk of short circuits when the system was charged (G6). This approach occurred after both the April and May earthquakes (G6). The necessity of this approach was expressed to the public in the newspaper *Republica* (29/04/2015), which noted comments from NEA officials explaining that field studies needed to be undertaken before power supply could be resumed, in order to keep consumers safe. G6 also believed having insulated lines helped prevent short circuits and fires.

G3 expressed challenges for the repair of the grid distribution system, as repair work needed to be undertaken by existing resources and manpower. G6 also expressed a challenge, noting that immediately after the earthquake, the employees of the NEA first had to deal with their own fears and problems before undertaking repair work. However, G6 believed the motivation of the NEA personnel to repair damage, despite taking personal safety risks, was a key reason the damage could be repaired as quickly as it was. G6 noted that further challenges around access to repair supplies was an issue as the NEA did not have a stockpile of spare parts to undertake repairs (G6). Both the Indian and Chinese governments helped this problem by providing transformers, cable and other parts (G3, G6). G1 described how technical assistance from India was also provided, which especially helped the repair of transformers within substation. A media report from *Republica* (29/04/2015) supports this, saying that a team of 16 technicians from the Power Grid Company of India worked to restore power supply from substations.

5.3.2 Community Rural Electric Entities

Community rural electric entities (CREEs), being independent from the NEA, utilised support from local NGOs after the earthquake. N2 worked with electricity cooperatives in affected rural areas and described the initial priority to disconnect lines from damaged houses. After about two days, lines began to be reconnected to households, but N2 describes how the need for public utilities to have electricity restored first was realised shortly after this began. Within about a week these services were being reconnected, and after this time police and army personnel came to assist in the disconnection and reconnection efforts (N2). After the earthquake, N3 expressed that many CREEs "*did not have electricity for months because there was nobody to support them"*. Throughout that time, lines were managed in risky ways with cases of raw trees being used as replacement poles (N3). This was a quick method which enabled supply to be reconnected, but it is a dangerous practice (N3). A lack of finance held back repair efforts for these co-operatives, and many co-operatives required donor aid to get their systems running again (N3).

Box 5.3.2: Community Rural Electric Entities

N3 explains how rural community electricity projects are operated in Nepal. Where the grid has not reached rural communities, the government offers a 90% subsidy for the investment required to extend the grid to that location (N3). The community must come up with the remaining 10%, and once they have done so and the system is established, the community becomes solely responsible for managing that system (N3). They then operate the system by purchasing electricity in bulk from the NEA and selling the electricity to the CREE members (N3). This arrangement gives control of the system to the community, but means financial viability is always an issue for CREEs (N3). As a result, the earthquake affected CREEs did not have the finance available to afford the cost of repairs (N3). About half a million households are currently connected to the grid through this system (N3). Support is available to these community grid connection projects, otherwise known as community rural electric entities (CREEs), through the non-profit organisation National Association of Community Electricity Users-Nepal (NACEUN) (N3). NACEUN lobbies for CREEs across Nepal and provides capacity enhancement to CREEs by providing training for technical and financial/administrative staff (N3). This training is undertaken each year in collaboration with the NEA (N3).

Sanjel and Nepal (unpublished) have produced a report detailing the experience of electricity cooperatives and the National Association of Community Electricity Users Nepal (NACEUN), which is the umbrella NGO representing electricity cooperatives. NACEUN undertook a relief program for the affected cooperatives, providing solar phone charging stations, improved cooking stoves, electricity hardware and safety equipment for repairs (Sanjel and Nepal, unpublished). Financial constraints meant that supplies could not be provided to repair all damages, with supplies concentrated on basic and urgent needs in the four most damaged districts (Sanjel and Nepal, unpublished).

N2 believed that accessing the required amount of manpower was one of the main challenges for these cooperatives. In order to mitigate this, N2 described how they mobilized teams of technicians of cooperatives in affected areas to help other co-operative systems in affected areas. However, a further challenge arose as these technicians had suffered their own losses from the earthquake (N2). To help these technicians, N2 described how they purchased materials such as tarpaulins and tents to provide a temporary shelter for their technician's families. This then allowed those technicians to focus more of their efforts on the electrical system repairs (N2). This challenge was not limited to co-operatives as the private sector involved in community micro hydro also faced a lack of manpower following the earthquake (P3). Despite the challenges of getting enough manpower, A1 believes rural communities have the technical capacity to maintain their own systems. N3 reflected this sentiment for grid connected co-operatives, although noted that irregular issues may require external help. The rural topography was a further challenge for co-operatives after the earthquake, as the absence of roads means infrastructure like poles, which weigh more than 100 kilograms, need to be carried in (N3, Sanjel and Nepal, unpublished). The difficulty in accessing electrical appliances and parts as the market had no supply and no stock was also an issue (N2).

5.3.3 Off-grid Systems

G2 described how off-grid systems experienced damage beyond their distribution components as many micro hydro systems were damaged also. G2 explained that the Alternative Energy Promotion Centre (AEPC), which is the government agency supporting off-grid systems, provided grants to off-grid communities to provide for the rebuild/repair costs of damaged micro hydro projects. A total of 49 projects where repaired through these grants (G2). However, the money available for these grants has now been taken up, so as per policy the AEPC can now only provide 80% of the rehabilitation costs leaving the community to pay the remaining 20% (G2). G2 believed that communities in the affected regions are not able to pay this 20% because of their poor financial capacity and need to address more important matters. It is worthwhile noting that until 2018, about 60% of the financial support for the AEPC came from foreign donors, but this support has now decreased to about 20% of the AEPC's running costs. This may have contributed to AEPC's inability to provide full repair grants (G2).

G2 also explained how, in the immediate aftermath of the earthquake, the AEPC was limited in their capability because their legal mandate to distribute resources required following usual procedure. Their legal mandate also restricted them from paying their staff more in order to encourage them to travel into areas with ongoing aftershocks to facilitate repairs (G2). Just as the NEA and electricity cooperatives had difficulty accessing repair supplies, the AEPC also found it difficult to source repair supplies from outside of Nepal, as it took time for parts to arrive from India and China (G2). Accessing remote communities without road access also added another challenge (G2).

In both off-grid systems and cooperative connected systems small solar devices were in high demand after the earthquake because some micro hydro systems or lines were not operational for more than a year (P1). These solar systems could provide lighting, radio and cell phone charging, and an example of one of the systems being offered by P1's company is pictured in **Figure 5.3.3**. P2, another independent power producer, also became involved in small solar home systems after the earthquake even though this wasn't a market they were involved in, because there was a lot of demand for these systems at the time.

Box 5.3.3: Alternative Energy Promotion Centre

G2 explained how micro hydro is supported by the AEPC. The AEPC supports capacity development and trains micro hydro operators for communities with off-grid systems (G2). This is motivated by the fact that every year, two or three untrained operators die from trying to repair systems (G2). The AEPC also provides management training (G2). In each batch 25 participants are trained, and this costs about 1.5 million NPR (about $13,500 USD), because the AEPC needs to provide lodging, food, and study costs for 28 days (G2). Unfortunately, the AEPC cannot provide enough training to meet the demand because of their limited budget (G2).

Figure 5.3.3: *The small solar devices which were in high demand after the earthquake, due to their ability to provide light and cell phone charging without access to electricity system.*

A combination of hierarchical and egalitarian actors contributed to the earthquake response through the community operated off-grid systems supported by government's AEPC. Comments from G2 explained that the AEPC provided grants to finance the repair of damaged micro hydro projects but was only able to provide 49 of these grants due to budget limitations (G2). The limited budget which the AEPC had to support communities in the repair of their micro hydro projects significantly weakened the capability of the AEPC and off-grid system operators to adapt to the external changes created by the earthquake. The further noted issues of a strict legal mandate and difficulty accessing repair supplies also weakened this capability to adapt. Where the hierarchical government and egalitarian cooperative actors failed to supply electricity after the earthquake, the individualistic private sector stepped in to provide small solar systems, with P1 and P2 both offering these systems despite P2's company originally being out of this market. Although the systems could only provide electricity supply for lighting, phone charging and radio, the ability for the private sector to step in where the other actors had failed demonstrates their strength to self-organise in response to external changes.

5.3.4 Unequal System Responses

Considering delivered energy services, The evidence from stakeholders show that the capability of the NEA managed grid system and the CREE and off-grid systems to respond to the earthquake damage was unequal. In Kathmandu, the NEA was reportedly able to repair the distribution system within three months through a systematic method where isolated parts of the system were inspected and repaired before being reactivated (G6). This was aided by the NEA's ability to draw on assistance from India and China to do this, although they did face issues accessing repair supplies (G6). As a hierarchal actor, the ability of the NEA to establish a systematic method for repairs and draw on international assistance provided the capability for the NEA-managed grid distribution system to adapt to the damage created by the earthquake.

The results given from stakeholders indicates that public utilities and some households within CREE systems had lines connected quickly, but others did not have an electricity supply for many months (N2). The capability for the CREEs to respond was weakened because of a lack of finance and support, which meant repair efforts were held back and lines were managed in risky ways (N2). However, the actions of NACEUN, as an egalitarian actor, provided support through technical, resource and financial assistance. To some extent, these actions provided the support to CREEs in place of the support which was given to the NEA-operated grid by the government. This demonstrates that in the CREEs case, a failure to be given support through a hierarchal actor necessitated that an egalitarian actor takes this role. However, NACEUN still had to focus resources on the most damaged districts as they did not have the resources to supply all needs (Sanjel and Nepal, unpublished). In this case, the egalitarian NACEUN actor provided some capability for the grid connected cooperative systems to adapt to external changes introduced by the earthquake, but this was limited by the support NACEUN could access from the government and their wider member community.

5.4 Actions to Increase Future Resilience

Key stakeholders mentioned several actions which have been suggested since the earthquake that would strengthen resilience in electricity systems in Nepal. In management infrastructure, G1 noted that the NEA plans to develop a second load dispatch centre in another area which can be used in the event that the existing load dispatch centre is disrupted by an earthquake. For generation infrastructure, G1 believed that the private sector needed regulation to reduce vulnerability to a future earthquake. G1 held this belief as they considered the resilience of government power facilities to be the result of the government following international standards and using international contractors. G1 therefore suggested that building standards, particularly for the private sector, would help reduce damage in the event of another earthquake; saying:

> *"I think we have to make some basic construction standards… what we found was that the independent power plants, they faced a lot of problems during the earthquake. As we are in the*

government sector, our power plants they have only a little damage… This maybe the cultural standard of independent providers". (G1)

P1 however contested this view, saying that it was hard to say whether private projects were more vulnerable than government projects because the earthquake was very site specific, and damages were fairly distributed to both government and private projects.

In the distribution sector, the government has been supporting NACEUN and community grid electricity co-operatives to replace 50% of wooden poles with steel poles, in an effort to improve physical resilience (N3). Steel poles are also replacing wooden and concrete poles in urban areas for the same purpose (G6). These poles are shown in **Figure 5.4**. Through the earthquake damage repairs, G6 believes there has been some degree of strengthening performed on the distribution system, despite there not being a strengthening program undertaken. In addition to the replacement of poles in the cooperative systems, NACEUN has increased resilience for the cooperatives by building capacity within the cooperatives to manage earthquake damage (Sanjel and Nepal, unpublished). This was done by coordinating meetings and discussion, organising supervision and consultation with stakeholders, and providing training for linesmen and accountancy staff (Sanjel and Nepal, unpublished). NACEUN also encouraged that risky transformers be repositioned to increase safety (Sanjel and Nepal, unpublished).

Figure 5.4: *Steel poles are being used to replace weaker wooden and concrete poles, which collapsed during the earthquake, damaging lines and cables.*

The experiences of CREEs following the earthquake demonstrates an ability to meet Sharifi and Yamagata's (2016) last component of adaptive resilience, which is an ability to learn following the earthquake and increasing coping capacity in the event of another disaster. The CREE cooperatives have been supported by the government and NACEUN to increase physical resilience through the replacement of wooden poles with steel poles (N3). This has occurred in urban areas for the NEA-operated distribution system also, however Sanjel and Nepal (unpublished) indicated that support from NACEUN has also enabled CREEs to build technical and administrative personnel capacity through training and communication.

5.5 Importance of Energy Resilience

The importance these results, which have been found using the concept of energy resilience to investigate the response of Nepal's electricity sector to the earthquake is evident when considering energy security, energy poverty and energy justice. Considering energy security at the national scale, the 150 MW loss of generation capacity and the damage to around 260 micro hydro plants represents a significant loss to the *availability* dimension of energy security from Sovacool and Mukherjee (2011). No evidence given from stakeholders suggests that this worsened *affordability* of electricity, which may be a result of the government fixing tariff prices without adjusting for operating costs until 2016 (ADB, 2017a). The model by Kruyt et al. (2009) suggests a loss to *availability* of energy would require that a nation increase *accessibility* of energy, which for Nepal's case, would translate to an increased import of electricity from India to fill the shortage in generation capacity. This relationship is blurred as the existing demand was less than the generation capacity prior to the earthquake, but electricity imports from India did increase by 160 MW across 2016 (Press Trust of India, 30/12/2016).

At a community and household scale, the impact of the earthquake on energy poverty and energy justice can be realised. There are three different ways an electricity consumer can access electricity in Nepal, either through the NEA-operated and partially privately generated grid, through a grid extension operated by a CREE, or through an off-grid system. After the earthquake the grid system became operational within 8 hours, despite a loss of 150 MW of generation capacity and damage occurring within the load dispatch centre. In earthquake affected areas, particularly within the Kathmandu Valley, parts of the distribution network were isolated and electricity supply lost. However, 75% of the supply in the Kathmandu Valley was restored within four days. In comparison to the grid supply system, consumers within CREEs and off-grid systems experienced significantly worse damage, with many consumers losing electricity for months. This was partly due to CREEs and off-grid systems supplying rural areas where the destruction of houses because of the earthquake was widespread, which consequentially resulted in widespread damage to the rural distribution networks. Collapsing buildings and infrastructure damage occurred for the NEA-managed grid distribution systems also, but the less extensive damage in urban areas meant electricity access in surviving neighbouring buildings at least provided an alternative source of electricity for lighting (N2).

These impacts have implications for energy poverty. A loss of electricity access, even if temporarily, means those households would have lost the economic, social and health benefits that come with electricity access (see **section 2.5**). The PDNA identified this as an issue, saying that the estimated 600,000 households which lost electricity services because of the earthquake consequentially suffered negative impacts on their ability to "*derive their livelihoods and generate income*" (NPC, 2015b: pg. 149). In addition, the PDNA reported that some women were required to increase their burden of work by gathering firewood in the absence of electricity access, while the loss of lighting meant a recognised deterrent to violence was lost (NPC, 2015b). The results presented in this study agree with the position of the PDNA and show that a significant number of users in all three electricity delivery systems would have lost electricity access, therefore worsening energy poverty issues.

Importantly, the extent to which the different electricity delivery systems lost electricity access was unequal. Although many grid-connected electricity users lost electricity access, the grid-distribution system recovered much faster than the other two delivery systems. These inequalities have implications for the principles of energy justice from Islar et al. (2017) as off-grid and CREE consumers lost the availability of quality energy services required to enjoy a minimum standard of wellbeing, which is the foundation of the intragenerational equity principle. The earthquake therefore deepened energy access inequality between grid users and CREE and off-grid users, at least temporarily while services where being installed.

5.7 Conclusion

This chapter has examined the response of the Nepal's electricity systems to the earthquake, using a range of stakeholder responses. The impact of the earthquake on electricity service supply was most severe for cooperative and off-grid users, with less persistent damage occurring in urban areas. The response in urban areas was also managed faster, and the grid electricity system adapted and responded to the earthquake in an expeditious manner. Where the cooperative distribution systems were left without support, the egalitarian actor NACEUN stepped in to provide that support. However, as with the AEPC's support for off-grid communities, a lack of finance hindered recovery efforts. Some efforts have been made since the earthquake with vulnerable poles being replaced with steel poles and enhancement of personnel capacity being undertaken in cooperative systems. These results are important because the 150 MW loss of generation capacity following the earthquake damaged the energy availability dimension of Nepal's energy security. The loss of electricity access to approximately 600,000 households would have also worsened energy poverty issues and the unequal response of the urban and rural distribution systems meant energy access inequality in Nepal was deepened.

6 Blockade Response

This chapter examines the response of Nepal's petroleum sector to the 2015-2016 blockade. This response had implications for Nepal's energy security and geopolitical relationships.

6.1 Introduction

This chapter explores Nepal's petroleum sector response to the 2015-2016 Nepal-India border blockade. This addresses the second primary research objective of this thesis and continues the use of the energy resilience concept from the previous chapter. Additionally, this chapter contributes to the gap in literature regarding the impact of the Nepal-India border blockade. Following the conceptual approach given in **Chapter Two**, this chapter examines the impact of the blockade on the petroleum sector by examining the way in which the controlling authority of the petroleum sector, the Nepal Oil Corporation (NOC), managed petroleum fuel systems through the blockade. Actions planned by the NOC to increase coping capacity against similar events are also explained. In applying an energy resilience approach to examining the petroleum sector response to the blockade, this chapter demonstrates that the blockade had implications for Nepal's energy security and geopolitical relationships.

To begin this chapter, it is useful to give the context to Nepal's petroleum sector as explained by O1, which indicates why Nepal was vulnerable to the blockade. As described in the energy overview chapter (**Chapter Three**), Nepal is a landlocked country and the only means of importing petroleum fuels is through road transport from the Indian Oil Corporation's (IOC) depot (O1). The NOC has contracts with the IOC which allows it to purchase crude oil on the international market in exchange for the refined petroleum products which the IOC provides to the NOC (Ebinger, 2011a). These products are sourced from five IOC depots or refineries within India, with the Raxual Depot being the supply point for the highest consuming central region (NOC, 2018b). These refined products are transported through a fleet of 1,700 contracted fuel trucks (NOC, 2018a). O1 illustrated the consequences of this reliance on overland fuel transport, saying "*Whenever there is any kind of road obstruction, then the supply is getting affected. This is the reality"*.

6.2 Impact of the Blockade

O1 described how the blockade impacted the NOC's operations. NOC Fuel trucks could not pick up fuel at the IOC depot, nor could they pass back into Nepal smoothly, so the supply of fuel was decreased (O1). This meant the amount of fuel being supplied to the NOC depot was not constant during the blockade. *"Sometimes we used to get 10-15%, sometimes 30-40%, sometimes it went up to 70%. There was various levels of obstruction."* (O1). The decrease in supply for transport fuels throughout the blockade is clearly shown in **Figure 6.2.**

The extent to which rural consumers were affected by the blockade is not clear from stakeholder responses. N3 believed these consumers did not feel the effects of the blockade as acutely as people in urban areas, as fuel use is mostly limited to biomass burning for cooking (N3). N3 however, along with G2, understood that the use of LPG in rural areas for cooking purposes has been increasing.

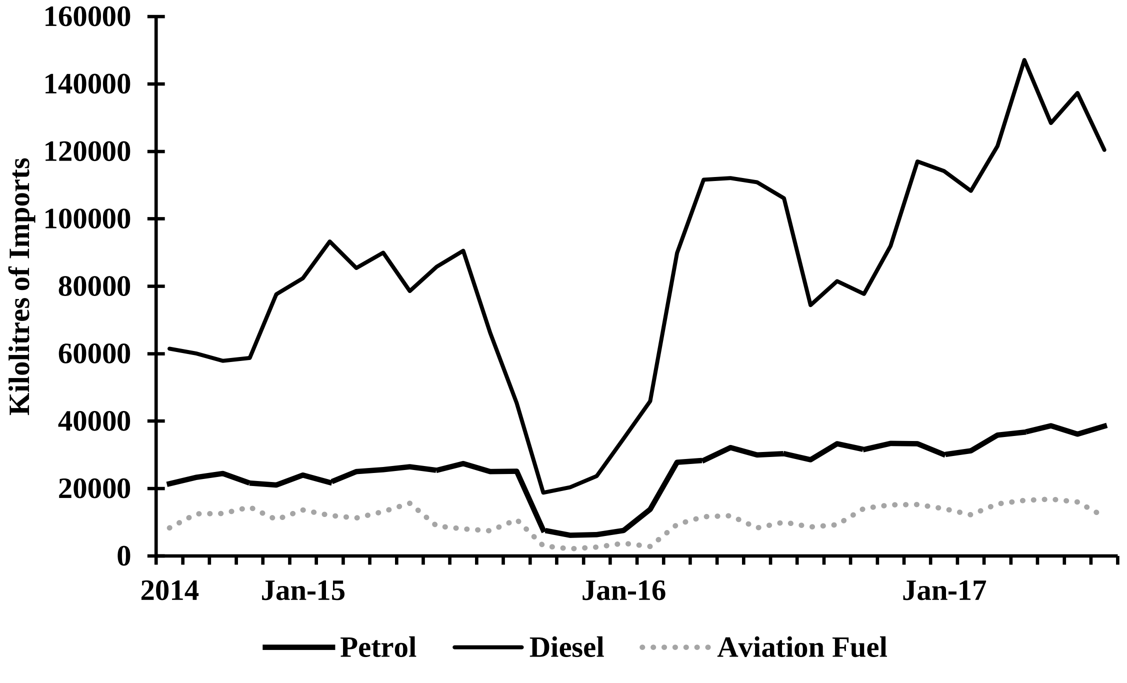

Figure 6.2: *Monthly fuel imports from mid-2014 until mid-2017. The blockade is clearly shown in the drop of imports between 2015 and 2016. (Data from NOC).*

The impact of the blockade was experienced by stakeholders outside the petroleum industry. Private power producer P2 believed the blockade increased demand for solar more than the earthquake did, as the fuel shortage meant businesses realised solar could play a role in providing their energy demands. Both NG5 and G7 described how the energy demand for cooking uses was picked up by electrical cooking appliances where LPG was unavailable. Electricity distribution systems were already overloaded and as this appliance use increased peak demand for electricity, transformers became overloaded and burnt out (NG5, G7). This issue was widespread (NG5, G7). G7 believed a result of the repairs to transformer damages has seen the distribution load capacity in Kathmandu slightly increased to around 400 or 500 MW.

The impact of the blockade was also realised beyond the energy sectors, as was reported clearly in the media. Rai (28/01/2016) described cases of job losses and reported statements from a former governor of the central bank, who said that malnutrition could rise as low-income people were losing jobs and paying more for food and fuel as a result of the blockade. Rai also reported statements from an economist who believed that the blockade would have a long-term impact by discouraging investors (28/01/2016). The Kathmandu Post (21/06/2016) acknowledged the damage which had occurred to commercial and industrial sectors with the fuel and material shortages disrupting distribution and production. Shrestha (21/11/2015), citing information from government departments, reported that the blockade would result in GDP growth contracting to -0.9%. This would see more than 800,000 people pushed into extreme poverty, which is 100,000 more than the 700,000 reported to have been pushed into extreme poverty because of the earthquakes (Shrestha, 21/11/2015; (NPC, 2015a)). In reality, the GDP growth decreased from 6.0% in 2014 to 3.3% in 2015 and 0.4% in 2016, so the real number of those pushed into extreme poverty is likely to be less than the 800,000 reported (World Bank, 2018e).

Outside of the media, the Nepal Economic Forum published a comprehensive post disaster assessment of the blockade, which detailed the impact of the blockade on various sectors (Shakya and Bhattarai, 2016). They reported that agricultural production fell due to shortages in fertilizers and increased input costs, tourism fell because of lower visitor numbers and increased operating costs for hotels and restaurants, and the health sector struggled due to the shortage in medicine and surgical equipment (Shakya and Bhattarai, 2016). For the commercial and industrial sectors, a loss of USD $2.0 - $2.7 billion was estimated due to the shortage of fuel and materials and the demurrage charges incurred as cargo trucks were delayed (Shakya and Bhattarai, 2016). This reportedly meant that 400,000 workers became unemployed as factories were forced to close or decrease production (Shakya and Bhattarai, 2016).

The blockade can be considered through Sharifi and Yamagata's (2016) components of adaptive capacity. The presented evidence suggests the NOC, as the hierarchical operators of the petroleum fuels sector, had little ability to withstand the shock induced by the blockade. This was a result of stockpile and supply inadequacies as the NOC has minimal storage capacity and no other source of fuels than the over ground, road-based supply from the IOC. These are two major vulnerabilities in the system.

6.3 Management of the Blockade

O1 describes how the quantity of fuel that was available during the blockade was distributed. Emergency fuel requirements, such as the needs of hospitals, were prioritised. Fuel was provided for public vehicles and public transport, but the normal supply of fuel could not be given to private vehicles. When there was enough fuel to supply to the market, it would be rationed at a limited quantity (O1). Consumers were notified of the quantity available via the newspaper, and different consumers could use particular petrol pumps according to the letter on the license plate (O1). During the blockade, China offered 1000 metric tons of petrol, a non-commercial quantity, to Nepal, and lifted all usual rules and regulations which were in place to do so (O1).

News reports describe the blockade management by the NOC in more detail. According to *Republica*, two-wheeled vehicles were given 3 litres per week, while private, government owned and taxi operated vehicles were given 10 litres per week (Dhungana, 28/09/2015). Public vehicles were given more fuel, with micro buses getting 15 litres, mini buses getting 20 litres, and large buses getting 30 litres of diesel on alternate days (Dhungana, 28/09/2015). *The Himalayan Times* supports this information, citing statements from a NOC spokesperson (Acharya, 27/09/2015). The *Republica* and *The Himalayan Times* also reported that the Ministry for Home Affairs helped manage the fuel shortage by enforcing odd-even rationing for vehicle use, where both private and public vehicles could only be used on alternating days determined by their number plate (Dhungana, 28/09/2015; The Himalayan Times, 26/09/2015). Shortly after rationing began, a report in *The Kathmandu Post* on the 14th of October described how some motorists were not able to receive their fuel ration despite queuing for 12 hours (Khanal, 14/10/2015). The disorder created by the fuel rationing then prompted criticism of the NOC for not managing the distribution well, although the deputy managing director of the NOC blamed issues with fuelling tankers as the cause for the distribution issues (Khanal, 14/10/2015).

In the domestic aviation sector, aviation fuel was supplied for domestic airlines by using the larger carriers of Nepal Airlines (the national airline) to fly to Kolkata, where they would fill their fuel tanks to the highest capacity (O1). The aircraft would then fly back to Kathmandu and their remaining fuel would be decanted and collected at the NOC depot (O1). This allowed the domestic airline services to continue operating throughout the blockade (O1). For international aircraft, they were requested not to take fuel in Kathmandu, and therefore were required to carry enough fuel on board to make their return journeys (O1).

Although it was not mentioned by stakeholders, the media reported the proliferation of the black-market in supplying fuel as a result of the blockade (The Kathmandu Post, 21/06/2016, Pattison, 3/03/2016).

Pattison (3/02/2016) described how thousands were smuggling fuel from India to Nepal, bringing in an unsupported claim of 100,000-150,000 litres of fuel each day. In 2014, approximately 3.3 million litres of petrol and diesel were imported each day, so if Pattison's claim of 100,000 – 150,000 litres is true, the black market supply would not have provided a significant alternative to the NOC's supply (NOC, 2018d). However, the high cost of fuel during the blockade still allowed for significant black-market economies to develop in towns near to the border (The Kathmandu Post, 21/06/2016; Shakya and Bhattarai, 2016).

The evidence presented here suggests the petroleum sector's inability to withstand shock meant the petroleum distribution system consequentially needed to change in character. The IOC possessed the capability to adapt and form this new character by managing the supplies of fuels which they could access, as O1 described. The prioritising of public and emergency vehicles, reorganisation of supply for aviation fuel, and the rationing of fuel for private vehicles demonstrates that the IOC had the capability to accommodate the external changes brought about by the blockade. This capability to adapt the petroleum fuels system to the external changes of the blockade demonstrates that the IOC possessed Sharifi and Yamagata's (2016) second component of adaptive resilience. The management of the blockade by the NOC also demonstrates an effort to retain the energy justice principle of intra-generational equity from Islar et al. (2017), as the prioritising of fuel supply for public and emergency vehicles meant minimal energy services were retained for all. Scholarly literature has not, however, acknowledged the response of the NOC to the blockade, while media articles have described, but not supported, the NOC's blockade response (Dhungana, 28/09/2015; Acharya, 27/09/2015).

6.4 Future Resilience in the Petroleum Sector

O1 pointed to two actions which are being taken to improve resilience in the petroleum sector, particularly against the threat of disruption to supply, which was experienced in the blockade. The first action is the construction of a pipeline which will connect the IOC depot to the NOC depot. With the pipeline installed, O1 believes there won't be any kind of surface obstruction to supply. Currently there are many factors involved in getting fuel from IOC depot to NOC depot as there are private contractors that need to drive the trucks from one side to the other. If these contractors suffer any issues, either technical or otherwise, the supply of fuel to NOC is affected (O1). With the pipeline, these obstructions to supply will be removed.

Additionally, O1 believes a blockade similar to the one experienced in 2015-2016 will not be able to disrupt fuel supplies because an official declaration of a blockade would be required to stop the flow of fuel through the pipeline. In the blockade, there was no official declaration as O1 believed this would have been viewed negatively for India in international politics; saying *"India, being a big country, [undertaking a] clamping blockade against a small country like Nepal doesn't give a good impression in the international arena"*. Such an official declaration was not given during the blockade because the

Indian government placed blame on protestors from the Madhesi community, who are an ethnic group which live in the South of Nepal near to the India-Nepal border (Agarwal, 1/10/2015; Dixit, 18/11/2015). This could justify the disruptions experienced by NOC suppliers, but such blame would not be able to justify the ceasing of fuel supply through a pipeline. For this reason, O1 believed the pipeline would prevent such a blockade occurring again in the future. O1 had sought confirmation from IOC staff on this issue:

> "*I had to seek confirmation – 'If we lay your pipeline what will you do? Last time we suffered a lot, getting the production out of the supply agreements. From NOC's side, we fulfilled all contractual obligations and then you didn't deliver the required quantity of fuel to us. If we lay a pipeline, what will be the scenario?' That was clearly discussed with them, and they have said sorry, for the last time… Both of the oil companies [IOC, NOC], we are very clear that with the laying of this pipeline the supply scenario will be strengthened, and it will be improved"* (O1)

The second action which will improve resilience in the petroleum sector is the development of stockpile capacity. There is currently a goal to achieve 90 days of fuel consumption storage in Nepal, as at present there are only around 5-6 days of consumption storage (O1). O1 suggested that a halt in supply takes around 15 days to recover, so a storage capacity of 15 days is required to allow petroleum supply to continue smoothly through a supply disruption. O1 proposed that the NOC has the capital and financial means to construct this storage themselves but describes a number of further challenges which need to be addressed. This includes the need for the NOC to meet international standards for fuel storage and handling, and this requires international experts (O1). Because no storage facility has been created in Nepal for 20 years there are no engineers or personnel with expertise in creating storage facilities available to the NOC (O1). As a result, the NOC is considering engaging international agencies such as the ADB to get that expertise, and possibly loan finance if it is offered (O1). Additionally, as a government agency the NOC must abide by strict rules when purchasing land for storage facilities (O1). It may be related to this issue that since the time of the research, Nepal's Commission for the Investigation of Abuse of Authority has continued an ongoing investigation against the NOC for irregularities while purchasing land for petroleum storage infrastructure (Himalayan Times, 6/08/2018).

Given the short time period which has passed since the blockade, it is difficult to use the comments from O1 to evaluate whether the IOC has the ability to learn from the blockade and increase coping capacity. If the pipeline and storage capacity improvements which O1 proposed are established successfully, Sharifi and Yamagata's (2016) third component would be met. Conversely, if the expertise and legal difficulties the NOC is facing in establishing the storage capacity prevent adequate storage capacity from being constructed, the NOC would fail to meet this component.

Figure 6.4a: *Pipes which will be used for the pipeline connecting the IOC and NOC depots. From NOC (2018e).*

Figure 6.4b: *NOC petroleum fuels storage. From NOC (2018e).*

6.5 Importance of Energy Resilience

The importance of resilience in Nepal’s petroleum sector during the blockade is demonstrated through the impact of the blockade on Nepal’s energy security. Winzer's (2012) framework for energy security demonstrates that the blockade was a fast change brought on by human-sourced risk, which caused a unique, national and sustained impact. The blockade demonstrated vulnerabilities in Nepal’s petroleum fuel systems, and this had a pronounced impact for Nepal’s national energy security. When considering the commonly used four A’s of energy security, the blockade significantly decreased the *affordability* of petroleum fuels for consumers and demonstrated an inability to *access* energy resources through India (Kruyt et al., 2009, APERC, 2007). The two energy security dichotomies by Kruyt et al. (2009) suggest that a decrease in *affordability* demonstrates a weakening in economic efficiency, while a decrease in *accessibility* demonstrates a weakening in regionalisation. This may have implications for energy futures, which is discussed in the next chapter. Although the *availability* of fuels was decreased in Nepal, the blockade was not related to a shortage in fuel on the global market so the *availability* of fuels in a nation-scale energy security sense was not affected. There has been no evidence to suggest the blockade created environmental or *acceptability* impacts aside from the decrease in petroleum consumption, although this was not sustained as, **Figure 6.2** shows petroleum imports increasing after the blockade ended.

Considering energy security and energy poverty at a household scale, Herington and Malakar (2016) believe that the blockade caused some individuals to move their energy use habits towards energy impoverishment in order to attain greater personal energy and human security. This was done, for example, by restaurants who changed their cooking methods to serve traditional dishes and wood-fired pizza that could be cooked with biomass and traditional stoves (Herington and Malakar, 2016). The results of this study do not totally agree with Herington and Malakar's (2016) suggestion, as both NG5 and G7 believed that some LPG users switched to using electrical cooking appliances during the blockade. P2 also believed the blockade increased demand for solar technology. These responses suggest that the blockade caused users to move their energy consumption habits horizontally towards other advanced energy resources in the face of adversity. Herington and Malakar (2016) do note that some users switched their cooking methods to electric appliances, and this study does not imply that Herington and Malakar's (2016) reverse energy ladder model is inherently wrong. What it does demonstrate is the fluidity of personal energy security where users are experiencing disruption to their existing energy consumption habits.

Although unanticipated through the literature review, the damage the blockade had to Nepal’s energy security may have had flow on effects for foreign policy. Since the blockade, Chinese investment into hydropower in Nepal has continued and the donation of petroleum from China proved that importing fuel, although not easy, is at least possible (Murton et al., 2016). Earlier this year, the contract for the construction of Nepal’s largest hydro dam was also given to a Chinese group (Sharma, 23/09/2018).

Further, an agreement has been signed between China and Nepal recognising the possibility of a rail connection from Kathmandu to China (Giri and Giri, 24/08/2018, Baral, 17/09/2018). It is difficult to say whether the impacts of the blockade have encouraged Nepal to strengthen ties with China, especially given that Nepali politicians have been accused of exaggerating India's role in the blockade for political gain (Jha, 06/02/2016). However, it stands that the blockade furthered a desire within Nepal to move away from an economic and political reliance on India.

6.7 Conclusion

The results presented in this chapter suggest that the NOC, as the monopoly operator of Nepal's petroleum sector, did not have a strong ability to withstand the shock to supply caused by the blockade. The NOC, however, did appear to manage the blockade in a way which retained supply for public and emergency vehicles, ensuring to some degree that the energy justice principle of intragenerational equity was met. The response from O1 indicated that the proposed cross boundary pipeline and goal to increase storage capacity within Nepal will increase the ability of Nepal's petroleum sector to withstand a similar blockade in the future. The blockade highlighted significant vulnerabilities in Nepal's petroleum sector, and the influence these vulnerabilities had on Nepal's national energy security was examined. In the next chapter, the lessons learned from the blockade will be used to critically analyse Nepal's potential energy scenarios, in a bid to examine how the resilience of Nepal's energy systems should be considered in the future.

7 Energy Futures

This chapter extends the energy sector overview given in Chapter Three to look at energy futures for Nepal. Three questions are asked: What future demand is likely for Nepal? How will this energy be supplied? And what does this mean for energy resilience?

7.1 Introduction

The preceding earthquake and blockade response chapters have shown that the response of earthquake systems to shocks has implications on energy security, energy justice and energy poverty in Nepal. Knowing that the resilience of energy systems is critical for understanding how different energy outcomes may be achieved, this chapter seeks to investigate what Nepal's energy futures could be, and in doing so, analyses what these futures mean for energy resilience. Stakeholder responses are used to do this, alongside the results of the previous chapters, surveyed policy and wider literature. This builds upon the energy sector overview chapter (**Chapter Three**).

The first part of this chapter shows that Nepal's future energy demand across the electricity and petroleum sectors will grow significantly, but with significant variability in growth possibilities. The second part of this chapter indicates how this demand may be met through hydropower, solar PV, and energy trading; across different distribution possibilities. The chapter then shifts to suggest the energy resilience implications of these energy futures. By providing this analysis of resilience in Nepal's energy futures, this chapter concludes that three axes of possibilities are emerging for Nepal's future energy scenarios. These are a centralisation of electricity systems versus an electricity sector which is distributed, the regional integration of Nepal's energy systems versus an isolation of Nepal's energy systems, and the use of fossil fuels in Nepal's energy systems versus the use of renewable energy. Using the evidence given throughout the earlier three sections, this chapter argues that these energy futures will have implications for energy security, energy poverty and energy justice in Nepal.

7.2 Future Growth of Electricity Sector

To develop an idea of the future for Nepal's energy systems, it is critical to understand the demand those systems will have to meet. By doing this, the chapter is able to assess the need to meet future demand alongside resilience issues. Stakeholder responses, policy and reviewed literature are given to suggest Nepal's future electricity demand.

7.2.1 Stakeholder Responses

Stakeholder responses suggest that it is not clear how much the demand in Nepal will grow in the future. N6 believed that the generation potential of Nepal is ultimately determined by its market, not the technically or economically feasible figures. Speaking on the domestic market, N6 said "*You will not realise a vibrant domestic market unless other supporting policies are put to place, on developing industries, promoting household electrical appliances…Until then you are a limbo where the domestic market is quite, in some sense, saturated."* Speaking of demand growth with the current policies in place, N6 said *"there is increasing demand, but that demand is nominal. It won't turn to 20,000 MW tomorrow".*

Whilst there are clearly some policy challenges for future demand, many stakeholders believe that Nepal has the potential to accommodate these. Indeed, A2 expressed that the potential for growth is high, saying "*The demand can grow exponentially… Nepal spends billions and billions importing natural gas for cooking purposes. If we can replace import of natural gas into the cylinders by electricity, then suddenly there will another be a rise of three or four thousand MW"*. A2 believed that a better option for Nepal, instead of exporting electricity to India (or even China) for manufacturing purposes, is to use that electricity within Nepal for those same purposes. The huge cost of energy imports to Nepal's economy was another issue A2 acknowledged.

If the demand for electricity cannot be met by the grid, load shedding may occur. Load shedding, which is the deliberate shut off of supply to certain areas of the grid at certain times, was used to manage the shortfall of electricity supply in Nepal until May 2018 when both the NEA and Prime Minister Oli stated that load shedding had ended in Nepal (Himalayan Times, 28/05/2018, Nepal Republic Media, 15/05/2018). N6 believes the previous load shedding has now been managed through three actions; with more electricity being purchased from India, the development of key transmission links, and better load management decisions being made. At the time of the interview, N6 described how these load management decisions were made to the benefit of the domestic sector and the loss to industry. Since this study's field research concluded however, media has reported that industrial load shedding has now ended from May 2018 (Nepal Republic Media, 15/05/2018). The possibility of load shedding returning if electricity growth cannot be met by electricity supply will need to be considered for Nepal's energy futures.

7.2.2 Policy Directions and Demand Projections

The policy documents surveyed indicate targets which, if achieved, would see the level of access and demand for electricity services rise significantly in the future. Nepal's Intended National Determined Contributions (2016) set targets to achieve 80% electrification by 2050 through renewable sources, while the Universalizing Clean Energy in Nepal (2018) plan seeks a more ambitious goal to ensure grid access for all by 2022. Meanwhile, the Nepal Sustainable Development Goals status and roadmap report (2017) seeks to achieve 99% access to electricity services by 2030, with 15,000 MW of installed generation capacity and a per capita energy consumption of 1500 kWh. While these targets differ between the policy documents, the motivations of these goals are to increase energy access, particularly to the poorest communities in rural areas of Nepal, and to provide higher quality electricity services (NPC, 2017a, NPC and NEA Engineering Company, 2018).

Demand projections analysed in the context chapter (see **Tables 3.3.1-3**) envisioned total electricity demand by 2030 increasing to somewhere between 12,200 GWh and 16,500 GWh (WECS, 2017) or 8100-23,300 GWh (Parajuli et al., 2014). In WECS (2017) projections, a generating capacity of 9000-13,300 MW would be required. Parajuli et al. (2014) did not provide required generating capacity, but their projections suggest that there will be increase in demand somewhere between 2-5.5 times the demand approximated in 2015. While useful, it is important to acknowledge that the precision of these projections cannot be held with great weight, as there is wide variance between projection scenarios and the projections given by Parajuli et al. (2014) and WECS (2017). Additionally, G6 expressed concern over the way demand is forecast, saying that the GDP based load forecasting which is currently used is not accurate because of the suppressed demand managed by load shedding.

Considering policy and demand projections alongside stakeholder responses, it is clear that electricity demand will grow significantly in Nepal's energy future. The degree to which this happens will be determined by Nepal's propensity to use electric appliances for cooking, to develop electricity consuming industry and to widen electricity access to more users. An inability to meet this demand in the future may result in the return of load shedding.

7.3 Future Growth of the Petroleum Sector.

The future of Nepal's petroleum sector will have implications for energy resilience, because **Chapter Six** demonstrated that the petroleum sector is vulnerable to supply shocks. Understanding how demand will grow in the sector is therefore essential for making an analysis on resilience in Nepal's energy futures. Stakeholder responses, demand projections and policy are used here to suggest the future of the sector.

7.3.1 Stakeholder Responses

Stakeholders provided insight into how the petroleum sector may grow in the future. O1 stressed the growth in petroleum imports which has been occurring since the blockade. O1 believes that the current 20% growth per annum being experienced now will not last, but consumption will continue to rise between 5-15%. **Figure 7.4** indicates the growth of petrol diesel and aviation turbine fuel in the last decade and reflects O1's comments. In particular, **Figure 7.4** shows that the use of diesel has grown significantly since the blockade.

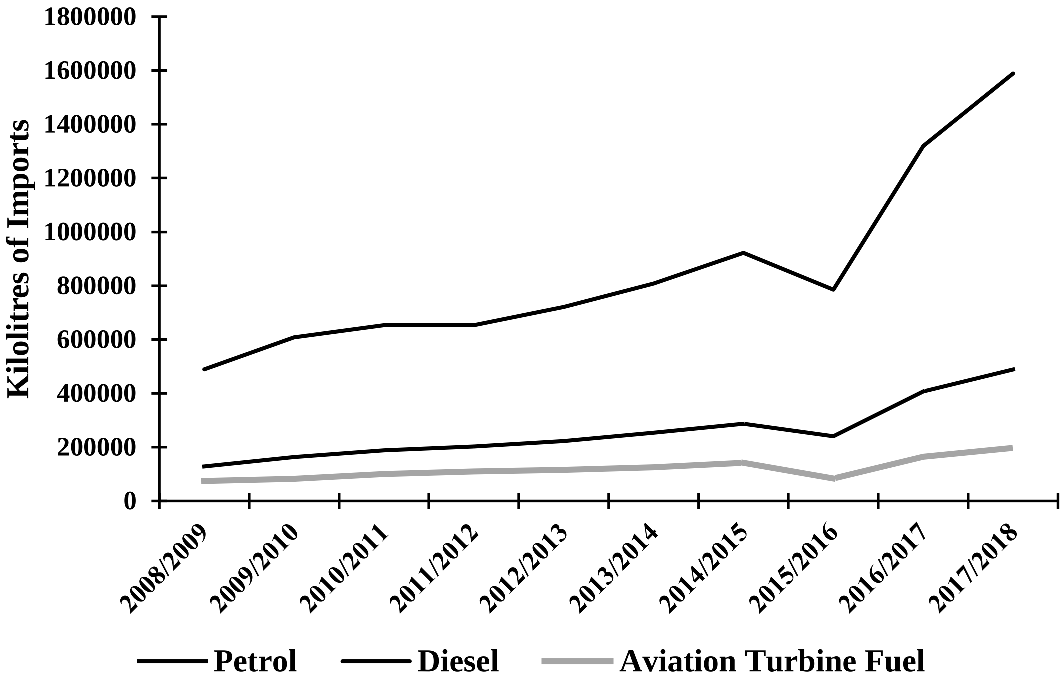

Figure 7.4: *Annual fuel imports (excluding LPG) from mid-2008 until mid-2018. The use of all three fuels has been increasing, especially after the blockade. Data publicly available from NOC (2018c)* .

G6 had a differing perspective to O1 and believed the potential for Nepal to transition towards a green economy would be largely realised in the future; saying:

> *"Nepal is going to become a green energy consumption country I think. This means less petroleum and thermal products… we will be reducing that. On transportation system only, we have that consumption. The remaining part we simply displace it - we have massive hydro power plants under construction, they give electricity that is totally clean energy, no carbon"*
>
> (G6)

A significant contributor to Nepal's transition towards a low carbon economy could arguably be an increased uptake in electric vehicles. Indeed, in public discourse, media articles have advocated electric vehicle use in Kathmandu to reduce national oil dependency, reduce air pollution, and reduce operating costs (Bhatta, 11/09/2018; Shrestha, 25/09/2018). Stakeholder responses however, generally did not discuss the potential for electric vehicles as alternatives to petroleum-based transport options in Nepal. N6 did note that there is no adequate supporting policy for electric vehicles, with electric vehicles effectively being taxed *"on par"* with petrol vehicles. Since the time of the research this appears to have changed, with Khanal (12/09/2018) reporting a policy decision from the government to reduce customs tariff (import tax) on electric vehicles from 30% to 10%, or to 1% for public electric vehicles. Reports of statements from the NEA also suggest the NEA is looking to install electric vehicle charging stations in Kathmandu to facilitate the promotion of electric vehicles (Himalayan Times, 23/09/2017; Mandal, 20/10/2017).

Beyond transport fuels, a significant component of the petroleum sector is the use of LPG for cooking purposes. NG5 believes there is some use of electrical cooking appliances in Kathmandu, but LPG is the majority. Evidence from Nepal's Central Bureau of Statistics (CBS) however, says "*It is interesting to note that in urban, the use of LPG gas has declined from last year and the use of electricity has increased. Now in 2015/16, in urban 53.3% are using LPG gas and 37.9% are using electricity which in 2014/15 was 58.3% for LPG gas and 33.0% for electricity."* (CBS, 2016: pg.4). It is not clear whether this decrease in LPG gas use has been sustained given that the decrease occurred in the year of the blockade.

7.3.2 Policy Directions and Demand Projections.

The surveyed policy does not provide established targets for petroleum fuel consumption in the future. The Nepal Sustainable Development Goals report (2017) does, however, set a target for petroleum consumption as a percentage of total energy consumption, to be restricted to 15% by 2050. This represents a growth of only 2.5% from consumption in 2014/2015 (WECS, 2017). This would contradict the growth expected by Parajuli et al. (2014), who forecast the percentage of LPG as a share of total energy consumption by 2030 to be between 7.7%-21% by 2030, which is a significant growth from the approximately 3% used in 2015. Likewise, petrol takes 3.2%-2.2% in 2030 across the three scenarios used in the forecast, which is a significant increase from the approximately 1% estimated for 2015 (Parajuli et al., 2014). It is difficult to anticipate total petroleum fuel consumption from Parajuli et al. (2014) and relate their projection to the Nepal Sustainable Development Goals report target, but these forecasts suggest that the growth shown in **Figure 7.4** will continue in the future.

This policy direction, demand projections and stakeholder responses present a conflicting future for Nepal's petroleum demand. On one side, O1 and the projections by Parajuli et al. (2014) suggest that petroleum consumption will continue to grow. On the other side, G6 and Nepal's Sustainable Development Goals report (2017) believe Nepal will lessen petroleum consumption growth by transitioning to a green economy.

Summary 7a: What Future Demand is Likely?

There were relatively few stakeholder responses that discussed how domestic electricity demand will grow in the future, but it is apparent that this demand can be viewed in two ways. By assuming that GDP growth will increase energy demand, energy projections from Parajuli et al. (2014) and WECS (2017) estimate that electricity demand will increase somewhere between 12,200 GWh to 23,300 GWh by 2030. In comparison, the available energy in 2018 in the electricity sector was 7,056 GWh (NEA, 2018). The alternative view of future energy demands can be taken from the policy goals, which would not only see the generation capacity of Nepal's electricity sector increase to 15,000 MW, but also see Nepal's electricity sector provide service to almost all consumers by some point between 2022 and 2030. In both views of future energy demand, the required generation capacity would be significantly higher than the roughly 1000 MW capacity which is established now (NEA, 2018). To achieve policy goals of providing electricity services to all consumers and thus address energy equity issues, the sources of this generation may require attention beyond their ability to produce a certain capacity of electricity.

Stakeholder responses from N6 and A2 suggest that the demand which will be experienced in the future will be strongly tied to the way policies influence how electricity demand is consumed. If manufacturing and cooking uses transition to consuming electricity, it could be expected that domestic demand will increase. Although it was not expressed through stakeholder responses or secondary sources, the strong potential for regional energy trade suggested by Chapman (2009), the World Bank (2008a), and the agreements Nepal has signed with SAARC, India, and Bangladesh, suggests that any surplus electricity generation should be able to be sold to South Asian energy markets if appropriate transmission links are in place. For this reason, it is perhaps more appropriate to expect the higher end of the electricity demand estimations.

The increasing demand for petroleum fuels expected by O1 and Parajuli et al. (2014) looks to continue as policy mechanisms to promote alternatives to petroleum consumption appear to be limited to the lower taxes on electric vehicle imports. This will have implications for energy security if Nepal's reliance on India is continued and may harm energy justice principles by increasing Nepal's greenhouse gas emissions. However, having access to petroleum fuels tends to provide greater mobility and health benefits which eases issues of energy poverty (Simcock and Mullen, 2016, Barnes et al., 2014).

7.4 Hydro Power

Discussions around hydro and the challenges in its development are well realised and developed in social, political and academic discourse (Lord, 2014, Dixit and Gyawali, 2010, Sovacool et al., 2011b). As a result, discussion of hydro from stakeholders dominates the responses given in this study. This is examined here by considering smaller hydro and larger hydro.

7.4.1 Smaller Hydro – Stakeholder Responses

Several respondents described the benefits and challenges associated with smaller hydro. P3, a stakeholder involved in private micro hydro, spoke positively of micro hydro by describing how it is a technology which can mostly be manufactured domestically, as only the generator must be imported into Nepal. To this stakeholder, micro hydro has an advantage over solar generation because solar requires that batteries be replaced reasonably often. In addition, P3 noted that there are many rivers across Nepal, so most areas have the potential for micro or mini hydro.

P3 also mentioned challenges to micro hydro development, expressing a belief that the private sectors participation in the micro hydro market does not seem to be encouraged by government policy. Bureaucratic barriers to private sector involvement in community micro hydro seemed apparent to P3, who believed that micro hydro should be made a 'priority sector' by the government in the same way agriculture is. From their perspective, there are also significant financial barriers to the increased uptake of micro-hydro as P3 believes it is difficult for the private micro hydro sector to facilitate loans. P3 also stated the demand in remote areas was shifting from a micro hydro to a mini hydro level of generation capacity, in order to meet the changing demands of the communities for appliance use. In capacity terms, mini hydro systems provide a greater electricity output than micro hydro systems, typically producing between 100 kW to 1 MW (Sovacool et al., 2011b).

A significant issue demonstrated through **Chapter Five** was the poor ability for smaller hydro projects to withstand earthquake damage. Although the AEPC had some ability to respond, a lack of finance hampered recovery efforts. This perhaps reflects the wider issue of financial limitations expressed by G2.

7.4.2 Smaller Hydro – Policy and Literature

Surveyed policy indicates that the 2001 Hydropower Development Policy continues to be the mechanism to promote rural electrification through micro and small hydro projects. Nepal's 2016 INDC also plans for an additional 50 MW of electricity generation from smaller hydro, while the 2018 Universalizing Clean Energy in Nepal plan would see 221 distributed hydro power projects constructed to achieve grid access for all. The 2012 National Rural and Renewable Energy Programme, which finished in 2017 sought to achieve 25 MW of smaller hydro power generation while its successor framework, the 2017 National Renewable Energy Framework, seeks to enable expansion of Nepal's renewable energy sector. Finally, the 2016 Renewable Energy Subsidy Policy continues to support smaller hydro power development. Together, these policy documents suggest micro hydro will continue to grow in the future, particularly as a mechanism for achieving rural electrification.

Existing literature has identified that micro hydro, along with having the fossil-fuel displacing and reliable supply benefits of hydro power, has the added benefit above grid energy technologies of being able to provide electricity to remote villages which the national grid is unlikely to reach (Karki, 2018). This benefit of having electricity from micro hydro in these villages is certainly considerable; Gurung et al. (2011) have used a case study in Tangting, Nepal, to show that the implementation of a micro hydro project and the corresponding access to electricity improved the health, sanitation, education, environment, and income of the community. Despite these benefits however, micro hydro is not commercially viable and is kept afloat by government and donor subsidies (Karki, 2018). In 2008, the average cost per household installation was US $234, with $144 of this cost being government subsidy, $84 being community contribution and $32 being loans (Mainali and Silveira, 2011).

Together, stakeholders, policy and literature suggest a positive future for smaller hydro in Nepal. Financial challenges and issues with private sector integration seem to persist, but the economic, education, healthcare and social benefits that micro hydro can provide to remote communities suggests that smaller hydro is well placed to tackle energy poverty issues in Nepal.

7.4.3 Larger Hydro – Stakeholder Responses

Key stakeholders provided a range of perspectives on larger hydro. A2 spoke strongly of the ability for Nepal to develop hydro power without foreign input with its existing financial and technical resources. For private investors, A2 says "*There is enough money in the market that people want to invest. It's only that people have no good, reliable projects to invest on",* suggesting that the ability for the private sector to develop hydro is not held back by financial constraints. For the government, A2 believes the financial ability to develop hydro is there, referring to an existing fund by saying "*for every litre of petrol that you buy, the government is laying a 5-rupee tax on it, specifically earmarked for Bhudi Gandaki Project. In the last five or six years we already have billions of Nepalese Rupees there, which is sitting idly, it's not being used".* For the largest, mega-scale projects, A2 does believe that external experts are still required for the design, but for small to large scale projects A2 believes there is the technical capacity within Nepal to do this. A2's position reflects that of Karki (2018), who also argues that there are now adequate technical, managerial and financial skills and resources in Nepal to allow small and medium hydro power projects to be completed independently. The main constraint for developing hydro which A2 expressed was the lack of guidelines for corporate social responsibility and compensation which should be provided to communities, being a deterrent for investment.

When considering whether the private sector or government sector is better suited to developing hydro, P1 argues that private developers are more cost effective. P1 described that:

> "G*overnment projects are very long and very expensive - Chameliya - it cost 3.2 million per MW. But most of the IPP's, they will complete that around 1 million per MW. Or maximum 1.5 million per MW. But that doesn't mean government projects are better. They are inefficient".*
>
> (P1)

Cost and time overruns from the public sector are recognised in the literature, with Sharma and Awal (2013) describing how international financial institutions require extensive environmental impact assessments and conditions which increase the development timeline and costs. Additionally, as the NEA is the sole operator of the transmission network, they are often required to construct long and expensive transmission lines to reach upcoming power projects (Sharma and Awal, 2013).

Multiple stakeholders identified a lack of policy to guide issues of affected community compensation and disputes as a challenge to developing larger scale hydro. N6 noted outdated government policy, conflict and disputes between community and developers, difficulties installing transmission lines, and the issue of dealing with corruption. N1 reflected the sentiment around community and compensation disputes, noting issues around water resource sharing and the discrepancies between those who benefit from large hydro generation and those who bear its costs. Similarly, A2 believed the lack of guidance as to what an acceptable demand from the community is means the community can demand however much they like, which leads potential investors to be deterred. On the other side of this issue, A2 also believed the lack of guidance means there is no minimum standard as to what should be given to the affected community, or what the corporate social responsibilities of hydro developers should be. Both N6 and A2 believe a recent move to have shares of a project given to affected communities has improved the community/developer dispute issue.

Stakeholders views on reserve hydro were generally supportive, with G4 believing that Nepal should promote large, reservoir type hydro power to allow water storage, and therefore allow generation to continue through dry periods. G4 also believes that hydropower is a good solution for meeting the growing energy demands of Nepal, because fossil fuel-based generation is environmentally unfriendly and expensive. N6 supported this view, saying *"Nepal desperately needs a few credible reservoir projects".* Part of the reasoning for this position was N6's belief that seasonal variability is "*one of the biggest limiting factors for hydro power projects".*

G6 believes reservoir hydro is necessary to increase Nepal's energy resilience, saying "*Now the time is for reservoir type of projects and energy storage systems… that is energy resilience".* G6 supported this statement by describing how the challenge of seasonal rainfall is an issue for hydro power, but also described how Nepal has an excellent potential for hydro because of the topography and the ability for Nepal to provide the raw materials needed for cement. G6 also saw the development of hydro in Nepal as a way to end the import of electricity generated through coal fired power plants in India during the dry season. With this being said, G6 acknowledged that sediment deposition and climate change will have an impact on hydro power generation.

G7 too supported reservoir hydro alongside run-of-river hydro, proclaiming that Nepal should develop reservoir hydro as soon as possible in order to address the issue of climate change exaggerating the melting process in the Himalayas. G7 believes that the exaggerated melting process otherwise has the potential to result in a 10-20% deficit in electricity generation.

There are clearly a range of different scales impacting upon the future potential of harnessing hydropower. Indeed, N6 acknowledged that issues arise with transboundary benefit sharing in the case of reservoir projects. Reservoir projects provide regular flow, which is beneficial for irrigation and flood control. These benefits are provided not only downstream within Nepal but also into India as well.

Discussions between India and Nepal on how those benefits are to be paid for, however, seem to get stuck (N6). N6 describes how the Government of Nepal has the view that India should pay for those benefits and believes greater cooperation between Nepal and India will be required if reservoir projects are to be built. This need for cooperation is a barrier to the private sector, as N6 believed the private sector is not capable of negotiations around water resources and benefit sharing with the Indian government. Further, N6 believed the private sector is unlikely to develop reservoir projects as the investment required is too great, and the scale of displacement and resettlement that would be required is far too great for the private sector to manage

A1 shared the position of N6 regarding the refusal of India to acknowledge the downstream benefits of reservoir hydro. On larger hydro generally, A1 had a slightly different perspective to other stakeholders and expressed that large scale hydro development has many negative impacts. A1 explains how climate change is used to justify these impacts in saying "*climate change has become a mantra to reintroduce dam building, that's all it is. Hydropower may be climate friendly, it's not social friendly and it's not environmentally friendly. Let's not forget that".*

7.4.4 Larger Hydro – Policy and Literature

Given the extensive responses given by stakeholders regarding larger hydropower, it is perhaps unsurprising that numerous policy documents support the development of larger hydropower in Nepal. The 2001 Hydropower Development Policy seeks to utilise hydropower to its maximum extent in order to meet domestic demand, while also incentivising foreign and domestic investment for hydropower. The 2018 MoU between Nepal and Bangladesh seeks to encourage joint cooperation for hydropower development, and Nepal's 2016 INDC seeks to generate 12,000 MW of hydroelectricity by 2030. The Nepal Sustainable Development Goals roadmap report seeks to achieve a more ambitious goal of 15,000 MW of generation across all sources by 2030, which would suggest a similarly large figure to the INDC for larger hydropower generation. The NEA's 2018 annual report suggests Nepal is making progress in achieving these goals, with more than 4500 MW of IPP generation capacity under construction or being planned (NEA, 2018). Thus, for the most part, the stakeholder responses align with the thrust of recent policy documents to promote larger hydropower development in Nepal.

Larger scale hydro power in Nepal has also been discussed within energy literature. Using an analytical hierarchy process, Singh and Nachtnebel (2016) surveyed 85 key stakeholders to suggest that a previous preference for small and medium hydropower development in Nepal is shifting towards medium and larger size hydropower development. The largest hydropower projects greater than 1000 MW, however, were found to be the least preferred hydropower option (Singh and Nachtnebel, 2016). Considering specific factors important for hydropower development, they identify equity as the most important social factor and power availability as the most important technical factor (Singh and Nachtnebel, 2016). In general, the economics, financing and developer were found to be the most important factors when considering hydropower development (Singh and Nachtnebel, 2016).

Sovacool et al. (2011b) have extensively researched the barriers for hydropower development in Nepal, identifying technical, environmental, economic, financial, political, regulatory, social and cultural barriers. These barriers are too lengthy and complex to be reproduced in detail here, so a summary is given **in Table 7.4.4**, taken from the paper by Sovacool et al. (2011b). Perhaps as a result of this research being published before the earthquake in 2015, there is no mention of hydropower's vulnerabilities as barriers for hydropower development, aside from the mention of climate change making hydrological variability worse (Sovacool et al., 2011b). This view aligns with the belief of Butler and Rest (2017), who argue that the risk of earthquakes to hydropower development was mostly denied prior to the earthquakes. More concerningly, Butler and Rest (2017) believe a denial around the uncertainty of risks, including those posed by earthquakes and those posed by climate change, continues to pervade in the hydropower sector in Nepal.

Table 7.4.4: Summary of barriers to hydropower development in Nepal. From Sovacool et al. (2011b) (p.3471).

Category	Explanation
	Hydrology and sedimentation
Technical and environmental	Logistical problems
	Equipment and maintenance
	Environmental impact assessments (EIAs)
Economic and financial	Poverty
	Financing
	Low electricity tariffs
	Long lead times
Political and regulatory	Maoist insurgency
	Poor institutional capacity
	Corruption
	Licensing
Social and cultural	Social opposition
	Unfamiliarity and poor local capacity
	No revenue connection
	Aid dependency

Sharma and Awal (2013) describe the importance for hydro power in Nepal, expressing that hydro power can help reduce the cost of petroleum fuel imports, provide water resource benefits and provide an export commodity for Nepal. Sharma and Awal (2013), however, also cover a number of issues associated with hydropower development and policy in Nepal, explaining that the strong seasonal variation in river flow means the run-of-river type hydropower facilities which are mostly in place in Nepal provide a fluctuating production of power.

Scholarly writers have described how Chinese involvement in hydropower development in Nepal is the "*leading vector*" for Chinese state-building and investment in the country (Murton et al., 2016: pg. 416).

Writing in 2016, Murton et al. believed there to be 17 hydropower projects under construction in Nepal which Chinese contractors were involved in, which they thought had been organised in such a way that demonstrated the Chinese hydropower sector was working with and in support of the Nepalese state. Besides helping Nepal reach its hydropower potential, the effect of this involvement is to provide some distance between Nepal and Indian hydro power developers, while also increasing Nepal's bargaining power (Murton et al., 2016). On the community scale however, the influence of a growing Chinese presence in certain areas because of hydropower development has led to adverse social effects and divergent results for social justice and empowerment (or disempowerment) of different groups (Murton et al., 2016, Lord, 2014). These consequences of Chinese involvement in hydropower development illustrate that any hydropower policy will have implications beyond energy systems on community and geopolitical scales.

Considering stakeholder responses, policy and literature on larger hydro together suggests that the role of energy resource will be expanded in Nepal's energy future. Stakeholders were generally supportive of the technology, and development of the technology domestically looks possible. The private sector is likely to have a large role in development of larger hydropower in Nepal, which is demonstrated by the NEA signing power trade agreements for more than 4500 MW of IPP generation (NEA, 2018). There are many challenges for larger hydro, with transboundary water resource issues, a lack of guiding policy for community compensation and dispute resolution, and adverse social affects being described by stakeholders and literature. However, if these challenges are addressed, the growth of hydropower in Nepal will be enabled. This will help meet Nepal's growing electricity demand and may play a role in shifting Nepal's economy to a green, renewable-based economy.

7.5 Solar PV

While hydropower attracts the greatest commentary amongst those who are contemplating the energy futures of Nepal, there is no question that solar potentially has a significant contribution to make. This lack of broader discussion may be a result of the technology still being in its early stages of energy sector integration. With this being said, solar PV has a large number of users in Nepal, but the total generating capacity of solar technologies is insignificant compared to that of hydro (K.C et al., 2011). Its benefits instead lie within the unique, modular nature of the technology which allows it to be established at the household scale. Solar PV was discussed by a number of stakeholders.

7.5.1 Solar PV- Stakeholder Responses

Solar PV was broadly endorsed by several key informants in interviews. P1 and P2 are independent power producers who do not focus on hydro power, but instead focus on solar and other alternative renewable energy sources. They both spoke very highly of solar PV technology and its potential. P1 expressed their belief that solar is a better alternative to micro hydro in off grid communities for a number of reasons, saying:

"*It looks like micro hydro is almost dead now. Nobody is going to make micro hydro anymore, because it takes you more than seven months, almost one year to make a small 10, 20 kW micro hydro project. And it always in a gorge, very deep down – it's high risk. Many of the employees get injured from getting down and up. The pain and all the hassle isn't worth it. You can simply replace by solar and solar can be produced next to your market centre in the village. The power house is just there, you can go and look after it, so operator doesn't have to stay in an isolated, remote river basin. He can just stay right in the village centre. Also, that means there is less loss in transmission because powerhouses are right there where the demand is"*. (P1)

Key informant P2 shares P1's belief that solar is a more resilient option than micro-hydro in remote communities because in P2's experience, micro hydro systems are vulnerable to minor technical issues which cannot be solved within the community. With this being said, P2 also recognises that solar panels can be poorly installed which reduces their generation capacity. Key informant P2 noted further advantages of solar, saying:

"*Solar makes perfect sense – because it's modular. You can put up as much as you want. It can be demand driven, because if you want a kilowatt of solar on your rooftop it's your decision, you don't need to get the community together and go through all the bureaucratic hurdles"*.

(P2)

In small solar home systems, a very low level of electricity is generated which cannot run large appliances (P2). P2 is trying to change this however, by setting up microgrids using solar which provide adequate generation capacity to run these larger appliances. Considering businesses, P2 believes solar is an excellent way of adding value, saying:

"*Small business, not even large industry scale business, think a small shop, hospital clinic, even a petrol pump, most of our best customers – they're petrol pumps. These kinds of businesses, they save a lot of money just by putting up solar and just by being energy independent. I think that's where solar has its advantages"* (P2)

Together, both P1 and P2 recognise that there has been a "drastic" loss of demand for residential solar home systems since load shedding ended. P1 remains optimistic however, and sees a large potential in Kathmandu for solar PV generation, saying:

"*The passionate ones, who still are championing green technology to be more self-reliant on electricity, their numbers are still there and still growing… I think in Kathmandu valley there are around 200,000 houses. If each house has say, 2 kW installed at their house, then it's already 400 MW. But that's not the case, that's the potential. The case is less than 20 MW I think"*. (P1)

One major challenge P1 considers for solar uptake in Kathmandu, however, is the poor air quality and resulting dust which collects on solar panels, as this dust reduces the efficiency of the solar panel by 30% to 40%. P2 believes the future of solar will be in a grid-solar interconnection where electricity is sold or fed into the grid during daylight hours, and electricity is taken from the grid during evening hours. In this situation, the need for electricity storage is negated, at least at the household level, bringing the costs for households to have solar down significantly (P2).

While expressing the benefits of solar PV, both P1 and P2 acknowledged a number of factors holding back growth in the solar sector. P1 believed a lack of big players in the market who are willing to spend money on promotional activities meant solar wasn't being realised as an attractive investment. The lack of financial arrangements for purchasing solar is another challenge, and P1 believes this may be due to banks not considering solar panels as resaleable. P2 also noted that solar PV has not yet been realised as a viable investment. P1 explained that there are financial challenges limiting the private sectors involvement in off-grid solar. Off-grid solar has a per unit cost which is around 4-5 times higher than grid electricity, at 40-50 rupees per unit (P1). The government does provide subsidies, which allows communities to own these systems if they can finance the remaining capital cost, but the limited subsidy which the government provides isn't enough to allow the private sector to make a return on their investment (P1). P1 emphasises this, saying: "*There is no role of private sector, private sector is more like an installer. We go there, do the bid, and get the engineering contract and all we do is installation. The ownership of the entire assets remains in the community".* As a result, the communities need to manage the systems they have, instead of paying a rate to a private company in a similar way someone in an urban area pays their power bill (P1).

7.5.2 Solar PV - Policy and Literature

The significant enthusiasm amongst some stakeholders for increasing the contribution of solar PV is also reflected in government policy. Policy documents aim to grow the number of users and create a significant level of generation, with the NRREP program having aimed to install 600,000 solar home systems by 2017 in order to improve living standards of rural communities. The 2018 Universalizing Clean Energy in Nepal envisions distributed solar PV as a contributor to grid electricity access, with 481 solar PV projects planned for completion by 2022. Nepal's INDC also suggests an ambitious target of 2,1000 MW of solar energy being generated by 2030.

Literature identifies that there are clear differences in which communities could benefit most from increased uptake of solar PV. Bhandari and Stadler (2011) argue for use of solar PV technology to achieve rural electrification where grid access is unlikely to be connected in the foreseeable future. They believe that the cost of PV systems means PV technology is not competitive in urban areas, but in rural areas where there are no other options for reliable electricity generation, solar PV would be able provide a small amount of electricity for lighting purposes. The results of Bhandari and Stadler's (2011) study suggests that solar PV may be important for achieving energy justice objectives, given that even a small amount of electricity access for lighting has been shown to provide education and health benefits (Zahnd and Kimber, 2009).

Together, stakeholder, policy and literature indicate the benefits solar PV can have in Nepal's energy future. The ability of solar to provide modular electricity benefits in both grid and off-grid systems provides reliability to consumers. Although solar PV has generally been limited to small home systems which provide very low levels of electricity, policy suggests that solar PV will have a more significant role in terms of generating capacity in Nepal's energy future. This will require that the economic issues associated with solar PV technology, particularly where batteries are required, be addressed.

7.6 Energy Trading

Trading energy is an alternative to producing energy domestically to meet Nepal's energy demands. If Nepal can produce a surplus of energy, energy trading could also provide a significant source of income for the country. This section presents stakeholder responses, policy and literature on energy trade with India and SAARC, and China.

7.6.1 Electricity Trade – Stakeholder Responses

Nepal's electricity trading was discussed by stakeholders. Currently, all of Nepal's electricity trading is with India, with G6 acknowledging the geographic constraint in trading electricity with China, as the distance between Nepal and China's population centres means India's energy consumption centres and export centres are more accessible to Nepal. G7 also recognized this challenge and mentioned that Nepal would need to sign a Power Trade Agreement with China to trade electricity. N6 believed Nepal would see an increase in domestic generation in the next year of around 200 to 300 MW, which would reduce the country's reliance on Indian electricity. N6 also described how the import of electricity from India is seasonal, with lack of water during the dry season reducing domestic generation and requiring imports to meet demand.

Most stakeholders were hesitant to support electricity trading with India. A1 did not believe electricity trading, both importing and exporting, was positive for Nepal, saying electricity trade was a "*waste of time. India has never offered a market price for energy so why bother?"*. In considering electricity imports, A1 expressed that it is important to acknowledge that much of the electricity produced in India and exported to Nepal is sourced from burning coal.

A2 acknowledged that the issue of unfair trading prices for electricity has removed the incentive for Nepali developers to produce electricity for export to India. A2 suggested however, that having Indian part ownership in hydro developments could help solve this issue as it would require that India be invested in ensuring a fair price for electricity is paid. A2 believes that implementing this idea would require government support.

When discussing energy trade, G7 noted that Nepal has no petroleum or precious mineral deposits and as such, said that "*hydropower could be the only natural renewable resources to be to be tapped, to utilized for national needs and to export to uplift the economy hardship of Nepal"*. To export this electricity, G7 believed India would be the best potential market, noting the short transmission lines and the existing Power Trade Agreement 2014 with India which requires that India has to offer cooperation for energy banking. After India, G7 believed *"Bangladesh would be another energy market to Nepal"* although this would require that India permit access across the 16km of Indian territory that separates Nepal and Bangladesh.

A1 and A2 stressed that the trade of electricity with India is not an issue limited to the energy sector, as large-scale electricity production from hydro dams in Nepal has benefits for water resources by ensuring a steady flow. Having a steady flow of water means areas downstream of the dam will have reliable access to water for irrigation, while flooding can be also be managed. A1 and A2 both believed that India refuses to acknowledge these benefits, which then causes negotiations between Nepal and India on the issue to break down.

N6 described a number of issues associated with the potential export of electricity to India. One issue is the lack of a competitive market, with N6 saying "*India is really promoting solar. The cost of solar is coming down like anything because there are a lot of subsidies being given by the government of India".* As a result of this low cost, hydro generated electricity is finding it difficult to compete. N6 showed this by drawing on case in the Indian State of Himachal Pradesh where licenses were released for 17 hydro projects, but only two developers were interested. As a result, N6 said "*Even in India the local developers are competing for that space. It is very difficult for them, the cost of solar has come down, hydro power is expensive because of a lot of things – social implications, environmental management. It's no longer being seen as a clean industry".* With it being difficult for Indian developers to compete against solar electricity prices, it would be very difficult for a Nepali developer to do so to (N6). N6 however, does believe that there would be a viable market for Nepali electricity in Bangladesh, but such market access would require Indian cooperation.

A2 had a different perspective, pointing to the under construction 900 MW Arun project which is currently being developed by state-owned Indian company SJVN Ltd. The development of this project is a clear signal that India is in need of further energy supplies, and A2 reflected this saying:

> "*India itself is facing energy crisis… they are going towards nuclear or solar in a big way. They may alleviate part of its energy crisis, but it may not be sufficient. They depend quite heavily on hydro power. Since they have not been able to sign agreements with Nepal, they are going towards Bhutan. They are constructing large dams in Bhutan – 1200 MW, 1300 MW."*
>
> (A2)

With this being said, A2 also believed that a policy of relying on importing electricity from India during the dry season instead of developing reservoir hydro in Nepal, even if the cost was cheaper, would not be accepted in Nepal. A2 explains that this non-acceptance is due to the lack of trust and mutual lack of confidence between Nepal and India based on Nepal's experience of dealing with India in the past, saying "*Nepalese Bureaucracy, Nepalese technical persons, Nepal's elite let say, do not think India is a reliable partner in such dealings".* To support this, A2 provided the example of the Koshi Treaty, which was an agreement allowing a barrage to be constructed for the purposes of flood control and irrigation that resulted in feelings of suspicion towards India (Jha, 2013).

7.6.2 Electricity Trade – Policy, Literature and Media

In considering the above responses, it is worth noting that Nepalese media has reported that the NEA intends to increase electricity imports from India by upgrading the Raxaul-Parwanipur and Kataiya-Kushaha transmission lines (Nepal Republic Media, 15/05/2018). In addition, the NEA reportedly plans to start energy banking with India (Nepal Republic Media, 15/05/2018).

Policy direction given by the documents surveyed suggest that regional energy trade may be possible. The SAARC Framework Agreement signed in 2014 enables member states to develop cross border transmission links and promotes cross-border trade. This agreement remains subject to mutual agreements between the concerned states but represents a step towards regional energy trading. The power trade agreement between India and Nepal, also signed in 2014, enables and encourages power trade between the two countries and requires both countries to ensure the unrestricted flow of power. Nepal has also signed a more recent non-binding Memorandum of Understanding with Bangladesh in 2018 which encourages both parties to take necessary steps towards grid connectivity and power trade between the two countries. Given that Nepal and Bangladesh do not share a border, such power trading will require permission from India, as suggested by N6. Outside of these bilateral and multilateral agreements, policy documents remain domestic focused with no other policy documents making clear objectives to promote energy trading.

Huda and McDonald (2016) suggest that a major challenge in enabling regional energy trade which would benefit Nepal is the preference for India to engage in bilateral agreements over multilateral agreements (Huda and McDonald, 2016). India has consistently refused land access for the import of electricity from Nepal to Bangladesh, and would instead prefer that India buy electricity from Nepal and sell it to Bangladesh itself (Huda and McDonald, 2016). From Nepal's side, cooperation with India has been undermined as any potential cooperative ventures with India have been subject to the political rhetoric and propaganda of Nepal's politicians amongst an unstable political environment. (Huda and McDonald, 2016). This politicisation of foreign policy issues is not restrained to Nepal and is common amongst some other countries in South Asia (Huda and McDonald, 2016).

The information presented here suggests the positions of stakeholder responses and policy and literature are not aligned. Electricity trading provides an alternative to domestic electricity generation, and the importing of electricity from India has been able to end the load shedding which Nepal faced. No stakeholder supported this, yet the NEA reportedly plans to increase Nepal's capacity to import electricity from India in the future (Nepal Republic Media, 15/05/2018). The opinions stakeholders did have on electricity trading were mixed. On one side, G7 believed the potential for Nepal to export electricity to India would have benefits for Nepal's economy and A2 recognised the potential for Nepal to export electricity to India. On the other side, G7 believed electricity was a waste of time as India does not pay a fair price for electricity and N6 believed the Indian market would not be viable for Nepali hydropower developers. Despite the negative stakeholder comments, the international agreements are in place through the SAARC Framework Agreement and Nepal's agreements with India and Bangladesh, the potential for electricity trading in Nepal is there. It would therefore be reasonable to expect that any generation in Nepal surplus to domestic demand in Nepal would be exported to India or to Bangladesh, if the remaining electricity trading issues are resolved.

7.6.3 Petroleum Trade – Stakeholder Responses

With no domestic reserves of petroleum, Nepal relies on fuel imports from India. In the year 2017 the costs of these imports reportedly reached 170 billion NPR (About 1.5 billion USD), worsening the significant trade deficit between India and Nepal (Bakhtar News Agency, 29/08/2018). As we have seen in the previous chapter, this reliance on India has significant implications for energy security and resilience.

Stakeholder O1 discussed the possibility for fuel trade with China and indicated that a long-term trade agreement for fuel with China has been signed. They also described a number of challenges, however, which come with importing fuel from China, including: the different driving techniques and road rules (China drives on the right, Nepal on the left); the language barrier; the very cold weather in Tibet which requires that special equipment be used in winter to clear roads; existing rules and regulations; and the challenge of importing liquid cargo because it requires better grade roads then solid cargo. Despite these challenges, O1 believes that it that it is possible to import fuel from China, and this was demonstrated during the blockade when China delivered 1000 metric tonnes of fuel to Nepal (O1).

Aside from Nepal's 2017 Sustainable Development Goals status and roadmap report seeking to restrict fossil fuel consumption to 15% of total energy consumption by 2030, there are no policy directions for petroleum trade suggested by surveyed policy documents.

7.6.4 Petroleum Trade – Policy and Literature

Unfortunately, there is a gap in the academic literature on the issue of Nepal's petroleum trading. The ADB has identified the lack of petroleum fuel storage facilities in Nepal as an issue which leaves the country vulnerable to supply shocks like that which was experienced in the blockade, but other than this there appears to be a lack of investigation into Nepal's petroleum sector in grey literature and policy documents as well (ADB, 2017a). The lack of policy and literature limits the ability here to suggest what role petroleum imports will have in Nepal's energy future. Given the difficulties expressed by O1 in importing petroleum from China, it would be reasonable to assume the status quo will remain and any domestic demand for petroleum will be met through supplies from India.

7.7 Distribution Options

The preceding chapters show that impact of shocks to the services which energy systems deliver cause the impacts for energy justice and energy poverty. Importantly, **Chapter Five** found that the different experiences of the grid, grid-connected and off-grid distribution systems contributed to energy justice and energy poverty issues. It is therefore necessary that this chapter extends beyond energy resources to consider how those three different systems may play a role in Nepal's energy sector future. In doing so, the results point towards options that might increase the resilience, equity and sustainability of Nepal's energy system in the future.

7.7.1 Distribution Options – Stakeholder Responses

The responses of stakeholders regarding the response to earthquake damage in distribution systems indicated that grid, grid-connected and off-grid options for distribution in Nepal had different responses. The benefits and challenges of the three options were also discussed by stakeholders, which allows for a suggestion as to the future for different distribution systems.

G3 and N6 stressed that the capacity of the distribution system needs to be upgraded by upgrading transformers and wires, in order to ensure the distribution system is able to provide for future demand. There is limited finance for doing this, and all materials are imported from India and China (G3). The ability to meet this growing demand was an issue G6 expressed concern about Kathmandu, as he believes 5-6 million people across the entire Kathmandu Valley are provided for by a system that has a capacity of 400-500 MW. A report by the ADB (2017b) supports this estimation, suggesting that the power available through the distribution system in the Kathmandu valley is about 400 MW. G6 explained that providing for the dynamic and increasing population within the valley with this distribution capacity is an ongoing challenge. With regards to the transmission system, N6 described an issue surrounding line development, as the land owners above which the transmission line runs are not compensated in the same way one is compensated with other infrastructure.

In discussing energy futures, N3 argues that grid connection has an advantage over off-grid supply in terms of capacity, saying:

> "*Ultimately, grid extension is the only solution… Because micro hydro and such only can give the power for lighting purposes. But if you are required to operate heavy loads, even rice*

cookers, or ovens, or do some business utilising electricity, then there will be the problem of power. Ultimately, we need to electrify through grid". (N3)

NG5 supported this point by describing how they had seen cases of people in rural areas having electrical cooking appliances but being unable to use them because the available voltage from their electricity system was too low. N3 believes remittances have allowed incomes to grow in rural areas which is increasing the demand for electricity to supply appliances. N3, however, expresses the challenge in meeting the growing demand, explaining that the infrastructure established by CREEs often does not have the capacity to absorb the extra load which comes with consumption growth. As demand grows, CREEs will therefore need to upgrade their systems. This can be financed in a similar way to the initial project establishment, where the government provides a 90% subsidy (N3). However, there is a long waiting time for this subsidy as numbers are limited and CREEs must wait in line (N3).

G2 notes that that some communities prefer the off-grid system because they own it. If a tariff is collected by the NEA from a national grid connected consumer, they pay the money to the government (G2). But in an off-grid system, the money goes back to the community (G2). With that being said, G2 also believes that as soon as the grid comes near to an off-grid system, the community generally prefers to have access to the national grid. G3 believes this is partly because many of the men in these communities work abroad, leaving mostly women in the remote rural areas. This then means if something is to be done for the off-grid system, the workforce available is smaller, so the communities prefer to have energy supplied from the national grid as the lack of workforce will no longer be an issue (G2). G2 explained that a Memorandum of Understanding has been signed between the NEA and the AEPC to ensure that where the national grid expands into an area with an established off-grid system, that system will become connected to the grid. This allows that off-grid system to sell power back into the national grid, and in one case a 23kW project was earning about $1000 USD a month from doing so (G3). Only two projects had been able to do this at the time of the interview, however.

7.7.2 Distribution Options – Policy and Literature

There has been some commentary on Nepal's grid distribution in academic literature. Nepal and Jamasb (2012) have argued that the NEA's distribution system should be unbundled from its generation and transmission systems and commercialised. In doing this alongside the establishment of an independent regulatory body, Nepal and Jamasb (2012) believe there would be greater transparency, accountability and competition in the energy sector. Gyawali (2014) also supports the unbundling of the distribution system from the generation and transmission systems by arguing that a separated distribution system is where poorer consumers are able to exercise influence, thus ensuring accountability and sensitivity towards the consumer's needs. Gyawali (2014) uses the example of CREEs as a separated, democratised distribution system and shows how the ability of consumers to influence that system has led to energy related benefits. CREEs have also discussed by Rana (2012), who praised the work of NACEUN for promoting the rural grid connection program and providing technical and expertise to CREEs. Because of the achievements of NACEUN and the rural grid connection program, Rana (2012) believed NACUN was hopeful that most households in Nepal could be connected to the grid within ten years. Yadoo and Cruickshank (2010) follow this support of CREEs and suggest that local cooperatives are a "*highly favourable delivery mechanism for rural electrification in developing countries*" (pg. 2946). The reasoning for Yadoo and Cruickshank's (2010) support included the promotion of transparency in the electrification process, the localisation of decision-making, the reduction of electricity theft and the ability for linesmen to respond immediately to service disruptions.

Surveyed policy has a strong direction to achieve rural electrification, with objectives towards this goal being present in the Hydropower Development Policy 2001, Universalizing Clean Energy in Nepal plan, Nepal Sustainable Development Goals status report, National Rural and Renewable Energy Programme Nepal (NRREP) and its successor the National Renewable Energy Framework (NREF), and the Renewable Energy Subsidy Policy. Perhaps one of the clearest rural electrification policy objectives among these documents is the case put forward by the Universalizing Clean Energy in Nepal plan to expand the grid to all consumers with 530 new substations and 7828 km of new transmission and distribution lines. The widespread acknowledgement of the need to achieve rural electrification amongst surveyed policy documents is indicative of the importance of rural electrification in addressing existing energy poverty and energy inequality issues in Nepal. However, Baral et al. (2012) has criticised Nepal's policy on rural electrification, however, for not promoting synergy between on-grid and off-grid policy objectives. From an external perspective, the issue of policy isolation appears to persist with the Universalizing Clean Energy in Nepal plan seemingly avoiding detailed discussion of the involvement of the much-hailed community electrification scheme supported by the authors above. Given that many energy policy objectives in Nepal have a track record of being missed, it is difficult to suggest the role that the centrally operated grid, community operated grid extensions or off-grid distribution systems will play in Nepal's energy futures based on surveyed policy (Sovacool et al., 2011b, Sharma and Awal, 2013). However, it is clear that achieving rural electrification is an issue which will need to be targeted.

The evidence presented by stakeholders, literature and policy suggests that grid distribution options will face challenges in building distribution capacity to meet future demand growth in Nepal. Policy objectives demonstrate that distribution systems will also need to grow in terms of users supplied, in order to achieve electrification goals and address energy poverty and energy justice issues. It is not clear how this second goal will be achieved. Both G2 and G3 acknowledged that grid connected options are best, as they can provide the quality of electricity required to run larger appliances. Grid-connected CREEs have been praised in the literature, which suggests that this distribution option would be best suited to achieving electrification goals. Where such a grid-connected system was not going to be possible for some time, an off-grid system could provide electricity access in the interim. G2 explained that a policy mechanism is in place to connect off-grid systems to the grid when the grid expands near to the community, so presumably these off-grid systems would retain ownership and become systems similar to CREEs. An approach to achieving rural electrification through expanding the CREE network and continuing the establishment of off-grid systems in the interim therefore seems to be the best option for Nepal's energy future. The issue of the leading Universalizing Clean Energy in Nepal plan avoiding discussion of CREEs, however, throws doubt into this approach as it is unclear whether government policy will promote the development of the CREE distribution option.

Summary 7b: How will future energy demands be supplied?

Benefits/Challenges: Smaller hydro appears to be the most easily developable power generation technology for Nepal. With most of the components being able to be manufactured domestically and the plentiful supply of water resources within the country, micro hydro has established (although financially limited) support from the government's AEPC. The biggest challenge holding back smaller hydro is the poor financial viability of the technology without subsidies. This has kept the private sector away from developing smaller hydro.

Discussion of larger hydro dominated stakeholder responses and it appears that Nepal is moving towards being able to develop hydropower projects of a greater size domestically. There is ample evidence of challenges for larger hydro power; with transboundary water resource challenges, public sector cost over runs, a lack of policy guiding community compensation and dispute resolution, seasonal rainfall and adverse social affects in areas with hydropower development being mentioned through stakeholder responses and literature. The benefits of larger hydro are also clear, however, as the technology presents a way to meet growing energy demands, end coal-fired power imports from India and provide electricity which can be sold to the South Asian electricity market. Stakeholders particularly focused on the energy storage benefits of reservoir hydro, which they saw as a way to overcome the seasonal variability issue with run-of-river hydro while also providing irrigation and flood control.

Solar technology has established use in Nepal and has proven able to make a start on addressing energy justice and energy poverty issues for rural people without grid access. The technology has the benefit of being modular so that generation capacity can be scaled up as needed. Solar can also be installed near to consumption points and is able to have minor issues managed by local personnel. There are significant challenges for solar, however, especially for off-grid solar where the need for batteries increases costs significantly. For the private sector, the high cost of off-grid solar when compared to the cost of grid delivered electricity has kept the private sector out of the market, and in grid connected areas a lack of financial arrangements has prevented solar panels from being realised as a viable investment. At this point of time, it is difficult to suggest the future for wind energy as wind speed data is required to assess wind energy plausibility.

Trading electricity within the South Asia region provides an alternative to producing electricity domestically, but no stakeholders suggested that this would be beneficial for Nepal. This is despite electricity imports from India being described as a key part of the actions taken to reduce load shedding. Discussion on electricity trade with India had mixed results. G7, a stakeholder from the government, saw potential for electricity exports to uplift Nepal's economy, but most other stakeholders were hesitant to support electricity exporting to India. This is possibly a result of these stakeholders being from NGO and academic sectors, who may inherently hold some adverse bias towards a government sector-controlled energy system. Policy and literature also conflict on energy trading, with literature expressing the persistent difficulties in regional energy trade but bilateral and multilateral agreements promoting energy trade within the South Asian region. Given that the policy mechanisms required to enable energy trade seem to be in place, it would be reasonable to assume (despite the perspectives of some stakeholders), that the potential for Nepal to engage in electricity trading will be a result of surplus or shortfalls in domestic generation and demand. Energy trading through petroleum fuels looks unlikely to shift away from a total reliance on India in the near future, because of the difficulties associated with the only other possible supply partner of China.

Potential for Growth: Smaller hydro looks to continue growing in Nepal, particularly as part of a push to continue electrification efforts towards all consumers through distributed generation. Larger hydropower also appears to have a positive future in Nepal as stakeholders suggested that financial and technical capabilities are in place for small to large hydropower development. This positive future is illustrated through the 4500 MW of hydropower currently under construction or being planned in Nepal (NEA, 2018). There is conflicting evidence that solar will grow in areas reliably serviced by the grid, as the reported drastic decrease in demand for households' systems since load shedding ended suggests that the growth of the technology is limited. P2, however, conversely believed that grid connected solar home systems will be the future for the technology. For larger systems at least, the use of solar technology seems to have a positive trajectory as the Universalizing Clean Energy plan foresees 481 solar PV projects and Nepal's INDC aims for 2,100 MW of solar energy to be generated by 2030. The degree to which Nepal's energy trading influences the supply of electricity in the future looks to be controlled by the ability of these generating technologies to provide a surplus or deficit to domestic demand. As petroleum fuels demand looks to continue increasing in the future, the only feasible option for Nepal's petroleum system to meet this demand is to continue importing fuel from India.

7.8 Threats to Nepal's Energy Futures

This chapter has presented a comprehensive evaluation of Nepal's future electricity and petroleum demand and suggested how hydropower, solar PV and energy trading will supply this demand. Using stakeholder responses, policy, literature and results given in **Chapter Five** and **Chapter Six**, this chapter now moves to address resilience in Nepal's energy future in light of the information given thus far.

7.8.1 Threats to Hydropower

Threats to hydropower generation were considered by a number of stakeholders and researchers for both smaller and larger hydro. Considering climate factors, N4 recognised that a shortage of water directly affects hydropower as stations will not be able to meet generation capacity, while a surplus of water during heavy rainfall events means there will be flooding and landslides. N4 believed heavy rain events increase sedimentation in the river, and this is a challenge for hydropower production. This position is supported in the literature, as sedimentation has been recognised as a threat to hydropower by Sangroula (2009), particularly with respect to the sustainability of reservoir-type projects. Additionally, in 2017 heavy rainfall was demonstrated to be a threat to hydropower as debris swept by floodwaters blocked intake channels to hydropower facilities, causing about 50 MW of national generating capacity to be lost (NPC, 2017b).

G4, a government expert who is outside of the energy sector, believes recent research shows that climate change will influence water resources by reducing flow during the dry season, and increasing extreme rainfall events in the wet season. This will have implications for all hydro power generation. With this being said, P3 believes climate change has not had much impact on micro hydro generation, as these projects are designed to operate in minimum flow conditions throughout the year. There has been research into the impact of climate change on hydropower generation by Shrestha et al. (2014). Their findings suggest that across the investigated scenarios, power production may decrease by at least 30% (Shrestha et al., 2014). In another study, Shrestha et al. (2016b) suggest power production for the Upper Tamakoshi Hydropower Project could change somewhere between +15.8% to -20.5% across different baselines, models, scenarios and forecast ranges. Shrestha et al. (2016b) argue that this wide variability across different factors suggests that uncertainty needs to be considered in order to address anticipated risks of hydropower development.

This uncertainty is clearly an issue that is being met with a response from the government and donor agencies. N4 described the UNDP supported government initiative to install meteorological stations in key locations to provide data for an early flood warning system. This system provides protection for people and hydro power infrastructure in downstream reaches as the stations monitor for heavy rainfall upstream. This programme has the added benefit of providing low flow and high flow discharge data which private hydro power producers can use, and N4 explained that these private power producers are willing to contribute to the operation costs of the metrological stations in order to access this data. This program therefore looks to be aiding in attracting hydro power investment.

Beyond climate related factors, seismic and glacial lake outburst floods (GLOFs) were recognised as risks to hydro. N4 acknowledged that earthquake risks pose a serious threat to hydropower, saying "*The landscape is very fragile. The geology is very fragile. The tunnelling and the other stuff required has to be thought of very seriously…. not a superficial assessment…because we are in the earthquake prone area".* N4 also drew attention to the GLOF which damaged the Bhotekoshi power plant. In this event, the GLOF occurred in Chinese territory, which made it difficult for the Nepali authorities and the UNDP to know what was happening with that lake (N4). The Bhotekoshi power plant was also the largest generation facility to be damaged by the earthquake, and the GLOF further damaged the power plant as repair works were beginning in 2016 (Tiwari, 10/04/2018). Sharma and Awal (2013) support N4's position, suggesting that GLOFs are major natural threats to hydropower which will increase in frequency in the future due to deglaciation and increasing temperatures in Nepal.

G2 identified that a threat to off-grid micro hydro arises in the monsoon season, as there is heavy rainfall during June, July and August. G2 explained that micro hydro projects are often landslide prone as powerhouses are commonly located near to erosion prone rivers. In making this argument, G2 drew on the particularly bad monsoon season in 2017, claiming that 15 micro hydro power projects were damaged by flooding or landslides (G2). This seems likely as the NPC reported a loss of about 50 MW of electricity generating capacity because of these floods (NPC, 2017b).

A recognition of landslides as a threat to hydro has been expressed in the literature, with Raut and Gudmestad (2018) blaming a lack of specific guidelines and a lack of finance as reasons why measures for avoiding landslides are not considered in hydropower development. Landslides were also recognised as a threat to hydropower after the earthquake, with at least 14 hydropower projects suffering landslide and rockfall damage (Shrestha et al., 2016a). When considering the threat of landslides to micro hydro facilities, G2 made a comparison against solar; saying that solar has the advantage over micro hydro because solar panels are used on the house.

G2, however, pointed out that when micro hydro systems need maintenance, the parts can mostly be sourced from within Nepal (G2). For solar systems on the other hand, almost all the parts must be imported, so there are implications for resilience there (G2). In summary, G2 said "*If there is some water resource, the people prefer to have micro hydro rather than a solar home system. If there is not this resource, then they prefer solar".*

Karki (2018) suggests that resilience can be improved for micro hydropower by connecting their local grids with other nearby local grids, to form 'mini-grids'. These mini-grids would provide the ability for nearby micro hydropower systems to provide for a nearby local grid if that grid's micro hydropower system stopped operating, and would also increase capacity which may help to address fluctuations in demand (Karki, 2018). In a similar manner, wind and solar PV power systems could also be introduced into mini-grid systems alongside micro hydropower to improve reliability, and this has been successfully tested in practice in Nepal by Bhandari et al. (2014).

The results presented in the earthquake response chapter (**Chapter Five**) clearly demonstrate that both smaller and larger hydro are vulnerable to earthquake damage. The most vulnerable projects were smaller hydro facilities, with around 260 projects destroyed. Further, **Chapter Five** suggested that many of those damaged projects were unable to undertake repairs because of a limited financial capacity. Smaller hydro is therefore threatened by a weak capacity to withstand and respond to earthquake damage. For larger hydro, the 150 MW of generation across thirteen power stations that was lost because of earthquake damage demonstrates a vulnerability of larger hydro projects. It appears, however, that much of this damage was able to be repaired quickly, with the lost generation capacity reducing to 96 MW within a month of the earthquake.

Together, the information given here suggests that a range of factors threaten hydropower in Nepal. Earthquake damage has most clearly been demonstrated by the previous earthquake response chapter (**Chapter Five**). Beyond this, climate factors of extreme rainfall, seasonal rainfall and GLOFs, as well as landslides and rockfalls, have been recognised as a threat to hydropower by stakeholders and literature.

7.8.2 Threats to Solar

Unfortunately, the results of this study do not indicate how solar PV technologies responded to the earthquake, but the NPC's PDNA indicates that 115,438 solar home systems and 156 institution solar systems were damaged because of the earthquake (NPC, 2015b). No suggestion is given as to how this damage occurred, but it would be reasonable to assume that it was probably a result of the widespread destruction of houses in earthquake affected areas given that solar systems are often installed on rooftops. In wider literature, heat waves, hail and strong winds have also been suggested as threats to solar PV generation (Patt et al., 2013).

7.8.3 Threats to Energy Trading

The most obvious threat to Nepal's energy trading systems is Nepal's reliance on India for petroleum fuels and electricity imports, as the blockade demonstrated that energy supplies from India can be strangled. The actions which the NOC is taking to improve resilience in the petroleum sector, as described by O1 in the previous chapter, suggest that the NOC has acknowledged this risk. Development of the petroleum fuels pipeline and increased storage capacity within Nepal would decrease the threat, but it remains that Nepal's reliance on India for energy imports presents a risk of energy supply shocks outside the control of Nepal's government and energy system actors.

Beyond these actions described by O1, the issue of Nepal's reliance on India was not made clear by stakeholder responses and has not been identified in wider literature. This may be a limitation of this study as few stakeholders involved in the petroleum sector were interviewed, but it may also suggest a wider sense of apathy in Nepal towards the risk of energy supply shocks. Given that Butler and Rest (2017) and Lord (2018) believe the concern regarding the risk of earthquake damage to hydropower in Nepal has fallen behind other priorities since the earthquake, a similar relationship with the blockade would not be startling. As threats to Nepal's petroleum sector were not discussed by stakeholders and are not suggested by wider literature, it is hard to suggest other threats to energy trading beyond supply shocks.

7.8.4 Threats to Distribution Systems

The earthquake and blockade response chapters both identified threats to distribution systems in Nepal. The earthquake clearly showed that all distribution systems are vulnerable to damage, but the NEA-operated grid distribution system was able to recover the fastest because of the lesser severity of damage in urban distribution systems compared to rural systems. The ability of the NEA to conduct an effective recovery process for the grid within Kathmandu also fastened the grid system's recovery. The blockade indirectly exposed the vulnerability of the NEA-operated distribution system because of the spike in electricity demand, which subsequently damaged transformers. Given that G3 and N6 stressed the challenge in meeting demand with the current NEA-operated distribution system, demand surges remain as a significant threat to this system.

N2 believed off-grid systems had more victims than their grid equivalent did after the earthquake. This suggests off-grid distribution systems are more vulnerable than their grid counterparts. N2 explained that this was because the grid has access to a greater pool of technical manpower and the government places a greater priority on the grid, while off-grid systems are remote and communication with the off-grid communities is challenging (N2). N2 did believe, however, that while the grid can be more reliable than the off-grid options, off-grid systems are a good solution until the grid will arrive in remote areas. For both systems, issues around human resources, appliances, material stocks and financial readiness are important when considering the ability to withstand and respond to shocks (N2). Policy is also an issue to consider, with N2 saying *"To address the disaster - it will not work with normal and general policy and actions. It should be different than the normal conditions. So, there should be appropriate policy, plans, resources; everything dedicated and intact, to address this kind of disaster".*

Stakeholders and literature have not identified further threats, however, the NPC has identified that the floods which badly affected the Terai region of Nepal in 2017 damaged the NEA-operated distribution systems. During this event, the submerging of substations in floodwaters meant that the Duhabi substation needed to be shut down, while transmission lines, poles, transformers and conductors were also damaged (NPC, 2017b). The damage to the electricity sector from these floods was estimated to be USD$2.1 million USD (NPC, 2017b).

Summary 7c: What does Nepal's energy futures mean for energy resilience?

Considering resilience, smaller hydro did not withstand or respond well to earthquake damage in affected districts. Relying on small hydro for electricity supply in rural areas may therefore have implications for energy justice and energy poverty in the wake of another disaster. For larger hydro, earthquake damage is clearly a risk to the system as at least 150 MW of generation was shut down because of earthquake damage. This damage did not cause the entire grid system to go offline however, and some of this damage appeared to be repaired quickly after the earthquake. Existing research has identified that larger hydro is likely to be affected by climate change, but there is a wide amount of uncertainty as to the magnitude of this impact. Additionally, extreme climate related events like heavy rainfalls, landslides and GLOFS have already proven to be a risk to both smaller and larger hydro. Beyond hydro, it is difficult to expand on the threats facing the alternative of solar generation in Nepal, but the results of this study suggest that small solar home systems are not able to withstand earthquake damage well.

For energy trading, the impact of the blockade to the petroleum sector demonstrated in **Chapter Six** clearly shows that energy trading systems in Nepal can be shocked by human-sourced risk. This risk has largely been ignored by stakeholders, media, policy and literature, however. Contractually, the energy trading agreements signed by Nepal suggest that political interference should not affect energy supplies. But, as explained by O1 in **Chapter Six**, contractual obligations did not prevent the blockade. The possibility of human sourced disruptions to energy systems may therefore need to be considered.

The impacts of energy resilience on the grid system will be felt by the consumers of the electricity service the grid provides, regardless of where that electricity is supplied from. All three distribution options experienced damage in the 2015 earthquake, which suggests that all three options are vulnerable to earthquake damage. However, the NEA-operated grid system withstood and recovered best to this damage, which indicates that the threat to distribution systems from earthquake damage is greater for CREEs and off-grid systems For off-grid systems, this vulnerability may be compounded as issues associated with communication, resource, financial and technical capacity, alongside the poor capacity for micro hydro and solar home systems to withstand earthquake damage, meant off-grid systems had more victims than grid connected communities after the earthquake. The greater vulnerability for off-grid systems therefore represents an energy justice issue.

7.9 Axes of Possibility for Nepal's Energy Futures

This chapter has examined what the future energy demands of Nepal will be, discussed how hydropower, solar PV and energy trading will supply this energy demand across different distribution systems, and suggested what these energy futures mean for energy resilience. This discussion has been limited in some areas because of gaps within wider literature, but a holistic analysis of Nepal's future energy systems has otherwise been provided. This drew on the energy sector overview given in **Chapter Three** and used stakeholder responses, policy and wider literature. In doing so the results presented in this Chapter drew on those brought forward in the earlier earthquake and blockade response chapters. A summary of the issues, benefits, threats and implications of the energy resources discussed in this chapter is given in **Table 7.10**.

To conclude this chapter, three axes of possibility for Nepal's energy futures are given. These axes have emerged from the results given in this chapter and draw upon the results identified in the earthquake and blockade response chapters (**Chapters Five** and **Six**). The different possibilities alongside these axes are a centralised electricity system versus distributed electricity systems in Nepal, an isolated energy sector versus a regionally integrated energy sector for Nepal, and an energy sector supplied by fossil fuels verses one supplied by renewable energy. These possibilities are not mutually exclusive, but each possibility holds different implications for energy security, energy poverty and energy justice. Having strongly demonstrated that energy resilience is an important and useful concept for wider energy studies literature, this thesis draws to a close by suggesting resilience implications for these energy futures. In doing so, the secondary research objective of this thesis is answered. This is not done to recommend certain energy futures over others, but to instead provide information to those who play a role in the future of Nepal's energy systems.

7.9.1 Centralisation of Electricity Systems versus Distributed Electricity Systems

An emergent possibility that came through this chapter was the possibility of having a more centralised electricity sector in Nepal or a more distributed electricity system. In a centralised sector, larger generation components would be the main source of electricity, which would take the form of larger hydro or electricity imports from India. The NEA-operated grid system would be the primary means of distributing this electricity. In a distributed or decentralised energy future, a greater importance would be given to smaller means of generation, such as the smaller hydro and solar options examined in this thesis. Community grid extension and off-grid distribution systems would be promoted as equals to the NEA-operated grid system.

This thesis has argued that both smaller and larger hydro have the potential to grow, and the 4500 MW of under construction and planned larger hydro demonstrates the progress which the larger hydro actors are making towards achieving this potential (NEA, 2018). This would suggest the generation components of a centralised system are moving into place. In the distribution sector, evidence from policy and literature advocates for the need to achieve rural electrification to address energy poverty and energy inequality issues. Stakeholders argued that grid connection was the best way to do this, although off-grid systems are effective for providing electricity access in the interim until grid access is achieved. Whether this grid connection is operated through the centralised NEA-operated grid or a decentralised community grid extension cooperative is less clear, with no direction evident from policy, stakeholder responses or literature.

Considering energy resilience for these two energy futures, this thesis has shown that the centralised systems withstood earthquake damage better and were able to recover from the earthquake much faster than the distributed micro hydro, household solar, community grid extension and off-grid systems. This was due in a large part to the vulnerability of rural houses to earthquake damage and the poor financial capacity of distributed system actors to recover from the experienced damage. Despite the vulnerability of energy systems in a distributed future, the successes of these systems have been expressed in the literature for providing electricity services to rural communities in a faster and more democratic manner than the NEA-operated grid. If this is true, then the distributed future will provide the greatest benefits to the energy poverty and energy justice issues which Nepal currently faces. This needs to be considered against the resilience benefits of a centralised energy future.

Table 7.10: Potential, benefits, issues, vulnerabilities and implications of Nepal's energy futures.

Sector	System	Likely to Grow?	Benefits	Issues	Vulnerabilities	Implications
Electricity	Smaller Hydro	Yes	Easily developed. Provides electricity to remote communities.	Private sector integration. Not commercially viable.	Vulnerable to earthquake damage. Heavy rainfall and landslides. GLOFs.	Energy poverty benefits. Energy justice benefits.
	Larger Hydro	Yes	Large electricity generation potential. Ability for projects (not largest) to be developed without foreign investment or technical assistance. Potential for water and energy storage.	Public sector cost overruns. Community compensation and dispute resolution. Transboundary water issues. Seasonal rainfall.	Vulnerable to earthquake damage. Heavy rainfall and landslides. GLOFs. Sedimentation. Reduced flow during dry season.	Political implications for Nepal's relationship with India and China. Energy security benefits.
	Solar	Yes, but conflicting evidence for smaller systems.	Modular. Can be installed near to consumption points. Small issues can be managed. Provides electricity to remote communities.	Cost per kW is greater than micro hydro. Dust collection on panels in Kathmandu. Lack of financial instruments promoting solar.	Vulnerable to earthquake damage if installed on vulnerable household.	Energy poverty benefits. Energy justice benefits.
	Electricity Trading	Depends on other factors.	Can provide electricity to meet domestic demand if domestic generation does not.	Historically unfair trading prices with India. Difficulty accessing Bangladeshi market.	Reliance on India presents risk of supply shock.	Energy security benefits. Consumption of fossil fuels.
Petroleum	Petroleum Trading	Yes	Provide modern energy resource and address energy poverty issues	High cost of imports	Reliance on India presents risk of supply shock.	Energy poverty benefits. Consumption of fossil fuels.
Distribution	Grid (NEA-operated)	Yes	Provides electricity service which can operate higher loads.	System losses. Meeting increasing electricity demand though higher system capacity.	Vulnerable to earthquake damage. Demand surges.	Least vulnerable to shocks.
	Grid-Connected (CREEs)	Not clear	Provide rural communities with electricity access. Provide electricity access through a locally empowered process.	Financial viability. Meeting increasing electricity demand though higher system capacity.	Vulnerable to earthquake damage. Weaker ability to recover from earthquake damage.	Energy poverty benefits. Energy justice benefits.
	Off-Grid	Potentially, in interim between grid connection.	Provide remote communities with electricity access. Electricity costs go back to the community. Able to be connected to grid when possible.	Difficulties operating higher loads. Difficulties maintaining systems with available workforce.	Vulnerable to earthquake damage. Weaker ability to recover from earthquake damage.	Energy poverty benefits. Energy justice benefits.

7.9.2 Regional Integration of Energy Systems versus Isolated Energy Systems

The second emerging axis of possibility for Nepal's energy futures are the two divergent futures where electricity and petroleum fuels may be imported and exported through the South Asia region in a regionally integrated energy future, or where Nepal may supply and consume its own energy resources in an isolated energy future. In the regionally integrated energy future, electricity would be exported if a surplus was generated and imported to meet unfulfilled domestic demand. Consumption of petroleum fuels would also be enabled through the continued growth of petroleum fuel imports. Conversely in an isolated energy future, energy trading would be limited and policy direction would aim to generate electricity for the purposes of meeting domestic demand, not for export. The growth of petroleum consumption would also be limited or discouraged in order to decrease the import of these fuels from India.

It would be reasonable to assume that any electricity generated in Nepal that is surplus to demand will be exported to India and not spilled, given that the power trade agreement signed between Nepal and India allows for this export to happen. How much electricity will be generated to allow this export to happen, and how much domestic demand there will be in the future, is not straightforward. Demand projections looking towards 2030 suggest a generation capacity significantly higher than the approximately 1000 MW of capacity available now will be required, but the 4500 MW of generation under construction or being planned also indicates a large amount of capacity will come online in the future. Therefore, the degree to which Nepal will engage in a regionally focused energy future will depend on the speed at which new generation capacity is constructed and the rate at which domestic electricity demand will grow. In the petroleum sector, the continuing growth of petroleum fuel consumption looks to continue. This will encourage a regionalised energy future as Nepal must continue relying on India for the supply of petroleum fuels.

The 2015-2016 blockade clearly demonstrated the energy resilience issues associated with relying on India as an electricity trading partner and petroleum fuel supplier. Actions such as increasing storage capacity and constructing the India-Nepal pipeline will help address these issues, but it remains that contractual obligations cannot ensure that energy trading will always operate as intended. This has to be considered with energy poverty and energy justice concerns in mind, as energy trading may enable consumers access to the various benefits of electricity and the cooking and mobility benefits of petroleum fuels which they may otherwise not have. This is exemplified by the increase in electricity imports from India in recent times which have helped end load shedding in Nepal.

7.9.3 Fossil Fuels versus Renewable Energy

The last axis of possibility separates the divergent energy futures of a renewable based energy sector in Nepal and an energy sector reliant on fossil fuels. In a renewable energy future, Nepal's electricity demand would mostly be generated from renewable sources, particularly hydro, within Nepal. Like the isolated energy future, this scenario would see electricity imports from India reduced to ensure electricity generation was renewable based. The growth of petroleum imports would be limited to reduce the use of fossil fuels within Nepal. In the fossil fuel-based future, electricity imports generated from thermal energy in India would continue while the growth in petroleum consumption would remain.

As Nepal has no reserves of fossil fuels and the energy resources available through energy trading are either fossil fuels or largely fossil fuel based, the level to which Nepal's energy systems are supplied by renewable or fossil fuel sources depends on the country's propensity to engage in energy importing. In a similar manner to that described for the second axis, if Nepal is able to generate enough electricity domestically to meet demand, fossil fuel-based electricity imports from India will not be needed. As mentioned above, however, it is difficult to suggest whether Nepal will meet domestic electricity demands with domestic generation as both sectors have the potential to grow significantly in the future. If petroleum fuel-based consumption patterns (particularly cooking and transport uses) can be replaced with electric options, then petroleum imports will be limited without compromising energy poverty. However, no major policy or incentive to encourage this replacement was identified in this study.

In a rather unfortunate manner, the energy future which has the least impact on climate change will face the greatest threats from climate change, as hydropower is vulnerable to changes in runoff, heavy rainfall events and GLOFs. In the fossil-fuel based future, the reliance on energy trading brings the vulnerability of relying on India, as described above. There are less implications for energy poverty through these divergent energy futures as both enable the supply of electricity, but the sustainability directed energy justice concerns would strongly support the renewable based option. If Nepal makes effective progress towards achieving its goals set out in the 2016 INDC, the country will move towards this renewable energy future.

8 Conclusion

This thesis has investigated the response of Nepal's energy systems to the 2015 earthquake and 2015-2016 blockade, and considered the resilience of Nepal's energy futures. In doing so, it has demonstrated that energy resilience is a useful concept and shown how the concept can be used to critically analyse future energy systems.

This thesis has filled a gap in the wider energy studies literature by building on the concept of energy resilience in a context where the resilience of energy systems has implications for energy security, energy poverty and energy justice. This required the concept of energy resilience to be developed through a conceptual framework, because existing uses of an energy resilience concept so far have been restricted to specific settings. The conceptual framework took the discourse of energy security from the highest level of energy studies thinking and used it to demonstrate how vulnerabilities to energy systems can be considered (Cherp and Jewell, 2011, Sovacool and Mukherjee, 2011). Issues associated with scale required that concepts of resilience also be drawn upon, and the concept of adaptive resilience from Sharifi and Yamagata (2016) was used to do this. Adaptive resilience provided an approach for examining energy system responses to the earthquake and blockade, and this approach was later employed throughout the earthquake response and blockade chapters. Relying on the concepts of energy security and adaptive resilience to investigate energy system responses, however, left out the investigation of roles and responsibilities which a range of specific actors within energy systems held (Meerow and Newell, 2016). To gain this insight, a third concept of cultural theory was introduced which provided a way of examining actors as hierarchical, individualistic, egalitarian or fatalistic agents (Verweij, 2018).

To demonstrate the importance of the energy resilience concept, the literature review was required to extend beyond a conceptual framework and introduce analytical tools which would show the implications energy resilience has on energy systems. Energy security literature provided one of these analytical tools by demonstrating the importance of energy resources on a higher scale, while energy poverty literature provided another, by demonstrating the importance of energy resources to economic and human development (Sovacool, 2012, Kruyt et al., 2009). The agenda of energy justice provided the third tool, as it allowed issues of inequality, sustainability and governance within energy systems to be examined (Sovacool and Dworkin, 2015, McCauley, 2017).

The earthquake and blockade response chapters investigated the response of the electricity and petroleum sectors, respectively, to the earthquake and blockade. This drew on this study's primary source of data collection, the 19 stakeholder interviews undertaken in Kathmandu. Media, policy and literature, and data analysis methods were also employed as secondary methods to strengthen the validity of the research in this thesis.

In using these methods, the earthquake response chapter identified the impact of the earthquake on the electricity sector, the way in which systems within the electricity sector responded to this impact, and the actions which have been taken to improve coping capacity in the future. This investigation showed that the impact of the earthquake was most severe for cooperative grid extension and off-grid users as the damage in urban areas was less persistent. The response in urban areas was also faster, largely because the cooperative systems and off-grid systems had limited financial capacity to respond. For the cooperative grid-extension systems affected by the earthquake, an egalitarian actor had to step in to provide the support which the hierarchical NEA provided for the grid distribution system. The results identified through this chapter were shown to have damaged Nepal's energy security by reducing the availability of energy resources, worsen energy poverty issues by taking away electricity access to approximately 600,000 households, and exacerbate energy justice issues by deepening urban/rural energy access inequality (NPC, 2015b).

The response which the petroleum sector had to the blockade was significantly different to the electricity sector's response to the earthquake. The NOC, as the monopoly operator of Nepal's petroleum sector, did not have a strong ability to withstand the blockade. Yet, the NOC was able to manage the decrease in supply of petroleum fuels in a way which promoted energy equity by providing supply for public and emergency vehicles. The ability of the NOC to withstand supply interruptions in the future may increase if the India-Nepal pipeline and proposal to increase petroleum storage capacity is completed successfully. It remains however, that the impact of the blockade indicated the risk of relying on India as the sole supplier of petroleum fuels as a vulnerability to national energy security.

Through the earthquake and blockade response chapters, this thesis showed how the concept of energy resilience can be used and showed why using the energy resilience concept is important. With these findings in mind, the thesis shifted in the energy futures chapter to look forward by examining how energy resilience could be considered in Nepal's energy futures. This chapter brought forward extensive evidence from stakeholder responses, surveyed policy and existing literature to build upon the energy sector overview given in **Chapter Three**. This allowed systems within the hydropower, solar PV, energy trading, petroleum and distribution sectors to be evaluated critically by considering what role each system may have in meeting Nepal's future energy demands. Drawing from the evidence presented in the earthquake and blockade response chapters, this chapter was able to provide insight into what the future of these energy systems might mean for energy resilience, energy security, energy poverty and energy justice.

The concluding argument of this thesis, as presented in the energy futures chapter, is a suggestion that resilience be considered across the three emerging axes of possibilities for Nepal's energy future. The first axis of possibility indicates that Nepal could have a distributed electricity sector, which would provide the greatest energy poverty and energy justice benefits, but would be vulnerable to shocks like that which were experienced in the 2015 earthquake. The second axis suggests a regionally integrated energy sector would provide access to an important electricity market and ensure electricity and petroleum demands will be met, but means a reliance on India is continued. Such a reliance on India resulted in the impacts of the blockade explained in **Chapter Six**. The last axis suggests that Nepal can reduce a reliance on fossil fuels by both generating enough renewable electricity to meet domestic demand and minimising petroleum consumption growth. In this future, Nepal's electricity generation would be vulnerable to climate and seismic related risks, but would provide the greatest benefits for sustainability related principles of energy justice.

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Appendix 1: Information Sheet for Interview Participants. [Reference Number: 18/003]
[31/01/2018]

POST-EARTHQUAKE ENERGY DIRECTIONS FOR AN URBANISING NEPAL

INFORMATION SHEET FOR PARTICIPANTS

Thank you for showing an interest in this project. Please read this information sheet carefully before deciding whether or not to participate. If you decide to participate we thank you. If you decide not to take part there will be no disadvantage to you and we thank you for considering our request.

What is the Aim of the Project?

The purpose of this research is threefold: firstly, to identify the challenges in Nepal's energy production, distribution and consumption systems, and analyse how they may change in an increasingly urbanising future, acknowledging the difficulties the 2015 earthquake added. Secondly, the possibilities for solving these challenges will be presented, which will be followed by an analysis of the environmental, economic, social and political contexts of Nepal. Combining these possibilities and contexts will then allow a commentary on the possible directions Nepal may take in the future towards solving the identified energy challenges. The research is being undertaken by Greg Underwood as part of the requirements for the Master of Planning course at the University of Otago.

What Type of Participants are being sought?

Participants will be individuals or representatives of organisations who have an interest above that of the general public, in Nepal's energy production, distribution and consumption systems. These stakeholders may be representatives from industry, NGOs, business or community groups, or government officials and academics. All participation is voluntary. Participants will have access to the findings of the research.

What will Participants be Asked to Do?

Should you agree to take part in this project, you will be asked to comment on a number of issues and trends on energy production, distribution and consumption in Nepal. The time commitment is expected to be around 60 minutes.

This may involve discussion of the 2015 earthquakes and it is understood that this may be distressing for some participants. Participation in the interview can cease at any time if an individual should feel any amount of distress.

Please be aware that you may decide not to take part in the project without any disadvantage to yourself of any kind.

What Data or Information will be Collected and What Use will be Made of it?

Information will be collected around the following topics:

1. Issues with energy production, distribution and consumption in Nepal, and, the way these issues may change in the future.

2. The relationship between the economic, social, environmental (particularly earthquakes and related hazards) and political contexts of Nepal, and the ways which these contexts are related to Nepal’s energy systems.

3. Existing and emerging energy technologies and their suitability for Nepal.

The raw data and information will only be accessed by the student researcher, field assistant, transcriber and supervisor Dr Douglas Hill of the University of Otago. The processed data in its final form as part of a Master’s Thesis will be publicly available online and in print.

The data collected will be securely stored in such a way that only the student researcher, field assistant, transcriber and Dr Douglas Hill will be able to gain access to it. Data obtained as a result of the research will be retained for **at least 5 years** in secure storage. Any personal information held on the participants such as contact details, audio recordings, after they have been transcribed will be destroyed at the completion of the research. The data derived from the research will, in most cases, be kept for much longer or possibly indefinitely.

The results of the project may be published publicly in a form other than a Master’s Thesis (such as a presentation, for example). The only personal information which will be published however will be the name of your organisation and your position within that organisation, and this will only be published if you voluntarily consent to this information being published by recording those details on the attached consent form.

The answers that you have provide the researcher and field assistant/translator can be reviewed by participants any time within two months of the interview. At your request statements and/or answers to a specific question or subject area can be withdrawn from the data/information you have supplied.

Can Participants Change their Mind and Withdraw from the Project?

In the event that the line of questioning does develop in such a way that you feel hesitant or uncomfortable, you are reminded of your right to decline to answer any particular question(s) You may also withdraw from the project at any stage during the interview or within two months after the interview without any disadvantage to yourself of any kind.

What if Participants have any Questions?

If you have any questions about our project, either now or in the future, please feel free to contact either: -

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This study has been approved by the University of Otago Human Ethics Committee. If you have any concerns about the ethical conduct of the research you may contact the Committee through the Human Ethics Committee Administrator (ph. +643 479 8256 or email gary.witte@otago.ac.nz). Any issues you raise will be treated in confidence and investigated and you will be informed of the outcome.

Appendix 2: Summarised Goals of Surveyed Policy

Title	Authoring Organisation	Year	Goals (Summarised)
The Hydropower Development Policy	Ministry of Water Resources	2001	– Hydropower to be utilized to maximum extent in order to meet domestic demand. – Incentives be placed to encourage transparent foreign and domestic investment in hydro power. – Rural electrification through small and micro hydro projects to be encouraged in order to make electricity services available to as many people as possible. – Downstream and environmental impacts/benefits to be considered and managed.
SAARC Framework Agreement for Energy Cooperation (Electricity)	SAARC	2014	– *"Member States may enable cross-border trade of electricity on voluntary basis subject to laws, rules and regulations of the respective Member States and based on bilateral/trilateral/mutual agreements between the concerned states."* – Article II – Member states may enable cross-border transmission planning, development, operation and maintenance. – Member states to also work towards exempting duties and taxes for cross-border trade, sharing technical data and information, and opening up the electricity sector to promote competition.
Agreement Between the Government of Nepal and the Government of the Republic of India on Electric Power Trade, Cross-Border Transmission Interconnection and Grid Connectivity	Government of Nepal, Government of India.	2014	– *"Enable cooperation in the power sector, including developing transmission interconnections, grid connectivity, power exchange and trading through the governmental, public and private enterprises of the two countries on mutually acceptable terms"* (Article I) – Both parties to encourage and facilitate investments that enhance power trade. – Both parties to work towards resolving and removing barriers, duties and taxes towards trading electricity. – Both parties to ensure unrestricted flow of power, subject to safety and stability requirements.
Memorandum of Under Standing (MOU) between the Government of Nepal And the Government of the People's Republic of Bangladesh on Cooperation In The Field Of Power Sector	Government of Nepal, Government of Bangladesh.	2018	– *"The parties shall enhance their cooperation in the field of power including investment and development of power generation projects for mutual benefit"* (Article II). – The parties are to encourage and facilitate joint co-operation for: o The development of power projects, especially for hydro power, transmission, energy efficiency and renewable energy; o The development human resources development and enhancement of productivity and efficiency;

			o Cooperation between public and private sector entities in the electricity sector; and o Joint venture investments in power projects between the two countries. – Both parties to take necessary steps for national and regional grid connectivity for power trade between the two countries.
Intended Nationally Determined Contributions (INDC)	Ministry of Population and Environment	2016	– Nepal plans to develop renewable energy as per the following: o *"4,000 MW of hydroelectricity by 2020 and 12,000 MW by 2030;* o *2,100 MW of solar energy by 2030 with arrangements to distribute it through the grid;* o *Additional 220 MW of electricity from bio-energy by 2030;* o *Additional 50 MW of electricity from small and micro hydropower plants;* o *Increase the share of biogas up to 10% as energy for cooking in rural areas; and* o *Equip every household in rural areas with smokeless (improved) cooking stoves (ICS) by 2030."* - Part 5a (pg. 7). – Promote public transport and use of bicycles; and introduce fuel tax in Kathmandu Valley. – By 2050. achieve 80% electrification with renewable resources and reduce fossil fuel dependency by 50% – INDC Seeks bilateral and multilateral support to create an enabling environment for private and foreign direct investments in low carbon technologies.
Universalizing Clean Energy in Nepal: A Plan for Sustainable Distributed Generation and Grid Access to All by 2022	National Planning Commission	2018	- Plan for sustainable distributed generation for each of the 753 municipalities and grid access to all by 2022, which requires: o 221 hydropower projects, 481 solar PV projects, and 50 biomass to electricity projects; o Eight 132/33 kV substations, 323 33/11 kV substations, 196 km 132kV lines, 5568 km 33 kV lines and 2063 km 11 kV lines installed through step-wise implementation.
Nepal Sustainable Development Goals: Status and Roadmap 2016-2030:	National Planning Commission	2017	- Affirms Sustainable Development Goal 7 (Ensure access to affordable, reliable, sustainable and modern energy for all) with specific targets to: o *Accessibility of 99 percent households to electricity;* o *Reduction to 30 percent - from nearly 75 percent now - the households who resort to firewood for cooking;*

			o *Limiting the use of LPG to less than 40 percent of the households;* o *Generation of 15,000 MW of installed capacity; and* o *Per capita electricity consumption increased to 1500 kWh* (pg. 31). - Improve energy efficiency in industry and appliance use. - Have 50% of public transport vehicles being electric vehicles by 2050. - Restrict growth of fossil fuel consumption as percentage of total to 15% by 2030.
National Rural and Renewable Energy Programme Nepal (NRREP) Programme Document	Alternative Energy Promotion Centre	2012	- Aims to "*to improve the living standard of rural women and men, increase employment of women and men as well as productivity, reduce dependency on traditional energy and attain sustainable development through integrating the alternative energy with the socioeconomic activities of women and men in rural communities"* (pg. iii). - Achieve the following within the five-year project duration: o Mini and Micro Hydro Power: 25 MW o 150,000 households benefitting from community electrification o Solar Home Systems: 600,000 systems o Improved Cooking Stoves: 475,000 stoves o Biogas: 130,000 household systems
National Renewable Energy Framework (NREF)	Alternative Energy Promotion Centre	2017	- Continuing from the programme above, this framework aims for: o *"Enhanced productivity and market-enabled expansion of Nepal's RE sector leading to improved access to energy for all"* (pg. 2). o To coalesce and coordinate policies and programs in the renewable energy sector. o Strengthen governance needed to foster development of the RE sector, increase demand, access and effective use of renewable energy technologies, support renewable energy technology supply, and increase access to finance for renewable energy products.
Biomass Energy Strategy	Ministry of Population and Environment	2017	- The strategy aims to o *Increase production of sustainable biomass energy by utilizing agriculture, forest residues and organic wastes.* o *To contribute to increased access to clean cooking technologies to all Nepalese households through the means of modern biomass energy.* o *To increase effectiveness and efficiency in the utilization and production of biomass energy.*

			○ *To partially substitute the utilization of diesel and petrol by bio-diesel and bio-ethanol.* (pg. 5).
Renewable Energy Subsidy Policy	Ministry of Population and Environment	2016	- Sets out the subsidy and credit provisions for renewable energy technologies, which varies by technology and region. - Aims to *"To reduce dependence on traditional and imported energy by increasing access to renewable energy for improving the livelihoods of people and create employment opportunities especially in the rural areas"* (pg. 4). - Aims to maximise energy service delivery, thereby *"reducing regional disparity, creating rural employment and enhancing livelihood of rural people particularly households from single women, low income, natural disaster victims and socio-economically disadvantaged groups"* (pg. 4). - Aims to support the growth of the renewable energy market, attract private sector investors, and aims to encourage public-private sector participation.
National Sustainable Transport Strategy (NSTS) for Nepal (2015~2040)	Ministry of Physical Infrastructure and Transport	2015	- Has a vision of *"Developing a transport system that is efficient, accessible, people-centric, affordable, reliable, safe, inclusive, environmental friendly, and climate and disaster resilient".* (pg. 11). - Seeks broad economic, environmental and social objectives, including the promotion of electric vehicles.

Appendix 3: Media articles analysed in this thesis.

Title	Author	News Agency	Date
Nepal spent Rs170b on gasoline last year		Bakhtar News Agency	29/08/2018
People feeling govt's presence: PM		The Himalayan Times	28/05/2018
Scheduled power outages formally comes to an end		Nepal Republic Media	15/05/2018
Nepal's Hydropower Battered but not Beaten by the Quake	Peter Fairley	IEEE Spectrum	11/05/2015
Post-earthquake potential: Energy Development is important	Devendra Adhikari	The Himalayan Times	4/02/2016
Areas under Balaju, Lainchaur, Teku sub-stations yet to get power supply		Nepal Republic Media	29/05/2015
CIAA's ongoing probe affects NOC's plans		The Himalayan Times	6/08/2018
Madhesi border blockade sparks anti-India feelings in Nepal	Bipin Chand Agarwal	Times of India	1/10/2015
India and Nepal Have No Choice but to End Their Border Dispute and Move On	Kunda Dixit	Times	18/11/2015
Country braces for negative economic growth in 33 years	Prithvi Man Shrestha	The Kathmandu Post	21/11/2015
Running on empty: Nepal's fuel smugglers defy border blockades	Pete Pattisson	The Guardian	3/02/2016
Blockade by India resulted in losses totalling Rs202 billion		The Kathmandu Post	21/06/2016
Down, down, down	Om Astha Rai	Nepali Times	28/01/2016
Govt introduces fuel rationing to ease crisis	Sujan Dhungana	Republica	28/09/2015

Nepal Oil Corporation enforces rationing of fuel	Puspa Raj Acharya	The Himalayan Times	27/09/2015
Nepal enforces road rationing from Sunday amid fuel shortage		The Himalayan Times	26/09/2015
Pvt vehicle owners wrestle for fuel	Rajesh Khanal	The Kathmandu Post	14/10/2015
India to supply additional 80 MW power to Nepal from Jan 1		Press Trust of India	30/12/2016
Mainstream electric vehicles with law	Shubhechchha Bhatta	Republica	11/09/2018
Time to go electric	Avaya Shrestha	Republica	25/09/2018
Charging ahead	Rajesh Khanal	The Kathmandu Post	12/09/2018
NEA to promote electric vehicles		The Himalayan Times	23/09/2017
NEA to take lead to promote electric vehicles	Chandan Kumar Mandal	The Kathmandu Post	20/10/2017
Reconstruction of Upper Bhotekoshi project begins	ANISH TIWARI	The Kathmandu Post	10/04/2018
Nepal Restores $2.5 billion Hydropower Plant Contract to Chinese Firm Gezhouba Group	Gopal Sharma	The Wire	23/09/2018
Nepal's Prime Minister Will Have a Tough Time Balancing India and China	Biswas Baral	The Wire	17/09/2018
Nepal, China agree on rail study	ANIL GIRI, SANJEEV GIRI	The Kathmandu Post	24/08/2018
End of the Madhesi blockade: What it means for Nepal	Prashant Jha	Hindustan Times	06/02/2016

Appendix 4: Photos relating to this research taken in the field.

Photo 1: Example of distribution lines attached directly to buildings in Kathmandu. Collapsing buildings in the earthquake damaged lines connected to buildings in this way.

Photo 2: Example of solar panels in Kathmandu. The dust on the panels is an issue as it reduces the panels efficiency.

Photo 3: Electric vehicle used for public transport in Kathmandu.

Photo 4: Micro hydro turbine in use in Dovan, rural Nepal.

Photo 5: Fuel supply truck in Kathmandu. Trucks like these are currently used to import transport fuels from India and supply fuel throughout Nepal.

Photo 6: Transformer within Kathmandu's distribution system. Increasing the capacity of this system is an ongoing issue.