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Analysis on Barriers of Renewable Energy Development -Context of Nepal

: An Analytical Hierarchy Process Approach

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Technology Management, Economics and Policy Program

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Abstract

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Energy is an indispensible requirement for socioeconomic, industrial, and technological development, which have brought about better living conditions for the society. The experts in the renewable energy sector argue that renewable energy technologies such as micro and mini hydropower, solar, wind, and biomass are not only financially viable solutions but also ultimate suitable energy source alternatives for the rural and remote areas in developing countries like Nepal. This notwithstanding, 33% of the households in the remote areas in Nepal do not have electricity access. The traditional, commercial, and renewable energy consumption ratios in Nepal have stood at 80, 17.43, and 2.6%, respectively. In the present energy mix scenario of Nepal, an observable change can be clearly seen in the share of renewable energy, which has increased from almost zero in 2004 to 2.6% in 2014.

Numerous barriers arise while developing renewable energy technologies. If such barriers are not properly addressed, development cannot be achieved. Moreover, if proper priorities are not set in addressing the barriers, it will not be easy to develop renewable energy technologies at a fast rate. In this research, an attempt was made to identify the barriers to the development of renewable energy from the Nepalese perspective, and to rank them. All together, 22 barriers were identified and listed through a review of the previous researches. These listed barriers were categorized into six dimensions: social, policy and political, technical, economic, administrative, and geographic barriers.

This study used the analytical hierarchical process (AHP) methodology for estimating and ranking the barriers to renewable energy development in the context of Nepal. Pair-wise comparisons were made based on experts' views provided by renewable energy professionals in the government, private sector, and academe. This research may provide a basic framework for the study of the barriers to renewable energy development in developing countries, especially in the context of Nepal. It is expected that this research will help the renewable energy technology regulators, experts, and researchers in their future researches.

Keywords: Analytical Hierarchical Process (AHP), Renewable Energy, Barriers, Context of Nepal, Dimensions of Barriers

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1 Introduction

This section of the research covers the overall introduction, purpose and motivation of research, objectives and research questions, and structure of the research.

1.1 Overall Introduction

Energy is an indispensible requirement for socioeconomic, industrial, and technological development, which have brought about better living conditions for the society. Some energy resources, however, have negative effects such as greenhouse gas (GHG) production and soil and water pollution by various contaminants. These negative effects have generally been ignored, however, with only the economic aspects being considered (Chatzimouratidis & Pilavachi, 2008). The rapid depletion of energy resources such as oil, coal, and gas is considered a major factor contributing to climate change. Various countries employ many different approaches to the development of renewable energy, which are possible alternatives to the traditional energy sources for addressing the climate change issue.

Due to this concern, electricity generation from renewable energy resources has increased in the form of isolated and distributed generation especially in the rural and remote areas in developing countries (Nigim, Munier, & Green, 2004). The present renewable energy technologies have obtained much attention due to their widespread potential and environment-friendly nature and due to the energy security concerns and the demand for cost-effective solutions in developing countries' rural and remote areas. Numerous barriers arise, however, while developing renewable energy technologies. If these barriers are not properly addressed, development cannot be achieved. The share of the renewable energy mix in the globally energy mix is

about 20%. The Kyoto Protocol[1] approval in 1997 was the first breakthrough for the development of renewable energy technologies, driving global attention towards the climate change issue. Such protocol is considered a pioneer in renewable energy development the world over (Darmani, Arvidsson, Hidalgo, & Albors, 2014).

Extractable potential of RETs[2] is many times more than current world energy demand, but there many limitations such as geographical, economical, organizational, and so on. Renewable energy technologies are globally accepted for the supply of energy, so we often called as renewable sources are the climate friendly alternate energy sources. Despite, developed countries achieved the noticeable access in basic energy supply, millions of peoples specially in developing countries, still lack of access to basic energy supply (Surendra, Takara, Hashimoto, & Khanal, 2014). About 1.3 billion people still have lack of access of electricity supply , majority of households from the South Asia and African continental (Yadoo & Cruickshank, 2012).

Currently renewable energy mix in overall national energy is significantly increasing both in developed countries, and developing countries. Developed countries are taken many initiatives for renewable energy sources for enhancing energy security ,and reducing the greenhouse gases (CHGs) emission (Nepal, 2012). Developing countries like Nepal, isolated renewable energy technologies have several benefits than doing national grid extension because isolated decentralized system can be located in the demand area which in turn reduces the transmission cost, and transmission losses (Nguyen, 2007). So these days renewable energy technologies are viewed as suitable option for magnifying rural and remote area basic energy supply, and

[1]an international treaty among industrialized nations that sets mandatory limits on greenhouse gas emissions

[2] Renewable energy technologies

improving the electricity access in those areas where extension of national grid not possible for few years (Gurung, Ghimeray, & Hassan, 2012). Because of the low socio-economic condition in the rural and remote area, the selection of the technologies is an important issue of implanting agencies, and private sectors. Projects selection is customarily done by seeing the economical feasibility and demand of communities.

Due to the various types of uncertainty like as limited resources availability, remoteness, socio-economic conditions, and accessibility (Nigim et al., 2004), selection of projects decisions were prevailing and delayed. Reliability of technologies has an considerable impact on life of technology, and regular running (A. H. Lee, Chen, & Kang, 2009). Clean development mechanism (CDM), one of the approved and under operation mechanism which was came from the Kyto Protocol means technology transfers from the developed nations to developing nations. This CDM could lead to green growth development in energy sector which can help economically reducing the greenhouse gases in world. This kind of mutual cooperation, and flexible mechanism could bring the acceleration of renewable energy in economically viable and technically feasible areas. The main goal of CDM is to achieve the sustainable development of energy in developing countries in coming years, however, there has been series of discussion about carbon development mechanism (Adhikari, Mithulananthan, Dutta, & Mathias, 2008). There are various kinds of advantages of growing the industry of renewable energy; however, capital of energy production is still considerable higher with compare to the conventional energy production. That’s main drawbacks why the investors do not take as priority sector to invest in RE industries. High capital cost barrier can be minimized with support in research and

developments, capital subsidy by government, and other direct and indirect incentives provided by government and other renewable energy development nodal agencies. Through this extent, community people initiation will be raised from the need the modern energy access which is helpful way of adopting renewable energy technologies.

Renewable energy technologies are practically suitable for rural and remote areas and can enable the optimization of the local energy resources. In some developing countries, electrification through off-grid solutions has been favored due to such countries' financial constraints (Miller & Hope, 2000). In addition, the power plants for renewable energy technologies are small, and they can be installed in different parts of the geographic area, which is cost-competitive compared with grid extension. Renewable energy technologies can be seen as more reliable from the perspective of the people in the rural areas, especially in developing countries (Pereira, Freitas, & Da Silva, 2010).

Renewable energy sources are contenders of traditional energy sources in the rural areas of developing countries. It must be kept in mind that there is a responsibility to provide modern energy access to such areas, which may be done through off-grid renewable applications (Painuly, 2001). Today, shifting from the use of non-renewable energy to the use of renewable energy is one of the priorities across the world for achieving a sustainable energy system. Many studies have suggested that renewable energy is capable of realizing a considerable share in the energy mix for meeting the present global energy demand (Reddy & Painuly, 2004).

Energy is a basic requirement for bettering people's living standards as it is needed mainly for lighting, cooking, heating and cooling, communication, and the procurement of many commodities essential

for everyday life. Renewable energy technologies are often seen as indispensible indicators of the socioeconomic development of countries like Nepal, which have an increasing dependency on energy imports form the neighboring countries. Renewable energy technologies are the alternative solutions for reducing the dependency on energy imports (Surendra, Khanal, Shrestha, & Lamsal, 2011). Hydropower, solar photovoltaic energy, solar thermal energy, wind energy, and biomass energy are the major examples of renewable energy.

Nepal's renewable energy sector faces many problems. Experts in renewable energy sector argue that renewable energy technologies like as micro and mini hydropower, solar, wind, and biomass are not the financially viable but also ultimate suitable alternate for the rural and remote areas in developing countries. Most hindering barriers for the renewable energy in developing countries are economic, institutional, technical, social, geographical barriers. Even though hydro power technology is mature renewable energy technology, vital institutional and structural barriers are needed to handle first. To address several kinds of barriers, not only markets will not remove but also government's intervention is prerequisite. The limited access in technology development and technology transfer also impacts negatively in acceleration of renewable energy in developing countries like in Nepal. In addition to that, subsidy is given to the conventional energy sources is also the considerable barrier for the RETs development. Still there is low electrification rate and low energy access, hence, there is potential of diffusion of bulk amount of renewable energy to address the basic energy needs in rural and remote areas community (Dulal, Shah, Sapkota, Uma, & Kandel, 2013). Increasing investment on research and development of renewable

energy technologies can reduce cost because of the learning curves; however, low income nations have difficulties in investing particularly in energy research and developments. Hence, increasing in development of RETS in developing nations critically depend from the technologies transfers form the developed nations (Nepal, 2012). Nevertheless, if developing nations will catch the path as same development path with industrialized, globally green house gases (CHG) would rise more sharply. In order to get the reverse way, the basic foundation should go with development of RETs. In the other hand, these technologies make the better living conditions and help to reduce poverty level in rural and remote areas of developing countries.

This research focused on identifying the barriers to renewable energy development in the context of Nepal, based on extensive literature review, and ranking them based on experts' views. There is limited policy effectiveness, however, in developing countries with a poor renewable energy infrastructure. In addition, there is incomplete policy formulation due to the lack of capacitated resources, the irrationality of the existing policies, and many other identified and unidentified barriers. Nepal is a South Asian country that is continuously trying to develop renewable energy, especially off-grid solutions, for its rural and remote areas. As a result, the government of Nepal has made renewable energy development a high priority. The main reason for this is that the government of Nepal has formulated an energy subsidy policy and is continuously providing support for renewable energy development so as to accelerate it.

There have been many studies on the development of renewable energy technologies. Some of such studies identified the barriers to such development, particular the problems concerning the development of hydropower. The identified barriers or problems were treated

individually for the issuance of specific recommendations. Based on the literature review, however, there has been no study that ranked the identified barriers to renewable energy development. From the perspective of this research, the different relevant experts in the governments, programs, private sector, and academe are considered the key personnel for the development of renewable energy technologies. As such, the research approach that was employed herein was the analytical hierarchy process (AHP), which is explained in detail in Chapter 4. The structure of this research considers the various aspects or dimensions of the barriers to renewable energy development in the context of Nepal and from the perspective of the experts in such field. This is a simple and unique approach to identifying the barriers to the development of renewable energy.

Based on the extensive literature review that was conducted herein, the calculation of the ranks or weights of the barriers to the development of renewable energy in the context of Nepal may be considered a research gap. First, this study identified the barriers that were most frequently raised by the relevant researchers in the context of Nepal, and listed them accordingly. Second, a survey was conducted to obtain the views of relevant experts. Finally, the identified barriers were ranked. This research was specific to Nepal; therefore, its outcomes may have useful implications for the government, renewable energy development agencies, and other stakeholders in terms of overcoming the barriers to renewable energy development that were identified, especially in the context of Nepal.

1.2 Purpose of the Research

Development of renewable energy has been focused in developed nations, however, in developing, and under developing nations still

considered as a new technology. We know that renewable energy technologies are clean which does not produce emission like green house gas (CHG). Renewable energy in developing countries is being considered as a favorable solution for the supply of basic electricity needs in the rural and remote areas. Another prospective, renewable energy technologies provide remarkable chances to supply the basic energy needs as a use of local available potentials, and isolated decentralized RETs are competitive with national supply electricity in developing countries (Gurung et al., 2012).

Although Nepal has the noticeable potentials of renewable energy, but there are many challenges to harness RETs such as technical, social, policy and political , economic and institutional (Benjamin K. Sovacool, Saroj Dhakal, Olivia Gippner, & Malavika Jain Bambawale, 2011). In order to increase share of renewable in energy in country's energy mix, many initiatives are needed to be taken by the government. There are many barriers discussed by the researchers those are needed to address for the speedy development of the renewable energy (Awan & Khan, 2014).

The motivation behind this research is to help Nepal, a country that has a high renewable energy potential, meet its electrification targets and the electricity demand of its rural and remote areas. To this day, 33% of the households in the remote areas in the country do not have access to electricity. Previous researchers have identified various barriers to renewable energy development and have treated them individually for the issuance of specific recommendations. As such, this study combined all the identified relevant barriers and ranked them based on the results of the calculation of their weights in terms of the degree to which they hinder renewable energy development.

Moreover, if priorities in addressing the identified barriers will not be properly set, it will be difficult to develop renewable energy technologies at a fast pace. This study was conducted to fill the research gap by listing the identified barriers to renewable energy development in the context of Nepal, and ranking them using the analytical hierarchy process (AHP), considering the following objectives.

The primary objective of this research was to identify the various barriers to renewable energy development in Nepal. This was done through an extensive review of the existing literature on the renewable energy technology development barriers. The study revealed the existing development barriers in Nepal's renewable energy sector. Various researchers have pointed out different barriers, but such identified barriers are more or less similar. In this research, through extensive literature review, the barriers were listed and categorized into six dimensions of barriers. From this, a hierarchal structure of renewable energy development barriers was formed.

The secondary objective of this research was to rank the identified barriers to the development of renewable energy technologies in Nepal. AHP was the tool that was used for ranking the barriers. The ranking was accomplished by analyzing the views of renewable energy experts that were obtained through a survey. This research assigned weights to the barriers based on the expert respondents, eventually coming up with a systematic hierarchy structure.

Finally, the main theme of the objectives was to come up with general recommendations and some policy suggestions for overcoming the major barriers to the development of renewable energy technologies, to ensure the success of the development efforts. Based

on this motivation and objectives, the following main research questions were adopted in this research.

- What are the ranks and weights of the different dimensions of barriers to the development of renewable energy?
- What are the ranks and weights of the barriers to the development of renewable energy within the different dimensions of barriers, and of the overall barriers?

To attain the aforementioned objectives of this research, the AHP framework MCDM was used.[3] This framework is a popular decision-making tool based on subjective judgments. This research framework, however, is generally based on the concept of renewable energy development in developing countries, specifically Nepal. Finally, this research identified the various barriers to the development of renewable energy and came up with their relative ranks in terms of the degree to which they hinder renewable energy development.

1.3 Structure of Research

This research was presented into six chapters as shown in figure 1. Chapter one briefly introduced the overall introduction and importance of renewable energy, also includes motivations, objectives of research, research questions and structure of research. The second chapter provides the background of the study, overview of energy scenario in Nepal, and renewable plans, policy, institutional arrangements, potential and installed. This chapter also presents review of barriers for the renewable energy development. Based on previous research and other extensive renewable energy articles review, barriers are arranged in six dimensions. Third chapter focuses on the literature review to investigate the how study is going on for the case of barriers of

[3] Multi criteria decision method

renewable energy developments in general. Third chapter also includes basic concepts of renewable energy, its advantages over other conventional energy sources. This chapter ends with hierarchical model for this research.

Chapter four covers the methodologies part of this study. Detailed description of analytical hierarchy process (AHP) model is presented. This multi criteria behavior model for the ranking barriers defined in the model. This chapter also explains the hierarchy structure formations steps for the AHP model. Chapter five includes the data analysis part, and result obtained and discussion of results. Chapter six comprises the overall conclusion of research performed, future research, and limitations.

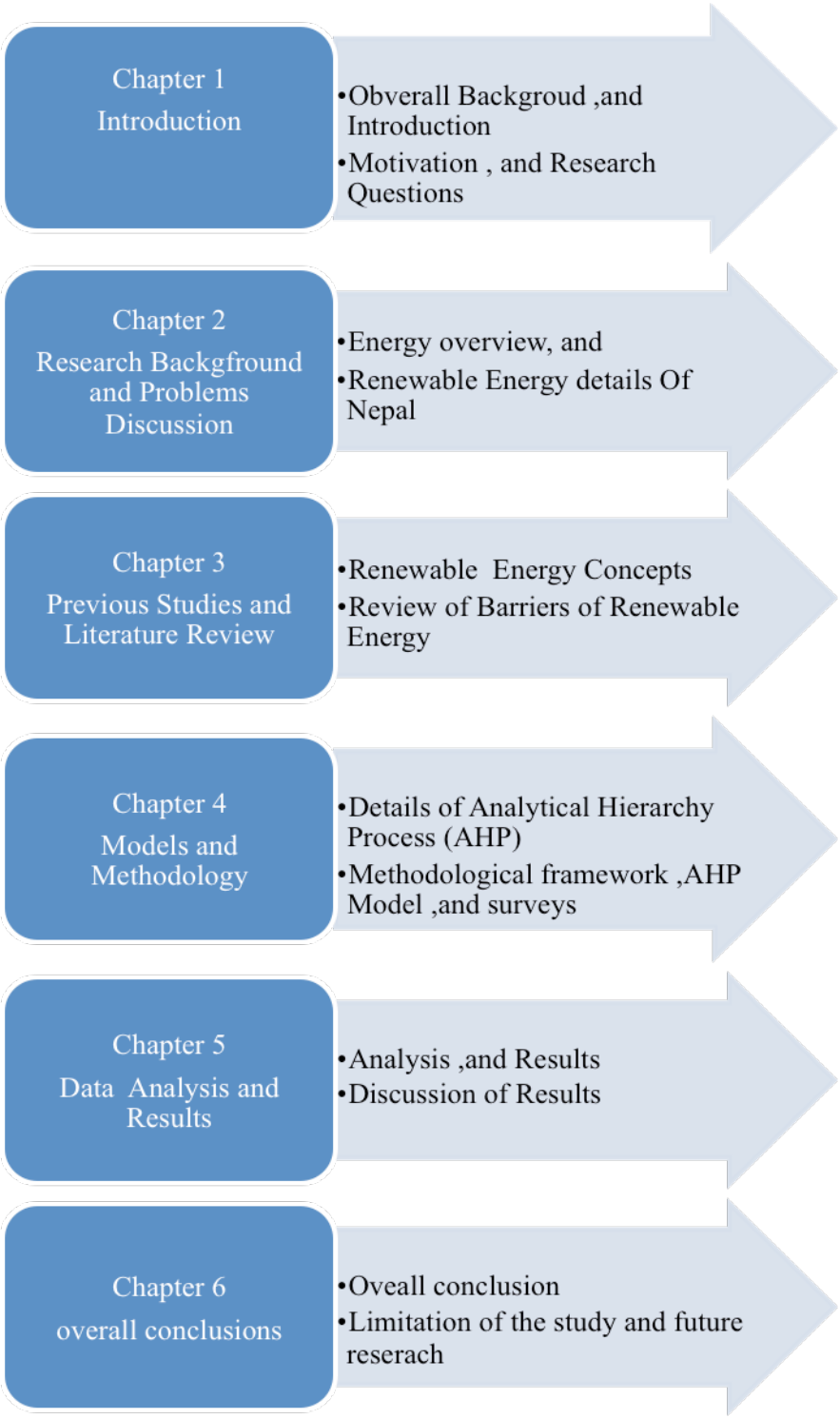

Figure 1: Structure of Research

2 Research Background and Problem Discussion

This chapter includes overall view of energy sector scenario, renewable energy details in Nepal, explores the barriers, and challenges of renewable energy smooth development in developing countries specifically in context of Nepal, and problem and opportunities discussion of renewable energy in Nepal.

2.1 Energy Sector Scenario in Nepal

Nepal's energy demand has been continuously growing with keeping pace with people's awareness about energy needs, and improving life conditions. Nepal's energy sector heavily depends on biomass energy sources. Nepal is a landlocked country which is in-between two giant countries China, and India. Nepal is one of the lowest per capita energy consumption country and don't have major accessible reserves like coal, natural gas, and petroleum products (Benjamin K. Sovacool et al., 2011). About 82% of the people live in country side areas. Nepal has started the formal planning of energy sector from the seventh national development plan, however, country still heavily dependent on traditional biomass. Residential sector is major energy consumption sector with around 89%. About 96% of residential consumption energy comes form the traditional energy sources like biomass and followed by commercial 3.6%[4].According National Planning Commission (NPC), 67% of households are electrified which accounts 58% from grid, and off-grid renewable solutions 9 %[5].

[4]http://www.wecs.gov.np/pdf/snyopsis.pdf-Energy Sector Synopsis Report, 2010

[5]http://www.npc.gov.np/images/download/13th-Plan.pdf

In terms of hydro energy, Nepal has abundant potential. Many studies estimated that Nepal has around 83,000 MW of potential mainly from thousands of fast flowing streams in mountainous, and terrain regions. So far country has only installed 746 MW of power which is negligible amount in terms of country's potential (Benjamin K. Sovacool et al., 2011). While reviewing the Nepal's energy polices, it can be foreseeable that moving towards throughout the clean energy sources like hydropower, solar, and biomass would be the main trend in upcoming years.

Three ministries primarily looks the energy sector of Nepal. Ministry of energy is responsible to national electricity planning, generation, policy formulation, and operation of national grid. Ministry of science, technology and environment is the responsible for the planning, policies, and development of renewable energy which also takes lead plan for the rural electrification through Alternative energy promotion centre (AEPC).[6] Imports and distribution fossil fuels is being done through the Ministry of Commerce and supplies through the Nepal Oil Corporation (NOC) which was established in 1970 as a state-owned trading company to deal with the import, transportation, storage and distribution of various petroleum products in the country[7].

Nepal's energy resources are presently classified into three categories namely the traditional (fuel wood, biomass), commercial (electricity and fossil fuels), and alternative (renewable energy resources). Traditional energy resources include fuel wood from forests, agricultural residues coming from agricultural crops and animal dung in dry form. Traditional energy resources can, of course, be termed as biomass energy resources since it only covers the bio

[6] http://www.aepc.gov.np/
[7] http://www.nepaloil.com.np/

materials for energy purpose. Energy resources coming under the commercial or business practices are grouped into commercial energy resources that are particularly included coal, electricity from national grid, and petroleum products. Biogas, solar power, wind and micro hydropower are categorized into alternative energy resources in Nepal. Such alternative resources are considered as supplement of conventional energy resources.

As shown in figure 2, traditional, commercial and renewable consumption ratios stood 80%, 17.43 % and 2.6 %respectively. From this statistics, it reveals that there is still high dependency on traditional energy sources. The total energy consumption fiscal in year 2013/2014 was 11,232 tons of oil equivalents. Similarly from figure 3–firewood accounts 72.6%, followed by petroleum products 11.3%, animal residue 3.8%, agricultural residue 3.6%, electricity 3.3%, coal 2.8%, and renewable 2.6% respectively.

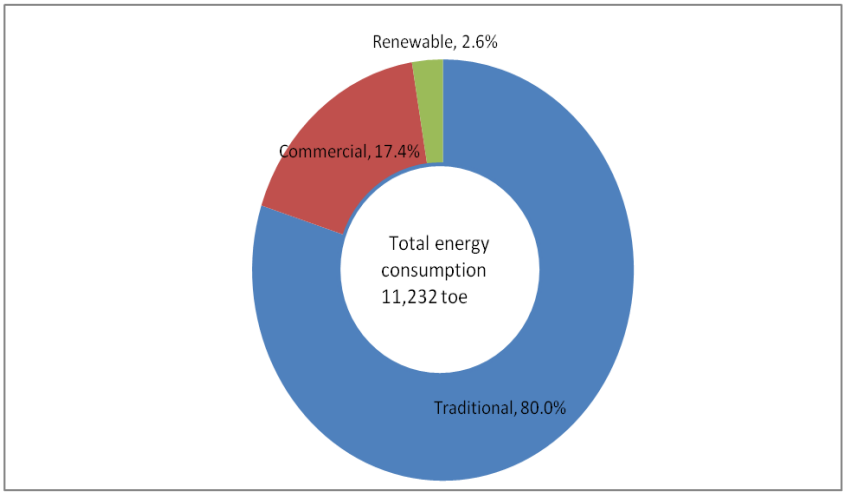

Figure 2: Share of energy consumption by type-2014

Source: Economic survey 2014/2015-Ministry of Finance, Government of Nepal

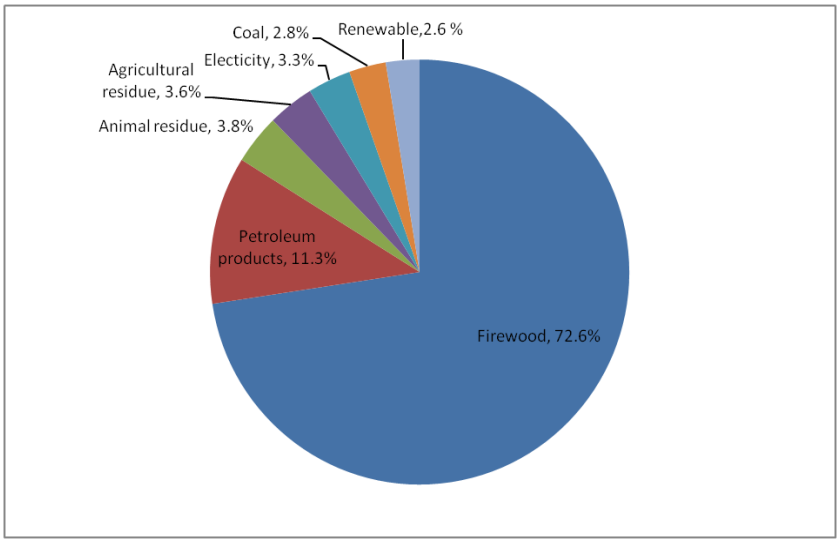

Figure 3: Division of energy mix by fuel type-2014

Source: Economic survey 2014/2015-Ministry of Finance, Government of Nepal

In Nepal, majority of the energy demand has been provided through traditional energy sources. Despite the country's high potential for generating energy through its renewable energy potential, the country is currently facing an energy crisis, which is worsening due to the government's failure to achieve notable progress in the production of renewable energy. Nepal's energy sources and their consumption statuses in the last five years are shown in Table 1.

The electricity production amounted to 746 MW in the fiscal year 2013/2014. In Table 2, it can be seen that the electricity demand has been continuously increasing, recorded as 1200.98 MW in 2013/2014. The production in the same fiscal year, however, was only 746 MW, which is 38% lower than the demand.[8] There is thus a huge gap between the energy supply and the energy demand, and as such, the

[8] http://www.mof.gov.np/uploads/document/file/Final%20Economic%20Survey%202071-72%20English%20(Final)_20150716082638.pdf

Nepalese have been experiencing power cuts lasting up to 12 hours in the dry season.

Table 1: Energy Consumption Status

	Tons of Oil Equivalent					
Energy Source	2008/9	2009/10	2010/11	2011/12	2012/13	2013/14
Traditional	**8085**	**8342**	**8500**	**7032**	**8017**	**8983**
Firewood	7301	7467	7606	6274	7153	8154
Agricultural Residues	244	324	331	310	353	403
Cow Dung	540	551	563	448	511	426
Commercial	**1138**	**1464**	**1580**	**1679**	**1854**	**1958**
Coal	181	286	293	348	415	320
Petroleum	775	965	1058	1083	1182	1264
Electricity	182	213	229	248	257	374
Renewable	**64**	**70**	**75**	**109**	**166**	**291**
Total	**9287**	**9876**	**10155**	**8820**	**10037**	**11232**

Source: Economic survey 2014/2015-Ministry of Finance, Government of Nepal

Government plans and polices are in line with development and promoting of grid distributed isolated power system, where grid electricity is being developing by the national electricity authority (NEA), and isolated distributed renewable energy technologies are developing by the Energy promotion Center (AEPC) (Mainali & Silveira, 2012).

Table 2: Electricity Demand, Consumption, Production and Physical Structures

	Particulars	Fiscal Year			
		2010/11	**2011/12**	**2012/13**	**2013/14**
1	Production(MW)	697.85	705.57	746	746
2	Transmission Line (Km)	1917.67	1987.36	1987.36	1987.36
3	Customer Number	1854275	2053259	2599152	2713804
4	Distribution Line	89108.86	95815.98	114160	116066
5	Available Energy (GWH)	3389.27	3858.37	4260.4	3092.47
6	High Demand (MW)	946.1	1026	1094	1200.98
7	Supply Gap (MW)	248	320.43	348	454.98

Source: Economic survey 2014/2015-Ministry of Finance, Government of Nepal

Those people living in rural area are spending at least one third of household expenditures on achieving energy requirements through various resources. In addition to that, they spend more time for energy management, specifically woman are spending more than 6 hours a day for the collection wood, cooking, and gathering agricultures products. Hence access to modern energy may become a significant changes in their living conditions (Sapkota, Lu, Yang, & Wang, 2014).Although the country is bestowed with hydropower potential having more than 6000 rivers, installed hydropower is only about 1 % of country's extractable potential (Gurung, Gurung, & Oh, 2011). Electricity market is still under the control of government through vertically integrated Nepal Electricity Authority (NEA) which is overall responsible for electrify generation, transmission and distribution (Benjamin K.Sovacool, 2011).

2.2 Renewable Energy in Nepal

2.2.1 Overview of Renewable Energy

Renewable energy is climate friendly which provides energy without emission of carbon dio-oxide (CO2), those resources can be replenished in environment form solar energy, wind energy, geothermal energy, biomass energy, wave energy, small scale hydropower (Luthra, Kumar, Garg, & Haleem, 2015).

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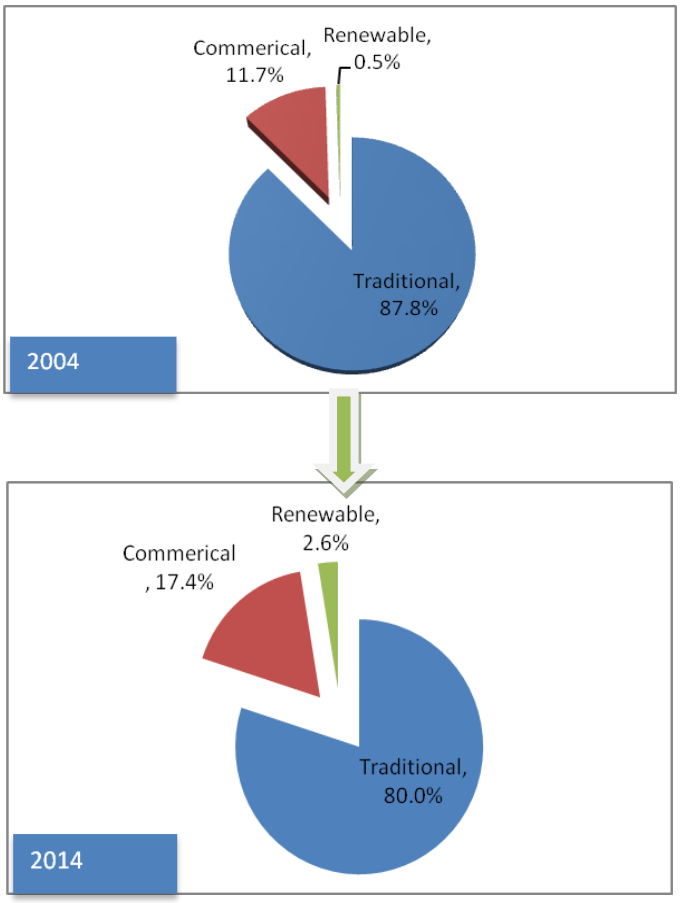

Figure 4: Development of Energy Mix

Source: Economic survey 2014/2015-Ministry of Finance, Government of Nepal

There has been a clearly observable change in the share of renewable energy in Nepal's energy mix, increasing form almost zero in 2004 to 2.6% in 2014. Figure 4 shows the energy mix changes in Nepal over a period of 10 years. Traditional energy had an 87.8% share in 2004, but in 2014, it had only an 80% share. The share of commercial energy increased from 11.7 to 17.4%. The country's traditional energy sources consist of fuel wood, agricultural residue, and animal residue while the commercial energy sources consist of petroleum products, coal, and electricity

2.6% of renewable energy mix is obtained through the consideration of energy development as an integral part of national development since 1985. Government of Nepal has established dedicated institution for renewable energy promotion, afterwards private sector was become an integral part of renewable energy technologies development. In addition to that, renewable energy sector is continuously supported by the various development partners through technical as well as financial support.

However cost of the renewable energy is expensive in comparison conventional energy sources, it became popular in rural and remote area of Nepal to provide modern energy access to rural communities. So today, government of Nepal is targeting renewable energy development in rural areas through the subsidy mechanism.

As renewable energy technologies could be considered one of the most favorable solutions to improve the modern energy access in rural and remote areas of developing world. We must keep in mind that people form the remote and rural areas of developing world are current focus area of the where population growth is higher. Thus renewable energy technologies are contenders to make differences of people lives. In Nepal, only 67% of population has facility of electricity connections

in households, which includes 9% from the renewable energy technologies. Based on literature review of various papers and reports related to Nepal's renewable energy, five renewable energies (hydropower, solar energy, wind energy, biomass energy and geothermal energy) have been categorized. Their potentials, current status, plan, policies and institutional development are explained below.

2.2.2 Renewable Energy Scenario of Nepal Based on the Potentials and Development Progress

2.2.2.1 Hydropower

Nepal has an around 83 GW hydropower potential, among which around 43 GW is technically and financially feasible from large hydropower (Gurung et al., 2012; Gurung et al., 2011; Sovacool, Dhakal, Gippner, & Bambawale, 2011). In Nepal, hydropower is mainly categorized into six types: "pico hydro" (1-10 kW potential), "micro hydro" (10-100 kW), "minhydro" (100-1000 kW), "small hydro" (1-10 MW), "medium hydro" (10-50 MW), and "large hydro" (above 50 MW). The pico and micro hydro systems are basically being developed for small communities, which are not connected to the national grid. With the support of a subsidy program for it, micro hydro is currently quite popular in the rural areas of Nepal, where it is being provided to meet the basic electricity needs of the rural households and of small enterprises like hullers, grinders, and expellers.

The government of Nepal has continuously given high priority to the development of hydropower. Based on the results of the economic survey conducted by the Ministry of Finance, a 746 MW hydropower (including thermal power) installed capacity was available in the

national grid as of the fiscal year 2013/2014, which was insufficient to meet the peak energy demand of the country in such year. Especially in the rural areas, which the national electricity line has not reached for some years, isolated micro hydro plants are emerging. Micro hydro is a decentralized renewable energy technology considered the most promising technology for rural areas. Nepal has a more than 50 MW potential of such type of isolated micro hydropower (Gurung et al., 2012). Around 25 MW has been installed to date, which is currently serving around 2.5 million households (Alternative Energy Promotion Center, 2015). Table 3 summarizes the status of hydropower development in Nepal.

Table 3: Summary of hydropower development in Nepal

Categories	No of Projects	Capacity (MW)
Installed	43	718
Generation License Issued	86	2096
Survey License Issued	269	5558

Source: Department of Electricity Development -2015 (DOED), Nepal

2.2.2.2 Solar Energy

Nepal is considered to have an energy intensity of 3.1-5.1 KWh/m^2 (Surendra et al., 2011), and according to a report from Alternative Energy Promotion Center (AEPC), the country's economically feasible potential is 2,100 MW for the grid-connected potential, but the off-grid potential may be bigger.[9] Overall, the country's exploitation of this

[9] http://www.aepc.gov.np/docs/resource/subreport/20130818124528_Solar%20and%20Wind%20Energy%20Resource-Assessment%20in%20Nepal.pdf

potential will mainly depend on the acceptability and affordability of the technology (Surendra et al., 2011). The small solar home system is becoming a cheaper solution for rural areas, and is becoming famous. As per the data from AEPC, around 0.4 million solar systems (solar home system and small solar home system) have already been installed in the rural areas of Nepal. The Nepalese government has been providing subsidies based on remoteness. The solar dryer and solar thermal technologies are still in the deployment and commercialization stages.

2.2.2.3 Bio-Fuel/Bio-Energy

2.2.2.3.1 Biogas

Most families in Nepal have at least one cow or buffalo in their home and use animal dung as fuel to produce a gas called “ gobar gas,” a form of biogas. The energy obtained in the form of methane gas from the biogas plant is useful for cooking. Based on the assessment report published by the government of Nepal, around 1 million households in the country have potential for producing energy from biogas plants (Surendra et al., 2011). Among them, around 0.25 million households have already installed biogas plants in their houses. At present, the biogas technology is one of the highly mature technologies in Nepal, and it gained the distinction of being the target of the first clean development mechanism (CDM) project of Nepal (Shrestha & Kojima, 1997).

2.2.2.3.2 Biomass (Improve cook stove, Metallic cook stove, Bio-briquetting)

A big percentage of the population heavily rely on the traditional solid biomass such as wood, agriculture, and animal residues for the energy that they need for cooking and heating purposes, which have a significantly low efficiency of 3-15% according to the World Health Organization (WHO).[10] The WHO also estimates that around 2.7% of the diseases in the world are contributed by the smoke emanating from solid biofuel, which in turn causes 7,500 deaths yearly. To address this health problem and to save the country's forests, the government of Nepal, through AEPC, has been launching a smokeless improved cooking stove. Around 6.5 million households have already installed this improved cooking stove without direct subsidy from the government.

Another biomass technology is bio-briquetting, which is the process of densification through the application of temperature and pressure on lighter and high-moisture bulk materials like crop and wood residue into a dry format to obtain better combustion efficiencies. Private and some non-profit organizations are involving themselves in the promotion of bio-briquetting. The idea of the biofuel is quiet new in the case of Nepal, but the government has already announced the biofuel development program. Two processing plants from the government and only a handful of private companies have started pursuing Jatropa plantation for commercial purposes, and established the Jatropha Research Center (Surendra et al., 2011).

[10]World Health Organization. (2007). Indoor air pollution: national burden of disease estimates.

2.2.2.4 Wind Energy

The theoretical potential is roughly considered to be around 3,000 MW, but Nepal has to date not achieved significant progress in the wind energy sector. Now, the government of Nepal is basically focusing on wind data collection for a detailed feasibility study. The subsidy policy has already addressed the need to develop a wind energy technology. There is a clear provision to provide a subsidy in the case of isolated wind energy. The insufficient research and development and the geographic conditions hinder the harnessing of the wind energy potential (Surendra et al., 2011).

It can be realized that Nepal has a huge potential of renewable energy, but there are many barriers to harnessing such potential to meet the energy demand. Around 1.7 million households, however, have already benefited from the development and use of different kinds of renewable energy technologies. Table 4 gives a summary of the progress of renewable energy development in Nepal to date.

Table 4: Brief Summary of Renewable Energy potential-Nepal

S.N.	Renewable Energy in Nepal	Available Potentials
1	Solar Energy	3.9 to 5.1 Kwh/m2-day, 2100 MW (grid Connected Potential)
2	Wind Energy	3000 MW
3	Bio-gas	1 million plants
4	Hydropower	43 MW (Economical) 83000MW (Technical)

Source: AEPC- SWERA Report, (Gurung et al., 2011; Surendra et al., 2011),

Table 5: Summary of renewable energy development

S.N	RE Type	Unit	Progress	HHs Benefited
1	Biogas Plants	Number	243,049	243,049
2	Micro hydropower	kW	~25,000	250,000
3	Solar Home System (SHS)	Number	278,211	278,211
4	Solar Tuki	Number	59,120	59,120
5	Solar Cooker/Dryer	Number	3,272	3,272
6	Improved Cook Stoves	Number	650,000	650,000
7	Improved Water Mill	Number	7,592	227,760
8	ISPS & PVPS	Number	983	147,450
9	Wind energy	kW	~10	
	Cumulative number of benefitted HHs			**16,88,489**

Source: Alternative Energy Promotion Center (AEPC) -2015, Nepal (Summarized of AEPC Statistics, obtained from www.aepc.gov.np)

2.2.2.5 Key Outcomes

Some of key outcomes have been achieved within the decade of renewable energy development. Following key outcomes are listed.

I. As per thirteen plans of national planning commission and economic survey of ministry of finance, about 9% of population has electrified from renewable energy technologies.

II. Biogas and Micro Hydro Projects are registered in Clean Development Mechanism (CDM) ("Alternative Energy Promotion Center," 2015)

III. Renewable Energy Policy, Subsidy Policy, and Delivery Mechanism are put in place ("Alternative Energy Promotion Center," 2015).

IV. Guidelines and technical standards have prepared for the development of different kinds of renewable energy("Alternative Energy Promotion Center," 2015)

2.2.3 Polices and Institutional Arrangements

2.2.3.1 Plans and Polices

Like many developing countries, government of Nepal is implementing the renewable energy projects. Because of this trend of increasing dependency of fossil fuel import from India, environmental concerns, and other heaths effects attached with this could be minimized through the development of isolated, decentralized and environment friendly renewable energy technologies. Off-grid solutions refer to provide access of electric power to rural areas communities. According to plans and policies, government of Nepal mainly focusing to provide lighting facility to rural communities through pico hydro , micro hydro, and cooking energy from biogas and ICSs (Mainali & Silveira, 2012).

Despite of government continuous efforts to promote renewable energy solutions, Nepal did not achieve prominent competitors with the traditional energy sources. There are many barriers whether it is economical barriers or geographical barriers in developing renewable technologies. It seems that barriers need to identified, and overcome in order to design coherent policy approaches to go the country opportunities. In this purpose, participation of all kinds of stakeholders in the process of identifying of barriers is needed. Different

stakeholders may have different perception on barriers, so policy advised may not be effective (Reddy & Painuly, 2004).

Rather than low population and scattered households in rural area of Nepal, social factors such as lack of education, social awareness, health, poverty and welfares are also considerable barriers. Development of renewable energy technologies is a suitable approach to overcome energy poverty, raising living standard, and sustainable socioeconomic development of rural communities (Javadi et al., 2013).

Policy is typically described as a principle or rule to guide decisions, and to achieve rational outcomes. Policy is not normally used to denote what is actually done; normally referred to as either procedure. Most of the developing countries have implemented different policies to bring electricity in rural areas as taking consideration of renewable energies, ownership energy, power transmission (Javadi et al., 2013). Followings are brief summary of polices, and plans of renewable energy sector of Nepal.

Table 6: Summary of Major Policies of Renewable Energy Nepal

S. N	Policy	Major highlights
1	Rural Energy (RE) Policy- 2006	<u>Overall goal</u> ✓ Reduce dependency on traditional energy & conserve environment by increasing access to RETs. ✓ Increase employment and productivity through RETs. ✓ Increase living standard of rural population by integrating RETs with social and

		economic activities <u>Main Policies</u> ✓ Emphasis to environment friendly, affordable and sustainable RETs ✓ Renewable Energy Fund to mobilize resources. ✓ Enhancing capacity of local bodies and facilitation by AEPC. ✓ Integration of RETs with economic and other developmental activities ✓ Arrangement shall be made for the MHP to connect in the grid (help for PPA) and formation of mini-grids. ✓ Special promotional activities focusing poverty reduction & positive impacts on women and children. ✓ Involvement of private sector, community and NGOs. ✓ Encourage community management and social mobilization in RETs promotion
2	Subsidy Policy -2013	<u>Objectives</u> ✓ Maximize service delivery and delivery efficiency. ✓ Access to pro-poor to use RETs ✓ Supply electricity and reduce supply/consumption gap between rural and urban area. ✓ Make use of grant assistance from donors/government in more effective and

		object oriented way. ✓ Support RET market by attracting private sector. ✓ Support long-term target of government <u>Highlights</u> Based on Category "A" VDCs, Category "B" VDCs, and Category "C" VDCs means very remote VDCs, remote VDCs, and accessible VDCs have different subsidy policy While designing the subsidy rate, the basis was 40% subsidy, 40% by the soft loan and 20% by the community or households in kind and cash. The additional subsidy per household will be provided to households with single woman, backward, disaster victim, conflict affected, poor and endangered ethnic group as identified by the Government of Nepal
3	Subsidy Delivery Mechanism 2014	<u>Highlights</u> ✓ Delivered from Commercial banks through CREF. ✓ Delivery mechanism is prepared and followed. ✓ The technical standard prepared by AEPC should be followed. ✓ Level of subsidy will be reviewed every two years.

		✓ No tax will be applicable in subsidy.
4	National 13th Periodic plan	<u>Highlights</u> ✓ Renewable energy were first addressed from seventh periodic plan(1985-1990) ✓ Long term vision to enhance economy and quality of life of rural people. Clean Cooking and Lighting Solution for all by 2017 ✓ By 2035 ,10% energy mix from renewable Energy ✓ BY 2035 , 30% electrification through renewable Energy
5	National Renewable and Rural Energy Program (2012-2107)	✓ Single Program Modality ✓ Starting Date: 16 July 2012 ✓ Duration: 5 years ✓ Budget: USD 170 Million

2.2.3.2 Institutional Developments

As shown in figure 5, Ministry of science, Technology and Environment is overall responsible for development of renewable energy. Ministry coordinates for policy formulations, plans, monitoring and evaluation of renewable energy projects. In addition to that National Planning Commission (NPC) coordinates with ministry and vice versa.

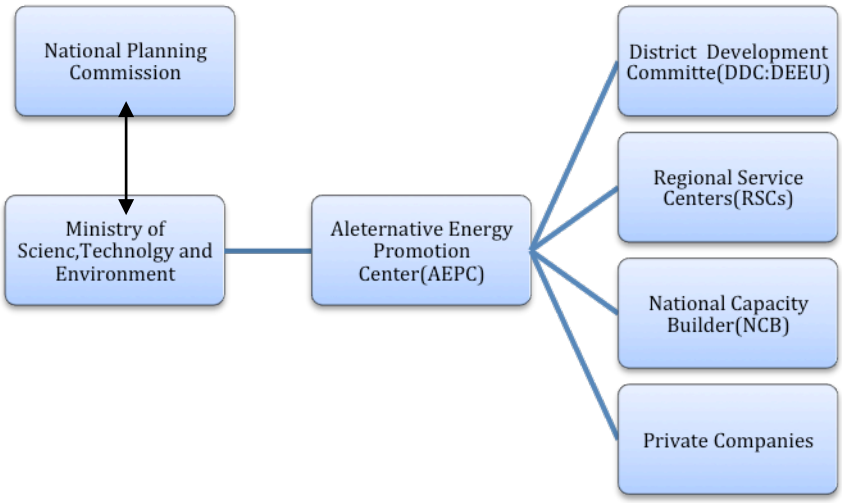

Figure 5: Institutional Arrangement for Renewable Energy Development in Nepal

Alternative Energy Promotion Centre (AEPC), is a Government institution established on November 3, 1996 under the then Ministry of Science and Technology with objective of developing and promoting renewable/alternative energy technologies in Nepal ("Alternative Energy Promotion Center," 2015). Major highlights of AEPC are listed as follows.

- National Executing Agency – Renewable energy programmers and projects.
- Government Institution under Ministry- Semi autonomous status.
- Mandate: Policy and Plan formulation, resource mobilization, technical support, Monitoring and evaluation, quality assurance, and coordination.
- AEPC board represented by public, private & financial sector

So AEPC is centralized institution dedicated towards overall development of renewable energy. Under the AEPC, District Development committee, District Energy and Environment Units (DDC: DEEUs) leads of renewable energy at district level. Similarly Regional service Centers are responsible for the development of renewable energy at regional Level. Some National capacity builders are doing the capacities building activities with the support from the AEPC. At local level, community organization, cooperatives and functional groups are fascinating promotions of renewable energy.

Prequalified private sector companies are overall doing manufacturing, supplying and installation of projects. AEPC updates the prequalified companies for the development of renewable energy on yearly basis. Currently following numbers of companies are prequalified and involving as private organizations for development.

- 82 Biogas companies
- 58 Micro/Pico-hydro electrification fabrication and installation companies
- 52 Micro hydro (survey/design) consulting firms
- 38 SSHS/ 37 SHS/ 12 ISPS companies and 6 solar thermal companies
- 32 Metallic ICS manufacturing companies
- 6 IWM manufacturing cum installation companies

2.2.4 Problem and Opportunities of Renewable Energy in Nepal

Nepal has abundant in terms of renewable energy resources (Hydro, Solar, wind, biomass etc).Different kinds of interventions are necessary to reduce barriers by the government specially in Asian countries (Dulal et al., 2013). Most vapid achievement in the

renewable energy development in rural areas of countries like Nepal is due to more costs of national grid extensions in (Nepal, 2012). However, many poor people can not afford to pay initial capital cost, so that most of the countries are providing capital subsidy to make affordable to support for low income people. Due to resources limitation, developing countries are not able to provide research and development, hence advantages of RETs uses heavily depends on assistance provided by the developed countries (Nepal, 2012). Renewable energy mix in the energy consumption is a possible solution, even though many countries initiated different policy options, development of renewable energy has experienced many barriers, and problems for smooth development (Darmani et al., 2014).

Many researchers pointed out how the barriers will be addressed that will affect the development of renewable energy. Nevertheless, researchers brought comprehensive framework to explain the barriers/problems of renewable energy development. Through extensive literature review, findings are somehow consistent and mainly dimension of barriers more or less same in the most of studies. Accelerating the deployment of renewable energy is current target, and aim in many countries, knowledge is essential to identity the most important barriers and problems which needs to address for acceleration of the renewable energy development. Researchers identified the various barriers, however, barriers are not ranked in terms of their weight to address the research gap on ranking barriers, and hence, this research provides comprehensive overviews of barrier, classification of those barriers with proper dimensions.

In case of developing countries, those renewable energy projects are contributing for betterment of socio-economic conditions. Small hydropower plants development are contributing considerable

economical development of rural area where national grid connection considered unavailable, also could be considered cost competitive generation cost, and optimization of local resources. Cost competitiveness, environment friendly and social acceptance heavily depend upon proper project selection (Kumar & Katoch, 2015).

Most of land of Nepal is covered by mountainous region, due to geographical constrains many areas that do not have electricity access. Despite having abundant potential of renewable energy, Nepal has not been able to capture potential of hydro because of technical as well as economical barriers. Today, Nepal is facing a massive shortage of electrical power as per demand. In addition to that there is not equitable access of electricity distribution and consumption among urban and rural areas communities (Gurung et al., 2011). Based on literatures and previous researches, following problems of renewable energy development are listed

- 85% population lives in rural areas and agriculture main occupation, so it is more costly to provide national electric access as well as they can not afford due to their low income.
- Only 67% of households have access to electricity including 9% from RETs, still there is 33 % households are waiting the electricity access
- About 66% of energy supplied is used for cooking, used from traditional sources of energy such as wood, animal dung
- Rich in water resources, and other renewable energies but development is still far behind as per demand.
- No proven reserves of fossil fuel, heavily depending on the imports from India for petroleum products
- Major portion of foreign earning goes for petroleum import which is a huge problem of trade deficit.

- Grid Expansion is technically and financially costly in rural areas due to country's geographical structure.

Nepal went through observable change in 2008 form internal conflicting politics to peace process arrangement. However, this kind political achievement with democracy system in governmental activities, government of Nepal has not focused in the economic development due to new constitution formation process. Targeted government system is needed with proper policy framework for speedy development of renewable energy.

It is clear that most key issue is how to move forward to address to key barriers seen in development of renewable in the context of Nepal. With the realization of this country's transition period, government agencies should try to remove the most ranked barriers for the acceleration of the development of renewable energy. To achieve success in renewable energy sector, government of Nepal has put significant budgetary provision in his policy. However, renewable energy has been accompanied with various unsuccessful stories.

Many researchers identified the barriers related to development of renewable energy in the context of Nepal, researchers were aware of the barriers that can be seen in the renewable energy sector. Given the above barriers explanations, it can be concluded that there is requirement of research to identify the most ranked barriers need to address first to overcome challenges in renewable sectors of Nepal. Identified barriers relative comparison is needed to find the relative weight of the barriers. The preceding chapters review the previous relevant literature, and come with research framework to address research gap especially in the context of Nepal.

3 Previous studies and Literature Review

This chapter describes literature review that are related to renewable energy and its development, contains four parts. The first part reviews the various concepts of renewable energy and definitions. The second part includes benefit of renewable energy reviewed. Third part of this chapter covers renewable energy applications. This chapter ends with fourth part, reviews the barriers of renewable energy development in context of Nepal and barriers are summarized.

3.1 Renewable Energy Concepts and Definitions

Renewable energy defined as it comes from the sources which are naturally replenished. Renewable energy could replace traditional source of energy mainly in four distinct areas such as electricity generation, heating and cooling purpose, fuels for the motors, and rural off-grid energy solutions. As per REN21[11] report, renewable energy is contributing 19% in global energy mix and 22% in electricity generation. This renewable energy mix is contributing as 9% coming from biomass, 4.2% as heat energy from biomass, 3.8% from hydropower and 2% electricity comes from wind , solar, geothermal, and biomass. However, other energy sources are concentrated in limited number of countries, renewable energy potential distributed all over the world. Worldwide renewable energy market is projected continue to grow in the coming years to address sustainable development. While in the many cases renewable energy technologies are best fits to rural areas for developing countries.

Fossil fuels brought climate change concerns as threatening level. Hence, renewable energy sources as become the essential for the 21st

[11] Renewable Energy Policy Network for the 21st Century

century. Increasing numbers of renewable energy projects demonstrates that future directions towards clean energy path of world. Green/renewable energy is defined as energy generation and used in ways that will not provide any adverse effect in climate change (Harmon & Cowan, 2009).The ability of renewable energy technologies is to supply energy without exhausting resources. The first step to address climate change issue is to use the existing resources efficiently and increase the use of resources that are renewable (Reddy & Painuly, 2004).

Hydropower, solar energy, biomass and bio-wastes are the sustainably available in Nepal. Adequate utilization of these resources could certainly contribute the country's energy demand. Having environment friendly, renewable energy also contributes to reduce indoor air pollution, and reduces the negative impacts on the natural environments (Surendra et al., 2011). In a national perspective of Nepal, biogas and ICSs have provided to minimize dependency on wood consumption of forest. The impact of biogas and ICSs technologies has reported better efficiency, reduced in firewood consumption, minimizing indoor smoke pollutants, and greater safety of people (Sapkota et al., 2014).

There can be found many studies on decision making of renewable energy planning, however, there are few research has been conducted on the developments of renewable energy sources (Kahraman, Kaya, & Cebi, 2009). There has been a possibility to innovate in the financial model of rural area electrification projects with renewable sources in developing nations. In order to establish benchmarking for the decision making on effective developments, criteria, and factor establishment which are assessed relative importance of each factors (Heo, Kim, & Boo, 2010).

3.2 Benefits

As per EPA[12], generation of electricity through the renewable sources which could restore for a short period of time will not diminish. Renewable technologies are taken as environment preferred to the traditional conventional energy sources and, while taking alternative of fossil fuels, have remarkable potential to reduce the greenhouse gas emissions to nature.

According to scholar schools[13] the attractive part of renewable energy is that will never run out and produces the sustainable way of energy development. Most of renewable energy is being considered as free fuel availability which in turn minimizes the operation cost. It may also give socio-economic benefits to many rural areas, as most of resources are situated far way from the city areas. Hence it could be considered as one of the alternatives for balancing the regional development through out the country. UCS[14] specified the multiple benefits of renewable energy in six points.

1. Little to No Global Warming Emission

People activities are causing the overload in nature with producing the carbon dioxide and so global warming which is measure cause of the temperature increase with creating harmful impacts on health, environment and ecology. So if the generation of electricity through renewable sources rather than conventional energy sources provides considerable advantages in people's health. Similarly air, and water

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[12]http://www3.epa.gov/statelocalclimate/state/topics/renewable.html

[13] http://www.solarschools.net/resources/stuff/advantages_and_disadvantages.aspx

[14] Union of Concerned Scientist- ww.ucsusa.org/clean_energy/our-energy-choices/renewable-energy/public-benefits-of-renewable.html#.VjIr8bcrJYw

pollution produced by the coal and gas power generation plants is one the cause of breathing problem, neurological damage, heart problems and cancer. Replacing use of fossil fuels with renewable energy has been to advantage on those mentioned health issues.

2. A vast and Inexhaustible Energy Supply

Fast moving winds, sunny day, residues of plants, thermal energy from the earth and moving water streams could give continuous replenished energy to meet energy demand.

3. Jobs and Economic Benefits

Renewable Energy sector is new sector and labor intensive sector while conventional fossil fuel energies are already matured technologies and mechanized with capital intensive. Thus, more green jobs are created from the renewable energy sector.

4. Stable Energy price

Renewable energy can help to stabilize energy prices in the future. The generation costs of renewable energy technologies have declined steadily, and are projected to drop even more.

5. More Reliable and Resilient Energy System

Solar and wind energy technologies are less prone to massive failures due to distributed of its nature. Distribution of technologies covers large geographical area, so even severe weather condition can not affect all area of distribution of technologies. Potentials are distributed towards the geographical regions; hence resources optimization could be achieved.

6. Improves the Energy Security

Every country in the world has not access of fossil fuel reserves and heavily depended on foreign supplies. This leads the affect in national energy policy. Also many time observed that fossil fuels are vulnerable with political situation, disputes of trade, and embargoes.

3.3 Renewable Energy Applications

In application level, renewable technologies are economically viable with compare to the conventional energy resources. For examples off-grid/isolated electrification through the min/ micro hydropower, solar photovoltaic (PV) mini-grid, generations from biomass, off-grid wind generation are the already exists in market as completive solution with conventional energy sources. Although, development of renewable energy is competiveness of several applications, renewable energy accounts small proportion of its contribution in energy mix. This may be due to several kinds of barriers for the deployment of renewable energy technologies , but several researcher pointed out the barriers may vary across nations based on their specific conditions (Jyoti P Painuly, 2001).

3.3.1 Developed Countries

Renewable energy is becoming as a part of energy system in developed country. Developing countries are seeing the alternate source of energy which would be positive impact in climate change issues. Developed nations are focusing more in the research and development of technologies. Their efforts have continuously increased. Thus share of energy mix from renewable technologies is increasing. Generation of energy from renewable sources is part of supply to national energy system in each developed countries. Hence,

renewable energy is taken as part to supply energy in national energy system which is sustainable and addressing the climate change issue. Most of developed countries are adopting the various kinds of policies. Among the renewable energy polices, Renewable Energy Portfolios Standards (RPS), and Feed in Tariff (FIT) are two main polices across developed countries.

The RPS mechanism generally places an obligation on electricity supply companies to produce a specified fraction of their electricity from renewable energy sources. Certified renewable energy generators earn certificates for every unit of electricity they produce and can sell to supply companies. The FIT is a policy mechanism designed to accelerate investment in renewable energy technologies. It achieves by offering long-term contracts to renewable energy producers, typically based on the cost of generation of each technology.

3.3.2 Developing Countries

Developing nations have sufficient amount of renewable energy potential such as solar, wind, geothermal, hydropower, and biomass energy. Development of renewable energy technologies, developing world could minimize the dependency on fossil fuel. Developing countries has still lack of electricity access in rural areas, where national grid extensions sometimes not economical viable. Often in those rural areas, isolated off-grid renewable energy may come with economical and sustainable, helps to replace the traditional sources of energy such as fire wood, kerosene lams and unprocessed traditional biomass.

There is no doubt that renewable energy technologies are sustainable technologies for the energy sector. These technologies could play the important role in reduction of poverty, extension of rural area

development, and improvement of health conditions of people. Energy use in rural areas may help to raise the income activities through energy based enterprises.

3.4 Review of Renewable Energy Development Barriers

Various researchers conducted the research and identified barriers for the development of renewable energies.

- Human resource, Policy, Lack of affordability, Institutional, Political and economical are the main barriers for renewable energy developments (K.C, Khanal, Shrestha, & Lamsal, 2011).
- Social acceptability, Financial capability and Political feasibility are needed to consider for the development of renewable energy (Bergner, 2013)
- Needs to bring favorable policy with the mechanism of competitive investment to address the foreign direct investment in the context of hydropower development (Gangol, 2014).
- Social issues, Economic issues, and Environmental challenges are seeing as difficulty for the development of hydropower (Kumar & Katoch, 2015)
- Technical challenges, Economic challenges, Political challenges, Social challenges and Environmental challenges should be consider for the development of the hydropower and renewable energy (Sovacools & Bulan, 2011)
- Social awareness and ownership, favorable regulations, reducing corruption, addressing poverty, fulfillment of institutional capacity are major the challenges for the development of the hydropower (Sovacool, Bambawale, Gippner, & Dhakal, 2011)

- It is necessary that rural companies are provided with appropriate advisory and business support services for the sustainable operation of renewable energy (Nepal, 2012)
- To develop the sustainable hydropower international collaboration, system approach, ongoing monitoring and strategic human resource management are the major factors(Liu, Zuo, Sun, Zillante, & Chen, 2013).
- Appropriate trade off between stakeholders, inter-relations between project participants' and hydropower projects externalities should be emphasize for the future development of hydropower (Zhuoyu, Qiang, Wang, & Lu, 2013)
- For the market of renewable energy, privates sector advocates organizational issues for business concerning, strategy, product development, regulation and customer values. Governmental authorities have an impact on the political, policy and business (Harmon & Cowan, 2009)

3.5 Barriers Identification in the Context of Nepal

Renewable energy development has various kinds of barriers of dimensions viz. economical barriers, social barriers, and environmental barriers, each of them should be considered, and proper addressed. To develop the Clean Development Mechanism (CDM) energy projects, there is need of capacity, and institutional development in developing nations. Under CDM energy projects, existing various barriers need to overcome effective, and efficient implementation of CDM oriented renewable energy projects (Adhikari et al., 2008). Energy use has positive effect on living standard; also energy consumption and climate change have a casual effect. For this reason, providing energy without affecting climate change is required, hence renewable energy

technologies are alternate solutions for a sustainable development in energy sector (Sapkota et al., 2014).

There are various stakeholders involved in energy sector; however, there is not sufficient coordination among the institutions. There must be utmost requirement of coordination between government authorities to perform the effective roles for smooth service delivery process. Government of Nepal is focusing in developing of hydropower, and other types of renewable energy which is identified as priority area of development in recent years. It's a crucial issue to formulate the diversified energy resources use plan, so distributed renewable energy potentials could be properly planned for the future pathway which is also suitable option off grid village solutions for the rural and remote areas. In order to provide effective development and support for the deployment of renewable energy projects, government of Nepal separate nodal agency Alternative Energy Promotion Center.

The renewable energy development barriers are the real and perceived phenomena within various dimensions of barriers in the context of Nepal, such as social, policy and political, technical, economic, administrative, and geographic barriers. Many researchers differentiate these barriers/challenges to renewable energy development within different dimensions. In the reviewed literature, several kinds of barriers were listed in the context of developing countries, specifically Nepal.

These barriers may be classified into the following six dimensions: (i) social barriers; (ii) political and policy barriers; (iii) technical barriers; (iv) economic barriers; (v) administrative barriers; and (vi) geographic barriers. While listing the barriers to renewable energy development in the context of Nepal, an extensive literature survey was performed, searching keywords such as renewable energy,

barriers, issues, challenges, and renewable energy development in Nepal. The Google, Google Scholar database, and Science Direct Online searching tools were used for the literature review. For Nepal, 22 barriers were listed and identified from the extensive review of journal papers, country reports, conference proceedings, and other relevant studies. Other developing countries' renewable energy development barriers were found to be somewhat similar to those for Nepal as the latter may have a similar situation as such other developing countries. The classification of the barriers into dimensions and the details of each barrier are briefly explained below.

3.5.1 Dimension 1: Social Barriers

The social barriers are related to the demand side in the course of the implementation of renewable energy development projects. This dimension of barriers is making it difficult to implement such projects from the social side. Thus, for this dimension of barriers, community- or household-level action is needed to achieve smooth implementation.

Lack of Public Awareness

The lack of information on the part of the consumers in the community causes a lack of awareness of renewable energy technologies, which clearly indicates the poor access of the members of the community to information on renewable energy resources compared to other types of commercial energy resources.

Lack of Consumer Paying Capacity

In the case of developing countries where a large percentage of the population still do not have access to electricity, off-grid renewable

energy technologies are primarily targeted at the rural and remote areas, where the people are poor customers and have a limited economic capacity.

Lack of Social Acceptance

People have different opinions about renewable energy technologies and have certain concerns about the type of power plant involved. Some people do not accept such technologies as consumers.

3.5.2 Dimension 2: Political and Policy Barriers

The policy and political barriers are mainly from the supply side. The government formulated the various existing policies based on its own view. The political situation also governs the development of renewable energy. Four specific policy and political barriers are listed here for analysis.

Lack of Transparency in the Decision-making Process

Many stakeholders raised the issue of the decision-making process; they want a transparent decision-making mechanism to be implemented in all the steps of renewable energy development.

Political Instability and Lack of Political Commitment

In the case of Nepal, as there are divergent political mindsets at the central and local levels due to the constitution formation process, the government is not stable and the political leader's commitment to renewable energy development is weak.

Absence of a Coherent Renewable Energy Policy

The relevant policies are formed mainly from the supply side, and as such, there is no coherent mechanism for policy formulation and for regular updates. Despite the existence of the government subsidy mechanism, the projects are still unaffordable for the rural communities as they have a high capital cost.

Corruption and Nepotism

In developing countries, there is a high possibility of corruption and nepotism in various activities, which causes a delay in the public fund release process and leads to the misuse of public funds.

3.5.3 Dimension 3: Technical Barriers

As is widely known, renewable energy technologies are relatively new compared to the conventional energy technologies. The research and development efforts on renewable energy technologies are continuously growing in the case of the developed countries, but in the developing countries, there are insufficient resources for such. Thus, developing countries like Nepal mainly depend on technology transfer from developed countries, and the quality of their renewable energy development is also compromised due to financial constraints. Within the technical dimension, four barriers are listed, as shown below.

Lack of Research and Development Facilities

Due to constraints in resources like financial and human resources as well as infrastructure, there is no research and development mechanism. Only through the process of long-term research and development can the cost of technologies be reduced and the technical

issues be solved as needed. Also, technological advancement can be achieved only through research.

Unreliable Supply

In most renewable energy technologies, generation is somehow unreliable compared to the conventional energy sources. The solar photovoltaic technology can produce electricity only in the daytime, while the sun is still up; similarly, hydropower can produce at full capacity during the rainy season, but there is insufficient water flow in the dry season. In addition, the varying wind speed causes the power generation to fluctuate.

Risk and Uncertainty

With all types of technologies, the market can notice the risks and uncertainties, such as those posed by natural disasters, technical failures, and climate change, and the private sector is naturally highly concerned about the pertinent risks and uncertainties, which will affect their investment decisions.

Absence of a Grid Connection Mechanism

When the national electricity grid extension reaches the isolated or off-grid renewable energy technology area, due to the absence of a grid connection mechanism for the connection of power to the national grid, energy cannot be supplied to the national grid. On the other hand, without a proper grid connection mechanism, renewable energy projects cannot be seen as economically viable and sustainable.

3.5.4 Dimension 4: Economic Barriers

The economic barriers also need to be addressed for the successful development of renewable energy technologies. One of the major problems in developing countries is the insufficient funds. Not only directly fund availability but also the mechanism of economic management is a crucial issue in renewable energy project financing. Within the economic dimension, five barriers are listed, as shown below.

High Capital Cost

One of the major barriers to renewable energy development is the high capital cost of energy generation compared with the development of the conventional energy resources. Although there has been a noticeable reduction in the cost of the technology involved, the cost is still high compared to that used for the development of the traditional energy sources.

Absence of a Credit Mechanism

One of the options for addressing the financial barrier is providing a credit facility for the renewable energy power producers. Off-grid technologies are being planned to be developed in the remote and rural areas, however, where the consumers have limited financial capability. Through a proper credit mechanism, the financial constraints can somehow be addressed.

Small Market Size

As is well known, the market size affects the cost of the technology as well as the investment from the private sector. Due to the lower

demand for renewable energy development, the market size is bound to be small, which can lead to the absence of competition in the market.

Lack of End Use (Insufficient Daytime Demand)

In off-grid renewable energy projects, there is a low electricity demand in the daytime due to the absence of energy use enterprises. Most of such projects have a high demand at night, for lighting purposes, which means there will be an excess of power in the daytime. Such projects can become sustainable and economically viable only when the available power is properly used.

Lack of Subsidies/Funds

Through the establishment of an energy subsidy policy endorsed by the government, the government will provide a renewable energy generation subsidy for the basic purpose of mitigating the high capital cost. There is a high demand for subsidies/funds, but due to the fund limitations in developing countries like Nepal, lack of funds is among the barriers to renewable energy development.

3.5.5 Dimension 5: Administrative Barriers

Policy by itself is not sufficient for the effective and efficient delivery of services by the government. The procedures to be carried out for development purposes are also important. Without an effective administrative system, the development target cannot be achieved. Thus, within the administrative barrier dimension, four barriers are listed: the human resources barrier, lack of coordination among the authorities, lack of institutional capacity, and delivery mechanism complexity.

Lack of Skilled Manpower

As is well known, skilled manpower is the key factor for the successful development of renewable energy technologies. Sufficient skilled human resources are the basic need for the smooth development of renewable energy. Different levels of skilled human resources can be seen, such as engineers, policy experts, technicians, and technical experts.

Lack of Coordination among Institutions

Sometimes, different government authorities or other development agencies can be observed to be doing the same work; that is, there is work duplication or overlapping of work areas. Proper coordination is thus the best way to achieve development. The lack of coordination among authorities is one of the barriers to renewable energy development.

Lack of Institutional Capacity

The institution that is mainly responsible for renewable energy development should be capable as per the concerned country's need. The institution must deliver its process-related work on time; as such, the lack of proper institutional capacity may be another barrier to renewable energy development.

Delivery Mechanism Complexity

In the context of Nepal, the private sector is concerned about the length of the procedures mentioned in the delivery mechanism, which is one of the hindrances to speedy development. Thus, the delivery

mechanism procedure should be in line with fast development procedures.

3.5.5.1 Dimension 6: Geographic Barriers

Nepal is a country with a diverse geographic structure, consisting of the Himalayan mountain region and flat-terrain regions. Due to its geographic constraints, there is a problem with regard to the transport of equipment. Transmission and distribution could also be problematic due to the scattered users in the project development area. Hence, in the geographic dimension, two barriers are listed, as shown below.

Transportation Problem

Renewable energy development is targeted at the remote and rural areas, where there is no road access for transport, which will ultimately make the project cost high and will make the project take a longer time to complete.

Scattered Households

Due to the geographic structure of Nepal, the households are scattered, making power transmission and distribution costly and difficult. As such, scattered households may be another barrier to renewable energy development in Nepal.

Table 7 presents a summary of the barriers to renewable energy development in Nepal, and their respective literature references.

Table 7: Summary of Barriers to renewable energy development-Context of Nepal

Dimensions	Barriers	Literature References
Social Barriers	Lack of Public Awareness	(Dulal et al., 2013; Gurung et al., 2012; Luthra, Kumar, et al., 2015; Jyoti P Painuly, 2001; Surendra et al., 2011; Yadoo & Cruickshank, 2012)
	Lack of Consumer Paying Capacity	(Gurung et al., 2012; Luthra, Kumar, et al., 2015; Jyoti P Painuly, 2001)
	Lack of Social Acceptance	(Chatzimouratidis & Pilavachi, 2008; Darmani et al., 2014; J.P. Painuly, 2001; Wang, Jing, Zhang, & Zhao, 2009)
Political and Policy Barriers	Lack of Transparency in Decision Process	(Jyoti P Painuly, 2001)
	Political Instability	(Bhattacharya & Jana, 2009; Brown, 2001; Dulal et al., 2013; Singh, 2013)
	Lack of Coherent Renewable Energy policy	(Darmani et al., 2014; Gurung et al., 2012; K.C et al., 2011; Luthra, Kumar, et al., 2015)
	Corruption and Nepotism	(Sovacool & Bulan, 2012; Benjamin K. Sovacool et al., 2011)

Technical Barriers	Lack of R & D Facility	(Jyoti P Painuly, 2001)
	Unreliable Supply	(Kahraman et al., 2009; Wang et al., 2009)
	Risk and Uncertainty	(Kahraman et al., 2009)
	Lack of Grid Connection Mechanism	(Amer & Daim, 2011; Awan & Khan, 2014; Bhutto, Bazmi, & Zahedi, 2012; Kahraman et al., 2009; S. K. Lee, Mogi, Kim, & Gim, 2008)
Economic Barriers	High Capital Cost	(Adhikari et al., 2008)
	Lack of Access of Credit Mechanism	(J.P. Painuly, 2001) (Dulal et al., 2013; Luthra, SanjayKumar, DixitGarg, & AbidHaleem, 2015; Nepal, 2012)
	Lack Sufficient Size of Market	(Ansari, Kharb, Luthra, Shimmi, & Chatterji, 2013; Dulal et al., 2013; Luthra, Kumar, et al., 2015; Jyoti P Painuly, 2001)
	Lack of End-Use (day time sufficient Demand)	(Nepal, 2012)
	Lack of Subsidies / Funds	(Adhikari et al., 2008; Javadi et al., 2013; Kahraman et al., 2009; Luthra, SanjayKumar, et al., 2015; Nepal, 2012)

Administrative Barriers	Lack of Skilled Human Resource	(Amer & Daim, 2011; Brown, 2001; Darmani et al., 2014; Dulal et al., 2013; Kahraman et al., 2009; Kumar & Katoch, 2015; Jyoti P Painuly, 2001; Singh, 2013; Yadoo & Cruickshank, 2012)
	Lack of Coordination between authorities	(Bhattacharya & Jana, 2009; Liu et al., 2013)
	Lack of Institutional Capacity	(Adhikari et al., 2008; Gurung et al., 2012; Nepal, 2012; Benjamin K. Sovacool et al., 2011; Yadoo & Cruickshank, 2012)
	Delivery Mechanism Complexity	
Geographical Barriers	Transportation Problem	(Fthenakis, Mason, & Zweibel, 2009; Surendra et al., 2011)
	Scattered Households	(Javadi et al., 2013)

3.6 Previous Studies Using of AHP

Sunil Luthra (2015) used AHP methodology for the research of barriers to renewable/sustainable energy technologies adoption for the Indian context for ranking barriers renewable of energy sector which research was formulated based on the previous research review, and summarized barriers in seven dimensions. Seven dimensions such as economical and financial, market, awareness and information, technical, ecological and geographical, cultural and behavioral, and political and governmental issues. Luthra summarized all together twenty eight barriers from literature review, and barriers are classified in above mentioned seven barriers. The study highlighted the importance of barriers to overcome slow development of renewable energy technologies in the context India.

Luthra performed expert survey based on AHP model pair wise comparison to get ranking of the barriers. The researcher strongly put his result obtained from AHP especially for the context of India. Study revealed that ecological and geographical barriers ranked as first followed by the political and government issues in dimension level. In global priority of barriers, lack of political commitment ranked as most important barrier followed ecological issues, scarcity of natural and renewable resources, lack of adequate government policies, geographic conditions respectively. The findings of research suggest that political commitment should be highly important for the adoption of renewable energy technologies. Study suggests that this is benchmarking to consider the barriers attention for designing the policy. This research may help to policy makers or mangers to give high attention to overcome potential barriers (Luthra, Kumar, et al., 2015).

Daim (2010) used the AHP model for the exploring the impact of technology development and adoption for sustainable hydroelectric

power and storage technologies in the pacific Northwest United States. Researcher performed the study based on extensive literature review; four criteria are listed as technological factors, economic factors, social factors, and environmental factors. Study summarized nine types of sub-criteria, and classified in above mentioned four factors. In this study researcher brought the seven alternatives of different kind hydropower. Based on hierarchy model formulation, researcher collected data from knowledgeable specialists in field of renewable energy. For this research, alternative have been obtained through the Delphi method and the rated perceived impacts have been judged through AHP methodology (Cowan, Daim, & Anderson, 2010; Daim, Yates, Peng, & Jimenez, 2009)

Wang (2009) is also used the AHP methodology to review on multi-criteria decision analysis aid in sustainable decision-making. Wang has listed the four dimensions namely technical, economic, and environmental and social for purpose of evaluating the energy supply system. He classified twenty nine evaluation criteria those are obtained from the extensive literature review. Research applied the process of systemic principle, consistency principle, independency principle, measurability principle and comparability principle for the criteria selection of energy evaluation. He applied different methods for calculating weight those summarized criteria, one of them was the AHP model as well (Wang et al., 2009)

Similarly in different perspective, Kim (2010) also used the AHP model for the analysis of the assessment factors for the renewable dissemination program using fuzzy AHP. Researcher divided the experts in two group policy makers, and specialist. The study presented the resulted in three different ways as overall results, policy maker's views, and specialist views. Kim also explained the obtained results those classified respondent perspective.

4 Models and Methodology

Many of the researchers so far on the barriers to or issues regarding the development of renewable/sustainable energy technologies used analytical hierarchy process (AHP) for analysis purposes (Ansari et al., 2013; Heo et al., 2010; Ji, Huang, & Sun, 2015; S. K. Lee et al., 2008; Luthra, Kumar et al., 2015). The following sections explain the details of AHP and its application in the previous researches.

4.1 Analytical Hierarchy Process

This part consists of two sections. The first section gives an introduction of the analytical hierarchy process (AHP) with basic mathematics. The second section reviews some past studies on the renewable energy development barriers and challenges that used the AHP methodology. AHP is a basic theory of subjective measurement and is the most popular tool for assigning weights for the comparison of certain criteria or alternatives. The comparison values may be taken from the survey of or actual measurement by the respondents using the fundamental scales (Saaty, 1987). Saaty was the one who came up with and developed the AHP multi-criteria methodology as an analysis and decision-making tool, with the help of a hierarchical structure (Saaty, 1980). AHP is an approach that requires the judgment of relative field experts with regard to the comparative importance of dimensions and sub dimensions.

According to Saaty, AHP provides a model for solving decision-making, ranking, and priority problems. AHP enables researches to come up with intuitive, rational, and irrational judgments at the same time period so that multi-criteria decision tools can be used. Different experts have different opinions, their views could be integrate and

synthesis. AHP doest not need the consistency of views provided by the individual. Inconsistency of results is viewed or can be calculated at the final stage of the AHP model**.** Mainly three basic principles which can be used to solved decision making problem in AHP model, they are decomposition of problem, relative or comparative judgments and synthesis of priorities. Comparative views from respondents make the comparison matrix to carry out relative importance of criteria in each level. While we perform the research in group of experts views for comparative judgments can be combined by applying the geometric mean to the views for the formation of comparison judgment matrix (T. L. Saaty, 1986). AHP is the useful way to formulate the structure of ranking of decisions to going down from goal to criteria decompositions it which could be understandable factors (T. L. Saaty, 1994).

As per the T.L Saaty (2008), this methodology could be used to make the subjective judgments based on the comparisons. It is the inescapable that we should have a systematic and organized process to come up decisions and collection of information related to them with comparison from the group. To get the ranking or weight in systematic way, it is needed to decompose the process in four steps as below.

1. Define the problem and determine the kind of knowledge sought.
2. Structure the decision hierarchy from the top with the goal of the decision, then the objectives from a broad perspective, through the intermediate levels
3. Construct a set of pair-wise comparison matrices. Each element in an upper level is used to compare the elements in the level immediately below with respect to it.
4. Use the priorities obtained from the comparisons to weigh the priorities in the level immediately below. Do this for every element.

Then for each element in the level below add its weighed values and obtain its overall or global priority. Continue this process of weighing and adding until the final results obtained or property with respect to which they are compared (T. L. Saaty, 2008).

It does not matter whether top-down or bottom-up approach is carried for formation of AHP model tree, it may depend on the availability of information, and level of knowledge for formation of criteria, sub-criteria, and alternative (Chatzimouratidis & Pilavachi, 2008). Structuring any the any kinds of decision/ranking problem hierarchically is a suitable technique for complex decision problem; there is neither single already defined hierarchical structure nor identifying criteria and sub criteria for AHP model. It is the flexibility model which allows us to manage and formulate the hierarchy model as per our situational need (Wind & Saaty, 1980).

Based on the literature review, we arranged AHP model based on our need for this research. The AHP methodology is structured to compare criteria with respect to criterion, in a natural pair wise mode. Comparison matrix resultant can be used for ranking of barriers of renewable energy in Nepal. For this raking of barriers in the context of Nepal, AHP could be explained in the following five steps.

4.1.1 First Step

Formulation of the hierarchical structure based on defining problem with a focus on the dimensions, and specific barriers within each dimensions. This was the process of decompose the problem into hierarchical tree as discussed above. This step is very crucial which finally leads to results. Related various literature have been reviewed for the formation hierarchical structure. When researcher has large number of barriers in ranking of problem, barriers were attempted

clustering in the dimensions (T. L. Saaty, 1994). Hierarchical structure has shown in figure 6.

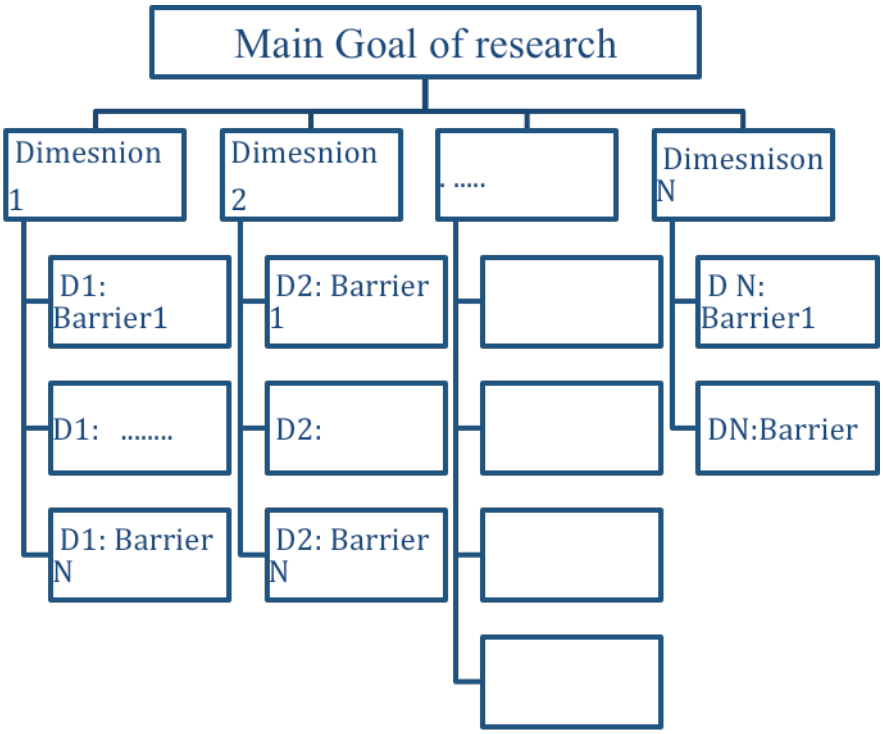

Figure 6: Example of formulation of hierarchical tree/Structure

Sources: Reference from (R. W. Saaty, 1987; T. L. Saaty, 1986, 1990, 1994, 2008; Wind & Saaty, 1980)

Levels of hierarchy structure could be defined as below.

Level1: Main goal of research is lies in level 1.

Level 2: Based on the goal, n mummer of dimensions can be identified. So dimension of barriers of renewable energy development could be listed in level 2.

Level 3: With in each dimension of barriers, specific barriers could be listed up to n number in each dimension. In each dimension number of barriers may be different. Specific barriers within each dimension may list level 3.

4.1.2 Second Step

The second step is formulation of the pair-wise comparison questionnaires for experts to provide their judgments based on the nine point scale. AHP model uses the ratio scales which interval scales. Comparison of level 2 and level 3 elements should be done in questionnaire format from the experts of relevant field. In level 2: with respect to main goal each of dimension comparison should be performed. In level 3: with respect to dimension, barriers could be compared in each separately in each dimension. Experts are requested to provide to their judgment based on nine point scale as below (R. W. Saaty, 1987).

Table 8: Views classification nine point scale

Judgments	Numeric Values
If Option A and Option B are equally important	1
Option A is moderately more important than Option B	3
If Option A is strongly more important than Option B	5
If Option A is very strongly more important than Option B	7
If Option A is extremely more important than Option B : Mark/Insert	9
Use even numbers for intermediate judgments	2,4,6,8

Sources: (R. W. Saaty, 1987; T. L. Saaty, 1986, 1990, 1994, 2008)

Thus, the relative comparison of the barriers should be numerical, ratio scales are only possible measurement if one wants to aggregated measurements as in weighted sum (T. L. Saaty, 1994).

4.1.3 Third Step

In third step, pair-wise comparison matrix will be constructed in dimension level 2 with respect to goal, and similarly within each dimension level, barriers comparisons matrix will be constructed with respect to each dimension. Let us assume A is comparison matrix as below,

$$A[a_{ij}] = \begin{pmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{n1} & \cdots & a_{nn} \end{pmatrix} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

The comparison matrix A is $n \times n$ real matrix, where n is number of dimension in for the level 2. But in level 3, n is numbers of barriers in each dimension Elements of pair-wise comparison matrix represent the relative important of between pair where A= $a_{ij,}$each entry represents the importance if ith criterion relative to the jth criterion for all i , j= 1, 2, 3…….n. If a_{ij}>1, then ith criterion is more important than jth criterion, while if a_{ij}< 1, then jth criterion is more important that ith criterion (R. W. Saaty, 1987; T. L. Saaty, 1990, 1994, 2008; Wind & Saaty, 1980). The relative important is chosen from a given 1 -9 scale. In dimension level one cone comparison matrix is formed and but level second level; Barriers level, number of comparison matrix depends on number of the dimensions. The entries a_{ij} and a_{ji} satisfies the following condition.

$$a_{ij} \times a_{ji} = 1 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

Two important issues in group decision making are: how to aggregate individual judgments in a group into a single representative judgment for the entire group and how to construct a group choice from individual choices. The reciprocal property plays an important role in combining the judgments of several individuals to obtain a

single judgment for the group. Judgments must be combined so that the reciprocal of the synthesized judgments is equal to the syntheses of the reciprocals of these judgments. It has been proved that the geometric mean, not the frequently used arithmetic mean, is the only way to do that. If the individuals are experts, they may not wish to combine their judgments but only their final outcomes obtained by each from their own hierarchy (T. L. Saaty, 2008).

4.1.4 Fourth Step

Fourth step is to compute the weights for both level 2(dimension) and level 3 (barriers).Consider [Aw = λ_{max}w] whereA is the comparison matrix of size n×n, for n criteria, also called the priority matrix and w is the Eigenvector of size n×1, also called the priority vector. λ_{max} is the Eigenvalue.Once the matrix is A is built, it has way to form A into the normalized pair-wise comparison matrix (T. L. Saaty, 1990, 1994). Normalize the column entries by dividing each entry by the sum of the column as below :

$$A_{norm} = [\overline{a_{ij}}] = {}^{a_{ij}}/_{\sum_{i=1}^{n} a_{ij}} \quad \text{.....(3)}$$

Finally, weight vector w (an n dimensional column vector) can be calculated by averaging the entries on of $A_{norm,}$ i.e. the overall row averages as bellow

$$w_i = {}^{\sum_{i=1}^{n} \overline{a_{ij}}}/_{n} \quad \text{..... (4)}$$

So from above calculation, we will get the weight of dimension, and also local weight of barriers within the respective dimensions. So multiplication of the weight of respective dimension and local weight of each barriers, gives the global weight of barriers which is our final target of calculation.

4.1.5 Fifth Step

Calculating the degree of consistency or inconsistency is as follows.

To calculate the inconsistency, λ max need to calculate first which lead to the consistency index and consistency ratio. Consider Aw = λ max *w where w is eigenvector (T. L. Saaty, 1990).

$$\begin{pmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{n1} & \cdots & a_{nn} \end{pmatrix} \begin{bmatrix} w_1 \\ \cdot\cdot \\ w_n \end{bmatrix} = A \times W = \begin{pmatrix} (Aw)_1 \\ \ldots \\ (Aw)_n \end{pmatrix} = \lambda\max \begin{bmatrix} w_1 \\ \cdot\cdot \\ w_n \end{bmatrix} \ldots\ldots\ldots (5)$$

Where

$$\boldsymbol{\lambda\max} = average\,\{(Aw)_1/w_1, \ldots\ldots\ldots\ldots, (Aw)_n/w_n\}$$

Then Consistency index (CI) is found by

CI=(λmax-n)/(n-1)…….(6)

Perfect consistent decision maker always get CI =0, but in real sense while providing relative judgments small values of inconsistency may be acceptable. In particular if consistency ratio

CI/ RI< 0.1

is acceptable range (Wind & Saaty, 1980), and this reliable result may be expected from calculation. RI is the Random Index that means consistency index when the entries of A are absolutely random. The standard values of RI for up to 10 criteria are shown below (T. L. Saaty, 1980).

Table 9: Values of Random Index (RI)

n	1	2	3	4	4	6	7	8	9	10
R.I	0	0	0.52	0.89	1.11	1.25	1.35	1.40	1.40	1.49

Source : (T. L. Saaty, 1994)

4.2 Methodological Framework

AHP model for this research could be understandable in two ways, dimension and barriers, and hierarchical structure formation

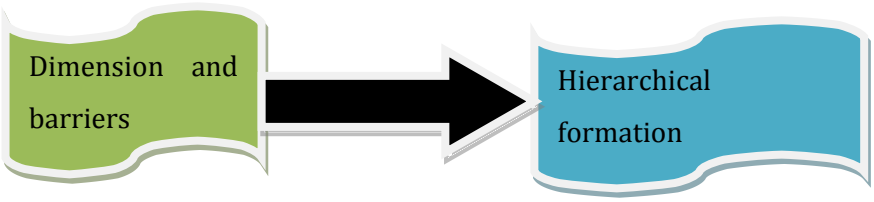

Figure 7: Two steps of AHP model development

As explained in third chapter, extensive review of literatures has been performed to identify the dimension of barriers and specific barriers with in these dimensions in order to get rank of barriers of renewable developments in Nepal. With respect to goal, seven dimension of barriers and twenty two barriers are listed which is explained in chapter third. In AHP model, research should be formed as a hierarchy, which means hierarchical model formation is occurred as a final stage. According to the AHP method, hierarchical structure tree is formed with goal of ranking barriers for the renewable energy development. The first level is called the dimension of barriers and second level is called barriers for this study. Hierarchical structure has shown as bellow in figure 8.

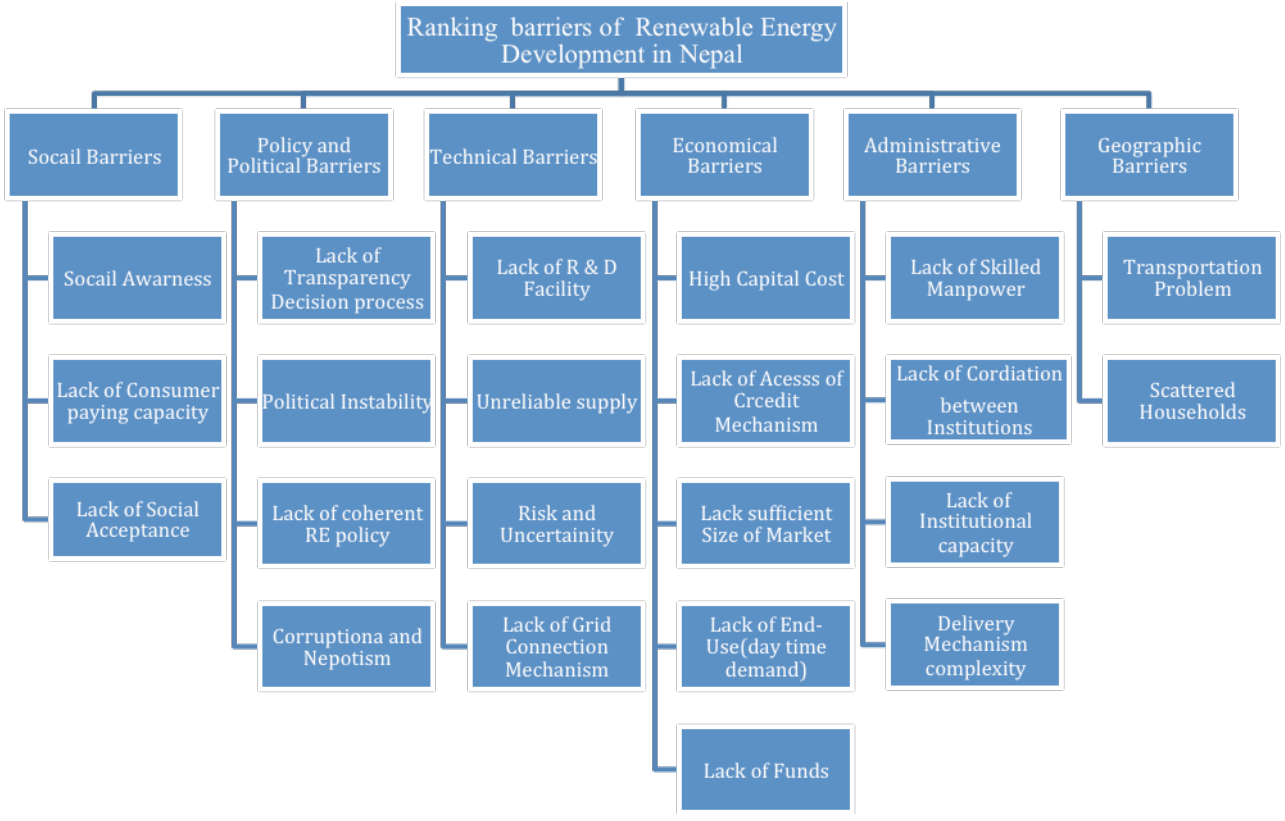

Figure 8: Hierarchical Structure of Research

Moreover, barriers of renewable energy development in context of Nepal based on the extensive previous literature are classified in six dimensions:

1. Social barriers
2. Policy and political barriers
3. Technical barriers
4. Economic barriers
5. Administrative barriers
6. Geographical barriers

Thereafter, above six dimensions have all together twenty two barriers, according the barriers nature; barriers are listed in relevant dimensions. The dimensions and barriers are depicted in AHP model which is shown in figure 8. Hence, based on this hierarchical model following hypothesis is formed for the six dimension of renewable energy barriers.

- H1 Social dimension related barriers affect the development of renewable energy development in the context of Nepal
- H2: Political and Policy dimension related barriers affect the development of renewable energy development in the context of Nepal
- H3: Technical dimension related barriers affect the development of renewable energy development in the context of Nepal
- H4: Economic dimension related barriers affect the development of renewable energy development in the context of Nepal
- H5: Administrative dimension related barriers affect the development of renewable energy development in the context of Nepal
- H6: Geographical dimension related barriers affect the development of renewable energy development in the context of Nepal

Above mentioned hypothesis could be explained in using AHP model, for this study in development of renewable energy.

4.3 Survey and Data

As already mentioned, this research used the AHP methodology for questionnaire formation, data collection through various experts, and analysis (Wind & Saaty, 1980). The AHP model was selected for the case of Nepal as it could best help identify the barriers to renewable energy development in the said country. With a hierarchical model, a questionnaire was developed. Specialists or experts in the renewable energy development field took part in the study by providing their judgments. Relevant experts from the private sector, the government, the program implementer, and the academe were chosen, after which the survey was performed and its results analyzed by comparing the barriers based on a qualitative nine-point scale.

4.3.1 AHP Survey

The AHP questionnaire was divided into three parts. The first part included the overview or background of the study and an explanation of the sample questions. The second part included pair-wise comparison questions for the seven dimensions and 22 barriers. The third part contained the demographic information of the participating experts, who were government, program, and academic experts. Based on the selection of the respondents, it can be seen that the experts belonged to the supply side. As per the AHP model, formal survey questions were formulated and included in the three main sections of the questionnaire.

- <u>Section 1: Introduction</u>

This section includes the short description of the research idea, research formulation, and intention of the research. This section also includes the advantages of this research in the context of Nepal's

renewable energy development. This part also includes hierarchical structure; explanation of barriers also expressed, and contact details for further advice. This section ended with examples of questionnaire for the making understandable to fill.

- Section 2: Pair-wise questions

In this section questionnaire are listed. Based on the main goal, ranking the barriers of renewable energy development, six dimension pair wise fifteen questionnaire listed. After first level dimension pair – wise questions, with in each dimension specific barriers comparison questions are listed. So in second level barriers questions are in listed 6 parts according with each dimension's barriers. At the end of this section two subjective questions were asked to get opinions of experts in barriers change in future time and any other barriers seen form the experts views.

- Section 3: Demographic Information

Final section of this survey questionnaire was general information about those who are participated in providing their judgmental views. Demographic information part covers the expert's name, their involvement type organizations. This part also covers their years of experience in renewable energy sector. Finally ends with contact address of respondents.

4.3.2 Data Collection

In this research, a survey was conducted based on a direct meeting with experts and through requests via e-mail. Thereafter, researcher collected 81 datasets of views of experts from Nepal. Out of the 81 datasets, six datasets were considered invalid as they were incomplete.

The survey questionnaires thus provided the complete views of 75 experts, which is 92.5% of all the respondents. The experts were classified into three groups, the first group consisting of government/program implementation experts, the second group experts from the private sector, and the third group academic experts.

4.4 Implications on the Existing Literature

Based on the research framework, objectives, research questions, and review of previous research related to renewable energy, this research has contribution in different context especially in the context of Nepal. Literature reviews of previous research reveals that not exactly this kind ranking barriers study has been conducted in the context of Nepal. So this study is aimed to provide insight view of barriers for the renewable energy development for the case of Nepal.

To this extent, we could not find such a research which deeply studied the barriers for renewable energy development in Nepal. Therefore, here in this research is different from the previous research in way that it involves experts from the government, private sector and academia for view of barriers. So, this research examined barriers mainly with supply side, however, this study is limited not going from the demand side. The originality of this research is ranking the barriers in the context of Nepal form supply side perspective, and provides basic research framework for other developing countries.

In sum up, this research gives contribution in renewable energy sector in Nepal and also framework for the developing countries for further studies for their specific need to address barriers in renewable energy sector. At first, it provides the foundation of existing literatures and identified twenty two barriers for the case of Nepal. Additionally,

this study serves the basic framework for the renewable energy development barriers in Nepal.

5 Analysis, Results, and Discussion

This chapter reveals the how the research methodology was used and how the results were obtained from the collected data. The empirical results that were obtained from the use of the AHP methodology are presented and discussed.

5.1 Empirical Results

As defined in the Methodology section, the AHP model consists of five stages. Based on the AHP model formation, a hierarchical structure was formed. Thus, for the calculation, all pair-wise comparison data that were provided by the experts were inputted. At the final stage of calculation, the results were synthesized based on all the data.

5.1.1 Inconsistency Results

Table 10 shows the different groups' participation and the overall consistency ratios in each group.

Table 10: All Groups' Inconsistency Results

Groups	Group 1 Government/ program implementation experts	Group 2: Private sector experts	Group 3: Academic experts
No. of respondents	51	20	10
Inconsistency	0.01	0.01	0.01
Overall inconsistency	0.01		

When the individual experts' views were scattered, the inconsistency or variation in their views was meaningful information to the researchers. As per the AHP model inconsistency results, that which is smaller than 0.1 is acceptable as results (Saaty, 1980). The inconsistency ratio of the different groups of respondents and the overall inconsistency were obtained from the calculations. The inconsistency results are shown in Table 10.

5.1.2 Overall Aggregated Results of Dimensions Hierarchy

This section presents the overall results based on the findings regarding the six categorized barrier dimensions. From the results presented in Table 11 and the synthesized results shown in Figure 9, the overall aggregated results from all the experts show that the policy and political barriers dimension (27.8%) had the greatest weight as a dimension of barriers to renewable energy development in the context of Nepal, followed by the economic barriers (24.7%), the geographic barriers (15.3%), the administrative barriers (13.5%), the social barriers (9.91%), and the technical barriers (8.9%).

Table 11: Ranking of dimension of barriers for Renewable Energy Development

Dimension of Barriers	Priority Weight	Priority Weight (%)	Rank
Social Barriers	0.099	9.91	**5**
Policy and Political Barriers	0.278	27.77	**1**
Technical Barriers	0.089	8.87	**6**

Economical Barriers	0.247	24.69	**2**
Administrative Barriers	0.135	13.48	**4**
Geographic Barriers	0.153	15.27	**3**

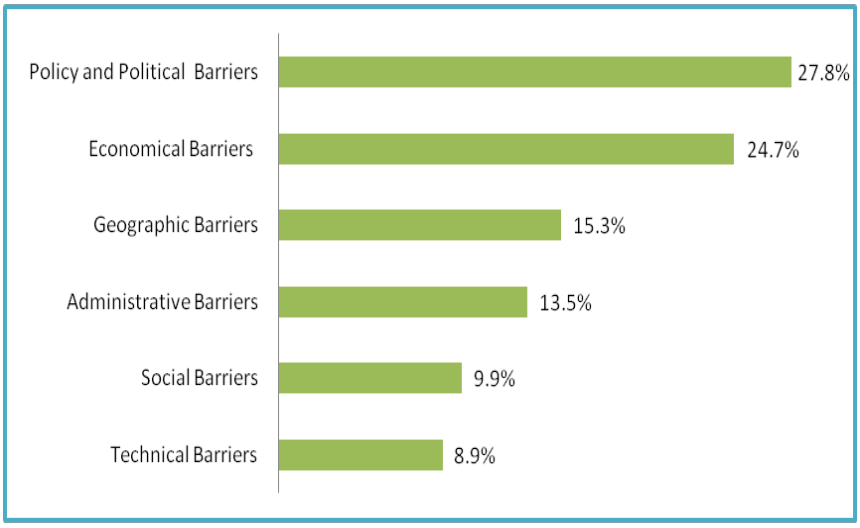

Figure 9: Synthesize of Dimensions and Prioritization

5.1.3 Results of Barriers within each Dimension

The weights of the barriers within each dimension in terms of the degree to which they hinder renewable energy development were calculated, and based on the results of the calculation, the said barriers were ranked. As can be seen in Table 12 and in the synthesis of the study results in Figure 10, “lack of consumer paying capacity” (48.2%) within the social barriers dimension was cited as the biggest barrier to the development of renewable energy in the context of Nepal, followed by “lack of public awareness” (33.7%).

Table 12: Ranking of barriers in "Dimension 1- Social Barriers" for the development of renewable energy

Barriers	Priority Weight	Priority Weight (%)	Rank
Lack of Public Awareness	0.337	33.74	**2**
Lack of Consumer Paying Capacity	0.482	48.25	**1**
Lack of Social Acceptance	0.180	18.04	**3**

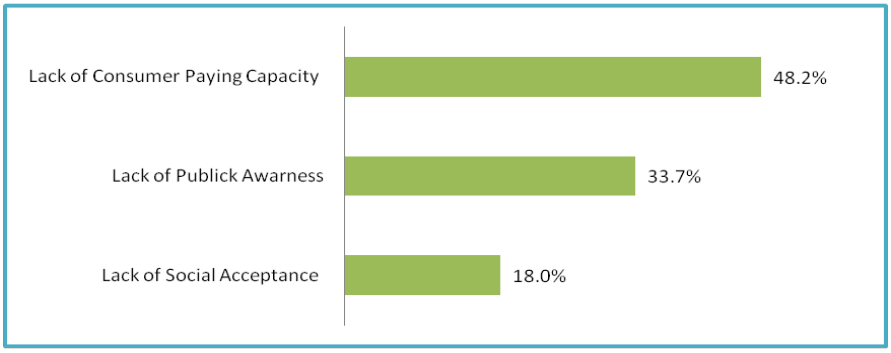

Figure 10: Synthesize of "Dimension 1- Social Barriers"

For the policy and political barriers dimension, as can be seen in the results presented in Table 13, "political instability" (32%) was cited as the biggest barrier to renewable energy development in Nepal, followed by "absence of a coherent RE policy" (26.8%), "corruption and nepotism" (21.1%), and "lack of transparency in the decision-making process" (20%).

Table 13: Ranking of barriers in "Dimension 2- Policy and Political barriers" for the development of renewable energy

Barriers	Priority Weight	Priority Weight (%)	Rank
Lack of Transparency	0.200	20.02	**4**
Political Instability	0.320	32.04	**1**
Lack of Coherent RE policy	0.268	26.83	**2**
Corruption and Nepotism	0.211	21.13	**3**

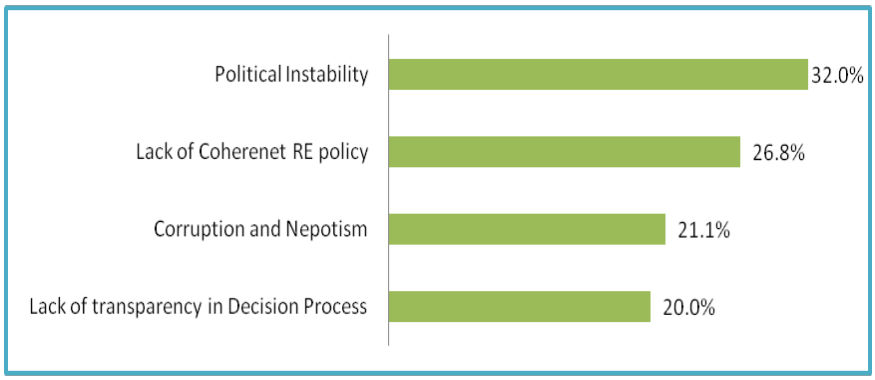

Figure 11: Synthesize of "Dimension 2- Policy and Political barriers"

As can be seen in Table 14 and in the synthesis of the study results in Figure 12, "lack of R&D facilities" (30.1%) was found to be the biggest barrier to renewable energy development within the technical barriers dimension, followed by "absence of a grid connection mechanism" (29.50%), "risk and uncertainty" (21.7%), and "unreliable supply" (18.7%).

Table 14: Ranking of barriers in "Dimension 3- Technical barriers" for the development of renewable energy

Barriers	Priority Weight	Priority Weight (%)	Rank
Lack of R & D facility	0.301	30.10	**1**
Unreliable Supply	0.187	18.70	**4**
Risk and Uncertainty	0.217	21.67	**3**
Lack of Grid Connection Mechanism	0.295	29.50	**2**

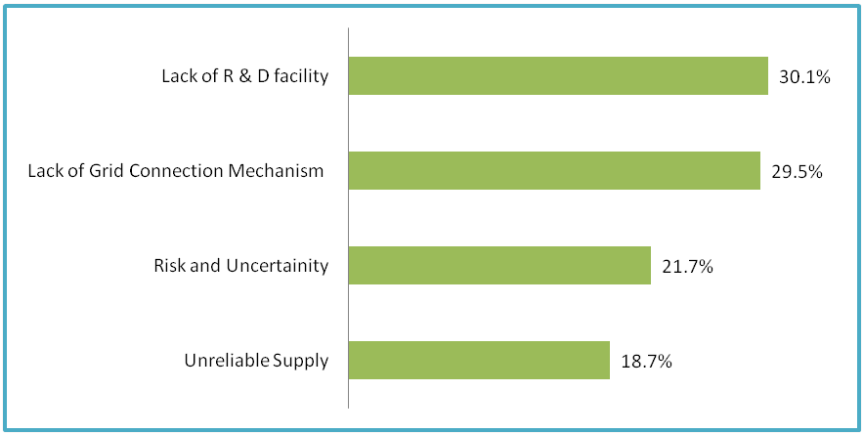

Figure 12: Synthesize of "Dimension 3- Technical barriers"

Within the economic barriers dimension, "lack of end use (insufficient daytime demand) (23.1%) was found to be the biggest barrier to renewable energy development, followed by "lack of funds" (22.5%), "absence of a credit mechanism" (21.39%), "high capital cost" (20%), and "small market size" (13.1%).

Table 15: Ranking of barriers in "Dimension 4- Economical barriers" for the development of renewable energy

Barriers	Priority Weight	Priority Weight (%)	Rank
High capital cost	0.200	19.96	**4**
Lack of access of Credit mechanism	0.214	21.39	**3**
Lack of sufficient size of market	0.131	13.06	**5**
Lack of End-use (day time demand)	0.231	23.15	**1**
Lack of funds	0.226	22.56	**2**

As can be seen in Table 16 and in the synthesis of the study results in Figure 14, "delivery mechanism complexity" (31.8%) was found to be the most influential barrier to renewable energy development within the administrative barriers dimension, followed by "lack of coordination among institutions" (26.9%), "lack of institutional capacity" (24.1%), and "lack of skilled manpower" (17.1%).

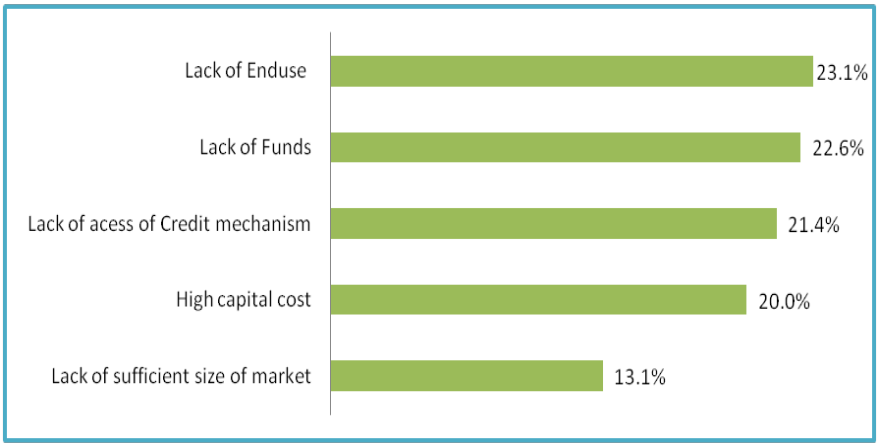

Figure 13: Synthesize of "Dimension 4- Economical barriers"

Table 16: Ranking of barriers in "Dimension 5– Administrative barriers" for the development of renewable energy

Barriers	Priority Weight	Priority Weight (%)	Rank
Lack of Skilled Man power	0.171	17.09	**4**
Lack of Coordination between Institutions	0.269	26.92	**2**
Lack of Institutional Capacity	0.242	24.19	**3**
Delivery Mechanism Complexity	0.318	31.78	**1**

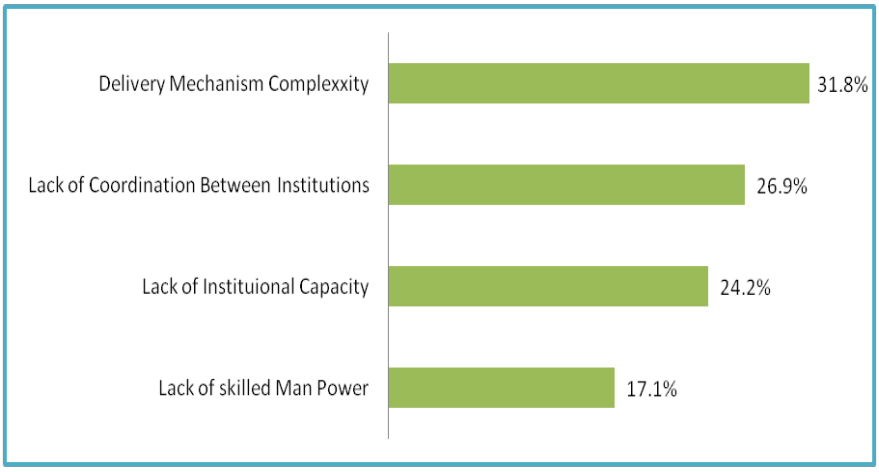

Figure 14: Synthesize of "Dimension 5– Administrative barriers"

Table 17 and Figure 15 show that "transport problem" (56.5%) was found to be the biggest barrier to renewable energy development in Nepal within the geographic barriers dimension, followed by "scattered households" (43.5%).

Table 17: Ranking of barriers in "Dimension 6– Geographic barriers" for the development of renewable energy

Barriers	Priority Weight	Priority Weight (%)	Rank
Transportation Problem	0.565	56.48	**1**
Scattered households	0.435	43.52	**2**

Figure 15: Synthesize of "Dimension 6– Geographic barriers"

5.1.4 Results of Overall Ranking of Barriers

The overall weights of the barriers in terms of the degree to which they hinder renewable energy development were calculated by multiplying the weight of each dimension by the priority weight of the barriers. The overall weights of the barriers and the ranks of all the barriers are summarized in Table 18, and the overall results of the barriers are synthesized in Figure 16.

In the overall results, "political instability" (8.9%) was estimated to be the biggest barrier to renewable energy development and was thus ranked first in the overall ranking of barriers, followed by "transport problem" (8.6%), "absence of a coherent RE policy" (7.4%), "scattered households" (6.6%), and "corruption and nepotism" (5.87). In the overall ranking, "lack of end use (insufficient daytime demand), "lack of funds," "lack of transparency in the decision-making process," "absence of a credit mechanism," and "high capital cost" were ranked

sixth, seventh, eighth, ninth, and tenth in terms of the degree to which they hinder renewable energy development. All those barriers had a more than 5% weight in the estimation herein. The results were checked in each group of respondents, but the resulting ranks of the barriers were not significantly different. Hence, in this paper, the overall results are presented. The weights and ranks of all the barriers are shown in Figure 16.

Table 18: The priority weighting and ranking of barriers to develop the renewable energy technologies

Dimension of Barriers	Weight of Dimension	Rank of Dimensions	Barriers for Development of Renewable Energy	Priority Weight	Overall Weight	Overall Weight (%)	Overall Rank
Social Barriers	0.099	5	Lack of Public Awareness	0.337	O.0334	3.34	**14**
			Lack of Consumer Paying Capacity	0.482	0.0478	4.78	**11**
			Lack of Social Acceptance	0.180	0.0179	1.79	**21**
Policy and Political Barriers	0.278	1	Lack of Transparency in Decision Process	0.200	0.0556	5.56	**8**
			Political Instability	0.320	0.0890	8.90	**1**
			Lack of Coherent RE policy	0.268	0.0745	7.45	**3**
			Corruption and Nepotism	0.211	0.0587	5.87	**5**
Technical Barriers	0.089	6	Lack of R & D Facility	0.301	0.0267	2.67	**17**
			Unreliable Supply	0.187	0.0166	1.66	**22**
			Risk and Uncertainty	0.217	0.0192	1.92	**20**
			Lack of Grid Connection Mechanism	0.295	0.0262	2.62	**18**

Economical Barriers	0.247	2	High Capital Cost	0.200	0.0493	4.93	**10**
			Lack of Access of Credit Mechanism	0.214	0.0528	5.28	**9**
			Lack of sufficient Size of Market	0.131	0.0322	3.22	**16**
			Lack of End-Use (day time demand)	0.231	0.0571	5.71	**6**
			Lack of Funds	0.226	0.0557	5.57	**7**
Administrative Barriers	0.135	4	Lack of skilled Man power	0.171	0.0230	2.30	**19**
			Lack of Coordination between Institutions	0.269	0.0363	3.63	**13**
			Lack of Institutional capacity	0.242	0.0326	3.26	**15**
			Delivery mechanism Complexity	0.318	0.0428	4.28	**12**
Geographic Barriers	0.153	3	Transportation Problem	0.565	0.0863	8.63	**2**
			Scattered households	0.435	0.0665	6.65	**4**

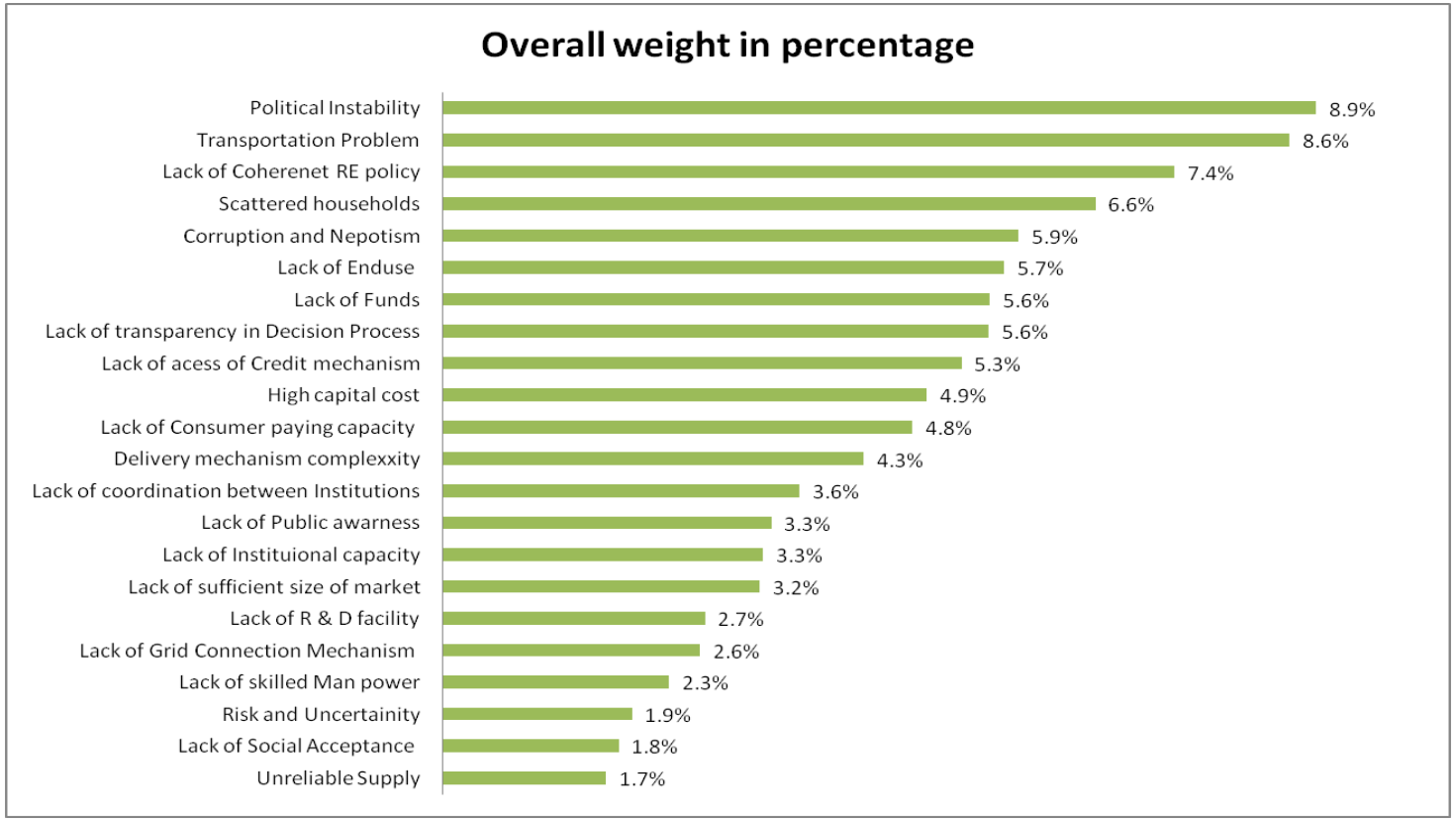

Figure 16: Synthesize of all barriers –Overall Relative Importance.

5.2 Discussion of Results

This section presents the results of the analysis and discussion of the barriers to renewable energy development in the context of Nepal. The barriers were listed and summarized from extensive literature review. According to the experts' views, the most important dimension of barriers is the policy and political barriers dimension, followed by the economic barriers dimension. Nepal is still a politically unstable country that has long suffered from internal political conflicts, which is affecting effective policy formulation for renewable energy development in the country. The policy and political barriers may be major obstacles to renewable energy development, according to the experts' views. The country's relevant policy is not favorable to the poor people living in the rural areas (Nepal, 2012). The policy impediment issue was also raised by the previous researchers, who also mentioned that implementing a subsidy policy is not effective due to the cumbersome delivery procedures involved. The users of the isolated renewable energy system are in very poor conditions; thus, the energy subsidy policy does not sufficiently address the economic-pyramid areas. The limitation of the country's economic resources is another major barrier because the rural electrification through the renewable energy project is expensive, with a high upfront cost. The high capital cost and the low load factors make it difficult to carry out renewable energy development projects (Gurung et al., 2011).

In the AHP model, the geographic barriers dimension is reported as the third most important dimension of barriers. The government of Nepal is focusing on off-grid renewable energy development projects for the electrification of remote rural areas that have yet to be reached by the national electricity grid. The development of renewable energy is costly due to the lack of transport road access as well as the high

transmission cost owing to the scattered households in the rugged mountains and the scattered settlements in Nepal (Surendra et al., 2011). This geographic nature of Nepal is making it more difficult to develop renewable energy in Nepal. The administrative and social barriers were found to be moderately important dimensions of barriers to the development of renewable energy in the country. The technical barriers dimension was reported as the least important barrier dimension.

A further ranking of the barriers within each dimension was obtained, as follows:

- "Lack of consumer paying capacity" was the highest-ranked barrier, and "lack of social acceptance" the lowest-ranked barrier, within the social barriers dimension. "Awareness of renewable energy" was ranked the second biggest barrier within this dimension. In the context of Nepal, renewable energy development is targeted at the remote and rural areas, where the people have limited opportunities for income generation; thus, the communities are not able to finance renewable energy projects.
- "Political instability" and "absence of a coherent RE policy" were ranked the first and second biggest barriers, and "lack of transparency" the smallest barrier, within the policy and political barriers dimension. At the very least, a common consensus between the political parties and the government policymakers is needed to accelerate the renewable energy development. Considering that it is an indisputable fact that energy is the primary requirement for economic development, the energy policy issues have not been given much attention in the policy debates in Nepal. The Nepalese government is providing a subsidy for fossil fuel use. Various discussions are required among all the stakeholders for the formulation of a coherent energy policy.

- In the technical barriers dimension, “lack of research and development” and “absence of a grid connection mechanism were the highest-ranked barriers to renewable energy development, and “unreliable supply” was the lowest-ranked. Technical expertise may be obtained from research and development endeavors, but a developing country like Nepal has limited resources, which in turn will result in insufficient resources allocation for research and development. Another major barrier is “absence of a grid connection mechanism.” Without this mechanism, the energy that will be obtained from renewable energy development projects may not be able to supply the national grid, which will make such projects unsustainable.
- In the in economic barriers dimension, “lack of end use (insufficient daytime demand)” and “lack of funds” are the biggest barriers to renewable energy development. “Absence of a credit mechanism” was also cited as a moderately big barrier while “small market size” was the lowest-ranked barrier. With the remote rural areas as the targets of renewable energy development, the available energy could not be fully utilized but only consumed for electrification purposes in most cases. Hence, although there is access to energy in the daytime, renewable energy development projects would not be able to generate sufficient financial returns to become an economically feasible project.
- “Delivery mechanism complexity” was the highest-ranked barrier to renewable energy development in the administrative barriers dimension, followed by “lack of coordination among institutions,” “lack of institutional capacity,” and “lack of skilled manpower,” which was reported as the smallest barrier. The delivery process is very crucial in this dimension. The process-related work is delaying the development of renewable energy. At the same time, different

institutions are involving themselves in the development of renewable energy, and there may be a lack of coordination among such institutions. There may also be work duplication. Also, the roles of the institutions in the various stages of renewable energy development may not be clear.

- "Transport problem" and "scattered households" were ranked as the first and second biggest barriers to renewable energy development within the geographic barriers dimension. The development of renewable energy is targeted at the rural and remote areas of Nepal, where the transport facilities are limited, which may delay the completion of the development project.

Those barriers whose overall weight has more than 5% weight are considered into most important barriers to renewable energy development in the context of Nepal. Based on this assumption nine barriers are listed in important barriers.

Table 19: High important barriers

Name of Barriers	Overall Weight	Rank
Political Instability	8.9%	1
Transportation Problem	8.6%	2
Lack of Coherent RE policy	7.4%	3
Scattered Households	6.6%	4
Corruption and Nepotism	5.9%	5
Lack of End-Use	5.7%	6
Lack of Funds	5.6%	7
Lack of Transparency in Decision Process	5.6%	8
Lack of Access of Credit Mechanism	5.3%	9

Table 20: Medium important barriers

Name of Barriers	Overall Weight	Rank
High Capital Cost	4.9%	10
Lack of Consumer Paying Capacity	4.8%	11
Delivery Mechanism Complexity	4.3%	12
Lack of Coordination Between Institutions	3.6%	13
Lack of Public Awareness	3.3%	14
Lack of Institutional Capacity	3.3%	15
Lack of Sufficient Size of Market	3.2%	16

Similarly, those barriers whose overall weight have less than 5%, and greater than 2 % are listed medium important barriers, and remaining barriers are listed in least important barriers. Classification of barriers is shown in tables 19, 20 and 21.

Table 21: Least important barriers

Name of Barriers	Overall Weight	Rank
Lack of R & D facility	2.7%	17
Lack of Grid Connection Mechanism	2.6%	18
Lack of skilled Man Power	2.3%	19
Risk and Uncertainty	1.9%	20
Lack of Social Acceptance	1.8%	21
Unreliable Supply	1.7%	22

6 Conclusions

6.1 Overall Conclusions

In the first chapter, the different issues regarding renewable energy development were explained. Based on such, the issues that motivated this research were presented. The purpose of the study, the research objectives, the research questions, and the expected contributions of the study were also presented in the first chapter. In the second chapter, the energy potential, current status of renewable energy development, and overall energy scenario in Nepal were reviewed. The second chapter also explained the problems and opportunities of renewable energy development in the context of Nepal. It was suggested that the participation in this study of different experts in the renewable energy development field would be key to capturing the different views on the barriers to renewable energy development in Nepal. Thereafter, a systematic review of the existing literature, policies, and documents on renewable energy development was performed.

In the case of developing countries, especially Nepal, the promotion of the development and use of renewable energy is one of the high priorities of the government. As such, in this study, the various kinds of barriers to renewable energy development were identified based on extensive literature review. Based on the nature of the identified barriers to renewable energy development, the barriers were classified into six dimensions, namely the social, policy and political, technical, economic, administrative, and geographic dimensions. Within these six dimensions, 22 barriers were listed, and each of these was explained thoroughly. Many researchers have identified the different barriers to renewable energy development in the context of Nepal, but they did not rank these in terms of the degree to which they hinder renewable

energy development in the said country. Thus, this study focused on ranking such barriers.

To achieve the aim of this research, the AHP methodology was applied based on the experts' views. As per the requirement of the AHP methodology, a hierarchical structure was formed and a survey questionnaire was prepared. Chapter 4 discusses the AHP methodology in detail. The estimation of the results obtained is presented in Chapter 5, along with a discussion of the said results.

Today, renewable energy plays an important role in both the developed and developing countries of the world. Many developed countries are developing renewable energy technologies to address the climate change issue, by reducing their fossil fuel use. In the case of developing countries like Nepal, however, renewable energy technologies are being considered as basic energy access solutions to the communities situated in rural and remote areas. There is no doubt that renewable energy development is a key issue both in the developed and developing countries. These days, renewable energy development is noticeably being focused on worldwide. It is believed that renewable energy could provide contenders for improving the lives of the people in rural and remote areas, through an alternative way of providing modern energy surplus. Renewable energy development is favored in Nepal for providing basic electricity access to the communities situated in the rural and remote areas through the off-grid solutions. Thus, the results of this study specifically pertain to Nepal and could not be generalized and applied to other countries.

Nepal is rich in renewable energy resources such as hydropower, solar energy, biomass, and wind energy. These renewable energy resources can provide future opportunities for green employment as well as a market for the private sector. The electrification rate of Nepal is still only 67% to date, so these kinds of off-grid renewable energy

technologies could be better alternatives for providing electricity access to the rural and remote areas of Nepal. Nepal has opportunities to sell carbon credits through the clean development mechanism (CDM). Despite the fact that the country has various kinds of opportunities, it will have to overcome a number of barriers to the development of renewable energy. Only after the removal of such barriers can Nepal achieve faster market penetration and a wider dissemination of renewable energy.

This research identified and ranked the barriers to renewable energy development in Nepal. A comprehensive literature review was performed for the identification of such barriers, and the AHP methodology was used for ranking the barriers. Pair-wise comparison data were collected from renewable energy sector experts. The AHP methodology was used to calculate the weights of the barriers in terms of the degree to which they hinder renewable energy development, and to rank such barriers. The ranks were obtained both at the dimension level and at the barrier level.

“Political instability,” “transportation problem,” “absence of a coherent RE policy,” “scattered households,” and “corruption and nepotism” were found to be the top five barriers to renewable energy development in the context of Nepal. “Political instability” was reported as the top-ranked barrier. The country-level political instability is affecting the renewable energy development in Nepal. From this study, it may be inferred that at the very least, a common consensus between the political parties and the government is needed both at the central and local levels for the country to be able to overcome the barriers to renewable energy development.

Nine barriers with more than 5% weights were cited as the biggest barriers to renewable energy development. Another seven barriers were classified as moderately large barriers, and the remaining six

barriers were listed as the smallest barriers as per the results that were obtained. “Unreliable supply” was reported as the least-ranked barrier. It may be inferred that the unreliable supply of energy from renewable energy resources is not a major barrier to the development of renewable energy in Nepal.

The ranked results were checked with a different group of respondents, but the ranked results were found to be not significantly different from the ones presented in this paper. Hence, the overall results are reported herein.

The estimation results were consistent, with their inconsistency found to be within an acceptable range. The results of this research are also consistent with those of the previous researches, and may be suitable considering the circumstances in the renewable energy sector of Nepal. Therefore, it can be inferred that the results that were obtained using the AHP model, which was constructed to rank the barriers to renewable energy development in terms of the degree to which they hinder such development, are consistent with the experts’ views.

This research may help in the understanding of the different kinds of barriers to renewable energy development. Ranking the barriers may help address the biggest barriers to renewable energy development in Nepal. This research presented a basic framework for ranking the barriers to renewable energy development in Nepal, which may help decision-makers arrive at good decisions effectively and efficiently. Understating the barriers to renewable energy development provides important lessons in policy formulation in developing countries like Nepal. This study provides decision makers with a baseline for making decisions while developing renewable energy development projects. The study is thus expected to provide an analytical and theoretical

background to the different stakeholders in renewable energy development.

Nepal may achieve significant progress in rural electrification with the development of renewable energy technologies, and can play a noticeable role in addressing the climate change issue. Moreover, renewable energy technologies will have an important role in providing energy access to and in the socioeconomic development of the rural communities in the country (Gurung et al., 2012). It is necessary to formulate a policy that will benefit the rural communities by considering the socioeconomic and geographic conditions of such communities.

The pertinent government agencies may take the lead in strengthening the relevant policies to overcome the country's energy potential weakness, by involving all the stakeholders in a transparent way. Frequent discussion among the political leaders both at the central and local levels seems a prerequisite to accelerating the development of renewable energy technologies. Striving to overcome the barriers from the supply and demand perspective in an effective way is necessary for the wider development of renewable energy resources in countries like Nepal (Nepal, 2012). It is also important for the private sector to understand the barriers to renewable energy development so that they could noticeably participate in overcoming the said barriers. For the sustainability of renewable energy development projects, the use of energy in the daytime is crucial. Together with renewable energy development, medium- and small-scale energy-based enterprise development may help increase the returns of the projects. The formation of a transparent decision-making process and credit provision may also accelerate renewable energy development.

This study can help the managers, policymakers, the private sector, and implementers involved in renewable energy development solve the energy supply and accessibility problems in Nepal. The framework that was employed in this study may be useful for the future researchers, who may use benchmarking to make a further contribution to the renewable energy sector.

6.2 Study Limitations and Future Research

This study was conducted using the AHP methodology for ranking the barriers to renewable energy development in the context of Nepal. All the comparative data that were used were collected from experts selected from the government, private sector, and academe. Naturally, the views of the respondents in this research may have been biased.

Based on literature review, all the barriers were identified and listed, after which they were ranked in terms of importance based on the opinions of the experts. Different multi-criteria decision-making methods were applied to solve this problem, and the results were compared.

In addition, the survey respondents were limited to the supply side. Thus, in the future research, demand-side experts may be included, which may provide a different scenario.

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Appendices

Appendix A-Survey Questionnaire

Survey on Barriers of Renewable Energy Development –Context of Nepal

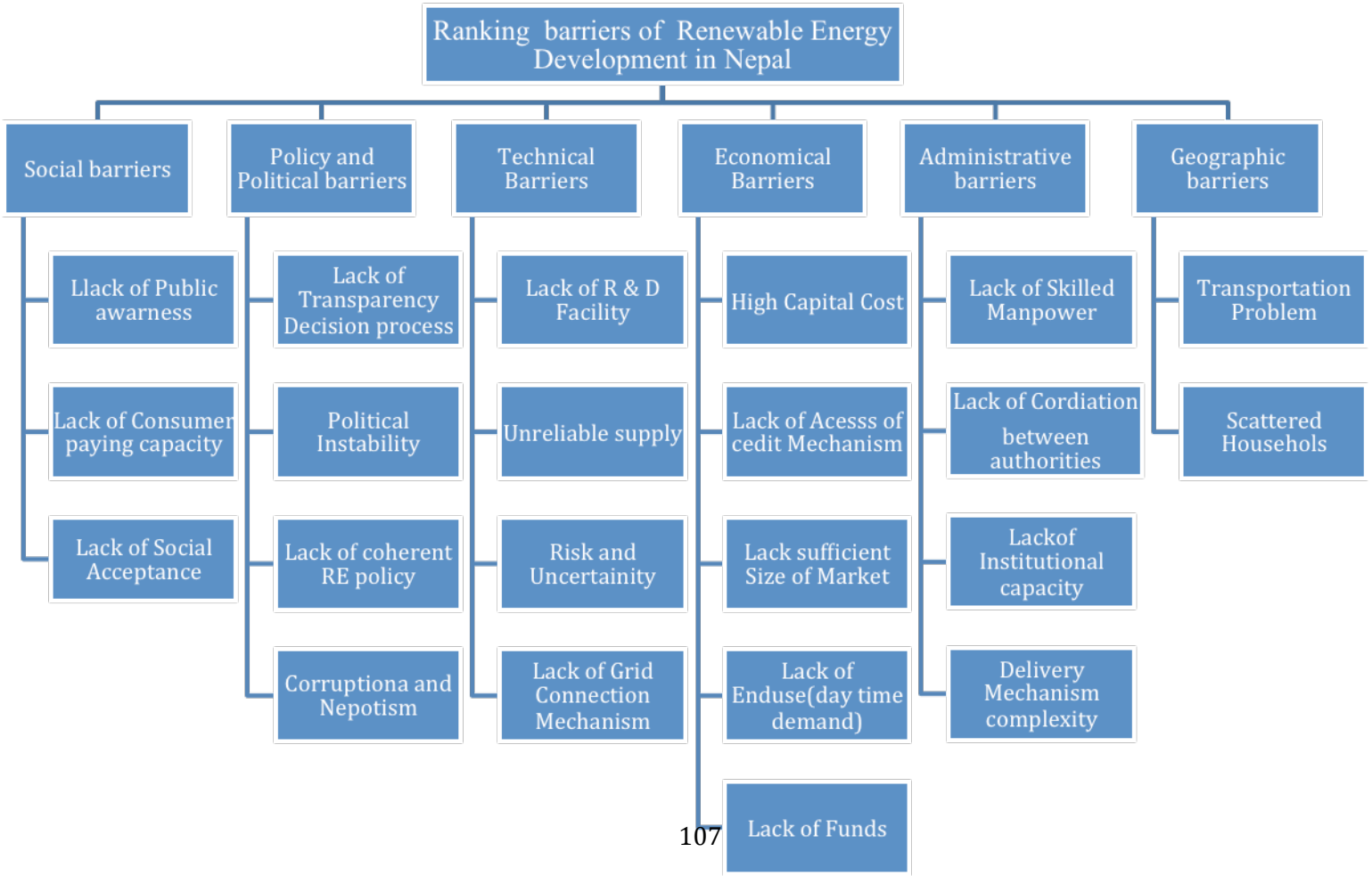
Researcher Mr. Laxman Prasad Ghimire is performing this research under the supervision of Professor **Yeonbae Kim.** This survey is carrying out with the cooperation of International Energy Policy Program (IEPP) of Seoul National University, South Korea, in order to study barriers of Renewable energy Development and for the purpose of the ranking barriers in the context of Nepal. This questionnaire attempts to raise the question of "What are major barriers of renewable energy development and their rank in the context of Nepal.

This questionnaire includes pair-wise comparison questions addressed to Renewable Experts, to seek their judgments representing the relative influence of pre-identified barrier dimensions and sub dimensions. Experts are expected to include university academics, professional engineers, planners, Private sectors etc. All your response to this survey will be confidential and used only for academic research purpose. The

information provided by participants will not be disclosed. The answers s/he gives will be only used for research purposes and for writing a master research.

If you have any comments, suggestions or questions about this survey, kindly contact us via e-mail at laxman@snu.ac.kr or lax059@gmail.com

Through a survey questionnaire, we intend to evaluate six dimensions by obtaining the views and opinions of experts. For a multi-criteria analysis, Analytic Hierarchy Process (AHP) is employed. The AHP is method designed to help in prioritizing very complex decision alternatives involving multiple stakeholders and multiple goals. Pair-wise comparisons are the fundamental buildings blocks of AHP. By using the questionnaire, the participants compare the relative importance of the dimension and sub dimension pair-wise with respect to the goal .As shown in Figure, the first level of hierarchy is the ultimate goal of the project; the second level represents the dimension barriers of which the projects are to be evaluated and, finally, the third level presents the sub-dimensions of barriers.


Ranking barriers of Renewable Energy Development in Nepal
Social barriers
Llack of Public awarness
Lack of Consumer paying capacity
Lack of Social Acceptance
Policy and Political barriers
Lack of Transparency Decision process
Political Instability
Lack of coherent RE policy
Corruptiona and Nepotism
Technical Barriers
Lack of R & D Facility
Unreliable supply
Risk and Uncertainity
Lack of Grid Connection Mechanism
Economical Barriers
High Capital Cost
Lack of Acesss of cedit Mechanism
Lack sufficient Size of Market
Lack of Enduse(day time demand)
Lack of Funds
Administrative barriers
Lack of Skilled Manpower
Lack of Cordiation between authorities
Lackof Institutional capacity
Delivery Mechanism complexity
Geographic barriers
Transportation Problem
Scattered Househols

Description of Barriers

Dimensions Barriers	**Sub-Dimensions of Barriers**	**Description**
Social Barriers	Lack of Public Awareness	Lack of information and awareness about renewable energy technologies, indicating relatively poor access to information to community compared to the conventional energy technologies.
	lack of Consumer paying capacity	Off grid Renewable technologies are primarily targeted at rural areas or poor customers, those have limited financial capacity.
	Lack of Social acceptance	Public opinion toward a type of power plant, lack of consumer acceptance of technologies
Political and Policy Barriers	Lack of Transparency in Decision Process	Lack of transparent decision process among stakeholders
	Political Instability and lack of commitment	Divergent political mindset of the governments, lack of stable government and political leader's commitment
	Lack of coherent renewable energy policy (RE Policy ,Subsidy policy)	Lack of coherent subsidy policy, Despite the government subsidy, projects is still unaffordable for rural communities since the initial costs is high

	Corruption and Nepotism	Corruption is may delay the process and misuse of funds
Technical Barriers	Lack of R & D facility	Lack of R&D programmes and mechanism. Long-term RET technology costs can be reduced through research.
	Unreliable Supply	Unreliable supply of electricity, like solar PV can produce electricity during day time only, in micro hydro, there is sufficient water in rainy season only, varying wind speed etc
	Risk and Uncertainty	Renewable energy by measuring the number of problems for failure(natural disasters, technical failure etc)
	Lack of Grid Connection Mechanism	When the national grid reaches to the off grid project, due to lack of mechanism for the connection to national grid line, electricity may not supply to national grid.
Economic Barriers	High Capital cost	High initial capital cost
	Lack of access of Credit/Mechanism	Lack of access of credit mechanism to producers or community
	Lack sufficient Size of Market	Due to less demand of renewable energy, market size would be smaller so becomes lack of Competition in Sufficient market base
	Lack of Energy use	In off grid renewable energy projects, there is lack of electricity demand

	Enterprises (day time sufficient Demand)	during day time because of the absence of energy use enterprises.
	Lack of Subsidies / funds	Renewable Energy heavily dependent on donor driven program, lack of sufficient fund
Administrative Barriers	Lack of Skilled Man Power	Lack of sufficient skilled human resources
	Lack of Coordination between authorities	Duplication work through out the government authorities, lack of coordination between authorities
	Lack of Institutional Capacity	Lack of capacity of institutional and their arrangements
	Delivery Mechanism and Procurement complicated process	Lengthy and time consuming process of the project approval and subsidy disbursement
Geographical Barriers	Scattered households	Due to geographical structural, households are scattered and transmission and distribution becomes costly and difficult
	Transportation Problem	For the installment , delivery of equipments is difficult due to limited road access

Explanation	Numeric Values
If Option A and Option B are equally important	1
Option A is moderately more important than Option B	3
If Option A is strongly more important than Option B	5
If Option A is very strongly more important than Option B	7
If Option A is extremely more important than Option B : Mark/Insert	9
Use even numbers for intermediate judgments	2,4,6,8

Example

Underline or color the relative weighting of your chosen factor according to the scale shown in the above table

Options A	**Extremely**		**Very Strongly**		**Strongly**		**Moderately**		**Equally**		**Moderately**		**Strongly**		**Very Strongly**		**Extremely**	**Options B**
Social Barrier	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Policy and Political Barrier

Social Barrier	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Technical Barrier

1. It shows **option A (Social)** and Option **B (Policy and Political**) **is equally important barriers** of renewable energy development.
2. It shows **Option A (Social) Very strong barrier in comparison with Option B (technical)**

With respect to Dimension of Barriers, Using The scale from 1 to 9 (Where 9 is extremely and 1 is equally important, please chose relative importance of options A (left column to options B(right Column)																		
Options A	**Extremely**		**Very Strongly**		**Strongly**		**Moderately**		**Equally**		**Moderately**		**Strongly**		**Very Strongly**		**Extremely**	**Options B**
Social Barrier	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Policy and Political Barrier
Social Barrier	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Technical Barrier
Social Barrier	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Economical Barrier
Social Barrier	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Administrative Barrier
Social Barrier	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Geographic Barrier
Policy and Political Barrier	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Technical Barrier
Policy and Political Barrier	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Economical Barrier
Policy and	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Administrative

Political Barrier																		Barrier
Policy and Political Barrier	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Geographic Barrier
Technical Barrier	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Economical Barrier
Technical Barrier	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Administrative Barrier
Technical Barrier	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Geographic Barrier
Economical Barrier	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Administrative Barrier
Economical Barrier	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Geographic Barrier
Administrative Barrier	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Geographic Barrier

Withrespect to social dimension																		
Options A	**Extremely**		**Very Strongly**		**Strongly**		**Moderately**		**Equally**		**Moderately**		**Strongly**		**Very Strongly**		**Extremely**	**Options B**
Lack of Public Awareness	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Lack of Consumer Paying Capacity
Lack of Public Awareness	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Lack of Social Acceptance
Lack of Consumer Paying Capacity	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Lack of Social Acceptance

Withrespect to Policy and Political Dimension, Using The scạle from 1 to 9 (Where 9 is extremely and 1 is equally important, please chose relative importance of options A (left column to options B(right Column)																		
Options **A**	**Extremely**		**Very Strongly**		**Strongly**		**Moderately**		**Equally**		**Moderately**		**Strongly**		**Very Strongly**		**Extremely**	**Options** **B**
Lack of Transparency in Decision Process	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Political Instability and commitment
Lack of Transparency in Decision Process	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Lack of Coherent Renewable Energy Policy(subsidy)
Lack of Transparency in Decision Process	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Corruption and Nepotism
Political Instability and commitment	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Lack of Coherent Renewable Energy Policy
Political Instability and commitment	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Corruption and Nepotism
Lack of Coherent Renewable Energy Policy(subsidy	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Corruption and Nepotism

Withrespect to Technical dimension, Using The scale from 1 to 9 (Where 9 is extremely and 1 is equally important, please chose relative importance of options A (left column to options B(right Column)																		
Options A	**Extremely**		**Very Strongly**		**Strongly**		**Moderately**		**Equally**		**Moderately**		**Strongly**		**Very Strongly**		**Extremely**	**Options B**
Lack of R & D facility	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Unreliability
Lack of R & D facility	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Risk and Uncertainty
Lack of R & D facility	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Lack of Grid Connection Mechanism
Unreliability	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Risk and Uncertainty
Unreliability	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Lack Grid Connection Mechanism
Risk and Uncertainty	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Lack of Grid Connection Mechanism

Withrespect to Economical Dimension,																		
Options A	**Extremely**	.	**Very Strongly**		**Strongly**		**Moderately**		**Equally**		**Moderately**		**Strongly**		**Very Strongly**		**Extremely**	**Options B**
High Capital Cost	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Lack of access of Credit Mechanism
High Capital Cost	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Lack of Sufficient Size of Market
High Capital Cost	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Lack of End-use (day time Demand)
High Capital Cost	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Lack of Funds
Lack of access of Credit Mechanism	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Lack of Sufficient Size of Market
Lack of access of Credit Mechanism	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Lack of End-use (day time Demand)
Lack of access of Credit Mechanism	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Lack of Funds
Lack of Sufficient Size of Market	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Lack of End-use

Lack of Sufficient Size of Market	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Lack of Funds
Lack of End-use (day time Demand)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Lack of Funds

Withrespect to Administrative Dimension,

Using The scale from 1 to 9 (Where 9 is extremely and 1 is equally important, please chose relative importance of options A (left column to options B(right Column)

Options A	**Extremely**		**Very Strongly**		**Strongly**		**Moderately**		**Equally**		**Moderately**		**Strongly**		**Very Strongly**		**Extremely**	**Options B**
Lack of Skilled Manpower	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Lack Coordination of Institutions
Lack of Skilled Manpower	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Lack Institutional Capacity(AEPC, RSC)
Lack of Skilled Manpower	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Subsidy Delivery Mechanism(complicated)
Lack Coordination of Institutions	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Institutional Capacity (AEPC, RSC)

Lack Coordination of Institutions	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Subsidy Delivery Mechanism(complicated)
Lack of Institutional Capacity (AEPC, RSC)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Delivery Mechanism Complexity

Withrespect to Geographic Dimension,																		
Options A	**Extremely**		**Very Strongly**		**Strongly**		**Moderately**		**Equally**		**Moderately**		**Strongly**		**Very Strongly**		**Extremely**	**Options B**
Transportation Problem	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Scattered Households

(Respondent Demographic and general Information)

Name

Gender ● Male ● Female

Organization ● Goverment ● NGO/INGO ● Private

Type	● Development Partner ● Other
Position	
Working Experience (Years)	Choose an item.
Email ID and Contact No	

Thank you very much for your time and cooperation!