Sustainable Management of Renewable Energy Systems in Bhutan

A dissertation submitted in partial fulfilment of the requirements for the degree of

‘Master of Science (M.Sc.) in Renewable Energy’

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November, 2012
Abstract

The Kingdom of Bhutan is a small country sandwiched between the two large countries in Asia, in terms of size and population. To the north lies China and India to the south, east and west. This is a country which follows the development philosophy of ‘Gross National Happiness’ in contrast to the conventional economic parlance called ‘Gross Domestic Product’. A reliable, affordable and sustainable supply of energy to its citizens is seen as one of the main inputs to a nation’s well being and growth. To this end, Bhutan strives to achieve 100% rural electrification by 2013.

To meet the above target in time, Bhutan faces a unique challenge. To extend the grid to every nook and corner of the country is technically infeasible and economically prohibitive. Other options, like small and micro hydropower systems and solar home lighting systems, are widely used to accelerate rural electrification programmes. Through provision of such modern forms of energy services, the lives of rural people have generally improved. However, Bhutan faces a series of sustainability challenges to keep such systems operational in the long run. Many projects have failed over the years and, even today, such projects are difficult to sustain without the government’s subsidy.

The main objective of this research is to diagnose the critical sustainability issues in the context of renewable energy projects and to understand their long term prognosis through an integrated approach. In order to achieve the higher goals of sustainability, it is essential to address the root cause of the problems, rather than prescribing end of the pipe technical fixes.

In this study, four renewable energy projects are reviewed and evaluated using a lifecycle sustainability matrix framework. The following are some of the key findings revealed through this research:

1. In terms of overall sustainability, the scores of small/micro hydropower projects are better than the solar projects in Bhutan.
2. For all the four projects reviewed, the sustainability scores are high during the time of planning and design phase, but decrease as and when the projects progress into the implementation and Operation and Maintenance stages.
3. A very low tariff structure for grid connected households is seen to be the main dissuading factor for people to accept off-grid options.
4. The projects have failed to stimulate income generating activities.

The key recommendations include the need to have a holistic project development approach in Bhutan, where the sustainability factors are consistently addressed and monitored throughout the project lifecycle. There is also disparity in terms of subsidy from the Government between those households connected to the grid and off-grid options. The Government needs to review its energy policies to strike a better balance. Further, provision of energy services do not necessarily guarantee automatic uptake of economic activities in rural areas. The Government needs to explore avenues to provide easy access to finance and markets for the people.
Acknowledgement

Many individuals and institutions both near and far, have made paramount contributions, in moulding and shaping this report. My list of names to say ‘thank you’ is quite long. Without any particular order or importance, I would like to thank the following institutions and individuals for their generous and unconditional support:

Firstly, I would like to thank the Department of Renewable Energy (DRE) of the Royal Government of Bhutan for granting me this wonderful opportunity, to pursue the master’s programme at Murdoch University in Western Australia. It is not very common to see an individual, being granted 730 days of paid leave from the office, anywhere else around the world. I feel very fortunate and indebted to the Royal Government of Bhutan for bestowing such a generous opportunity upon me.

The Norwegian Assistance for Development (NORAD), the Government of Norway deserves a special place in this acknowledgement space. Without their funding, learning new knowledge and wisdoms from the southern hemisphere of the globe would have remained a mere dream.

I owe very special thanks to my dissertation guides, Dr. Samuel Gyamfi and Dr. Tania Urmee for their wholehearted support and unwavering guidance, throughout my research. I’m also grateful to Dr. Trevor Pryor (Academic Chair), who showed me the direction and light, whenever I got lost in the wilderness of problems, with his vast wisdom and experience. They are the ones, who showed me that, there is more than one way to skin a cat or go to Rome.

I would also like to extend my sincere gratitude to Mr. Mewang Gyeltshen, Mr. Chhimi Dorji, Mr. Sherab Jamtsho and Mr. Choten Duba of the DRE, Bhutan for providing information and data when I needed the most. I’m also thankful to Mr. Ngawang Choeda of the Department of Hydropower and Power Systems, and Mr. Sonam Phuntsho of the Bhutan Power Corporation.

Last, but not the least, I would like to thank my family for their unfathomable sacrifices shown in different ways, so that I can realise my dreams one fine day. My dear mom and sister from Bhutan and my wife have been a constant source of love and affection, which as a human being need the most. I’m deeply thankful to my wife, who took so much pain in ironing out the grammatical errors from this report. Before I conclude the list, it won’t be fair,
if I don’t mention the name of one special person – Lhacham Uden Threngwa, my dearest daughter; whom I had to depart from after six months of her arrival into this world. Humankind can never coin a word nor invent a machine which can weigh and scale such sacrifices. Only the ultimate almighty, with its pure soul and infinite power can know. They are my beacon of hope and sources of inspiration. If I have become a better human being, it is solely because of those names listed above. I’m grateful to all for showing me the light at the end of the tunnel.

Ugyen
Murdoch University,
Western Australia, 2012
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Acronyms and Abbreviations

ADB  Asian Development Bank
AUD  Australian Dollar
BC   Barefoot College
BEA  Bhutan Electricity Authority
BPC  Bhutan Power Corporation
BREP Bhutan Renewable Energy Policy
CDM  Clean Development Mechanism
DOE  Department of Energy
DPT  Druk Phunsum Tshogpa
DRE  Department of Renewable Energy
EA   Electricity Act
EDP  Economic Development Policy
FYP  Five Year Plan
GNH  Gross National Happiness
JICA Japan International Cooperation Agency
MDGs Millennium Development Goals
MHP  Micro Hydropower Project
MoEA Ministry of Economic Affairs
NEC  National Environment Commission
NREL National Renewable Energy Laboratory, USA
RGoB Royal Government of Bhutan
SHDP Sustainable Hydropower Development Policy
SHP  Small Hydropower Project
TERI The Energy Research Institute
UNO  United Nations Organisation
<table>
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<tr>
<th>Currency Unit</th>
<th>Ngultrum (Nu)</th>
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<tr>
<td>1 AUD</td>
<td>= Nu. 50 (Approximate)</td>
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- kW: kilowatt
- kg: kilogram
- kWh: kilowatt hour
- km: kilometre
- km²: square kilometre
- MW: megawatt
- MWh: megawatt hour
- m: metre
- m²: square metre
- GW: gigawatt
- M³: cubic metre
- W: watt
- Wh: watt hour
CHAPTER – I
Thesis Background

“Sustainability is a new idea to many people, and many find it hard to understand. But all over the world there are people who have entered into the exercise of imagining and bringing into being a sustainable world. They see it as a world to move toward not reluctantly, but joyfully, not with a sense of sacrifice, but a sense of adventure. A sustainable world could be very much better than the one we live in today.”

Donella H. Meadows, The Limits to Growth: The 30-Year Update

1.1 Introduction

This chapter highlights the background information on the motivation of the study, research and sub research questions, research framework and thesis outline. A brief explanation on the research framework is also provided in this section.

1.2 Motivation for the study

I have served as an Engineer for the last five years in the Department of Energy (DOE) in Bhutan and then as a Deputy Executive Engineer for a while before I took study leave to pursue the Masters Programme at Murdoch University in Western Australia. Within that time period in the civil service, I had a wonderful opportunity to work in off-grid electrification projects, particularly, solar and micro hydropower projects in Bhutan.

The Kingdom of Bhutan follows the development philosophy of ‘Gross National Happiness’ (GNH) where the happiness of people is considered more important than the economic growth. This sounds bizarre from the economic perspective, but it makes sense from the sustainable development point of view. The GNH has four pillars: 1. Sustainable and equitable economic development, 2. Conservation of the environment, 3. Preservation and promotion of culture, and 4. Good governance. The rural electrification is considered as one of the main avenues to bring sustainable and equitable economic development to Bhutan.
The Government of Bhutan aspires to achieve 100% electrification in the country by the year 2013. In an attempt to achieve the above electrification target on time, a huge amount of resources are deployed (for both grid and off-grid) by the government under the accelerated rural electrification programme. It is envisaged that 88% of the rural households will be connected to grid and the remaining 12% will be provided with off-grid electrification options like solar and micro hydropower. The sustainability of rural electrification projects, in particular, solar and micro hydropower projects is one of the most pressing issues in Bhutan. There are ample instances, where such projects have failed, causing frustrations and creating dissatisfaction amongst the general populace. On one hand, there is a strong political will to wrap up the electrification works as soon as possible, while on the other hand, there are deep rooted sustainability issues.

Different people have different theories on why projects fail and how they can be made successful. More often, people focus only on a single issue and fail to understand the complex interactions of widespread and deep rooted sustainability problems. Therefore, to bring various sustainability issues and solutions under one umbrella, there is a need for an integrated approach and a unifying framework.

### 1.3 Research Question

Considering the problems of sustainability of renewable energy projects in Bhutan, what is the best unifying framework that can be used to assess the deep rooted problems in various stages of the project life cycle so that an integrated approach can be used to tackle the problems?

### 1.3.1 Sub research questions

1. What are the policies, plans and programmes of the Royal Government of Bhutan to develop renewable energy systems?
2. What are the barriers and constraints to using renewable energy systems in Bhutan?
3. How can we apply the concept of project life cycle assessment framework to tackle the issues of sustainability through an integrated approach?
4. What are the different policy recommendations that can be made to the Department of Renewable Energy (DRE) so that the future renewable energy projects are implemented in a sustainable manner?

1.4 Research framework

The framework of the research is shown in the diagram below. It is essential to note that the sustainability assessment matrix is being developed and case studies of different renewable energy projects are tested against this matrix.

Figure 1: The research framework

1. Resource assessment:
   The Kingdom of Bhutan is endowed with plenty of renewable energy resources. The assessment of renewable energy resources like solar, hydropower and wind etc. are necessary as this will form a basis for any decision maker and system designer to make the right choice of the technology.

2. Review of policies:
   It is essential to understand the different energy policy instruments and their influences on renewable energy initiatives. It is a prerequisite to have supportive
energy policies to develop renewable energy technologies, so that they become competitive with incumbent technologies.

3. Review of energy institutions:
   It would be difficult to set up a sustainable energy service delivery mechanism without having strong underpinning institutional settings. The review of existing energy institutions, their roles and interactions with the other institutions is necessary.

4. Identification of sustainability issues:
   There is a wide range of sustainability problems including technological, institutional social and economic issues. The solutions to such problems can be found through a clear understanding of the true nature of the problems that are rooted deep inside the complex fabric of the society.

5. Sustainability assessment matrix:
   The sustainability assessment matrix is developed to assess the sustainability of renewable energy projects by considering the various stages of a project’s life cycle. Each stage of the project life cycle is weighed against three sustainability factors: 1. Social sustainability, 2. Economic sustainability and 3. Environmental sustainability.

1.5 Thesis Structure

The different chapters of the report are presented in following sequence:

The Motivation for study, the research question and the research framework are introduced in the chapter –I.

The Chapter – II presents general background on Bhutan including the development philosophy of the country, energy institutions and energy policies. The status and progress of rural electrification works, both on-grid and off-grid, are also presented.

In Chapter – III, a review on the assessment of renewable energy resources is presented. The endowment of solar, wind, micro hydropower, biomass and geothermal resources is assessed.
The assessment methodology for renewable energy projects, based on project life cycle versus sustainability factors, is introduced in Chapter – IV.

Chapter – V deals with four different renewable energy case studies. Evaluation results and comparisons of them are presented in this chapter.

The conclusions and recommendations, along with the recommendations for future work are presented in the last Chapter of this dissertation.
CHAPTER – II
The Energy situation in the Kingdom of Bhutan

2.1 Introduction

The general background of the Kingdom of Bhutan, including geography, climate, economy and its people are described in this section. The energy situation in the country, institutional mechanisms, energy policies and rural electrification projects in Bhutan are also elaborated in depth in this chapter. A brief note on the development philosophy of Bhutan – Gross National Happiness (GNH) is also highlighted.

2.2 Bhutan – Country profile

The Kingdom of Bhutan is a small country, with the population of 634,982 in Southeast Asia lying in between the People’s Republic of China to the north and the Republic of India to east, south and west. It is a mountainous country, nestled in the eastern ranges of the great Himalayas with the total area of 38,394 square kilometres (Population & Housing Census of Bhutan 2005). Though it is a small country, it experiences a wide range of climatic conditions, as the altitude varies from 100 metres above the sea level in the southern foothills to over 7,500 metres in the northern Himalayan ranges. More than 72% of its land is covered by forest, forming a natural habitat for many endangered flora and fauna in Asia. The country has one of the richest biodiversities in the world and has been declared as one of the top ten biodiversity ‘hotspots’ in the world (DOE 2010). Bhutan has also one of the lowest population densities in Asia at around 16 people per square kilometre. 70% of them live in the rural areas, practicing subsistence farming.

Figure 2: Location of Bhutan in Southeast Asia (Source: Terralaya Travels 2012)
Bhutan is known as the last Shangrila, whose development philosophy is guided by the Gross National Happiness (GNH) in contrast to the conventional economic concept of Gross Domestic Product (Gyeltshen 2006). The Royal Government of Bhutan earnestly believes that the ultimate aim of life is happiness and all the development policies are oriented towards enhancing the happiness of its subjects. It has been successful in persuading United Nations (UN) to adopt Happiness as the 9th Millennium Development Goal (MDG) very recently (GNHC 2012).

2.3 Overview of energy institutions

The Electricity Act for the Kingdom of Bhutan was passed in the year 2001, and was instrumental in bringing major reforms to the energy sector. The erstwhile Department of Power, which was established in 1965, was divided into three agencies namely, the Department of Energy, the Bhutan Electricity Authority and the Bhutan Power Corporation (Dorji 2007).

As per the Bhutan 2020: A vision for peace, prosperity and happiness document, the Royal Government of Bhutan envisages adding 2000MW of electricity generating capacity by 2012 and 3000MW by the year 2017. The policy document further states that, Bhutan shall achieve 100% electrification by the year 2020 (RGOB 1999). Keeping in mind that Bhutan is still a developing country, where most of the developmental activities are donor aided, such targets by any standard are ambitious.

In the year 2008, Bhutan became a constitutional democracy under the Druk Phunsum Tshogpa (DPT) government. Since then, there have been many changes in the long term plans and policies at the national level, particularly in the energy sector. The new government envisions achieving 100% electrification by 2013; seven years ahead of the initial plan and building generation capacity of 10,000MW by 2020 through mega hydropower projects. The Government, realizing the significance of added responsibilities of the Department of Energy and the monumental challenges lying ahead, further divided the department into three agencies in 2012: 1. The Department of Hydropower and Power Systems, 2. Department of Renewable Energy, 3. The Department of Hydro-meteorological
2.4 Energy Situation in Bhutan

The Power System Master Plan of Bhutan estimates that the total hydropower potential is 30,000 MW with the production capability of 120,000 GWh annually. The current generation capacity stands at 1488 MW after commissioning of the 1020 MW Tala Hydroelectric Project in 2006-2007, which is approximately 5% of the total hydropower resource (SHDP 2008).

Tshering and Tamang (2004) state that, Bhutan being a landlocked country coupled with rugged terrains does not provide economic advantage to the country. Instead, such a geographical landscape poses huge challenges for implementing any developmental activity. However, as every cloud has its silver lining, such mountainous terrain with the abundant river systems is found to be suitable to generate hydro electricity, which is matched by the
huge demand across the border in India, one of the world’s fastest growing economies in 21st century. The development of mega hydropower in Bhutan can mainly be attributed to ‘market-pull’ rather than ‘technology-push’. Ever since the commissioning of the 336 MW Chukha Hydroelectric Plant in 1986, Bhutan has never turned back and has pursued hydropower development as one of its main economic avenues. At present, 40% of the country’s revenue is generated through the sale of electricity to India, facilitated by an exemplary relationship between the two countries (Tshering and Tamang 2004).

Bhutan faces a unique challenge in terms of the overall energy trade balance with India. Bhutan has no known fossil fuel reserves and depends exclusively on India for the same. Over the last five years, the electricity generation from the hydropower plants remained nearly constant but the fossil fuel imports have been increasing at an alarming rate. Towards the end of the year 2011, Bhutan imported fossil fuel worth about Nu. 5.5 billion (AUD 110 million) against the electricity export of Nu.10 billion (AUD 200 million). Though the net trade balance in terms of energy export and import is positive, the gap is getting narrower every year (Kuensel 2012). The figure 4 shows the energy trade balance between India and Bhutan for the period 2008-2011.

![Energy trade balance for the year 2008-2011](Source: Kuensel 2012)

The Rural Electrification Master Plan (2005) for Bhutan was prepared with the technical assistance of the Japan International Cooperation Agency (JICA). As per the Master Plan, it recommends electrifying 88% of the total households through the grid and the remaining 12% through off-grid electrification. The target, as per the initial plan, was to achieve 100% electrification by the year 2020 (Dorji 2009).
The present government (DPT) has set ambitious targets for many economic activities, particularly in the energy sector. The new government envisions achieving 100% electrification by the year 2013 and to build electricity generation capacity of 10 GW through mega hydropower projects by the year 2020 (Gyeltshen n.d).

![Energy Demand of Bhutan in 2010](Source: DOE 2010)

To this effect, many plans and policies have been put in place with greater urgency such as the Sustainable Hydropower Development Policy 2008, the Accelerated Rural Electrification Plan and the Draft Renewable Energy Policy 2012. However, how Bhutan is going to sustain such leap frogging economic and social activities in the long run is yet to be seen.

### 2.5 Overview of Rural Electrification

During the 9th Five Year Plan (2002 – 2007), with the technical assistance from JICA an “Integrated Master Plan Study for District wise Rural Electrification in Bhutan” was prepared. Since then, there has been a clear road map for achieving 100% electrification in Bhutan.
2.5.1 Electrification through grid

The people prefer grid connection since the services delivered by the other options, especially the renewable energy technologies are limited and is compounded by high upfront costs. In the year 2005, the Japan International Cooperation Agency (JICA) conducted a study and found that the cost to electrify one household on average would be between USD 1800 and USD 2000 (JICA 2005). As this estimate was done in 2005, the average cost would have increased by now, given the fact that most of the households near to transmission and distribution lines are now electrified. To electrify the remaining houses, the infrastructures needs to penetrate further, thus incurring a higher cost. The number of households has also increased over the years due to population growth. The cost of the materials and the labour charges could also have increased by many fold as the inflation rate was recorded at a staggering 13.5% in the second quarter of the year 2012 (Kuenselonline 2012).

The Bhutan Power Corporation, which is a government owned utility company, is solely responsible for the distribution of electricity in the country. It also provides the transmission infrastructure for the electricity generating companies to export electricity to India (BPC 2011). Figure 6 shows the electrification of households in the different five year plans (FYP) and future projections.

![Electrification chart](image)

Figure 6: Rural electrification achievements and future projections (Source: JICA 2005)
2.5.2 Off-grid Options

The connection of the grid to every household in the country is financially prohibitive and technically not feasible. The only option left for the government is to deploy off-grid electrification options like solar, small hydro and wind energy technologies as the rural households in Bhutan are scattered and sparse in nature. The high cost of the rural electrification programmes put the Government under tremendous pressure to mobilise the resources. The situation becomes more difficult, if the grants from donor countries are not forthcoming.

The Government of Bhutan realized that, extending grid connection to the doorsteps of all households is not possible. Therefore, it has initiated a proactive off-grid electrification programme to electrify those households which are remote and isolated. Thousands of houses in the remote hamlets of the country are supplied with solar home lighting systems and small/micro hydropower plants. The solar electrification projects in Bhutan can be traced back to the early 1980’s, but the records are quite sketchy as there was no central coordinating agency and most of the projects were carried out by the different agencies on an ad-hoc basis, depending on the need and the availability of financial resources (UNDP 2002).

However, after the formation of the Department of Energy (DOE) in 2002, the Renewable Energy Division of the DOE was delegated the responsibility of coordinating off-grid electrification projects. The number of solar home lighting systems installed is estimated to be around 6000 in off-grid areas across the country. To accelerate the rural electrification programme, the National Solar Energy Programme was initiated. Road maps were also framed to complete the off-grid electrification before 2013 as per the vision of the new government (RED 2010).

As of now, there are 15 operational micro hydro plants with a total capacity of 1350 kW and nearly 1800 households are connected to these systems. Such small hydro plants are funded by the government of Bhutan, Government of Japan, the Government of India and the e7 nations (Dorji 2007). Many such plants are managed by the Bhutan Power Corporation, but there are a few micro hydropower plants which are managed exclusively by the community.
2.6 Energy policies and regulations review

2.6.1 Policy background

The policies, be they at the national level or at the local level, play a pivotal role in shaping the destiny of different projects. Some projects may not achieve their intended benefits, even if they are technically feasible as some policies may not favour such undertakings. Some may succeed, even though there are technical and financial challenges, provided there are supportive policy frameworks. However, it is important to note that the government is not a single policy space. There are multiple policy regimes to deal with different issues and each of them does not act in isolation. The policies interact with each other and the final outcome is determined by how they complement or contradict with each other, thus, moulding the ultimate national objectives.

In this section, there are several different policies, which pertain to the development of renewable energy resources in Bhutan. They are reviewed and their influences on each other is analysed.

2.6.2 Bhutan Electricity Act – 2001

The Electricity Act (EA) for the Kingdom of Bhutan was enacted by the National Assembly of Bhutan in the year 2001. One of the fundamental reasons behind the enactment of the Electricity Act 2001 was to restructure the power supply industry, and to establish the Bhutan Electricity Authority (BEA) in an attempt to bring efficiency and transparency to the system. The Act states that institutionalising the BEA as an autonomous body will ensure a transparent regulatory regime by defining roles and responsibilities of the electricity suppliers by laying down the standards, codes and specifications and protecting the interest of the general public at the same time. The Act also emphasises the creation of an enabling environment to encourage private participation to bring competition and enhance throughput, amongst others.

Clause 61.1 of the EA 2001 is particularly relevant for renewable energy development, where it states the need to develop renewable energy resources and to take environmental
considerations into account when developing the electricity supply industry (Electricity Act of Bhutan 2001).

2.6.3 Bhutan Renewable Energy Policy 2012 (Draft)

The Royal Government of Bhutan recognizes the need to enhance energy security and diversify the energy supply mix. Until today, energy generation was highly dominated by the hydropower systems (which are also renewable) and contributions from other sources are negligible. As detailed in the Integrated Energy Master Plan (2010) for Bhutan, such a situation might lead to a scenario called “Dutch Disease” in classic economic parlance. Concentrated investment in a single sector may create a distortion in the other viable economic options, which is reminiscent of Bhutan’s dependence on the hydropower resource (DOE 2010).

After realising the importance of having diverse supply options to ensure long term energy security for sustainable development, the Department of Renewable Energy (DRE) has drafted the Renewable Energy Policy 2012, which is due for enactment. Prior to this policy document, the erstwhile Department of Energy drafted a policy document titled ‘National Renewable Energy Policy and Programmes for Sustainable Development’ in 2008 but it never got materialised. The current draft policy document is a rejuvenation of the earlier efforts and it is seen as much more relevant, considering the regional as well as the global situation.

The draft policy document, holistically and comprehensively states both the long term as well as the short term objectives. The types of renewable energy technologies to be pursued, and the roles and responsibilities of different institutions and organisations are also specified in the document. The target for the generation capacity of electricity, through the mix of renewable energy resources is set at 20 MW excluding the power generation from the large hydropower sector (Draft Renewable Energy Policy 2012).
2.6.4 Economic Development Policy-2010

The Economic Development Policy (EDP) was framed by the Government of Bhutan to create an enabling environment to carry out coordinated economic activities in the country. The policy document was prepared through a wide range of consultations involving stakeholders from all the economic sectors. The policy document envisages taking advantage of the fast growing economies of India and China. To maintain an economic growth rate of 9% per annum, and to become a middle-income nation by the year 2020, are some of the highlights of the policy aspirations.

The Energy sector is considered by the government as one of the most important economic sectors, since hydropower is the mainstay of Bhutan’s economy. In order to accelerate economic growth and to ensure sustainable development, high priority is given to developing indigenous energy resources like hydro, solar, wind and biomass. The EDP 2010 specifically states the desire to have national renewable energy policy under clause 7.2.10.

“While hydropower development shall be one of the main thrust of government; an integrated approach shall be pursued to meet different energy needs in the most efficient manner. A National Renewable Energy Policy shall be adopted within the 10th Five Year Plan”.

Further, the policy also states the need to create budget mechanisms to fund renewable energy initiatives and to protect the catchment areas (EDP 2010).

2.6.5 Bhutan Sustainable Hydropower Development Policy 2008

The revenue generated through the sale of hydropower has been the mainstay of Bhutan’s economy. The hydropower plants contribute significantly to overall GDP growth of the country and might contribute more in the foreseeable future. Bhutan, being a developing country, has a domestic demand for energy that is growing very fast every year and the need to meet demand in a sustainable manner is a daunting challenge. At the same time, there is also growing pressure to enhance revenue generation through the sale of surplus energy generation in the region. Under the framework agreement signed between the Royal Government of Bhutan and the Government of India for cooperation in the field of
hydropower, the Indian Government has agreed to buy a minimum of 5000MW capacity of electricity from Bhutan by the year 2020. To meet the growing demand for energy, the policy document states, that the Government of Bhutan intends to develop at least 10,000 MW of electricity generation capacity by the year 2020 (Bhutan Sustainable Hydropower Policy 2008).

Apart from mega hydropower development, the policy also acknowledges the need for the development of clean and renewable energy resources. One of the objectives of the policy is to contribute towards the development of clean energy, to mitigate the problems related to global warming and climate change.

In order to boost the uptake of renewable energy resource development in Bhutan, the policy specifically states the need to have a ‘Renewable Energy Development Fund’. To quote clause 5.7.1 of the policy document –

“A part of the upfront premium received from the developers shall be allocated to a Renewable Energy Development Fund. The RGOB will use the fund for project development activities including project profiles and reports, site investigation and studies, processing of clearances, acquisition of land, promotion of projects, and facilitation for the accelerated development of hydropower resources”.

2.6.6 Conclusion

Majone (1989) mentions the problem of interaction of too many policies where: ‘solution begets new problems in the form of policy overlaps, jurisdictional conflicts and unanticipated consequences’. The multiple policies put in place to deal with one problem through different avenues may not necessarily solve the problem. The crowded policies can affect the overall national objectives positively or negatively as some policies can complement each other whereas some policies can counteract and contradict (Majone 1989).

Through this study, all four different policies reviewed are found to be complementing and reinforcing the renewable energy resources development in Bhutan. The Electricity Act 2001 states the need to develop renewable energy resources and to take environmental
considerations into account in the development of the energy supply infrastructure. The Act also affirms the significance of internalizing the externalities while developing any projects, especially the impacts of large hydropower projects on the environment. The Bhutan Sustainable Hydropower Policy states the need to create a renewable energy development fund, so that through this budget mechanism, the renewable energy projects can be implemented in a sustainable manner. The Economic Development Policy (2010) highlights the urgent need to pass the National Renewable Energy Policy within the 10th Five Year Plan (FYP). Figure 7 is the diagrammatic representation of how different policies are designed in favour of renewable energy promotion in the Kingdom of Bhutan.

Based on the forgoing review and findings, it is fair to conclude that at the policy level, the objectives to develop renewable energy in Bhutan are evident. All the policies are complementary and seen supportive of each other, which signifies Bhutan’s desire to take a green path to development.
CHAPTER – III
Energy Resources Endowment

3.1 Introduction

Assessment of renewable energy resources is very important and will go a long way in spearheading the future projects. One of the major reasons for the failure of renewable energy projects in the developing parts of the world can be attributed to poor assessment of the resources. This has led to wrong design of the systems in many cases and consequent failure of the projects in the long run.

This chapter assesses the endowment of different renewable energy resources in the Kingdom of Bhutan like solar, wind, small hydro, biomass and geothermal.

3.2 Small hydropower resource

Water is considered as one of the most important renewable energy resources in Bhutan. Most of the policies and plans are oriented towards harnessing the optimum hydropower output. Bhutan, being a landlocked country, only 8% of its land is suitable for agriculture. However, there are more than 70% of its population depending on the same small area, provides little economic advantage (Gyeltshen 2005). Currently, there is no known fossil fuel reserve, and the economy depends exclusively on foreign imports. Nonetheless, the steep mountainous terrains with bountiful river systems make Bhutan an ideal place to harness hydropower potential.

The total hydropower resource estimated till now, stands at 30,000 MW, out of which, 23,523MW have been identified to be economically and technically feasible. The Royal Government of Bhutan, therefore has been steadfast in harnessing as much hydro electricity as possible, to generate revenue through the sale of electricity to India, and to meet its own domestic demand at the same time. In the year 2010, the total hydropower generation capacity was 1,488 MW which is 5% of the total resource available. However, it has been envisaged by the Government that, by the year 2020, the total generation capacity is expected
to reach 10,000 MW, thus increasing from 5% to 30% of the total resource available within the ten year time frame.

The assessment of large hydropower potential in Bhutan, it is well documented, but till now, there isn’t any comprehensive studies being carried out to assess the potential of small and micro hydropower. Bhutan receives very good rainfall during summer (monsoon) season and all the river systems are fed with the melting of snows during the winter season. An isohyet map of Bhutan is as shown in the figure below:

![Isohyet map of Bhutan](image)

**Figure 8: Isohyet map of Bhutan**  
(Source: e7 Bhutan Micro Hydropower CDM Project)

Based on the above map, it can be seen that the average rainfall per annum varies from 400 mm to 5000 mm throughout Bhutan. Therefore, there is more potential to trap hydropower resource in southern districts than the northern areas.

### 3.3 Solar Energy Resource

Bhutan enjoys very good sunshine especially during the winter season (December, January and February) with a high clearness index (Clearness index is the ratio of average global irradiation measured on the earth’s surface to the extraterrestrial irradiation). The occurrence of such natural phenomena becomes useful when the river systems in Bhutan dry up, and as a result, the power generation from hydropower plants drop significantly. It is during this
Sustainable management of renewable energy systems in the Kingdom of Bhutan

season, that Bhutan ends up importing electricity from India at higher rates than what they sell. There is indeed a good opportunity to complement power generation from solar systems during the lean seasons, so that the import of power from India can be reduced. It has been reported in the national newspaper, the Kuensel, that between October 2011 and March 2012, Bhutan imported electricity from India worth, 30 million Ngultrum (AUD 0.6 million).

Figure 9: Import of electricity into Bhutan during winter (Source: Kuensel 2012)

In the year 2009, the National Renewable Energy Laboratory (NREL) of the United States conducted a study to assess the solar and wind energy resource for Bhutan. The Department of Renewable Energy, erstwhile the Department of Energy used a global solar radiation value of 4.4 kWh/m$^2$ per day while designing solar home lighting systems for off-grid areas of Bhutan (Gyeltshen 2006). The irradiation value used for the design of the systems remained the same for all the systems supplied all over Bhutan without taking site and seasonal effects into account. Owing to this, solar systems in some regions worked well, whereas others have failed. NREL mainly produced two different high resolution solar resource map for Bhutan namely, the Direct Normal Irradiation (DNI) map and the Global Horizontal Irradiation (GHI) map.

3.3.1 Direct Normal Solar Radiation (DNI)

Figure 10 shows the direct normal solar radiation for Bhutan and it can be seen that the value of DNI ranges from 2.5 kWh/m$^2$/day to 5.0 kWh/m$^2$/day (DNI is the amount of solar
radiation received per day averaged over the year by a surface per unit area when it is held normal to the direction of the sun). The solar radiation resource increases from south to north, which is the reverse of the isoyet map shown for the hydro resource, which further reinforces that fact that these two resources can complement each other.

Figure 10: Direct Normal Solar Radiation map of Bhutan  (Source: NREL 2009)

### 3.3.2 Global Horizontal Solar Radiation

The Global Horizontal Solar radiation is the sum of beam and diffuse solar radiation falling on a horizontal surface on the earth. The value ranges from 4.0kWh/m²/day to 5.5kWh/m²/day across Bhutan, which is a good resource for the flat plat collector (Cowlin and Heimiller 2009), see Figure 11.

Figure 11: Global horizontal surface solar radiation of Bhutan (Source: Cowlin and Heimiller 2009)
3.4 Wind Energy Resource

Until now, there has not been much work done to assess and exploit the wind energy resource in Bhutan. There are weather stations around the country, but the wind data are not actually being used to assess the wind energy potential to generate the electricity. The latest wind resource assessment was carried out by the National Renewable Energy Laboratory (NREL) in 2009.

Figure 12: Annual wind power density at 50m (Source: Cowlin and Heimiller 2009)

Based on the above wind map, it can be seen that the wind potential in Bhutan is moderate and localised. The wind resource which is available, generally falls into the class 3 category (5 - 5.5 m/s) as defined by NREL. Contrary to the general notion of having higher wind resources on top of the mountains and hills, it has been determined, that the wind flows follow the orientation of the valleys, where the major river systems of Bhutan exist.

Dorji (2009) opines that, since most of the regions where the wind resource exists are accessible by road and are near to grid infrastructures; there is an opportunity to develop utility scale wind generation and to electrify off-grid areas through the stand alone systems
(Dorji 2009). Since wind energy is an intermittent source of energy, feeding into its existing grid has always been an issue with the utility companies. However, the technology is developing very fast, in developing more efficient wind turbines. There is an opportunity in the future to complement hydropower generation and enhance the energy security for Bhutan by tapping the wind energy resource.

### 3.5 Biomass Energy Resource

Bhutan has enough biomass resource, since more than 72% of the land is covered by the forest. The biomass resources are mainly used for heating and cooking purposes, especially in the rural hamlets of the country. Bhutan has one of the highest per capita fuel wood consumptions in the world – see Figure 13 and 14. On the average, the per capita fuel wood consumption per annum in rural Bhutan stands at staggering 1200 kilograms as shown in figure 13 (Palit and Garud 2010).

![Figure 13: Comparison of per capita fuel wood consumption in the developing countries](source)

A study conducted by the erstwhile Department of Energy under the Integrated Energy Management Master Plan project (IEMMP), revealed that 96% of the fuel wood consumption takes place in rural Bhutan (Palit and Garud 2010).
Figure 14: Energy consumption by fuel in the residential sector of Bhutan (Source: Palit and Garud 2010)

It is estimated that, the growing stock of forest in Bhutan is 527.5 million cubic metres, out of which, 3.9 million tonnes (0.85 million cubic metres) are considered as the annual sustainable yield. Bhutan being a rugged mountainous country, the accessibility of such a resource is the major concern. Nearly 30% of its land is kept as protected areas. Therefore, nearly 60% of the biomass resources are not accessible for extraction (DOE 2005). There are other biomass resources like crop residues, animal residues and municipal wastes, which are increasingly gaining popularity to generate energy, although they are relatively lesser in quantity. Urban waste, in particular, serves dual purposes - to manage wastes and to turn waste into energy. A study conducted by JICA in 2005, shows that Bhutan has enough animal wastes, which can be used for energy generation. Table 1 shows the types of different domestic animals, which can be the source of the animal wastes.
Table 1: Estimation of animal wastes for bio-energy generation

<table>
<thead>
<tr>
<th>Dzongkhag[1]</th>
<th>Cattle</th>
<th>Buffalo</th>
<th>Yaks</th>
<th>Horses</th>
<th>Mules</th>
<th>Donkeys</th>
<th>Sheep</th>
<th>Goats</th>
<th>Pigs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thimphu</td>
<td>6,990</td>
<td>-</td>
<td>8,699</td>
<td>968</td>
<td>75</td>
<td>2</td>
<td>18</td>
<td>6</td>
<td>762</td>
</tr>
<tr>
<td>Paro</td>
<td>12,102</td>
<td>-</td>
<td>3,158</td>
<td>1,084</td>
<td>146</td>
<td>7</td>
<td>15</td>
<td>58</td>
<td>2,511</td>
</tr>
<tr>
<td>Haa</td>
<td>9,639</td>
<td>-</td>
<td>5,629</td>
<td>810</td>
<td>530</td>
<td>25</td>
<td>173</td>
<td>12</td>
<td>1,179</td>
</tr>
<tr>
<td>Chhukha</td>
<td>24,870</td>
<td>67</td>
<td>-</td>
<td>591</td>
<td>56</td>
<td>10</td>
<td>1,375</td>
<td>5,739</td>
<td>3,154</td>
</tr>
<tr>
<td>Samtse</td>
<td>29,341</td>
<td>743</td>
<td>-</td>
<td>209</td>
<td>100</td>
<td>2</td>
<td>4,659</td>
<td>10,916</td>
<td>1,185</td>
</tr>
<tr>
<td>Punakha</td>
<td>12,125</td>
<td>-</td>
<td>24</td>
<td>1,019</td>
<td>42</td>
<td>3</td>
<td>-</td>
<td>152</td>
<td>640</td>
</tr>
<tr>
<td>Wangduephodrang</td>
<td>20,893</td>
<td>-</td>
<td>3,057</td>
<td>1,722</td>
<td>78</td>
<td>21</td>
<td>3,884</td>
<td>139</td>
<td>3,304</td>
</tr>
<tr>
<td>Gasa</td>
<td>863</td>
<td>-</td>
<td>4,051</td>
<td>380</td>
<td>264</td>
<td>4</td>
<td>196</td>
<td>-</td>
<td>38</td>
</tr>
<tr>
<td>Tsirang</td>
<td>14,645</td>
<td>382</td>
<td>-</td>
<td>339</td>
<td>9</td>
<td>1</td>
<td>1,189</td>
<td>5,441</td>
<td>1,451</td>
</tr>
<tr>
<td>Dagana</td>
<td>14,296</td>
<td>107</td>
<td>-</td>
<td>383</td>
<td>33</td>
<td>10</td>
<td>732</td>
<td>3,612</td>
<td>2,378</td>
</tr>
<tr>
<td>Bumthang</td>
<td>10,002</td>
<td>-</td>
<td>2,672</td>
<td>1,299</td>
<td>107</td>
<td>8</td>
<td>2,147</td>
<td>28</td>
<td>30</td>
</tr>
<tr>
<td>Trongsa</td>
<td>11,336</td>
<td>-</td>
<td>-</td>
<td>390</td>
<td>50</td>
<td>6</td>
<td>1,337</td>
<td>7</td>
<td>350</td>
</tr>
<tr>
<td>Zhinggang</td>
<td>12,156</td>
<td>-</td>
<td>-</td>
<td>1,434</td>
<td>230</td>
<td>14</td>
<td>7</td>
<td>112</td>
<td>1,618</td>
</tr>
<tr>
<td>Sarang</td>
<td>26,611</td>
<td>425</td>
<td>-</td>
<td>473</td>
<td>7</td>
<td>2</td>
<td>1,588</td>
<td>4,371</td>
<td>1,640</td>
</tr>
<tr>
<td>Mongar</td>
<td>26,635</td>
<td>-</td>
<td>46</td>
<td>2,123</td>
<td>505</td>
<td>27</td>
<td>105</td>
<td>341</td>
<td>4,398</td>
</tr>
<tr>
<td>Lhuntse</td>
<td>14,089</td>
<td>-</td>
<td>44</td>
<td>1,768</td>
<td>160</td>
<td>22</td>
<td>279</td>
<td>7</td>
<td>1,617</td>
</tr>
<tr>
<td>Yangtse</td>
<td>12,505</td>
<td>-</td>
<td>115</td>
<td>1,753</td>
<td>216</td>
<td>18</td>
<td>47</td>
<td>48</td>
<td>2,793</td>
</tr>
<tr>
<td>Trashipang</td>
<td>308,258</td>
<td>-</td>
<td>7,369</td>
<td>45,264</td>
<td>719</td>
<td>42</td>
<td>5,047</td>
<td>104</td>
<td>5,640</td>
</tr>
<tr>
<td>Punagatshel</td>
<td>8,570</td>
<td>-</td>
<td>-</td>
<td>479</td>
<td>407</td>
<td>37</td>
<td>20</td>
<td>91</td>
<td>1,414</td>
</tr>
<tr>
<td>Samdrup Jongkhar</td>
<td>21,967</td>
<td>29</td>
<td>60</td>
<td>1,842</td>
<td>635</td>
<td>22</td>
<td>61</td>
<td>281</td>
<td>2,599</td>
</tr>
<tr>
<td>TOTAL</td>
<td>597,893</td>
<td>1,753</td>
<td>34,924</td>
<td>64,330</td>
<td>4,369</td>
<td>283</td>
<td>22,879</td>
<td>31,328</td>
<td>40,701</td>
</tr>
</tbody>
</table>

(Source: Gyeltshen 2006)

[1] Dzongkhag means District in the local language in Bhutan

3.6 Geothermal Energy Resource

Geothermal energy has been known to the Bhutanese people for many years. It is known as ‘tsachhu’ in local dialect, which means hot water or the hot spring. In the north, it is found in the places like Gasa, Punakha, Upper Trongsa, Bumthang and Lhuntse districts. In the south, it is found in the Rongkhola and Bhurkhola regions. The temperature of hot spring water ranges between 40°C – 50°C.

The hot water is used for bathing, as it is believed to have medicinal and healing properties. So far no comprehensive studies have been carried out to assess the magnitude of resource. There is an opportunity to explore further, to determine the feasibility of using hot water for the electricity generation and district heating in the near future (TERI 2010).
Since, the temperature of the hot water is quite low (40 – 50°C), the possibility of using it for power generation and district heating is quite limited. Nonetheless, there exists an opportunity to use this geothermal resource for those activities requiring low thermal energy like soil warming in cold regions, mushroom growing and therapeutic purposes. Figure 15 below shows the direct use applications chart for geothermal energy resources.

Figure 15: Direct use application for geothermal resources (Source: Geoscience Australia 2012)
CHAPTER – IV
Assessment Methodology

4.1 Introduction

This section mainly focuses on developing the methodology to assess the sustainable viability of renewable energy projects in Bhutan. It begins by defining the term ‘sustainable development’ and delves into its specific dimensions - social, economic, technological and environmental. An assessment matrix is developed to weigh the sustainability factors against different stages of the project life cycle. It starts from conception till end of life of the project. This matrix will be used to assess four different case studies and the comparisons shall be drawn there from.

4.2 Defining sustainability

In the last few decades, humankind have realised that, pursuing economic growth alone does not contribute to the overall human development. After the publication of the Burndtland Report: “Our Common Future” in 1987, there was renewed interest and many expressed an urgency to address sustainability issues, which are detrimental to ‘our common future’. As per the Burndtland report, sustainable development is defined as ‘development that meets the needs of the present without comprising the ability of future generations to meet their own needs’ (WECD 1987), which was echoed by the Prime Minister of Bhutan at the Rio+20 submit in 2012 in Brazil, when he stated that ‘sustainability means survival’ of all sentient beings on this earth (Sustainable development means survival, 2012).

In many countries, even today, economic growth is considered as the single most important dimension for measuring human progress. Other variables such as wellbeing of the society and the health of our environment remain sidelined in many decision making processes. Boss (2004) opines that the new measurements are required for evaluating the performance of any project concerning sustainability, and information based on economic sustainability alone is inadequate (Saad 2001).

Bieker et al (2001) propose four possible scenarios namely: the business case, the human case, the green case and the three pillar sustainability case as shown in figure 16:
In the business case, economic sustainability can be achieved through the use of social productivity and resources from the environment. In such a situation, only the economic agenda is realised at the cost to society and the environment. In the human case, social sustainability is achieved based on level of economic throughput and the availability of natural resources from the environment, so is the ecological sustainability, which can be attained through society’s will to safeguard the environment and judicious economic pursuance. In order to have sustained growth of this humankind, it is necessary to limit our consumption and growth to within the carrying capacity of our Earth. Nature’s capability to replenish capital stock should exceed our consumption levels, if the human race is to continue its journey to eternity. This underlines the need to have balanced growth as shown in case 4 of the Figure 16 where economic sustainability, environment sustainability and social sustainability are all achieved simultaneously.

4.3 Sustainability variables

Over the years, there have been numerous and diverse ways of representing the dimensions of sustainable development – a concept which is complex and fairly a new and evolving. It is quite difficult to compare or relate non-quantifiable variables like environmental and social cost/benefits with economic variables, which can be measured and quantified. Some would
argue that, representing such variables on the same platform is like comparing apples with oranges. However, it is essential to note that, environmental and social dimensions deserve no lesser treatment than economic variables and must not be ignored at any cost, if sustainable development is to be achieved. As per the World Conservation Union (IUCN 2006), the three variables of sustainability are represented in the form of three pillars as illustrated with the Venn diagram below. The sustainability is achieved at the intersection of all three variables as shown in figure 17.

Figure 17: Venn diagram showing where the three pillars intersect to achieve sustainability (Source: IUCN 2006)

Figure 17 clearly shows the need for an interdisciplinary and integrated approach in understanding the true essence of sustainability. The use of such a Venn diagram has been successful in educating the general public in relation to sustainability (Todorov and Mariova 2009). However, it is a static model with limited informative value, where outcomes of the inevitable interaction of different variables are hard to comprehend.

Estes (1993) states that the two sustainability dimensions - economic and environment is widely and consistently defined in the literature but social aspects are mostly interpreted. This social variable became implicit in the context of political stability, institutional building, cultural sensitivity, and conflict resolution. Due to this shortcoming, social issues merely got
reflected, and in most of the cases, they were overlooked while designing projects (Estes 1993). As per (McConville 2006), this social dimension can be further divided into variables like socio-cultural respect, community participation and political cohesion. For the purpose of this report, a policy framework is added and the last variable is now called, the political cohesion and policy support framework. The resulting five sustainability factors used in this work are summarised in Table 2.

Table 2: Five sustainability factors

<table>
<thead>
<tr>
<th>Social sustainability</th>
<th>Economic sustainability</th>
<th>Environmental sustainability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Socio-cultural respect</td>
<td>Need for sufficient local resources and capacity to sustain the project in the long run without external aid.</td>
<td></td>
</tr>
<tr>
<td>Community participation</td>
<td>Natural resources, non-renewable resources in particular, are not depleted for short term gain.</td>
<td></td>
</tr>
<tr>
<td>Political cohesion and policy support</td>
<td>A project built on complete understanding and respect for a community’s tradition and core cultural values.</td>
<td></td>
</tr>
<tr>
<td>Harmonizing projects with the host nation’s development priorities with appropriate policy support.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(Source: Adapted from McConville 2006)

4.4 Stages of project life cycles

Patel and Morris (1999) state that, project life cycle is “the sequence of phases through which the project will evolve. The basic life cycle follows a common generic sequence: Planning, Design and Development, Production, Handover and Post Project Evaluation. The exact wording varies between organisations and industries”. It is possible for different agencies to place varying importance on different stages of the project life cycle, based on the resources and details required. McConville (2006) states that project life cycle, is a nonlinear and forward thinking process. For instance, a rural water supply project and a rural energy supply project can have different stages of project development, since the need, technology, and implementation methods are different. Therefore, the generic life cycle of an energy generation project is divided into five stages: Project planning, conceptual designs and
feasibility studies, design and action planning, implementation, and operation and maintenance which are shown in the figure 18:

![Flow of life cycle processes](image)

Figure 18: Life cycle process of an energy project (Adapted from McConville 2006)

### 4.4.1 Project planning

All projects begin with the planning stage with the intention to address a specific issue or a need. The questions that we ask at this stage are: why such intervention is necessary? Is there any demand for the project? What is the priority of this need when compared with overall national goals? It is a process of gathering and analysing the background information of the prospective project. For instance, the energy projects are either proposed by the community (bottom up) to the concerned government, or by the government itself to another funding agency (top down) for a particular community. Consequently, a wide variety of data and information are collected through site visits, public consultations and the data collection processes. This information is finally assessed by the experts and based on their
recommendations; the decision to proceed or not to proceed is made by the higher management.

4.4.2 Conceptual design and feasibility study

Once the need is assessed, the next step begins with conceptual designs and a feasibility study. It is an iterative process, where a wide range of options is considered, taking various factors into account, including socio-economic, environment, technical and political issues. The different options of intervention are put on the table for brainstorming session with all the stakeholders so that the issues, both tangible and intangible, are discussed in detail. The feasibility study on conceptual design will delve deep into the strengths and weaknesses of different options. For renewable energy projects, the use of the RETScreen, HOMER, RAPSIM, and TRNSYS tools can be quite useful to determine the viability of the proposed projects.

4.4.3 Design and Action Planning

In this stage of the project life cycle, an appropriate design is selected and the action plans are drawn up to implement the project. A detailed technical design and a comprehensive financial outlay are prepared. In most cases, the action planning takes place in conjunction with the design phase, as the change in one of them will have an impact on another. There are three phases in action planning: Identification of tasks, assigning roles and responsibilities, and the sequencing tasks (Peace Corps 2000). For successful and smooth implementation, it is important to identify what needs to be done, by whom it should be done and when it must be completed? By sorting out all of these issues, it shows clear pathways and well defined actions to be taken by the individuals and institutions.

4.4.4 Implementation

The implementation is a process where plans and strategies (blueprints) framed in earlier phases of the project life cycle are put into action. It includes both preconstruction and construction works. The preconstruction involves site preparation such as building access roads, preparing necessary amenities for the people who will be involved in project works, procurement of supplies and equipment manufacturing. Under the construction phase, the
actual equipment and accessories are put in place for the purpose it was designed. The Implementation also includes, training and educating the beneficiaries about the project, so that, they remain well informed about the strengths and limitations of the project.

4.4.5 Operation and Maintenance

The operation and maintenance stage of the project is where the project produces its intended outcomes. For instance, the electricity generation and supply from a small hydropower plant to a remote community. When all the foregoing stages are implemented in a coordinated manner, the project becomes operational and starts benefiting the people. The management of the project becomes the central issue: how is the project to be operated? How must it be maintained? And which financial models and mechanisms are to be put in place for its sustainability? This stage of the project also provides a window of opportunity to assess its performance in terms of economic, technical, environmental and social outcomes.

4.5 Matrix Framework

A matrix framework is an effective and useful tool for assessing the sustainability of any project. It allows each element of the matrix to be evaluated separately, highlighting the strengths and weaknesses of the project, allowing the decision makers and project managers to assess specific areas for improvement. The matrix framework is simple and easy to understand, yet a very powerful tool for conveying a message to those people, who make decisions. The weak linkage in the matrix can easily be identified so that decision makers or project managers can immediately take remedial measures.

As shown in table 3, the sustainability matrix framework is developed by arranging sustainability factors (Socio-cultural respect, community participation, political cohesion and policy support, economic sustainability, and economic sustainability) in one direction and five stages of project life cycle (project planning, conceptual design and feasibility, design and action planning, implementation, and operation and maintenance) in the other. This matrix framework will be used to evaluate the sustainability of renewable energy projects in Bhutan.
Table 3: Sustainability factors versus project life cycle matrix

<table>
<thead>
<tr>
<th>Project life cycle</th>
<th>Sustainability factors</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Socio-cultural respect</td>
</tr>
<tr>
<td>Project Planning</td>
<td>(1,1)</td>
</tr>
<tr>
<td>Conceptual design and feasibility</td>
<td>(2,1)</td>
</tr>
<tr>
<td>Design and action planning</td>
<td>(3,1)</td>
</tr>
<tr>
<td>Implementation</td>
<td>(4,1)</td>
</tr>
<tr>
<td>Operation and maintenance</td>
<td>(5,1)</td>
</tr>
<tr>
<td>Total</td>
<td>20</td>
</tr>
</tbody>
</table>

(Source: Adapted from McConville 2006)

4.6 Scoring Guidelines

The following section provides the baseline, for giving scores in each cell of sustainability matrix shown above. All 25 cells shall have distinct scores, based on the assessment carried out by the evaluator. For instance, the very first cell (1, 1), which is the intersection of the planning stage and socio-cultural respect of the matrix is given a score, based on four different criteria. Each sustainability criterion evokes a different question, whether or not the sustainability factors are addressed through the different stages of project life cycle. In order to assess the sustainability of the project, an independent evaluator can award different scores in all cells depending on the number of sustainability recommendations completed. For the purpose of this evaluation, a minimum score of 0 (zero) and a maximum score of 4 (four) is used, indicating poor and excellent evaluations respectively. If a cell in the matrix scores 4, this indicates that, all four assessment criteria are fulfilled. The score is 0, if none of the criteria specified is fulfilled. The overall possible score for the matrix is 100, but for each sustainability factor and project life cycle stage, the maximum score is 20. For the evaluation purpose, all five different sustainability factors are given equal importance, hence, equal weight factors for all.
Element (1, 1) – Project planning: Socio-cultural respect

The Project planning is one of the earliest and the most important activities undertaken while implementing any project. The success or failure of any projects will depend on the robustness of the planning phase. For this reason, it is a prerequisite to have a sound and clear planning stage. Factors that could be considered at this stage include needs and resources assessment, taking into account the cultural and social values of the community. The overall design of the project should be in harmony with the existing cultural fabric of the society, respecting their values, beliefs, taboos and sentiments in using energy. The following are four recommended tasks which need to be addressed during project planning phase:

- Identify traditional beliefs and social preferences in using a particular energy system,
- Recognise gender role in using energy
- Understand the level of community knowledge about energy
- Does the target community have other preferred energy options?

Element (1, 2) Project planning: Community participation

While developing any energy project in a community, it is necessary to involve beneficiaries in every stage of the project life cycle. Engaging the community in every phase of the project, can instil a sense of ownership, which could be instrumental to the success of the project. The Community consultation is a very important aspect of the project planning process, involving as many local people as possible, so that their views and concerns are fully taken into consideration. This can be achieved by completing the following recommended tasks:

- Understand local development priorities through public consultations.
- Identify the stakeholders and local leaders, who can make decisions.
- Determine the type of political organisation and cohesion at local level.
- Reach a consensus that the proposed energy option is appropriate and acceptable

Element (1, 3) Project planning: Political cohesion and policy support

It is essential to understand the political situation at the local level, overall guiding policy framework at the national level and the existing institutional setup. The implementation works at the local level should be coherently integrated with the regional or national development policies and plans, which can assure long term support for such initiatives. For instance, any energy project in Bhutan can only be successful and sustainable, if it is in line
with the principle of Gross National Happiness (GNH) and the National Renewable Energy Policy of Bhutan. The following are the recommended tasks to satisfy this element.

- Conduct situational analysis of regional and national issues, such as political structure and stability, government policies and foreign aid.
- Ensure that, the proposed initiative is in line with the regional and national development priorities.
- Research the history of energy projects implemented in the past.
- Is there a robust institutional set up to support such initiatives?

**Element (1, 4) Project planning: Economic sustainability**

This element of the matrix focuses on the economic situation of the community, such as affordability and willingness of the end users to pay for the energy services. In the Bhutanese context, it is not unusual to see some of the remote people still practicing the barter system, where the people exchange goods for services or vice versa. Therefore, it is important to align any new initiatives into such prevailing economic conditions. The other important aspect of economic sustainability is to gather enough information, on the ability of local people to pay for such energy services. When we deal with remote communities, such a question on the purchasing power of people becomes politically sensitive, as many live below the poverty line and in some cases, in abject poverty. To achieve sustainability, the following are the recommended tasks to be completed:

- Understand the overall economic situation, both at the national and local level, including poverty level, living costs, unemployment rate and the resource flow.
- Understand how the general economic situation is affected by prevailing energy issues.
- Identify the community’s monetary and non-monetary resources,
- Study and understand the willingness of the people to pay for the energy services.

**Element (1, 5) Project Planning: Environmental sustainability**

During the time of the need assessment, one must take environmental factor into consideration. How could the proposed energy project impact on biodiversity and the ecosystems of the area? The impact can be both positive and negative, and in recent years, the need to conduct environmental impact assessment has become very common for many proposed projects. The planning phase of the project is an opportunity to garner information
on local and regional climate and environmental constraints, which can have the potential to influence the project sustainability directly or indirectly. For instance, many Bhutanese believe that some elements of nature are manifestations of God, where human interventions are considered anti-social. The majority of lands in Bhutan are protected national parks, where economic activities in its vicinity are subject to strict scrutiny. All these factors need due consideration for any new project proposal. The following are the recommended tasks that need to be considered for sustainability studies.

- Identify indigenous resources for energy generation.
- Gather climate and environmental factors that need to be reflected in the project design.
- Identify the potential environmental issues at local, regional and national level.
- Determine the community’s willingness to accept intrusion into their local environment.

**Element (2, 1) Conceptual design/feasibility: Socio-cultural respect**

This element of the project focuses on assessing the appropriateness and culturally sensitive issues during the design phase. It is essential to design and build projects based on the society’s cultural values and existing technical systems. The socio-cultural constraints and limitations like gender roles, seasonality of labour and perception of energy use, should be identified. There is also a need to identify, how such intervention can have an impact on a society’s culture. The following four criteria are expected to be fulfilled to achieve sustainability objectives:

- Determine how such energy intervention will have an impact on a community’s cultural values.
- Assess the community’s capacity to operate and maintain the energy systems.
- Does the system design respect gender roles.
- Evaluate the potential social ramifications of such designs.

**Element (2, 2) Conceptual design/feasibility: Community participation**

Involving the concerned community throughout the design and feasibility studies, can lead to more robust and sustainable designs. More often, the community remains sidelined during the project design process, and their views and concerns are ignored. It is necessary to have strong communication links with the local people, as they know about the local resources and
site conditions through their experience more than anyone else. Giving due recognition to community input, can be vital for the successful design of projects, so that the critical issues are not overlooked. Through community consultation and participation only, the project objectives and expected outcome becomes clear to all the stakeholders. The following tasks are recommended for this element of matrix.

- The project objectives are clearly defined and accepted by all the concerned stakeholders.
- Identify a representative committee, who can make decisions on behalf of the community.
- Provide viable technological options to the community for their evaluation and feedback.
- Community formally selects an appropriate option, understanding its associated constraints and limitations.

**Element (2, 3) Conceptual designs/feasibility: Political cohesion/policy support**

No project can work in isolation and achieve its goals in the larger interest of the society. Therefore, it is important to consider cohesion between institutions, stakeholders and individuals and overall guiding policy during the conceptual design stage. It is possible, that a similar project would have been implemented earlier by other organisations and their experience can have vital input in conceptual designs of any new projects. This can only happen through close collaboration. The following are the recommended tasks for this element:

- Develop a working relationship with partner organisations
- Consult designs and feasibility studies of other similar projects.
- Integrate existing technologies/programs into to conceptual designs.
- Explore potential organisations and institutions for supports (fund/expertise).

**Element (2, 4) Conceptual designs/feasibility: Economic sustainability**

The economic viability of the project depends mainly on the initial upfront cost, operation and maintenance costs and ability of the people to pay for energy services provided. The economics part in the conceptual design, mainly involves the cost estimates of the project and ability of the community to pay for the energy services. For the long term sustainability of
any project, cost reduction is necessary and this can be achieved through the use of locally available resources. Any project design, whose design principle is based on the use of indigenous resources, can be more sustainable, if certain parts need replacing after some time. The economic viability further improves, if the operation and maintenance is carried out by local technicians rather than involving external technicians, who can at times be more expensive and difficult to retain for longer duration. The following are recommended tasks for this element.

- Estimate upfront cost of conceptual designs.
- Estimate O&M and disposal cost
- Assess ability and willingness to pay for energy services.
- Assess economic viability of project for long term sustainability.

**Element (2, 5) Conceptual design/feasibility: Environmental sustainability**

A viable and sustainable design is the one that does not destroy the environment in the name of development. This can happen, through over consumption of raw materials and by releasing pollutants in to the environment. The proper selection of the site is important, so that there is minimal footprint on the local environment. However, the compromise has to be made, since energy generation plant has to be in the vicinity of load by taking economic and technical factors into account. A good conceptual design is one, which is optimally designed and strikes a balance between the different competing sustainability factors. The recommended tasks for this element are:

- Evaluate the capacity of sustainable energy use
- Consider how different environmental constraints will impact the conceptual designs.
- Assess land requirement for various energy supply options.
- Assess raw material required for energy generation for different options.

**Element (3, 1) Design and action planning: Socio-cultural respect**

The development of an action plan can be a challenge, since the project developers usually don’t have first hand information about the community. The action plan should be based on the socio-cultural fabric of the local community. There can be a huge difference in the expectations of people from different backgrounds and such differences should be mutually
harmonised. A society can have a unique belief and understanding of different gender roles, which must be identified through the public consultation. Failing to do so, can create complications in the future, which can potentially lead to failure of the project. The other important aspect is seasonality of the labour force. The people don't remain in a confined village or available for work at all times. For instance, a seasonal migration is very common in remote Bhutan, where people migrate from winter residence to summer residence during cold months and vice versa during the warm months. There are also religious holidays (Duezangs and Duechhens), where people are not available for work; also people need time for agricultural works. All these factors need to be identified and synchronised with the project action planning phase. The following are the list of recommended tasks that need to be completed for this element:

- Understand the social structure of the community
- Consider the seasonality and availability of local work force.
- Understand the socially accepted gender roles and responsibilities.
- Determine the gender equity, through resource and opportunity distributions.

**Element (3, 2) Design and action planning: Community participation**

The project designs and action plans should be open for review and discussion in the public domain. This can happen through the involvement of the local community and seeking their views and concerns with regard to the designs of the project. The design should only be approved in consultation with the local people, so that people remain fully informed about the project. The action planning, should also define the roles and responsibilities of the people very precisely. Solicitation of community input to refine and finetune the project design is essential.

- Final design is accepted based on community’s consensus.
- Solicitation of community’s input to refine and finetune the project design
- Community’s members are fully involved in sequencing implementation schedule.
- Mutual agreement of time schedule between project developers and local people.

**Element (3, 3) Design and action planning: Political cohesion/policy support**

While developing any projects, the multiple parties are usually involved. There is a need to keep all the stakeholders within the loop of project design and action planning process. The exact roles and responsibilities, while developing a project, need to be precisely and
unambiguously defined, in order to avoid future conflicts and misunderstanding. Usually, there is a high possibility of duplication of efforts and resources. The action planning should also take overall guiding policy measures into consideration and any action plans built on the strengths of existing policies can solve potential and unforeseen sustainability problems in the long run. The following are some of the recommended tasks to be completed for this element:

- Delineation of action plans for different parties involved.
- Agreement on financial plans and commitments.
- Mutually agreeable project timeline is framed, taking the convenience of different parties into consideration.
- Final design and action plans are presented to all the parties involved.

**Element (3, 4) Design and action planning: Economic sustainability**

Prior to the project implementation phase, it becomes indispensable to agree on the budget requirement and procurement planning. The final agreement on the budget can happen through a series of iteration process, modifying and changing the scope of works to achieve the most cost effective solution. To attain such financial objectives, the need to consider local resources and labour, wherever possible is necessary. The following are the recommended tasks:

- Verification of costs and availability of resources.
- Confirm community’s contribution, both monetary and non-monetary resources.
- Finalization of project cost estimates by taking local contributions into consideration.
- Development of locally oriented action plan of the project.

**Element (3, 5) Design and action planning: Environmental sustainability**

During the construction stage of the project, the need to assess the ecological footprints becomes important. The environmental impact can be minimised through the use of locally available renewable resources, and employing environmentally friendly construction techniques. The final design and action planning should firmly address the ways and means to minimise wastes, energy use, noise and visual impacts on the local environment. The following are some of recommended tasks for this element:

- Use of locally available renewable resources.
- Minimisation of wastes, pollutants and energy use.
- Availability of seasonal resources is considered.
- Develop a firm environmental mitigation plans to correct any adverse impacts.

**Element (4, 1) Implementation: Socio-cultural respect**

Throughout the project implementation, it is essential to respect the normal routine and habits of the local community. This calls for a judicious and reasonable implementation schedule, based on the prevailing cultural fabric and social norms. There are seasons, where people are not readily available for work, as they are engrossed in agricultural work. There are also days where, people have to observe religious and local holidays. All these factors should be considered, while implementing any projects. Forcing people to work against the above social and cultural values, can frustrate people and reduce cooperation. The local women too should play a critical part during project implementation, which is often overlooked. Implementing the project, along these lines has the potential to increase the sense of ownership from the very early stages of the project development. The following are recommended tasks to satisfy this element:

- Setting of a realistic implementation schedule, based on the availability and working culture of local people.
- Consider force majeure throughout the implementation process.
- Encourage women to participate in implementing the project.
- Give due respect to local monuments and shrines.

**Element (4, 2) Implementation: Community participation**

The capacity building of local people through training and education will go a long way in sustaining the project in the long run. Above all, engaging the people during the time of project implementation can give first hand training and in situ education. Periodic community consultation, with regard to the project progress, is necessary, particularly, with the local leaders and key players. This will help to solve the unforeseen hurdles encountered during the time of construction. The following are some of the recommended tasks to complete this element:

- Organisation of periodic public meetings and consultations.
- Work closely with local leaders in organising labour force required.
- On-the-job training for local people.
- Set up a proper communication channel to report on the work progress and problems.
Element (4, 3) Implementation: Political cohesion/policy support

Since multiple parties are usually involved in implementing any projects, a collaborative cohesion and synchronisation of efforts is important. There is a need to have a robust communication channel, where different parties can share knowledge, skills and experiences with one another. The project developers can share the new knowledge and skills required in implementing the project with the local people. At the same time, the community too can share their experiences of the project with the project developers. The following are some of specific tasks that need to be completed for this element:

- Keep partner institutions fully informed on training and labour requirements.
- Discuss different roles and responsibilities of different parties.
- The construction site should be open and accessible to the independent bodies for inspection.
- All parties should be fully informed on the status and progress of the construction work.

Element (4, 4) Implementation: Economic sustainability

The community can make a significant contribution towards the project implementation, both in terms of monetary and non-monetary contributions. All of these costs shared by the local people should be quantified and auditable by them, so that they too can see how much locals have contributed and thereby increase the sense of ownership and pride. As far as possible, using locally available resources and manpower can bring down the overall cost of the project. If locally available resources cannot be used directly, modifying what is available and providing training to local people, instead of involving experts from outside, can bring down the cost and address economic sustainability issues in a big way. The following are some of the recommended tasks:

- Encouraging the community’s contribution towards the project.
- Use of locally available resources and expertise.
- Keeping a record of expenditures and reviewing them from time to time.
- Sharing the financial report with the community, hence increasing transparency.
Element (4, 5) Implementation: Environmental sustainability

The implementation phase of the project is one of the major project life stages, where there can be maximum impact on the environment. The impact includes, use of energy, water resources, disposal of wastes, construction of access roads and removal of trees and encroaching into wild life habitats. Well planned strategies are necessary to reduce such ecological impacts, as some impacts can be irreversible or reversible with great difficulty. The following are some of the recommended tasks:

- Environmental constraints identified during the design phase have to be closely observed during the implementation phase.
- Minimisation of environmental impacts through a close monitoring process.
- Initiate sensitisation regarding waste disposal and reuse.
- Restore damaged ecosystems after the implementation works.

Element (5, 1) Operation and maintenance: Socio-cultural respect

How the community receives the project and how satisfied they are, can only be seen when the project is in operation. In terms of energy projects, the beneficiaries of the project will react, based on how an energy system delivers energy in terms of adequacy and reliability. Different people will perceive things differently and change their behaviour in unique way. It is very difficult to know beforehand, how a society will accept the project, especially in developing countries, where such projects are installed and commissioned in an entirely unique fabric of a society. The satisfaction level can be different for men, women and children. If so, the socio-cultural constraints should be revisited and modified in harmony with the local settings. The following are the recommended tasks to be completed to satisfy this element:

- Identify unanticipated socio-cultural constraints faced during the project operation.
- Discuss maintenance issues faced during the time of operation.
- Ensure that the cost and benefits are equally shared amongst all parties concerned.
- Assess how gender role and traditional beliefs affect the project’s operation and maintenance works.
Element (5, 2) Operation and maintenance: Community participation

Once the project is in place, the community should operate and maintain the system with less external supports. The concerned community should be fully trained on basics of operation and maintenance of the system. In the event of major breakdown, technical backstopping should be provided by the project developer or by the government. To achieve this objective, a proper institutional setup is necessary, where there is an effective communication channel for the transfer of information. It is essential to have village committee, overseeing the overall management of the project and dealing with unanticipated issues. The village committee should be empowered and they must be responsible for selecting the local plant operator through a transparent and unanimous selection process. The following are some of the recommended tasks for this element:

- Formation of a village working committee to oversee the overall management of the project.
- Involvement of the community in the operation and maintenance of the project.
- Keeping a record of the project’s performance and submit the periodic reports to project developers.
- The community should be empowered to solve conflicting interests and issues at the local level.

Element (5, 3) Operation and maintenance: Political cohesion/policy support

After commissioning of the project, the next step that remains is to hand over the same to the local community. The formal handing and taking over, take place in the presence of all the parties involved from planning to commissioning of projects. However, it is not the end of the story for the different parties involved, as further guidance and assistances are necessary in future. The community alone is not in a position to address unforeseen future problems and complications. The partner institutions must provide policy guidance, technical backstopping, financial support and periodic training of the community to build their capacity in order to sustain the project in the long run. The following are some of the recommended tasks to satisfy this element:

- Formal handing and taking over of the project.
- Defining clear roles and responsibilities of different organisations.
Local institutions and the community are empowered to make certain decisions on behalf of the community.

Frame a strategy to share monitoring and evaluation reports with all the partner institutions from time to time.

**Element (5, 4) Operation and maintenance: Economic sustainability**

To keep the system operational, the economic factor becomes an important issue. The system needs plant operators and technicians, who should be paid. The periodic maintenance and overhauling of system components from time to time requires money, without which, the project sustainability becomes questionable. The project should generate its own O&M cost through the collection of service fees. If not, there should be subsidy arrangements from the government to fill the resource gap. The Government subsidy is very common in developing parts of the world, where the paying capacity of community is very low. Therefore, it is essential to have long term financing support and cost sharing mechanisms put in place. The following are the recommended tasks to achieve economic sustainability:

- Estimate a long term O&M cost, which is realistic.
- Assess the affordability and willingness of the community to pay for service.
- Estimate the long term financial gap that might arise for system upkeep.
- Work out the subsidy and financial support needed, based on robust financial mechanisms.

**Element (5, 5) Operation and maintenance: Environmental sustainability**

Throughout the project operation, care must be taken to minimise the environmental impacts. The impacts can come in the form of waste disposal, use of consumables, noise and visual impacts etc. Some of the environmental problems would not have featured in the project design and action planning phase. Therefore, reassessment of environmental impacts should be carried out and solutions must be sought, so that the project has minimal ecological footprint. There should also be some end-of-pipe solutions ready to address some of the inevitable environmental problems, for instance, treating of waste disposals. The following are some of the recommended tasks to satisfy this element:

- Develop plans to minimise environmental damage as far as possible.
- Seek environmentally friendly end-of-pipe solutions to treat and dispose of wastes properly.
- Explore alternative plans to reduce ecological impacts.
- Keep a record on the monitoring and reporting of project performance for future reference.
CHAPTER – V
Case Studies

5.1 Introduction

In order to understand the sustainability issues pertaining to the renewable energy projects in Bhutan, careful selection of projects is essential. It is very important to understand in depth, the objectives and models of the projects, particularly with regard to their sustainability concepts. The different projects follow different methodologies in addressing a wide range of issues such as financing mechanisms, management setup, operation and maintenance arrangements and in addressing environmental and social concerns.

For the purpose of evaluating the sustainability of the projects, four different projects were selected. The selection criteria are based on technology, regional representation and the type of management model being implemented.

5.2 A Community Managed Model – Chendebji Project

5.2.1 Project background

Chendebji is a small and remote village in Trongsa district in central Bhutan (Lat. 27° 29’ N., Long. 90° 20’ E.). The village is situated near the bank of Lamchelachu (river) and lies 2500 metres above sea level. This village is located about 150 km to the east of the capital city Thimphu. It has about 50 households, a dispensary and a school. The river is fed by the monsoon rain in summer, which lasts from May to September and the melting of snow and glaciers in the winter season, which lasts from December to February (e7 2005).

Figure 19: Location of Chendebji Micro Hydropower Plant (Source: Shiraishi 2009)
Prior to electrification in 2005, the people of Chendebji had no access to any form of modern energy services. The people used fuel wood for cooking and heating, and kerosene for lighting purposes. Realising the importance of modern energy services to fuel socio-economic progress, the people of Chendebji requested the government to explore avenues to electrify Chendebji in the consultation meetings, which were held in the years 2003 and 2004.

![Project Boundary](source)

Figure 20: The project areas of Chendebji Micro Hydro Project (MHP) (Source: e7 2005)

Chendebji micro hydropower plant, with the capacity of 70 kW was commissioned in the year 2005. It was funded mostly by e7 group as a Clean Development Mechanism (CDM) project. The e7 is a group of nine electricity companies (now 10) in G8 nations, whose vision is to cooperate in the field of energy related issues around the world, with the special focus on environmental conservation and sustainable energy development.

### 5.2.2 Objectives of the Project

As per the National Environment Commission of Bhutan (NEC), the main objectives of the Chendebji project are as follows:

1. To demonstrate the Clean Development Mechanism (CDM) under the Kyoto Protocol of the UNFCCC on the micro hydropower plant model,
2. To electrify the rural village of Chendebji through the construction of a micro hydropower plant,
3. To present the constraints encountered, and corrective measures undertaken at the various international discussion forums in order to contribute to the CDM rule making process,
4. To pilot the Clean Development Mechanism (CDM) project to alleviate poverty in developing countries,
5. To improve living conditions and health of the people by reducing indoor smoke from fuel wood and kerosene.

5.2.3 Project Technologies

Electricity Generation
For any project, if the operation and maintenance is to be taken care of, by the local people, it is always a prerequisite to keep the technology as simple as possible. It is not always easy to find someone in the remote villages who can read and write. In order to keep the project design simple, a cross flow type turbine and a reversible flow pump were initially considered, which has a simple structure, and is easy to operate and maintain. Based on the general premise that the hydro power station will be mainly operated by the local people, the cross flow turbine was finally selected for Chendebji, as it is simple and cost effective. Table 4 shows the main specifications of the project:

Table 4: Technical specifications of the project

<table>
<thead>
<tr>
<th>Plant output (kW)</th>
<th>70</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effective head (m)</td>
<td>50</td>
</tr>
<tr>
<td>Maximum operating water (m³/s)</td>
<td>0.2</td>
</tr>
<tr>
<td>Turbine Type</td>
<td>Cross-flow turbine</td>
</tr>
<tr>
<td>Inlet valve</td>
<td>Sluice valve</td>
</tr>
<tr>
<td>Generator Type</td>
<td>Horizontal shaft, revolving-field type, three-phase synchronous generator</td>
</tr>
<tr>
<td>Rated voltage (V)</td>
<td>400</td>
</tr>
<tr>
<td>Rated power factor</td>
<td>0.8 lagging</td>
</tr>
<tr>
<td>Frequency (Hz)</td>
<td>50</td>
</tr>
</tbody>
</table>

(Source: e7 2005)
Transmission and distribution systems

There are two transmission and distribution lines going out from the power house to Chendebji village. Through the single circuit of 230V/400V three-phase four-wire type, the power generated is directly transmitted and distributed to the village at the same voltage as that of the generator outlet. However, in order to supply power to the other side of the river, the voltage is stepped up from 400V to 11 kV by a transformer via a single circuit of 11 kV three-phase three-wire line. The total length of 230V/400V distribution line is around 3 kilometres, while the 11 kV line is 1.36 kilometres. The power is distributed to every facility and household through 230V distribution systems. An energy meter is installed at every consumer’s inlet to record the quantity of energy consumed.

Figure 21: A typical Chendebji household with distribution lines (Source: Shiraishi 2009)

5.2.4 Operation and Management Model

The management arrangement of Chendebji Power Plant is well known in Bhutan. Attempts have been made to replicate it in some other projects like the 100 kW Sengor micro hydro plant. It is widely known as the ‘Chendebji Model’ and is based on an idea, that a community should be involved in every aspect of the project implementation process.
The project was commissioned in October 2005 by the e7 group and subsequently, the ownership was handed over to the erstwhile Department of Energy (DOE) of the Royal Government of Bhutan. The responsibility to operate, maintain and manage the project was handed over to the local community. Currently, the monitoring of the project is done under the direct technical guidance of the Ministry of Economic Affairs. The e7 provides necessary training with regard to implementation of the monitoring process (e7 2005).

To this effect, the Chendebji Micro Hydropower Management Committee (CMHMC) was formed, assisted by the Trongsa District Administration and erstwhile DOE. The members of the Committee include the District Administrator, local leaders and the representatives from the energy department. The role of the government is to deal with policy issues, provide technical assistance and sanction subsidies for the major procurement of spare parts, while the day to day functioning of the project is carried out by the local community themselves.

The CMHPC has responsibility and power to select and appoint local technicians (2 for Chendebji) to look after daily operation and maintenance aspects, manage revenue collected from energy sales and maintain data of the plant’s operation. The local technicians are paid approximately AUD 65 per month, from the fund collected as a salary for their service. The Bhutan Power Corporation (BPC), an electricity utility company of Bhutan, provides periodic training to the local operators on the O&M aspects (Dorji 2005).
Figure 23 shows the institutional and management arrangement of the Chendebji Micro Hydropower plant:

![Institutional Arrangement for CMHP](Source: DOE 2005)

**5.2.5 Evaluation of the Chendebji MHP**

Based on the sustainability assessment matrix developed in Chapter IV, the Chendebji project is evaluated as shown in table 5. For a detailed evaluation report, please refer to Appendix A, attached to this report.
Table 5: Evaluation of the Chendebji MHP

<table>
<thead>
<tr>
<th>Project life cycle</th>
<th>Sustainability factors</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Socio-cultural respect</td>
</tr>
<tr>
<td>Project Planning</td>
<td>3</td>
</tr>
<tr>
<td>Conceptual design and feasibility</td>
<td>3</td>
</tr>
<tr>
<td>Design and action planning</td>
<td>2</td>
</tr>
<tr>
<td>Implementation</td>
<td>2</td>
</tr>
<tr>
<td>Operation and maintenance</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>12/20</td>
</tr>
</tbody>
</table>

From a sustainability perspective, the project does well during the initial stages of the project life cycle. The project planning stage receives nearly the maximum score in every element under the sustainability factors. The aggregate score for this stage of project life cycle is very high (18/20), which indicates, greater emphasis on sustainability was shown during the time of project planning.

The total score for conceptual design and feasibility is 14/20, which can be rated as a good score. The only weak linkage is the element (2, 2) with the score 2/4. The community was not fully involved during the conceptual design phase. The project designers and external consultants, usually come with the notion that the technical inputs from the local people will be very insignificant. However, it is essential to note that the knowledge and wisdom of the local people cannot be ignored, since they are people who know best about the site.

The design and action planning stage of the project life cycle (14/20) scores well. The community participation and the socio-cultural respect become less and less important for the designers, mainly because such people tend to believe that it is redundant to consider such variables, which are already covered in the project planning stage.

The score for the implementation stage is 12/20, which is a reasonable score, but obviously not on par with the earlier stages of the project life cycle. Though the scores for some other
elements have remained the same as those for the design phase, the scores for environmental sustainability and economic sustainability have dropped. This shows fact that, the project can be designed very well, but there is no guarantee that it will be implemented as designed.

The operation and maintenance stage of the project scored the lowest points (10/20). The project was finally handed over to the local people and they have been in constant touch with the project developers. However, the score is poor for the socio-cultural respect, the economic and environmental factors. This demonstrates the fact that, unless the end users are fully informed about the project’s objectives, strengths and limitations, it will be difficult to achieve sustainability.

5.3 Rangjung Small Hydro Project (A BPC owned Project)

5.3.1 Project Background

Rangjung is a small village located in the eastern corner of Bhutan, in Trashigang district. It is one of the earliest small hydropower projects built as a part of a rural electrification scheme. One of the main objectives of the project was to stimulate social and economic development of rural areas in the eastern Bhutan. The project was initially planned to be 1.1 MW, but later it was changed to 2.2 MW, considering the rapid growth of energy demand in eastern Bhutan. The project was mostly funded by the Austrian Development Co-operation (ADC). The transmission and distribution works were funded by the Asian Development Bank (ADB) and Dutch Co-operation (SNV).

The hydropower plant began its operation in December 1995, supplying electricity to most parts of Trashigang and Trashi Yangtse districts, benefiting thousands of households in the region. The official inauguration took place on 22nd April 1996.
5.3.2 Project Objectives

The main objectives of the 2.2 MW Rangjung small hydropower plant are as follows:

1. To encourage and support the people in using renewable energy.
2. To reduce the consumption of fuel wood, to protect Bhutan’s rich forest land, and safeguard the environment, ecology and biodiversity.
3. To improve the health of the people through the provision of affordable energy services, thus, reducing exposure to indoor smoke.
4. To bring light to rural homes and help the government to initiate rural electrification.
5. To facilitate students to study at night and thus improve the quality of education.
6. To incentivise the rural community in setting up cottage agro-based industries to supplement income from farm produce.

5.3.3 Project Technologies

Rangjung small hydropower plant is a high head, low discharge power generation system. Initially, the project was designed with the capacity of 1.1 MW to supplement two existing micro hydropower plants in the district – Khaling (600 kW) and Chenary (750 kw) hydropower plants. It was found that these two micro hydropower plants were insufficient to
meet the growing demands and both the Austrian Government and the Bhutan Government felt the need to increase the plant capacity of Rangjung SHP. At the same time, the economic viability of the project, deteriorated owing to a massive increase in the foreign component cost (Electro-mechanical equipment) and devaluation of the local currency. The only way to improve the economic viability was to increase its capacity through certain modification, as there was enough electricity demand (OEZA n.d).

Figure 25: A typical Bhutanese house in Rangjung with power lines and a satellite dish (Source: OEZA n.d)

Figure 26: Saling village in the Trashigang district (Source: OEZA n.d)

The Royal Government of Bhutan submitted a formal request to the Austrian Government, for the need to increase its capacity from 1.1 MW to 2.2 MW. The request was reviewed and
endorsed by the donor country in 1994. The modifications on civil works were carried out and the electromechanical equipment was re-ordered. Accordingly, the head of the plant was increased to 170 metres and the flow to 1.6 cubic metres per second. The overall system was designed to use Pelton turbines (A turbine which is used for high head, low discharge systems). There was 450 km of transmission and distribution lines built for this project, benefitting 23,000 people in the eastern regions of Bhutan.

Table 6: Project details of Rangjung SHP

<table>
<thead>
<tr>
<th>Project feature</th>
<th>Rangjung</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intended power supply</td>
<td>To mini grid Stand alone</td>
</tr>
<tr>
<td>Plant capacity</td>
<td>2.2 MW</td>
</tr>
<tr>
<td>Plant type</td>
<td>High Head, Run-of-river plant</td>
</tr>
<tr>
<td>Power transmission &amp; distribution line length</td>
<td>450 km</td>
</tr>
<tr>
<td>Population served</td>
<td>2300</td>
</tr>
<tr>
<td>Installed capacity per capita served</td>
<td>0.1 kW</td>
</tr>
<tr>
<td>Transmission distance per capita served</td>
<td>19.6 m</td>
</tr>
</tbody>
</table>

(Source: OEZA n.d)

5.3.4 Management and institutional setup

As mentioned in earlier sections, the Department of Power (DOP) was divided into three agencies namely: the Department of Energy (DOE), the Bhutan Electricity Authority (BEA) and the Bhutan Power Corporation (BPC) in the year 2002. Consequently, most of the small and micro hydropower plants were handed over to BPC for operation, maintenance and management. Here, the communities have no role for the operation and maintenance of hydropower plants, as the BPC is solely responsible for the overall management of the plant. If they have any genuine and specific issues with regard to the power supply, it is first submitted to the block committee, which further contacts the district administration. The district administration uses its own discretion, either to contact the Ministry of Economic Affairs or the BPC, depending on the specificity of the issues. The policy issues are dealt by the Ministry, whereas the BPC is responsible for management and technical issues (Dorji 2007).
Rangjung small hydropower plant is one of many small hydropower stations, which are currently managed by the BPC. The plant has designated engineers and technicians, deployed by the BPC. They look after every aspect of the plant, starting from generation to the provision of energy services to the consumers. During the time of major breakdown, the technical personnel from the Begana Maintenance Unit (BMU) from Thimphu (A hydro facility maintenance unit set up by the BPC) are deployed in order to make the plant operational. Figure 27 shows the institutional arrangements of the Rangjung small hydropower plant.

Figure 27: Institutional arrangement of the Rangjung small hydropower plant

5.3.4 Evaluation result of Rangjung MHP

Table 7 shows the evaluation results for the Rangjung MHP. For more detail, please refer to Appendix B, attached to this report.
Table 7: Evaluation results for the Rangjung SHP

<table>
<thead>
<tr>
<th>Project life cycle</th>
<th>Sustainability factors</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Planning</td>
<td>Socio-cultural respect</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Community participation</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Political cohesion &amp; policy support</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Economic sustainability</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Environmental sustainability</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td><strong>17/20</strong></td>
</tr>
<tr>
<td>Conceptual design and feasibility</td>
<td>Socio-cultural respect</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Community participation</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Political cohesion &amp; policy support</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Economic sustainability</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Environmental sustainability</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td><strong>14/20</strong></td>
</tr>
<tr>
<td>Design and action planning</td>
<td>Socio-cultural respect</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Community participation</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Political cohesion &amp; policy support</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Economic sustainability</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Environmental sustainability</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td><strong>13/20</strong></td>
</tr>
<tr>
<td>Implementation</td>
<td>Socio-cultural respect</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Community participation</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Political cohesion &amp; policy support</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Economic sustainability</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Environmental sustainability</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td><strong>11/20</strong></td>
</tr>
<tr>
<td>Operation and maintenance</td>
<td>Socio-cultural respect</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Community participation</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Political cohesion &amp; policy support</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Economic sustainability</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Environmental sustainability</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td><strong>9/20</strong></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>64/100</strong></td>
</tr>
</tbody>
</table>

From the foregoing project evaluation result of the Rangjung SHP, the score is highest (17/20) during the time of project planning. All sustainability factors are well addressed during this phase. The total score for conceptual design and feasibility is 14/20 and 13/20 for design and action planning, which is also a good score. During these two phases of the project life cycle, the socio-cultural respect and community participation were not well addressed.

For the time of implementation, the scores are very poor for socio-cultural respect, economic sustainability, and environmental sustainability. This can mainly be attributed to practical limitations faced during the time of construction and commissioning. All projects are time bound, and to meet the deadlines, the project implementers get less time to consider holistic approaches.

The total score for the operation and maintenance stage is the worst (9/20). The plant operators are mainly concerned about generating power without any disruption. In doing so, the local people are less and less involved. The environmental concerns like proper disposal of wastes and the aquatic life of the river systems are not well addressed.
5.4 Getena Solar Project

5.4.1 Project background

The Getena model is one of the most infamous solar home lighting projects implemented by the Department of Renewable Energy. This model is an archetypical example of a project where there is a well intended management model being framed, but it failed to yield any promising result, when implemented. This model was conceptualised by the erstwhile DOE after its earlier solar programs, which were highly subsidised faced series of sustainability issues. This initiative by the Government was an attempt to embrace a new management model, which is practicable and socially acceptable.

Figure 28: A prototype of a Bhutanese house with a solar panel (Source: MOEA 2012)

Getena is a small block, consisting of remote villages in the Chukha district in south western Bhutan. It has got around 132 households, one Basic Health Unit (BHU), one Natural Resource Centre and a primary school. Prior to the year 2000, the people of Getena had no access to modern forms of energy services. The fuel wood and kerosene were the predominant forms of fuel used by the community for cooking and lighting purposes. The people are mostly small farmers who still practice subsistence farming, depending on agriculture and livestock, leading the life of pre-modern era.
The Department of Renewable Energy (erstwhile DOE) initiated a pilot project in 2005 to electrify these households through solar home lighting systems. The off-grid electrification was one of the main mandates of the Department and this project was one of these programmes (Tshering 2006). The following are some of the main objectives of the Getena pilot project:

1. To electrify Getena households through solar home systems,
2. To initiate a revolving fund mechanism,
3. To create a Village Solar Committee (VSC) for sustainable management,
4. To reduce fuel wood and kerosene consumption,
5. To address health, education and gender issues

The Government of Bhutan provided a capital subsidy, where the upfront capital cost and installation charges were borne by the government. However, the responsibility to keep the systems operational was handed over to the community, through the creation of a Village Solar Committee (VSC). The revolving fund mechanism was started, where each household had to contribute Nu.5000 (AUD 100) upfront. This is not a contribution towards the capital cost of the systems, but it remains in the community’s account for future O&M requirements. The amount collected was deposited in a local bank (Bank of Bhutan, Chukha) under the Getena community’s account. The fund was managed by the VSC, starting from collection to depositing it in the bank and maintaining the records. The idea behind the fund was that, whenever a household collects spare parts, the amount is deducted from his initial deposit. The household has to replenish the fund as and when a minimum limit is reached.

Figure 29: A villager inspecting his solar panel on his rooftop (Source: MOEA 2012)
In addition to their initial deposits, each household had to contribute Nu.30 (AUD 0.6) per month to meeting the local technician’s salary. The local technicians were supposed to look after basic maintenance aspects of the systems in the village, and seek necessary assistance for complicated technical issues from DOE as and when warranted. Figure 30 shows the institutional and financial arrangement for the Getena solar energy project.

5.4.2 Evaluation of the Getena solar project

Table 8 shows the evaluation results for the Getena solar home lighting system project. The detailed evaluation report for the same is attached as Appendix C.
The project planning stage scores the maximum points (13/20). The total score is not up to the mark, as one would expect. This shows that the project was not planned in a coherent manner from the beginning. The socio-cultural respect, political cohesion and policy support framework, and environmental sustainability factors were not addressed properly during the planning process.

The poor project planning was followed by a poor design and action planning phase. The scores for conceptual design and feasibility, and design and action planning are 10/20 and 7/20 respectively. The erstwhile Department of Energy used a rough solar radiation value of 4kWh/m²/day, irrespective of location and time of the year. When inaccurate data are being used, it leads to wrong design, which is one of the reasons of failure of the solar projects.

The scores for project implementation (8/20), and O&M (8/20) are also very poor. The economic and environmental sustainability scores are very low. The people of Getena failed to honour the initial agreement of contributing Nu.5000 (AUD 100) towards a revolving fund. The monthly collection of Nu.30 (AUD 0.6) per household to meet local technicians’ salary was also not honoured. The used batteries pose serious environmental concerns as there is no proper arrangement to recycle or dispose of them in a well planned manner.
5.5 Barefoot College (BC) Model

5.5.1 Project background

The Barefoot College is a non-governmental organisation (NGO), established in 1972 at Tilonia in Rajasthan, India. This organisation has been providing basic services and solutions to rural problems with an objective of making a marginalised section of society, self-reliant and sustainable. The BC has been actively engaged in solar energy programs, water issues, health care, rural handicraft development, women’s empowerment and waste land management issues over last the 40 years (BC 2012).

In the year 2007-08, the Asian Development Bank selected the BC to carry out a solar energy project in Bhutan, to electrify remote households under the Japanese Fund for Poverty Reduction (JFPR) grant. In an endeavour to address sustainability issues with regard to solar energy programmes in Bhutan, it was anticipated that the ‘barefoot approach’ should be used to test, if such a model would work in Bhutan. With the funding from the ADB, the BC in coordination with the DOE, 504 houses in 13 districts were electrified using solar home lighting systems. The BC also trained 35 women (Barefoot solar engineers) from these villages for 6 months in India, on the operation and maintenance aspects (BC 2008).

Figure 31: Bhutan map showing the BC solar project sites (Source: BC 2008)
Dorji (2009) has unwittingly mentioned that the foregoing model is the ‘Tarayana Model’, which in fact, is a Barefoot College model. The Tarayana Foundation, an NGO in Bhutan had no role in masterminding this model. The Tarayana Foundation would have provided facilitation during the time of project implementation. The fundamental concept of the model was based solely on the belief, experience and expertise of the BC, in overcoming rural energy problems through the application of ‘barefoot solutions’.

It is a well accepted fact, that a lack of energy services is linked to a lack of opportunities and it is strongly linked to poverty in the developing world. The provision of energy services to the people has a multidimensional role in the society in bringing positive socio-economic impacts. The following list highlights some of the salient objectives of the solar energy program implemented by the BC:

1. To provide sustainable and clean energy to isolated villages,
2. To train local women as Barefoot Solar Engineers for O&M, and
3. To establish rural electric workshops in the villages

The Department of Renewable Energy (DRE) was designated an executing agency, on behalf of the Royal Government of Bhutan and the Barefoot College, as an implementing agency of the project. The project had a steering committee chaired by Director General of erstwhile Department of Energy and they met on quarterly basis to provide overall guidance and direction of the project. Figure 32 shows the rural workshop and solar engineers initiated by the BC.

Figure 32: A rural electronics workshop and BC Solar Engineers  (Source: BC 2008)
The BC, as an international NGO, was responsible for the project implementation, inclusive of community mobilization, education and awareness raising, livelihood enhancement, as well as developing and strengthening the community based organisation and institutional mechanisms (ADB 2011). Figure 33 shows the schematic project implementation arrangement.

Figure 33: JFPR Project implementation arrangement (Source: Adapted from ADB 2011)

5.5.2 Evaluation of the BC solar project

The following table shows the evaluation results for the Barefoot College solar project. A detailed evaluation report is attached as Appendix D.

Table 9: Evaluation result of BC project

<table>
<thead>
<tr>
<th>Project life cycle</th>
<th>Sustainability factors</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Socio-cultural respect</td>
<td>Community participation</td>
</tr>
<tr>
<td>Project Planning</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Conceptual design and feasibility</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Design and action planning</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Implementation</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Operation and maintenance</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>13/20</td>
<td>11/20</td>
</tr>
</tbody>
</table>
The Barefoot College solar project scores fairly well for project planning, conceptual design and feasibility, and implementation stages with 13/20, 12/20 and 12/20 respectively. As per the project report document, efforts have been made to address social, economic and environmental issues. In order to operate and maintain the solar systems in the long run, capacity building of the local people was one of the main components of the project.

Various consultation meetings were held by the representatives of the Barefoot College and the Department of Renewable Energy with the local people. There were thirty five women who were nominated by the communities, from different districts of Bhutan to be trained on operation and maintenance aspects of solar home lighting systems. These women were trained for six months at the Barefoot College in India.

There were eighteen rural electronic workshops established across the project sites to carry out major and minor repairs of the solar systems. This is one of the new initiatives taken by the BC to address the maintenance issues at grass root level.

The scores for the design and action planning, and the O&M stages were 8/20 each, which is very low. The reason for this is that the recommended tasks for most of the sustainability factors were not completed during these two stages. For instance, proper solar resource assessment was not carried out. The systems were undersized (37 Wp panel with 40 Ah deep cycle battery) when compared to government funded projects. Such systems have failed to meet the expectations of people, which ultimately forced people to overuse batteries, leading to failure of batteries.

The monthly fee was not enforced, much to the discouragement of women solar engineers, who were suppose to make a living through such financial arrangement. Consequently, there was no sense of ownership amongst the people. To retain solar technicians in the village became an uphill task. The long term sustainability of this project is questionable, as these problems begin to surface.

5.5 Review and comparison of results of case studies

In total, four renewable energy projects in Bhutan (2 solar projects and 2 small/micro hydro projects are evaluated based on certain evaluation criteria (see Appendices). The evaluation results show the strengths and weaknesses in different life cycle stages, which contribute to
the overall success or failure of the projects. The overview of the assessments is presented by the project life cycle stage and the sustainability factors.

5.5.1 Review of small/micro hydro projects

An assessment overview of the Chendebji MHP and the Rangjung SHP are shown in figure 34.

From the above two web diagrams, it can be seen that the general patterns of the project life cycle stages scores are similar in nature. The scores are high for the project planning stage, and scores for the design stage are not bad either. However, the score is very poor for the operation and maintenance stage in both the cases.

The Rangjung SHP is operated and maintained by a utility company (BPC). Therefore, the community has no roles and responsibilities to decide its O&M aspects. The Chendebji MHP is managed by the community, but the local plant operators are not well qualified enough to keep track record of plant’s operation and to perform timely performance analysis.

The economic and environmental sustainability is also questionable, as both the plants operate mostly under subsidy from the government, since the revenue they generate is not sufficient to justify its O&M costs. The impact on the aquatic life of the plants is also not monitored and reported during this stage.
The comparison of the two hydropower projects, with respect to life cycle performance is shown in figure 35.

![Project life cycle comparison](image)

**Figure 35: Life cycle comparison of Chendebji MHP and Rangjung SHP**

The project breakdown by the sustainability factors are shown in figure 36:

![Project breakdown by sustainability factors](image)

**Figure 36: Project breakdown by sustainability factors**
From figure 36, it can be seen that the Chendebji MHP, which is a community managed project receives more balanced sustainability scores, except for socio-cultural respect. But, this is not true for the Rangjung SHP, which is a utility managed project. The political cohesion and policy support scores the highest. As in the Chendebji’s case, the score is very low for socio-cultural respect, which is mainly because; such projects are mainly designed in a top down approach, where the community involvement is very little.

The project breakdown by sustainability factors for the above two hydro projects is shown in figure 37. From the figure, it can be seen that scores are generally identical with the highest scores being given to political cohesion and policy support.

![Figure 37: Project breakdown comparison of sustainability factors](image)

<table>
<thead>
<tr>
<th></th>
<th>Socio-cultural respect</th>
<th>Community participation</th>
<th>Political cohesion &amp; policy support</th>
<th>Economic sustainability</th>
<th>Environmental sustainability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chendebji</td>
<td>60%</td>
<td>60%</td>
<td>80%</td>
<td>65%</td>
<td>65%</td>
</tr>
<tr>
<td>Rangjung</td>
<td>50%</td>
<td>60%</td>
<td>80%</td>
<td>65%</td>
<td>65%</td>
</tr>
</tbody>
</table>
5.5.2 Review of solar projects

An assessment overview of the Getena solar project and the Barefoot College solar project are shown in figure 38.

![Project breakdown by life cycle stages](image)

**Figure 38:** Project breakdown by life cycle stages for the Getena and BC projects

The project evaluation scores are similar, except for the project implementation stage, where the BC project has performed better than the Getena solar project. Both the projects score highest at the project planning stage and the lowest during the operation and maintenance stage. The general scores of the two projects gradually fall, as the project progresses towards the operation and maintenance stage. Such a phenomenon demonstrates the fact that, the project developers have sufficient knowledge about sustainability but have failed to transfer this knowledge to the concerned community.

The transfer of knowledge about sustainability is not automatic, from the project developer to the community. The rural people of Bhutan are generally illiterate, which makes difficult for them to be convinced and educated on the sustainability issues. Especially, in developing countries, the overall expectations of the people are that the government is responsible for everything. Due to such prevailing social perception, it becomes an uphill task for the project developers to instil the sense of ownership in people.
The above findings are further supported by the bar diagram as shown in figure 39:

Figure 39: Comparison of life stage scores of the Getena and BC projects

The project breakdown by the sustainability factors are as shown in the web diagram below. A distinct similarity between the Getena project and the BC project is that, each project performs reasonably well in terms of community participation; political cohesion and policy support, but performs very poorly in economic and environmental sustainability.

Figure 40: Project breakdown by sustainability factors
The Getena solar project is a government funded project, where planning and design of the project was executed in a top down approach. The result of such an approach is reflected by poor score for socio-cultural respect. This shortcoming is slightly improved in the BC project, which was implemented by an NGO. This shows that NGOs can work in closer collaboration with the people at the grass roots level.

It can also be seen that both the solar projects perform poorly, with respect to economic and environmental sustainability. There were no financial contributions towards capital costs, and monthly contributions to meet the salaries of local technicians were not honoured by the communities, thus, failing to encourage local technicians to maintain the systems and in some cases, local technicians have migrated to urban areas where they can use their expertise to make living. With regard to environmental sustainability, there are no plans to recycle lead acid batteries or strategies to dispose of them in an appropriate manner.

The project breakdown comparison in terms of sustainability factors is as shown in figure 41.

![Figure 41: Comparison of sustainability factors of two solar PV projects](image)

<table>
<thead>
<tr>
<th></th>
<th>Socio-cultural respect</th>
<th>Community participation</th>
<th>Political cohesion &amp; policy support</th>
<th>Economic sustainability</th>
<th>Environmental sustainability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Getena</td>
<td>40%</td>
<td>65%</td>
<td>60%</td>
<td>40%</td>
<td>20%</td>
</tr>
<tr>
<td>BC</td>
<td>65%</td>
<td>55%</td>
<td>60%</td>
<td>50%</td>
<td>35%</td>
</tr>
</tbody>
</table>
5.5.3 Overall comparison of solar and micro/small hydro projects

In order to understand, which of these two renewable energy options can best meet the energy demand in rural Bhutan in a sustainable manner, a comparison is drawn, based on the above evaluations. The average scores of each technology for life cycle stages and sustainability factors are calculated and comparisons are made based on these values.

From figure 42, we can conclude that the average scores of small/micro hydropower technology are higher than the average scores of solar PV technology. This is mainly because; the micro/small hydro projects are constructed in a planned and coherent manner, involving a lot of effort and resources. However, this is not true for solar projects in Bhutan. In some cases, solar home lighting projects are considered as pre-electrification processes, where the government intends to extend the grid in future if possible. The first preference of the people is always grid, no matter how far their houses are from the grid infrastructure. The people accept the solar option as the last resort. In either case, the sense of ownership of the project is very low, which is reflected in the evaluation scores.
The average project breakdown scores for sustainability factors are shown in figure 43.

![Figure 43: The project breakdown comparison by sustainability factors](image)

The overall average scores for small/micro hydro technology are higher than the solar PV technology. The difference in score is quite small for socio-cultural respect and community participation, but it is substantial for political cohesion and policy support, economic sustainability and environmental sustainability factors. Small/micro hydro projects do have dedicated operators on site for system upkeep, but for solar systems, once installed, they remain unattended and are not maintained until the systems start showing signs of failure. For instance, the solar panels remain uncleansed from the dusts, dirt and bird droppings which can reduce its efficiency.
The overall comparison of two different technologies can also be represented by web diagrams as shown in figure 44.

Figure 44: Overall comparison of solar and micro/small hydro projects in terms of sustainability

From the figure 44, it can be seen that the area covered by average scores of small/micro hydropower projects exceeds the area covered by the average scores of the solar projects. This clearly shows that micro/small hydropower projects are more sustainably managed than solar projects. The utility of the micro hydropower projects is more than solar, hence, greater customer satisfaction and the willingness to pay for the service is greater.

However, the utility of the solar systems is limited to lighting only; whereas people’s requirements go beyond such basic lighting facility. As the living standard of people increases, they too want to use rice cookers, water heaters and fridges, etc. The reliability of solar energy output is also questionable as its resource is intermittent in nature. The limitations of solar technology reduce the people’s confidence and sense of ownership, which ultimately has a detrimental impact on the larger goal of sustainability.
CHAPTER VI
Conclusions and Recommendations

6.1 Conclusions

Rural electrification is considered to be one of the most important developmental activities in Bhutan. Bhutan aspires to achieve 100% electrification by 2013 compared with the initial plan to achieve this target in 2020. The extension of the grid, standalone micro hydropower and solar home lighting systems are some of the options considered by the government. To this end, a large proportion of the national budget and donors’ funds are allocated to accelerate the rural electrification programmes.

The rural electrification is one of the most highly subsidised projects in Bhutan. For those households connected to the grid, the maximum tariff is Nu. 2.14/kWh (AUD 4¢/kWh), which is one of the lowest tariff rates in the world (BPC 2012). The stand alone systems (micro hydro and solar) are provided to the people with 100% capital subsidy.

Bhutan has a long history of sustainability issues, particularly, the off-grid systems. The revenue generated through the sale of electricity from micro hydropower plants is not enough to meet the operation and maintenance costs (Dorji 2007) and many solar projects have failed over the years. Such challenges are simply going to get bigger, as more of such systems are put in place. Without proper strategies to tackle these issues, the sustainability problems will continue, thus tarnishing the reputation of renewable energy systems.

In an attempt to address the aforementioned sustainability issues, an assessment matrix framework is being used, so that it can serve as a guide to decision makers, project designers and project managers. Identifying the fundamental problems from the very early stages of the project, and taking remedial measures in time, can solve many of teething problems and increase its sustainability. The assessment tool was used to carry out ex post evaluation for four projects, and based on assessment criteria; it was found that micro hydro projects are more sustainable when compared to solar PV projects in Bhutan.
McCornville (2006) pointed out that, there is a likelihood of treating different stages of project in isolation by creating guidelines. It is essential to keep in mind that, all the stages of project are heavily interrelated and interconnected. Each of them cannot be treated in isolation. Another drawback of such a framework is that, it cannot be used for universal application without changing the criteria. The practitioners must use fair judgement while selecting guidelines for assessment, so that it becomes relevant and applicable to a specific project.

### 6.2 Recommendations

#### 6.2.1 Resource assessment

Bhutan does not have reliable and credible renewable energy resource data at present. Most of the solar home lighting system designs are based on 4kWh/m²/day, which is an approximate assumption. It is essential to note that, resources availability varies from place to place and from time to time. The latest information on solar and wind resources is the NREL Report 2009, which is mostly based on satellite imaging. There is a need to validate those data with ground measurements. There is also no resource assessment carried out for small and micro hydropower, in spite of having numerous rivers and streams in Bhutan. There exist a huge opportunity to tap such resource and enhance energy security in the country.

#### 6.2.2 Design and Technology

Renewable energy is a highly site specific resource. It is important to choose an appropriate technology to meet a particular demand, based on resource availability. In Bhutan, solar home lighting systems are mainly used in off-grid areas, irrespective of resource availability. This could be one of the main reasons, why solar systems have a very poor success rate. Other options like wind, micro hydropower and biomass technologies or combination of these options (hybrid system) need to be explored so that the communities get the right technology to meet their energy demands.
6.2.3 Holistic implementation approach

Most of the renewable energy projects in Bhutan are outsourced to private contractors to undertake the implementation process. As the project progresses from planning and design to the implementation stage, the involvement of local people decreases. This is a crucial diversion point where communities can get excluded from the project activities. The views, concerns and issues of the community are not important to the private contractors, as it is going to take time and resources to incorporate such social dimensions. The government should find avenues to encourage private contractors to engage local people throughout the implementation process.

6.2.4 Load growth

It’s normal to see the demand for energy increase over time, for different reasons. Therefore, a provision must be built into the design stage itself to accommodate future load growth. A strong advocacy program is necessary to educate the people, for instance, the consumers must know that if they wish to add load to the system in the future, they must add system components like solar panels. The same applies to micro hydro plants in choosing flow rate and the head of the system.

6.2.5 Resuscitation of failed systems

Many solar systems have failed over the years, mainly due to the breakdown of batteries and controllers. However, most of the solar panels and wirings are intact. The economic benefit is going to be immense, by reviving these systems with new batteries, LEDs and controllers, rather than restarting the project from scratch.

6.2.6 Productive use of renewable energy systems

Although, many rural households are electrified through grid or off-grid means, it has failed to stimulate productive use of such technologies. The ability of the people to pay for energy services is very low in rural Bhutan. The people have to take their access to modern energy services as an opportunity to engage in income generating activities, which can not only
enhance a family’s income, but will also help to sustain renewable energy technologies in the long run.

6.2.7 Incentives and subsidy

There exists a huge disparity between those households connected to grid and off-grid facilities. Those households connected to the grid, enjoy both capital and O&M subsidy, whereas off-grid households are provided with only a capital subsidy. There is a need to strike a balance between these two, by creating a judicious and cautious incentive and subsidy scheme in Bhutan.

6.3 Recommended future work

As is evident from the foregoing chapters, the life cycle evaluations of the four different case studies were purely based on the literature survey. On site survey and consultation was not possible considering the time, distance and resource constraints. Some readers may find this to be one of the main drawbacks of this report. This is true. In order to fill this gap, an extensive literature review was conducted, based on publication by the different organisations, institutions, authors, and media reports, so as to make the project evaluations balanced, fair and transparent. I have also used my own personal judgement, based on six years of my experience with the off-grid electrification projects in Bhutan.

Putting the above shortcomings aside, the project life cycle assessment matrix framework introduced in chapter 4, is a powerful tool. It provides a way to incorporate different sustainability factors and the project life cycles in one matrix framework. Another very important advantage of this assessment framework is that, the criteria are not rigid. The project evaluators can tailor the criteria as per their requirement and understanding. Such flexibility offered by this tool, makes it suitable to apply to a wide range of projects.

It is recommended to carry forward this study with the field visits, so as to bring greater accuracy in the ex post evaluation scores. It would also be worthwhile to test this matrix framework for other renewable energy projects like biomass, wind and tidal systems and examine its appropriateness and applicability.
REFERENCES

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APPENDICES

Appendix A: Evaluation of Chendebji Micro Hydro Project

**Element (1, 1) – Project planning: Socio-cultural respect**
- Identify traditional beliefs and social preferences in using a particular energy system. ✔
- Recognise gender role in using energy. ☑
- Understanding the level of community’s knowledge about energy. ☑
- Does the target community have other preferred energy supply options? ☑
  (Score: 3)

**Element (1, 2) Project planning: Community participation**
- Understand local development priorities through public consultations. ✔
- Identification of stakeholders and local leaders who can make decisions. ✔
- Determine the type of political organisation and cohesion at local level. ✔
- Reach to a consensus that proposed energy option is appropriate and acceptable. ✔
  (Score: 4)

**Element (1, 3) Project planning: Political cohesion and policy support**
- Conduct situational analysis of regional and national issues, such as political structure and stability, government policies and foreign aid. ✔
- Ensure that proposed initiative is in line with the regional and national development priorities. ✔
- Research the history of energy projects implemented in the past. ☑
- Is there a robust institutional set up to support such initiatives? ✔
  (Score: 3)

**Element (1, 4) Project planning: Economic sustainability**
- Understand the overall economic situation at national including poverty level, living costs, unemployment rate and resource flow. ✔
- Understand how general economic situation is affected by prevailing energy issues. ✔
- Identify the community’s monetary and non-monetary resources. ✔
- Study and understand the willingness of the people to pay for the energy services. ✔
  (Score: 4)

**Element (1, 5) Project plan: Environmental sustainability**
- Identify indigenous resources for energy generation. ✔
- Gather climate and environmental factors that need to be reflected in project design. ✔
- Identify potential environmental issues at local, regional and national level. ✔
- Determine community’s willingness to accept intrusion into their local environment. ✔
  (Score: 4)
Element (2, 1) Conceptual design/feasibility: Socio-cultural respect

- Determine how energy service intervention will have impact on community’s cultural roles.
- Assess community’s capacity to operate and maintain the energy systems.
- Does system design respects gender roles.
- Evaluate potential social ramifications through such designs. (Score: 3)

Element (2, 2) Conceptual design/feasibility: Community participation

- The project objectives are clearly defined and accepted by all concerned stakeholders.
- Identify a representative committee who can make decision on behalf of the community.
- Provide viable technological options to the community for their evaluation and feedbacks.
- Community formally selects an appropriate option understanding its associated constraints and limitations. (Score: 2)

Element (2, 3) Conceptual designs/feasibility: Political cohesion/policy support

- Develop working relationship with partner organisations.
- Consult designs and feasibility studies of other similar projects.
- Integrate existing technologies/programs into to conceptual designs.
- Explore potential organisations and institutions for supports (fund/expertise). (Score: 3)

Element (2, 4) Conceptual designs/feasibility: Economic sustainability

- Estimate upfront cost of conceptual designs.
- Estimate O&M and disposal cost.
- Assess ability and willingness to pay for energy services.
- Conduct economic viability of project for long term sustainability. (Score: 3)

Element (2, 5) Conceptual design/feasibility: Environmental sustainability

- Evaluate the capacity of sustainable energy use.
- Consider how different environmental constraints will impact the conceptual designs.
- Assess land requirement for various energy supply options.
- Assess raw material required for energy generation for different options. (Score: 3)
Element (3, 1) Design and action planning: Socio-cultural respect

- Understand the social structure of the community. ✔
- Consider the seasonality and availability of local workforce. ✗
- Understand the socially accepted gender roles and responsibilities. ✔
- Determine the gender equity through resource and opportunity distributions. ✗  
  (Score: 2)

Element (3, 2) Design and action planning: Community participation

- Solicitation of community’s input to refine and finetune the project design. ✗
- Final design is accepted based on community’s consensus. ✔
- Community’s members are fully involved in sequencing implementation schedule. ✗
- Mutual agreement of time schedule between project developers and local people. ✔

  (Score: 2)

Element (3, 3) Design and action planning: Political cohesion/policy support

- Delineation of action plans for different parties involved. ✔
- Agreement on financial plans and commitments. ✔
- Mutually agreeable project timeline is framed taking the convenience of different parties into consideration. ✗
- Final design and action plans are presented to all parties involved. ✔

  (Score: 3)

Element (3, 4) Design and action planning: Economic sustainability

- Verification of costs and availability of resources. ✔
- Confirm community’s contribution both monetary and non-monetary resources. ✔
- Finalization of project cost estimate by taking local contributions into consideration. ✔
- Development of locally oriented action plan of the project. ✔

  (Score: 3)

Element (3, 5) Design and action planning: Environmental sustainability

- Use of locally available renewable resources. ✔
- Minimisation of wastes, pollutants and energy considered. ✔
- Availability of seasonal resources is considered. ✔
- Develop a firm environmental mitigation plans to correct any adverse impacts. ✔

  (Score: 4)

Element (4, 1) Implementation: Socio-cultural respect

- Setting of a realistic implementation schedule based on availability and working culture of local people. ✔
- Consider force majeure throughout the implementation process. ✗
- Encourage women participation in implementing the project.
- Give due respect to local monument and shrines. (Score: 2)

**Element (4, 2) Implementation: Community participation**

- Organisation of periodic public meetings and consultations.
- Work closely with local leaders in organising labour force required.
- On-the-job training for local people.
- Set up proper communication channels to report the work progress and problems. (Score: 3)

**Element (4, 3) Implementation: Political cohesion/policy support**

- Keep partner institutions fully informed on training and labour requirements.
- Discuss different roles and responsibilities of different parties.
- Construction site should be open and accessible for independent bodies for inspection.
- All parties should be fully informed on the status and progress of construction works. (Score: 3)

**Element (4, 4) Implementation: Economic sustainability**

- Encouraging community’s contribution towards the project.
- Use of locally available resources and expertise.
- Keeping track record of expenditures and reviewing time to time.
- Sharing financial report with the community, hence increasing transparency. (Score: 2)

**Element (4, 5) Implementation: Environmental sustainability**

- Environmental constraints used during the design phase observed during implementation phase.
- Minimisation of environmental impacts through close monitoring process.
- Initiate sensitisation regarding waste disposal and reuse.
- Restore damaged ecosystem after the implementation works. (Score: 2)

**Element (5, 1) Operation and maintenance: Socio-cultural respect**

- Identify unanticipated socio-cultural constraints faced during the time of project use.
- Discuss maintenance issues faced during the time of operation.
- Ensure that the cost and benefits are equally shared amongst all parties concerned.
- Assess how gender role and traditional beliefs affect the project’s operation and maintenance works. (Score: 1)
Element (5, 2) Operation and maintenance: Community participation

- Formation of working village committee to oversee the overall management of the project.☑
- Involvement of community for operation and maintenance of project. ☑
- Keeping track record of project’s performance and submit periodic reports to project developers.☑
- The community should be empowered to solve conflicting interests and issues at local level. ☑ (Score: 3)

Element (5, 3) Operation and maintenance: Political cohesion/policy support

- Formal handing and taking over of the project. ☑
- Defining clear roles and responsibilities of different organisations. ☑
- Local institution and community is empowered to make certain decisions on behalf of the community.☑
- Frame a strategy to share monitoring and evaluation reports with all partner institutions from time to time. ☑ (Score: 3)

Element (5, 4) Operation and maintenance: Economic sustainability

- Estimate a long term O&M cost which is realistic. ☑
- Assess the affordability and willingness of community to pay for service. ☑
- Estimate the long term financial gap that might arise for system upkeep. ☑
- Workout subsidy and financial support needed based on robust financial mechanisms. ☑ (Score: 2)

Element (5, 5) Operation and maintenance: Environmental sustainability

- Develop plans to minimise environmental damage as far as possible. ☑
- Seek environmentally friendly end-of-pipe solutions to treat and dispose wastes properly. ☑
- Explore alternative plans to reduce ecological impacts. ☑
- Keep monitoring and reporting project performance for future reference. ☑ (Score: 1)
Appendix B: Evaluation of Rangjung Small Hydro Project

**Element (1, 1) – Project planning: Socio-cultural respect**

- Identify traditional beliefs and social preferences in using a particular energy system. ✓
- Recognise gender role in using energy. ✓
- Understanding the level of community’s knowledge about energy. □
- Does the target community have other preferred energy supply options? ✓
  (Score: 3)

**Element (1, 2) Project planning: Community participation**

- Understand local development priorities through public consultations. ✓
- Identification of stakeholders and local leaders who can make decisions. ✓
- Determine the type of political organisation and cohesion at local level. ✓
- Reach to a consensus that proposed energy option is appropriate and acceptable. ✓
  (Score: 4)

**Element (1, 3) Project planning: Political cohesion and policy support**

- Conduct situational analysis of regional and national issues, such as political structure and stability, government policies and foreign aid. ✓
- Ensure that proposed initiative is in line with the regional and national development priorities. ✓
- Research the history of energy projects implemented in the past. □
- Is there a robust institutional set up to support such initiatives? ✓
  (Score: 3)

**Element (1, 4) Project planning: Economic sustainability**

- Understand the overall economic situation at national including poverty level, living costs, unemployment rate and resource flow. ✓
- Understand how general economic situation is affected by prevailing energy issues. □
- Identify the community’s monetary and non-monetary resources. ✓
- Study and understand the willingness of the people to pay for the energy services. ✓
  (Score: 3)

**Element (1, 5) Project plan: Environmental sustainability**

- Identify indigenous resources for energy generation. ✓
- Gather climate and environmental factors that need to be reflected in project design. ✓
- Identify potential environmental issues at local, regional and national level. ✓
- Determine community’s willingness to accept intrusion into their local environment. □
  (Score: 3)
Element (2, 1) Conceptual design/feasibility: Socio-cultural respect

- Determine how energy service intervention will have impact on community’s cultural roles.✓
- Assess community’s capacity to operate and maintain the energy systems.✗
- Does system design respects gender roles.✓
- Evaluate potential social ramifications through such designs.✗ (Score: 3)

Element (2, 2) Conceptual design/feasibility: Community participation

- The project objectives are clearly defined and accepted by all concerned stakeholders.✓
- Identify a representative committee who can make decision on behalf of the community. ✓
- Provide viable technological options to the community for their evaluation and feedbacks.✗
- Community formally selects an appropriate option understanding its associated constraints and limitations.✗ (Score: 2)

Element (2, 3) Conceptual designs/feasibility: Political cohesion/policy support

- Develop working relationship with partner organisations. ✓
- Consult designs and feasibility studies of other similar projects.✓
- Integrate existing technologies/programs into to conceptual designs.✗
- Explore potential organisations and institutions for supports (fund/expertise).✓ (Score: 3)

Element (2, 4) Conceptual designs/feasibility: Economic sustainability

- Estimate upfront cost of conceptual designs.✓
- Estimate O&M and disposal cost. ✓
- Assess ability and willingness to pay for energy services. ✓
- Conduct economic viability of project for long term sustainability.✗ (Score: 3)

Element (2, 5) Conceptual design/feasibility: Environmental sustainability

- Evaluate the capacity of sustainable energy use. ✓
- Consider how different environmental constraints will impact the conceptual designs. ✓
- Assess land requirement for various energy supply options. ✓
- Assess raw material required for energy generation for different options.✗ (Score: 3)

Element (3, 1) Design and action planning: Socio-cultural respect
- Understand the social structure of the community. ✓
- Consider the seasonality and availability of local work force. ✗
- Understand the socially accepted gender roles and responsibilities. ✓
- Determine the gender equity through resource and opportunity distributions. ✗
  (Score: 2)

**Element (3, 2) Design and action planning: Community participation**

- Solicitation of community’s input to refine and finetune the project design. ✗
- Final design is accepted based on community’s consensus. ✓
- Community’s members are fully involved in sequencing implementation schedule. ✗
- Mutual agreement of time schedule between project developers and local people. ✓
  (Score: 2)

**Element (3, 3) Design and action planning: Political cohesion/policy support**

- Delineation of action plans for different parties involved. ✓
- Agreement on financial plans and commitments. ✓
- Mutually agreeable project timeline is framed taking the convenience of different parties into consideration. ✓
- Final design and action plans are presented to all parties involved. ✓
  (Score: 3)

**Element (3, 4) Design and action planning: Economic sustainability**

- Verification of costs and availability of resources. ✓
- Confirm community’s contribution both monetary and non-monetary resources. ✓
- Finalization of project cost estimate by taking local contributions in to consideration. ✓
- Development of locally oriented action plan of the project. ✓
  (Score: 3)

**Element (3, 5) Design and action planning: Environmental sustainability**

- Use of locally available renewable resources. ✓
- Minimisation of wastes, pollutants and energy considered. ✓
- Availability of seasonal resources is considered. ✓
- Develop a firm environmental mitigation plans to correct any adverse impacts. ✗
  (Score: 3)

**Element (4, 1) Implementation: Socio-cultural respect**

- Setting of a realistic implementation schedule based on availability and working culture of local people. ✗
- Consider force majeure throughout the implementation process. ✗
- Encourage women participation in implementing the project. ✗
- Give due respect to local monument and shrines. ✓ (Score: 1)
Element (4, 2) Implementation: Community participation

- Organisation of periodic public meetings and consultations. ✔
- Work closely with local leaders in organising labour force required. ✔
- On-the-job training for local people. ✔
- Set up proper communication channels to report the work progress and problems. ✗ (Score: 3)

Element (4, 3) Implementation: Political cohesion/policy support

- Keep partner institutions fully informed on training and labour requirements. ✔
- Discuss different roles and responsibilities of different parties. ✔
- Construction site should be open and accessible for independent bodies for inspection. ✗
- All parties should be fully informed on the status and progress of construction works. ✔ (Score: 3)

Element (4, 4) Implementation: Economic sustainability

- Encouraging community’s contribution towards the project. ✔
- Use of locally available resources and expertise. ✔
- Keeping track record of expenditures and reviewing time to time. ✔
- Sharing financial report with the community, hence increasing transparency. ✗ (Score: 2)

Element (4, 5) Implementation: Environmental sustainability

- Environmental constraints used during the design phase observed during implementation phase. ✔
- Minimisation of environmental impacts through close monitoring process. ✔
- Initiate sensitisation regarding waste disposal and reuse. ✔
- Restore damaged ecosystem after the implementation works. ✗ (Score: 2)

Element (5, 1) Operation and maintenance: Socio-cultural respect

- Identify unanticipated socio-cultural constraints faced during the time of project use. ✗
- Discuss maintenance issues faced during the time of operation. ✔
- Ensure that the cost and benefits are equally shared amongst all parties concerned. ✗
- Assess how gender role and traditional beliefs affect the project’s operation and maintenance works. ✗ (Score: 1)

Element (5, 2) Operation and maintenance: Community participation
Formation of working village committee to oversee the overall management of the project. ☑️
Involvement of community for operation and maintenance of project. ☐
Keeping track record of project’s performance and submit periodic reports to project developers. ☑️
The community should be empowered to solve conflicting interests and issues at local level. ☐ (Score: 1)

**Element (5, 3) Operation and maintenance: Political cohesion/policy support**

- Formal handing and taking over of the project. ☑️
- Defining clear roles and responsibilities of different organisations. ☑️
- Local institution and community is empowered to make certain decisions on behalf of the community. ☐
- Frame a strategy to share monitoring and evaluation reports with all partner institutions from time to time. ☑️ (Score: 3)

**Element (5, 4) Operation and maintenance: Economic sustainability**

- Estimate a long term O&M cost which is realistic. ☐
- Assess the affordability and willingness of community to pay for service. ☑️
- Estimate the long term financial gap that might arise for system upkeep. ☑️
- Workout subsidy and financial support needed based on robust financial mechanisms. ☑️ (Score: 2)

**Element (5, 5) Operation and maintenance: Environmental sustainability**

- Develop plans to minimise environmental damage as far as possible. ☑️
- Seek environmentally friendly end-of-pipe solutions to treat and dispose wastes properly. ☑️
- Explore alternative plans to reduce ecological impacts. ☑️
- Keep monitoring and reporting project performance for future reference. ☑️ (Score: 2)
Appendix C: Evaluation of Getena Solar Project

Element (1, 1) – Project planning: Socio-cultural respect

- Identify traditional beliefs and social preferences in using a particular energy system. ✔
- Recognise gender role in using energy. ✔
- Understanding the level of community’s knowledge about energy. ❗
- Does the target community have other preferred energy supply options? ❗ (Score: 2)

Element (1, 2) Project planning: Community participation

- Understand local development priorities through public consultations. ✔
- Identification of stakeholders and local leaders who can make decisions. ✔
- Determine the type of political organisation and cohesion at local level. ✔
- Reach to a consensus that proposed energy option is appropriate and acceptable. ✔ (Score: 4)

Element (1, 3) Project planning: Political cohesion and policy support

- Conduct situational analysis of regional and national issues, such as political structure and stability, government policies and foreign aid. ✔
- Ensure that proposed initiative is in line with the regional and national development priorities. ✔
- Research the history of energy projects implemented in the past. ❗
- Is there a robust institutional set up to support such initiatives? ❗ (Score: 2)

Element (1, 4) Project planning: Economic sustainability

- Understand the overall economic situation at national including poverty level, living costs, unemployment rate and resource flow. ❗
- Understand how general economic situation is affected by prevailing energy issues. ✔
- Identify the community’s monetary and non-monetary resources. ✔
- Study and understand the willingness of the people to pay for the energy services. ✔ (Score: 3)

Element (1, 5) Project plan: Environmental sustainability

- Identify indigenous resources for energy generation. ✔
- Gather climate and environmental factors that need to be reflected in project design. ✔
- Identify potential environmental issues at local, regional and national level. ❗
- Determine community’s willingness to accept intrusion into their local environment. ❗ (Score: 2)
Element (2, 1) Conceptual design/feasibility: Socio-cultural respect

- Determine how energy service intervention will have impact on community’s cultural roles.
- Assess community’s capacity to operate and maintain the energy systems.
- Does system design respects gender roles?
- Evaluate potential social ramifications through such designs. (Score: 2)

Element (2, 2) Conceptual design/feasibility: Community participation

- The project objectives are clearly defined and accepted by all concerned stakeholders.
- Identify a representative committee who can make decision on behalf of the community.
- Provide viable technological options to the community for their evaluation and feedbacks.
- Community formally selects an appropriate option understanding its associated constraints and limitations. (Score: 2)

Element (2, 3) Conceptual designs/feasibility: Political cohesion/policy support

- Develop working relationship with partner organisations.
- Consult designs and feasibility studies of other similar projects.
- Integrate existing technologies/programs into conceptual designs.
- Explore potential organisations and institutions for supports (fund/expertise). (Score: 2)

Element (2, 4) Conceptual designs/feasibility: Economic sustainability

- Estimate upfront cost of conceptual designs.
- Estimate O&M and disposal cost.
- Assess ability and willingness to pay for energy services.
- Conduct economic viability of project for long term sustainability. (Score: 2)

Element (2, 5) Conceptual design/feasibility: Environmental sustainability

- Evaluate the capacity of sustainable energy use.
- Consider how different environmental constraints will impact the conceptual designs.
- Assess land requirement for various energy supply options.
- Assess raw material required for energy generation for different options. (Score: 2)

Element (3, 1) Design and action planning: Socio-cultural respect

- Understand the social structure of the community.
- Consider the seasonality and availability of local work force.
Understand the socially accepted gender roles and responsibilities.

Determine the gender equity through resource and opportunity distributions. (Score: 1)

**Element (3, 2) Design and action planning: Community participation**

- Solicitation of community’s input to refine and finetune the project design.
- Final design is accepted based on community’s consensus.
- Community’s members are fully involved in sequencing implementation schedule.
- Mutual agreement of time schedule between project developers and local people. (Score: 1)

**Element (3, 3) Design and action planning: Political cohesion/policy support**

- Delineation of action plans for different parties involved.
- Agreement on financial plans and commitments.
- Mutually agreeable project timeline is framed taking the convenience of different parties into consideration.
- Final design and action plans are presented to all parties involved. (Score: 3)

**Element (3, 4) Design and action planning: Economic sustainability**

- Verification of costs and availability of resources.
- Confirm community’s contribution both monetary and non-monetary resources.
- Finalization of project cost estimate by taking local contributions in to consideration.
- Development of locally oriented action plan of the project. (Score: 1)

**Element (3, 5) Design and action planning: Environmental sustainability**

- Use of locally available renewable resources.
- Minimisation of wastes, pollutants and energy considered.
- Availability of seasonal resources is considered.
- Develop a firm environmental mitigation plans to correct any adverse impacts. (Score: 1)

**Element (4, 1) Implementation: Socio-cultural respect**

- Setting of a realistic implementation schedule based on availability and working culture of local people.
- Consider force majeure throughout the implementation process.
- Encourage women participation in implementing the project.
- Give due respect to local monument and shrines. (Score: 2)

**Element (4, 2) Implementation: Community participation**
Sustainable management of renewable energy systems in the Kingdom of Bhutan

- Organisation of periodic public meetings and consultations.
- Work closely with local leaders in organising labour force required.
- On-the-job training for local people.
- Set up proper communication channels to report the work progress and problems. (Score: 3)

**Element (4, 3) Implementation: Political cohesion/policy support**

- Keep partner institutions fully informed on training and labour requirements.
- Discuss different roles and responsibilities of different parties.
- Construction site should be open and accessible for independent bodies for inspection.
- All parties should be fully informed on the status and progress of construction works. (Score: 2)

**Element (4, 4) Implementation: Economic sustainability**

- Encouraging community’s contribution towards the project.
- Use of locally available resources and expertise.
- Keeping track record of expenditures and reviewing time to time.
- Sharing financial report with the community, hence increasing transparency. (Score: 1)

**Element (4, 5) Implementation: Environmental sustainability**

- Environmental constraints used during the design phase observed during implementation phase.
- Minimisation of environmental impacts through close monitoring process.
- Initiate sensitisation regarding waste disposal and reuse.
- Restore damaged ecosystem after the implementation works. (Score: 0)

**Element (5, 1) Operation and maintenance: Socio-cultural respect**

- Identify unanticipated socio-cultural constraints faced during the time of project use.
- Discuss maintenance issues faced during the time of operation.
- Ensure that the cost and benefits are equally shared amongst all parties concerned.
- Assess how gender role and traditional beliefs affect the project’s operation and maintenance works. (Score: 1)

**Element (5, 2) Operation and maintenance: Community participation**

- Formation of working village committee to oversee the overall management of the project.
- Involvement of community for operation and maintenance of project.
Keeping track record of project’s performance and submit periodic reports to project developers. ☑️

The community should be empowered to solve conflicting interests and issues at local level. ☑️ (Score: 3)

**Element (5, 3) Operation and maintenance: Political cohesion/policy support**

- Formal handing and taking over of the project. ☑️
- Defining clear roles and responsibilities of different organisations. ☑️
- Local institution and community is empowered to make certain decisions on behalf of the community. ☑️
- Frame a strategy to share monitoring and evaluation reports with all partner institutions from time to time. ☑️ (Score: 3)

**Element (5, 4) Operation and maintenance: Economic sustainability**

- Estimate a long term O&M cost which is realistic. ☑️
- Assess the affordability and willingness of community to pay for service. ☑️
- Estimate the long term financial gap that might arise for system upkeep. ☑️
- Workout subsidy and financial support needed based on robust financial mechanisms. ☑️ (Score: 1)

**Element (5, 5) Operation and maintenance: Environmental sustainability**

- Develop plans to minimise environmental damage as far as possible. ☑️
- Seek environmentally friendly end-of-pipe solutions to treat and dispose wastes properly. ☑️
- Explore alternative plans to reduce ecological impacts. ☑️
- Keep monitoring and reporting project performance for future reference. ☑️ (Score: 0)
Appendix D: Evaluation of Barefoot College Project

Element (1, 1) – Project planning: Socio-cultural respect

- Identify traditional beliefs and social preferences in using a particular energy system. ✔
- Recognise gender role in using energy. ✔
- Understanding the level of community’s knowledge about energy. ✔
- Does the target community have other preferred energy supply options? ☑

(Score: 3)

Element (1, 2) – Project planning: Community participation

- Understand local development priorities through public consultations. ✔
- Identification of stakeholders and local leaders who can make decisions. ✔
- Determine the type of political organisation and cohesion at local level. ☑
- Reach to a consensus that proposed energy option is appropriate and acceptable. ✔

(Score: 3)

Element (1, 3) – Project planning: Political cohesion and policy support

- Conduct situational analysis of regional and national issues, such as political structure and stability, government policies and foreign aid. ❑
- Ensure that proposed initiative is in line with the regional and national development priorities. ✔
- Research the history of energy projects implemented in the past. ❑
- Is there a robust institutional set up to support such initiatives? ☑

(Score: 2)

Element (1, 4) – Project planning: Economic sustainability

- Understand the overall economic situation at national including poverty level, living costs, unemployment rate and resource flow. ☑
- Understand how general economic situation is affected by prevailing energy issues. ✔
- Identify the community’s monetary and non-monetary resources. ✔
- Study and understand the willingness of the people to pay for the energy services. ✔

(Score: 3)

Element (1, 5) – Project plan: Environmental sustainability

- Identify indigenous resources for energy generation. ✔
- Gather climate and environmental factors that need to be reflected in project design. ✔
- Identify potential environmental issues at local, regional and national level. ☑
- Determine community’s willingness to accept intrusion into their local environment. ☑

(Score: 2)
Element (2, 1) Conceptual design/feasibility: Socio-cultural respect

- Determine how energy service intervention will have impact on community’s cultural roles. ✓
- Assess community’s capacity to operate and maintain the energy systems. ✓
- Does system design respects gender roles. ✓
- Evaluate potential social ramifications through such designs. ✓ (Score: 3)

Element (2, 2) Conceptual design/feasibility: Community participation

- The project objectives are clearly defined and accepted by all concerned stakeholders. ✓
- Identify a representative committee who can make decision on behalf of the community. ✓
- Provide viable technological options to the community for their evaluation and feedbacks. ✓
- Community formally selects an appropriate option understanding its associated constraints and limitations. ✓ (Score: 2)

Element (2, 3) Conceptual designs/feasibility: Political cohesion/policy support

- Develop working relationship with partner organisations. ✓
- Consult designs and feasibility studies of other similar projects. ✓
- Integrate existing technologies/programs into to conceptual designs. ✓
- Explore potential organisations and institutions for supports (fund/expertise). ✓ (Score: 3)

Element (2, 4) Conceptual designs/feasibility: Economic sustainability

- Estimate upfront cost of conceptual designs. ✓
- Estimate O&M and disposal cost. ✓
- Assess ability and willingness to pay for energy services. ✓
- Conduct economic viability of project for long term sustainability. ✓ (Score: 2)

Element (2, 5) Conceptual design/feasibility: Environmental sustainability

- Evaluate the capacity of sustainable energy use. ✓
- Consider how different environmental constraints will impact the conceptual designs. ✓
- Assess land requirement for various energy supply options. ✓
- Assess raw material required for energy generation for different options. ✓ (Score: 2)

Element (3, 1) Design and action planning: Socio-cultural respect
Understand the social structure of the community. ✓
Consider the seasonality and availability of local work force. ✗
Understand the socially accepted gender roles and responsibilities. ✓
Determine the gender equity through resource and opportunity distributions. ✗
(Score: 2)

**Element (3, 2) Design and action planning: Community participation**
- Solicitation of community’s input to refine and finetune the project design. ✗
- Final design is accepted based on community’s consensus. ✗
- Community’s members are fully involved in sequencing implementation schedule. ✓
- Mutual agreement of time schedule between project developers and local people. ✓
(Score: 1)

**Element (3, 3) Design and action planning: Political cohesion/policy support**
- Delineation of action plans for different parties involved. ✓
- Agreement on financial plans and commitments. ✓
- Mutually agreeable project timeline is framed taking the convenience of different parties into consideration. ✗
- Final design and action plans are presented to all parties involved. ✗
(Score: 2)

**Element (3, 4) Design and action planning: Economic sustainability**
- Verification of costs and availability of resources. ✗
- Confirm community’s contribution both monetary and non-monetary resources. ✓
- Finalization of project cost estimate by taking local contributions in to consideration. ✗
- Development of locally oriented action plan of the project. ✓
(Score: 2)

**Element (3, 5) Design and action planning: Environmental sustainability**
- Use of locally available renewable resources. ✓
- Minimisation of wastes, pollutants and energy considered. ✗
- Availability of seasonal resources is considered. ✗
- Develop a firm environmental mitigation plans to correct any adverse impacts. ✗
(Score: 1)

**Element (4, 1) Implementation: Socio-cultural respect**
- Setting of a realistic implementation schedule based on availability and working culture of local people. ✓
- Consider force majeure throughout the implementation process. ✗
- Encourage women participation in implementing the project. ✓
- Give due respect to local monument and shrines. ✓ (Score: 3)
Element (4, 2) Implementation: Community participation

- Organisation of periodic public meetings and consultations.
- Work closely with local leaders in organising labour force required.
- On-the-job training for local people.
- Set up proper communication channels to report the work progress and problems. (Score: 3)

Element (4, 3) Implementation: Political cohesion/policy support

- Keep partner institutions fully informed on training and labour requirements.
- Discuss different roles and responsibilities of different parties.
- Construction site should be open and accessible for independent bodies for inspection.
- All parties should be fully informed on the status and progress of construction works. (Score: 3)

Element (4, 4) Implementation: Economic sustainability

- Encouraging community’s contribution towards the project.
- Use of locally available resources and expertise.
- Keeping track record of expenditures and reviewing time to time.
- Sharing financial report with the community, hence increasing transparency. (Score: 2)

Element (4, 5) Implementation: Environmental sustainability

- Environmental constraints used during the design phase observed during implementation phase.
- Minimisation of environmental impacts through close monitoring process.
- Initiate sensitisation regarding waste disposal and reuse.
- Restore damaged ecosystem after the implementation works. (Score: 1)

Element (5, 1) Operation and maintenance: Socio-cultural respect

- Identify unanticipated socio-cultural constraints faced during the time of project use.
- Discuss maintenance issues faced during the time of operation.
- Ensure that the cost and benefits are equally shared amongst all parties concerned.
- Assess how gender role and traditional beliefs affect the project’s operation and maintenance works. (Score: 2)

Element (5, 2) Operation and maintenance: Community participation
- Formation of working village committee to oversee the overall management of the project. 
- Involvement of community for operation and maintenance of project. 
- Keeping track record of project’s performance and submit periodic reports to project developers. 
- The community should be empowered to solve conflicting interests and issues at local level. (Score: 2)

**Element (5, 3) Operation and maintenance: Political cohesion/policy support**

- Formal handing and taking over of the project. 
- Defining clear roles and responsibilities of different organisations. 
- Local institution and community is empowered to make certain decisions on behalf of the community. 
- Frame a strategy to share monitoring and evaluation reports with all partner institutions from time to time. (Score: 2)

**Element (5, 4) Operation and maintenance: Economic sustainability**

- Estimate a long term O&M cost which is realistic. 
- Assess the affordability and willingness of community to pay for service. 
- Estimate the long term financial gap that might arise for system upkeep. 
- Workout subsidy and financial support needed based on robust financial mechanisms. (Score: 1)

**Element (5, 5) Operation and maintenance: Environmental sustainability**

- Develop plans to minimise environmental damage as far as possible. 
- Seek environmentally friendly end-of-pipe solutions to treat and dispose wastes properly. 
- Explore alternative plans to reduce ecological impacts. 
- Keep monitoring and reporting project performance for future reference. (Score: 1)