A CRITICAL REVIEW ON SOLAR HOME SYSTEM PROGRAM FOR MONGOLIAN HERDERS

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Declaration

I declare that this dissertation is my own account of my research and contains as its main content work which has not previously been submitted for a degree at any tertiary education institution.

Purevdash Solikhuu
Abstract

In developing countries, one of the most effective ways of accessing electricity for rural people is off-grid based renewable energy electrification program. The most widely used renewable energy technology by rural household is a solar home system (SHS). These systems can supply electricity to relatively dispersed populations and require low maintenance as well as low operational costs. The capacity of the SHS used by rural families varies between 30 and 100 watts which have the potential to meet basic electrical needs. On the other hand, the option of extending the grid and alternative energy sources such as diesel engines and wind turbines are not the least cost effective and technically feasible options for providing electricity to low densely populated areas in the long term.

Mongolia is the most sparsely populated nation in the world and a quarter of the population is made up of nomadic herders who live in remote areas. Herders move 3-4 times during a year with all of their belongings in search of pasture land for their livestock. Solar energy has been one of the main energy sources for herders compared to other renewable energy technologies and diesel generator because SHSs are transported easily and provide basic needs of the nomadic herders. The Mongolian Government implemented the “100,000 solar ger (tent) electrification” program between 1999 and 2012 and distributed 100,146 solar home systems to a half million herders.

This dissertation will investigate the Mongolian SHS program and identify the success and failures of the SHS program. This is based on two different surveys obtained by summarising the views of policy makers and herders who bought SHS under the program. The outcomes of these surveys will be used to provide recommendations for improving the future SHS project in Mongolia.
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List of Acronyms

ADB  Asian Development Bank
ERC  Energy Regulation Commission (of Mongolia)
GHG  Greenhouse Gas
kW   Kilowatt
kWh  Kilowatt Hour
MOM  Meteorological Organization of Mongolia
MW   Megawatt
NSOM National Statistics Office of Mongolia
NREL National Renewable Energy Laboratory (of the USA)
NREC National Renewable Energy Centre (of Mongolia)
GOM  Government of Mongolia
PV   Photovoltaic
RE   Renewable Energy
REAP Renewable Energy and Rural Electricity Access Project
SHS  Solar Home System
WB   World Bank
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Chapter 1- Research overview and methodology

1.1. Research Overview

Mongolia is the most sparsely populated nation in the world with a population of three million citizens (World Bank, 2014). Almost 20% of the Mongolian population is still engaged in a nomadic lifestyle and live in rural areas. Nomadic families move from one place to another every season in search of pasture land for their livestock which accounts for more than 40 million. Therefore, the Government of Mongolia (GOM) has prioritized the use of renewable energy to supply electricity to herders in remote areas of Mongolia.

Mongolia has an enormous renewable energy resource and is known as the “Land of Blue Sky” because of its clear skies. The country has over 270 sunny days in a year. About 70% of the Mongolian territory has high solar resource accounting for 5.5-6.0 kWh/m² per day, and the remaining land area receives solar intensity in the range of 4.5-4.5 kWh/m² per day. Therefore, solar energy has been one of the main energy sources for herders. Portable solar home system is the best electrification option for herders compared to other renewable energy technologies such as diesel generators and small wind turbine because SHSs are transported easily and meet the needs of nomadic herders who often move one place to another. These systems not only supply electricity to herders but also reduce air pollution in rural areas.

At the beginning of the century, the Mongolian Government approved a “100,000 solar ger (tent) electrification” program with the aim of providing electricity to herders living in remote areas using small-scale solar home systems. In this scheme, 100,146 solar home systems with the average capacity of 50W were distributed to half a million herders who were traditionally adapted to the nomadic way of life (Jayawardena et al., 2012). The government achieved its
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goal of distributing 100'000 SHSs to herders successfully in 2012. In this program, the upfront cost of the SHS was subsidized by 50% with the support of donor countries (Benjamin et al, 2011).

Today, herders equipped with SHS are using electricity for basic needs such as lighting, watching TV and listening to the radio. There is also an increasing usage of cellular phones among rural people through the expanding the mobile network in rural areas. This reduces the isolation of the herders and helps connect them to the wider world.

Figure 1.1. Common herder family using portable SHS in a rural area.

Source: Renewable Energy and Rural Electricity Access Project.

However, as more electric appliances are used today due to improved living standards of the herders, the SHS capacity needs to be upgraded. Additionally a significant number of nomadic families (16’985) still lack access to electricity because they are not capable of buying SHS from the market (NSOM, 2017). The Mongolian SHS market is at its nascent level and relies
on imported expensive solar systems. Therefore, some herders are not able to purchase SHS from the market due to their financial constraints. In this situation, upgrading the SHS program is important to enhance market scale, expanding the distribution network of SHS to reach more remote areas, and enabling the program in being sustainable for a long time.

It is therefore crucial for the Mongolian Government to develop a new SHS program based on previous experiences and distribute the new SHS at lower costs to herders in remote areas who lack access to electricity. A detailed study is required to investigate previous SHS program and to identify drivers and barriers that were experienced during the implementation of the SHS program. This will be based on the outcome of survey results from the policy makers and herders using SHSs. Finally, this research will provide recommendations for the improvement of the future SHS program.

1.2. Rationale of the research

The Mongolian SHS program achieved its goal to scale up rural electrification by distributing 100’000 SHSs and this achievement is regarded as one of the successful SHS programs in the developing countries (World Bank, 2014). As a result of the program, herder households experienced improvement to their quality of life using SHSs. However, the program has only reached to about 74% of Mongolian herders (ADB, 2015) and around 19’985 herders still have no access to electricity in the rural areas and are in need of SHSs for their daily life (NSOM, 2017). The current market price of a SHS with the capacity of 100W is around 800$. This equates to half of the herders’ yearly income. Thus, herders without electricity are not able to buy new systems due to their financial issues. Rural household incomes are quite low and are typically seasonal due to the reliance on herding. Livestock is the main income
generating resource for herder families. Moreover, financial institutions do not offer loans to the herders because their income is not durable and they have few assets.

Despite the benefits of the Mongolian SHS program, today the SHS market is confronted with issues. These include the high upfront cost of SHS, reliance on imported systems from other countries, lack of electrification program for herders, barriers related to public awareness, and political commitment to high scale energy systems rather than small systems such as SHS. The previous program subsidized 50% of the SHS cost and herders paid half the initial cost of the system. It was tough for private companies to compete with the subsidized Government program and scope to involve the private sector was insufficient. As a result, the private sector did not benefit from this program. Therefore, the Mongolian Government should place high priority on expanding electricity access for all herder populations. As a result, all herders can improve their quality of life through lighting, entertainment, and comfort without relying on costly and polluting energy resources such as kerosene, candle and wood.

1.3. Research objectives

The outcomes of this research are:

- To critically assess the Mongolian SHS program and identify drivers and barriers based on the surveys
- To determine a list of important recommendations for the policy makers to improve future SHS program in a sustainable way.

The knowledge gained from this study can be used to assist in designing a new SHS program for providing electricity to the herders. The target audience includes policy makers and
researchers. Another contribution of this research is to increase the public awareness among herders who use the SHS and private sector participants who sell SHS in the market.

1.4. Research questions

Three main research questions control the focus of this study.

I. What lessons have been learned from Mongolian SHS program?
   - What were the drivers and barriers of the program?
   - Was the program sustainable?

II. What should be considered in the future SHS program in order to minimize issues and enhance benefits regarding herders’ SHSs utilization?

Literature review and two surveys involving herders and policy makers were conducted to answer these questions. After conducting the surveys, the data collected was analyzed critically and a list of recommendations provided to policy makers to improve future Mongolian SHS program.

1.5. Research Methodology

This section explains the methodology used in this research and is illustrated in the figure 1.2. A comprehensive literature review was undertaken on the Mongolian SHS program for herders. The literature review provided the background information on the Mongolian SHS program and helped identify its shortfalls as well as drivers behind the SHS program. The information acquired from the review is summarized and presented in following chapters. Based on the information obtained from the literature review, questionnaires for herders and policy makers were prepared to collect data. The information from the survey was also used to collate participants’ view of the program. The collected data was analyzed in detail and
summarized using qualitative and quantitative analysis. Following the data analysis, the drivers and barriers that were experienced during the pre- and post-implementation of the SHS program were identified and summarized as lessons learned. Finally, based on the lessons learned, recommendations were made for the future SHS program.

Figure 1.2. The flow chart of research methodology.
1.5.1. Literature review

The investigation of the Mongolian SHS program was based on a literature review and surveys. A literature review was undertaken to gather detailed information on the previous “The National 100,000 solar ger” program. The review also compared the Mongolian SHS program with other SHS programs implemented in developing countries. However, the Mongolian SHS program cannot be directly compared with SHS programs implemented in other developing countries due to differences in cultural, social, economic and institutional factors. Despite this, the Mongolian SHS program has own strengths and weaknesses. Thus, it examined other SHS programs implemented in developing countries to derive best practices from successful SHS programs. Journal articles and reports regarding SHS programs implemented in developing countries were downloaded from the Online Library of the Murdoch University. All information obtained was investigated in detail.

The Mongolian Ministry of Energy also provided information on the SHS program. This information included final reports of the SHS program, herders’ average daily electricity consumption, some technical drawings and contact numbers for the herders which were used for the phone survey. The final report of the Mongolian SHS program developed by the Renewable Energy and Rural Electricity Access Project financed by the World Bank included the total number of SHSs distributed to herders, the design of SHSs and information of installed capacity of SHSs.

The Mongolian energy sector information was acquired from the Energy Regulatory Commission of Mongolia and translated by the author of this paper. The data on the total number of Mongolian herders in remote areas and their source of electricity were obtained
from the National Statistics Office of Mongolia. The Mongolian solar market information and the market price of SHSs were used to investigate the affordability of herders to purchase SHS systems. This information was obtained from websites of companies’ websites that produce and import solar PV systems. Information relating to Mongolia, its economy, weather conditions, administration structure, population, etc. was acquired from the websites of relevant Mongolian governmental organizations.

1.5.2. Data collection

The research design was based on both qualitative and quantitative processes. These methods required obtaining a view of all stakeholders associated with the SHS program including herders using the PV systems, project designers, government officers, researchers and private sector participants. The questions in the surveys were open-ended and semi-structured. The first survey was for herders who bought the PV systems under the program. The second survey targeted the program implementers, researchers and policy makers to gather their views on the program.

**Phone Survey:** Herders using the PV systems were interviewed by a phone call. Potential herder participants were identified with the assistance of the project implementers and the Government officers who worked on this program. The sample size for this survey was calculated using the Raosoft online sample size calculator and 70 participants were recruited from the 100,146 herders who use SHSs for their daily lives. The margin of error was considered as 10% in this study. The total list of the participants was obtained from the Ministry of Energy of Mongolia where the researcher has personal contacts. The Mongolian
Ministry of Energy supported the research and provided information as needed according to an agreement between the researcher and the Ministry of Energy.

A semi structured survey questionnaire was used in the phone interviews. The questionnaire for herdsmen is attached in Annex 1. The interview over the phone lasted around 20-25 minutes and notes were taken by the researcher during this time. The following four questions were asked over the phone.

- Social, economic and environmental impacts of the “100’000 Solar Ger (tent)” program in the Mongolian countryside.
- Issues encountered during the operation of a solar home system.
- Opinion of the herdsmen about purchasing a new solar home system if the Mongolian Government offered subsidized, higher capacity solar home systems through the upgraded “solar ger” program
- Factors/considerations perceived to be essential for the success of upgraded program.

**Email Survey:** The project designers, government officers, researchers and people working on the SHS program were involved in the email survey. The participants were chosen from the Ministry of Energy, National Renewable Energy Centre and some universities using the researcher’s personal contacts. These participants were identified as being relevant to the previous “100’000 solar ger” program and chosen based on their experience with this project. The questionnaire for the participants of the email survey is attached in Annex 2. The following information was obtained from the participants through the email survey:

- Main issues faced in the planning, implementation and evaluation stages of the “100,000 solar ger” program
- The main reasons behind the success of the “100,000 Solar Ger (tent)” program.
• Important indicators in the upgraded solar PV electrification program for the herders.

• Opinions of the participants relating to the upgraded Solar PV electrification program for the herders in Mongolia.

1.5.3. Data analysis

Once data had been collected with the permission of the Human Research Ethics Committee of Murdoch University, survey findings were analyzed in detail using SPSS and NVIVO software packages and summarized using qualitative and quantitative analysis. The frequency distribution was used for analyzing the social, economic and environmental impacts of SHS used in the Mongolian Herders. For the email survey analysis, the criteria for the success of the program and issues relating to the program were analyzed using the frequency distribution. This was based on interpretative philosophy. The analysis examined the meaningful content of the data by using content analysis method. Survey findings were critically analyzed in chapter-4. Following data analysis, the drivers and barriers that were experienced during the pre- and post-implementation of the Mongolian SHS program were identified and summarized as lessons learned. Finally, based on the lessons learned, recommendations were made for the future SHS program.
Chapter II – Country profile

2.1. Demographic information

Mongolia is a vast landlocked country located in the Northeastern part of the Asian continent between the People’s Republic of China and Russia. With an area of 1,564,116 square kilometers, Mongolia is the 19th largest country in the world in terms of its land size which is four times larger than the land area of Japan (CIA, 2017).

The latitude and longitudes of the Mongolian territory are between 41°35’N-52°6’N and 87°47’E-119°57E. The total length of the entire Mongolian border is 8,114 km. Russia borders 3,485 km to the north, while the border with China along the southern, eastern and western parts of the country accounts for 4,677 km. The distance from the North to the South is 1,259 km and 2,392 km from West to East (NSOM, 2009). The following map shows Mongolia and its bordering countries with provincial boundaries and their provincial capitals.

Figure 2.1. The geographical location of Mongolia.

Source: http://www.nationsonline.org/oneworld/map/mongolia_map2.htm
The Gobi desert region is located in the eastern and southern part of Mongolia, while the northern and western parts are mountainous areas. The topography of Mongolia is mainly plateau, with an average elevation is 1580 m above sea level. The Altai Mountains in the southwest is the highest point in elevation with 4374 m while the lowest point is 560 m above sea level in the Eastern part.

2.2. Population

Mongolia is a land of young people. Around 70% of the Mongolian population is under thirty years of age, and 40% of this group consists of children under the age of 16. Mongolia is an ethnically homogenous state, with 90% of the population belonging to the Khalkha and Buriat Mongols. The Kazakhs, a Turkic Muslim population, represent the largest minority. 4.5% of the population represents Kazakh and remaining population comprises of Chinese, Russian and Korean nationalities (NSOM, 2016).

The total population of Mongolia as of December 2016 was estimated at 3,057,778, an increase of 29.6% compared to 1990 (NSOM, 2016). The capital city of Ulaanbaatar is the economic, political and cultural center of the country. The population of Ulaanbaatar is accounted for around 45.6% of the total population in 2015, increasing from 586,228 in 1990 to 1,396,228 in 2015 mainly due to movement of rural population. The urban population was 2,096,180 (68.5%) which includes provincial centers, and the urban households’ distribution is 67.4%. The percentages of the total population living in other urban areas and rural areas are 22.9% and 31.5% respectively (NSOM, 2016).

The Mongolian population has been growing continuously. Mongolia has experienced an increase in total fertility rate from 2.1 in 2000-2005 to 2.5 in 2010-2015. The average life
expectancy was 66.02 years for men and 75.84 years for women and 69.89 years for the population. An average Mongolian household consists of 4.3 people (NSOM, 2016).

Table 2.1. Mongolian population by regions

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<tbody>
<tr>
<td>Ulaanbaatar</td>
<td>642,036</td>
<td>794,730</td>
<td>1,015,950</td>
<td>1,244,449</td>
<td>1,396,288</td>
</tr>
<tr>
<td>Western region</td>
<td>422,977</td>
<td>413,649</td>
<td>383,921</td>
<td>357,148</td>
<td>390,594</td>
</tr>
<tr>
<td>Khangai region</td>
<td>531,163</td>
<td>550,206</td>
<td>526,937</td>
<td>521,745</td>
<td>577,252</td>
</tr>
<tr>
<td>Central region</td>
<td>437,730</td>
<td>444,303</td>
<td>431,460</td>
<td>450,710</td>
<td>485,525</td>
</tr>
<tr>
<td>Eastern region</td>
<td>209,094</td>
<td>200,217</td>
<td>192,813</td>
<td>186,916</td>
<td>208,119</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>2,242,998</strong></td>
<td><strong>2,403,105</strong></td>
<td><strong>2,551,081</strong></td>
<td><strong>2,760,968</strong></td>
<td><strong>3,057,778</strong></td>
</tr>
</tbody>
</table>


The average population density is two people per square km and therefore, Mongolia is considered as one of the most sparsely inhabited countries in the world. Migration to the capital city, Ulaanbaatar has been dramatically increasing in the last few years. Today, the majority of the Mongolian population resides in the major cities. For example, the population density in Ulaanbaatar is 297.1 people/km$^2$, while it is 0.9 people/km$^2$ in the Western part of Mongolia.

2.3. Political and Administrative structure

In 1992, the Mongolian parliament approved a new constitution and established a democratic parliamentary republic country. The Mongolian political structure consists of separate judicial, executive and legislative powers. The president is the head of state and representative of the national unity. Mongolia's constitution guarantees to all citizens the right to own property,
personal freedom, freedom of religious expression, and social rights such as education and healthcare.

As a unitary state, Mongolia is divided into 21 provinces. Each province is subdivided into soums and soums further into baghs. In the capital city, Ulaanbaatar consists of districts which are second level administrative units. A further subdivision of the district is known as “khoroo”. Khoroo and baghs are the smallest administrative precincts in Mongolia. Provinces and municipalities are presented in the Figure 2.2.

![Figure 2.2. The administrative division’s map of Mongolia.](http://ontheworldmap.com/mongolia/administrative-divisions-map-of-mongolia)

There are a total of 330 soums in the provinces and under the soums, there are 1613 baghs. In the capital city, Ulaanbaatar municipality is consists of 9 districts and 152 khorooos (ALAGCM, 2017).
All provinces and the municipality are empowered by laws to set up a local government administration. This administration is responsible for implementing various government plans with the local budget set and approved by the central government. The majority of Mongolian herders belong to the smallest administration unit, bagh.

2.4. Climate

Mongolia has a continental four distinct seasons with long, cold winters and short, hot summers. The temperatures range temperatures between -15°C and -35°C in winter and +10°C and +35°C in summer. The lowest temperature in the north reaches -40°C at night in winters due to cold air blowing from Siberia while summer days of +40°C occur in the Gobi desert. Ulaanbaatar is the coldest capital city in the world due to its annual temperature of -
1.3°C. Between March and May, it is mostly windy from the direction of west to northwest with an average wind speed of 2 – 5 m/sec. The country experiences heavy snowfall in winter and strong dust in summer. Around 26 dust storms occur in a year due to the dry environment. These dust storms then travel to East Asian countries such as Korea and Japan. Mongolia has an abundance of sunny days with an average of 230-260 days and 2600-3300 hours of sunshine in a year. Thus, Mongolia is also known as “the country of blue sky” (NAMEM, 2017). The Mongolian climatic conditions are unequal throughout the territory. The below figure illustrates the seven different climate zones.

![Figure 2.4. The map of climate classification of Mongolia.](image)

Annual precipitation in Mongolia is differentiated from North to South due to its four seasons, and geographical characteristics, as shown in figure 2.5. The majority of the precipitation occurs in the summer (IRIMHE, 2017). The Northern part of the country including Khuvsgul, Altai, and Khentii mountains receive the majority of the precipitation with the average of 200 to 350 mm/year, while annual precipitation is lowest in the southern Gobi desert with less than 50 mm/year. By contrast, it is less than 100 mm in the Gobi regions. Some parts of the Gobi desert have not experienced rainfall for several years.

Figure 2.5. Annual precipitation in Mongolia (1961-1990).

2.5. Economic situation

The Mongolian economy has traditionally been dependent on farming and herding, even though the mining sector has become the largest contributor to the economic growth. Mining contributes to one-third of the gross domestic product (GDP) and 80% of the total export sales of a product with two main mineral deposits of coal and copper. Although GDP per person has increased from $3,181 USD to $3,971 USD between 2000 and 2015, showing a 19.9% increase. World Bank Mongolia categorized Mongolia as a lower middle-income economy as its per capita GDP rose from $3,181 USD to $4,056 USD between 2000 and 2013. However, this is still considered low. The economic scale is relatively small – the total GDP in 2015 was US$11.8 billion (Focus Economics, 2017).

Table 2.2. Mongolian Economy Data

<table>
<thead>
<tr>
<th>Indicators</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population (million)</td>
<td>2.8</td>
<td>2.8</td>
<td>2.9</td>
<td>2.9</td>
<td>3.0</td>
</tr>
<tr>
<td>GDP per capita (USD)</td>
<td>3,783</td>
<td>4,377</td>
<td>4,598</td>
<td>4,166</td>
<td>3,971</td>
</tr>
<tr>
<td>GDP (USD bn)</td>
<td>10.5</td>
<td>12.4</td>
<td>13.3</td>
<td>12.2</td>
<td>11.8</td>
</tr>
<tr>
<td>Economic Growth (GDP, annual variation in %)</td>
<td>17.5</td>
<td>12.5</td>
<td>11.6</td>
<td>8.1</td>
<td>2.4</td>
</tr>
<tr>
<td>Unemployment Rate</td>
<td>7.7</td>
<td>8.2</td>
<td>7.9</td>
<td>7.9</td>
<td>7.5</td>
</tr>
<tr>
<td>Inflation Rate (CPI, annual variation in %)</td>
<td>9.2</td>
<td>14.3</td>
<td>10.5</td>
<td>12.8</td>
<td>6.6</td>
</tr>
<tr>
<td>Trade Balance (USD billion)</td>
<td>-1.8</td>
<td>-2.4</td>
<td>-2.1</td>
<td>0.5</td>
<td>0.9</td>
</tr>
<tr>
<td>Exports (USD billion)</td>
<td>4.8</td>
<td>4.4</td>
<td>4.3</td>
<td>5.8</td>
<td>4.7</td>
</tr>
<tr>
<td>Imports (USD billion)</td>
<td>6.6</td>
<td>6.7</td>
<td>6.4</td>
<td>5.2</td>
<td>3.8</td>
</tr>
<tr>
<td>International Reserves (USD)</td>
<td>2.5</td>
<td>4.1</td>
<td>2.2</td>
<td>1.7</td>
<td>1.3</td>
</tr>
<tr>
<td>External Debt (% of GDP)</td>
<td>91.4</td>
<td>124</td>
<td>144</td>
<td>172</td>
<td>183</td>
</tr>
</tbody>
</table>

The Mongolian GDP increased to 9.9% and 8.9% in 2007 and 2008, respectively. In 2011, it peaked at 17.5% due to increased income from the mining sector, increased market prices for copper and gold, and stable inflation level. Mongolia has a lot of potentials to grow its economy within the next few decades. These potentials include untapped huge mineral resources, a high literacy rate, proximity to the markets in China and Russia, vast, beautiful land areas for tourism, cultural heritage and unique natural ecosystems.

Figure 2.6. Gross Domestic Product growth in Mongolia between 2011 and 2015.


The Mongolian economy is also expected to benefit from the second phase of the Oyu Tolgoi gold and copper mining project owned by Rio-Tinto (66%) and the Mongolian Government (34%). The construction work of the second phase commenced in 2015 with the total investment of $5.4 billion. However, the country should build high scale power plants in the mining regions to power the mining factories and to meet the increasing demand for the energy from other sectors such as construction and agriculture sectors and also a growing population.
2.6. Current Situation of the Energy Sector

The Mongolian national energy system consists of five independent energy systems including the Central Energy System (CES), the Western Energy System (WES), the Eastern Energy System (EES), the Southern Energy System (SES) and the Altai-Uliastai Energy System (AUES), as illustrated in Figure 2.7. Despite the country’s huge geographic area and relatively small population, all provinces and most settlements are connected to the high-voltage transmission lines while only five settlements are supplied energy by renewable and diesel hybrid systems. Therefore, Mongolia is one of the countries with the high electricity access rate accounting for 98% (ERC, 2016).

The energy sector is one of the monopolistic sectors in Mongolia as the majority of the energy companies are state-owned. Salkhit Wind Park became the first private electricity producer in 2013. The Mongolian government has privatized three of the electricity distribution and sales companies in Khuvsgul, Byankhongor and Darkhan provinces. Thermal plants and heat distribution companies in Uvs and Khovd province are also privately-owned. However, all transmission companies are state-owned in Mongolia.
According to a report by the Energy Regulatory Commission of Mongolia (ERC), the total installed capacity of the power plants is 1,082 MW. Coal has been the main energy source in Mongolia, due to its reach resources and it accounts for 85% of the total installed capacity. The rest of the power obtained from diesel generators (7%), hydropower plants (2%), Salkhit wind park (5%) and small scale renewable power plants (0.62%). In 2016, coal power plants produced 95.8% of total electricity supply while renewable energy power plants’ supplied 4.22%. The electricity generation increased by 28.3% from 2011 to 2015 as shown in Table 2.3, as a result of the dramatic increase in demand (ERC, 2017).
### Table 2.3. Annual electricity production by different energy sources in 2016 (million kWh)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal power plants</td>
<td>4,450.0</td>
<td>4,775.5</td>
<td>5,014.0</td>
<td>5,191.3</td>
<td>5,415.8</td>
<td>5,555.9</td>
</tr>
<tr>
<td>Diesel generators</td>
<td>20.2</td>
<td>28.7</td>
<td>5.4</td>
<td>8.2</td>
<td>6.0</td>
<td>3.8</td>
</tr>
<tr>
<td>Solar power plants</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.6</td>
<td>0.5</td>
<td>0.3</td>
</tr>
<tr>
<td>Hydropower plants</td>
<td>52.6</td>
<td>52.1</td>
<td>59.9</td>
<td>66.3</td>
<td>59.3</td>
<td>84.7</td>
</tr>
<tr>
<td>Salkhit wind park</td>
<td>-</td>
<td>-</td>
<td>52.9</td>
<td>125.4</td>
<td>152.5</td>
<td>157.5</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>4,522.8</strong></td>
<td><strong>4,856.3</strong></td>
<td><strong>5,132.2</strong></td>
<td><strong>5,391.9</strong></td>
<td><strong>5,634.2</strong></td>
<td><strong>5,802.4</strong></td>
</tr>
</tbody>
</table>


In 2016, the peak load reached 975 MW, using 83% of installed capacity in the central energy system. As a result, Mongolia has encountered a serious shortage of power. Electricity imports from neighboring countries rose rapidly from 181 GWh to 1,419.1 GWh between 2005 and 2016 due to the increased electricity demand during the peak demand hours. The Mongolian installed capacity is not sufficient to power the Oyu Tolgoi mine which commissioned its first phase in 2012 and therefore electricity is being imported from China to run this mine. Additionally, Tavantolgoi coal mine is expected to start in 2020 its operation with the demand of 300MW. As a result, the Mongolian electricity demand in the future is expected to double by 2023 as indicated in Figure 2.8.
ERC has issued licenses for construction of new power plants with the total installed capacity of 1500 MW, including five wind farms (502.4 MW). The state policy on energy was approved by the Mongolian parliament in 2015 with the purpose of determining expected results of policy in stages between 2015 and 2030. According to this policy, the Mongolian government has set a target to increase the share of renewable energy capacity to 20% by 2023 and 30% by 2030 and decrease its greenhouse gas emission from traditional power generation. Some renewable projects are planned in the policy papers with the aim of exporting excess electricity to South Asian countries. These include high-scale hydropower plants (300 MW), wind parks and solar farms (300 MW), and pumped storage hydropower plants (100 MW). However, the electrification requirement of the herders is not considered in the Government’s short and mid-term scenarios. Thus, this research will provide some recommendations to policy makers to develop future electrification program for herders who have no access to electricity in the remote areas.

Figure 2.8. Future power demand in Mongolia.


A critical review on solar home system program for Mongolian herders
2.7. Renewable Energy Development in Mongolia

Mongolia is endowed with significant renewable energy resources and has a small but diversified portfolio of renewable energy technologies, including on-grid and off-grid schemes. With appropriate care to match the technology to the environmental conditions, renewable energy technologies are well suited for both urban and rural energy applications in Mongolia. The Mongolian Government has taken subsequent action by approving renewable energy law and programs to restructure the energy sector as well as attract private investment to renewable energy sector (The State policy on Energy, 2015). While the hydropower plants are the first renewable energy source used in Mongolia since the 1950s, nowadays high scale on-grid wind power plants and solar farms are being used to provide power to consumers as a result of Government support. In addition, about 20% of the Mongolian population, mainly herder families, use PV systems for their daily lives in rural areas.

With the continuous drop in cost of renewable energy technologies and increasing domestic energy demand, Mongolia has great opportunity to boost the number of solar and wind power plants using its huge untapped renewable energy resources. The Mongolian Government has set an ambitious goal in its State policy on energy adopted by the Parliament in 2015 to increase the portion of the renewables in the country’s electricity generation from 20% to 30% between 2020 and 2030 (The State Policy on Energy, 2015). With its given enormous renewable energy potential and the relatively small size of the Mongolian energy market, in time this goal is achievable. However, the Mongolian Government aims not only increase the production of renewable energy for the domestic market but also export the excess wind and solar energy generated to South East Asian countries by getting involved in a regional
integrated power market. According to the research conducted by the National Renewable Energy Laboratory (NREL) in the United States, the annual electricity generation from both solar and wind farms in Mongolia is estimated at 12,897 TWh. These resources are higher than the total electricity use of China (12,000 TWh) in 2030 (Energy Research Institute for National Development and Reform Commission, 2015). The following section presents the current status of renewable energy (RE) development in Mongolia including renewable energy resources and its utilization.

2.7.1. The benefits of renewable energy utilization in Mongolia

The Mongolian ecological system is relatively fragile and sensitive to global warming. According to scientific studies, the Mongolian annual average air temperature had increased by 2.14°C from 1940 to 2007 due to intensifying global warming; this is three times higher than the world average (0.7°C). As a result, about 70% of the total territory has become a desert resulting in the local warming that enhances the risk to the traditional livestock herding in Mongolia (MNEM, 2010). One-third of the population following a nomadic way of life is completely dependent on nature and prevailing weather conditions. Thus, the pastoral population and herders are the most vulnerable groups to climate change impacts because of the loss of livestock (MNET, 2010).

The energy sector is the largest greenhouse gas (GHG) emitter in Mongolia. Aging coal-power plants producing over 90% of the heat and electricity requirements of the country is the predominant source of CO$_2$ emissions. It is projected that CO$_2$ emissions from coal power plants in 2020 will be almost seven times as much as the emission in 1993 due to population growth and increasing energy demand (ADB, 2015). The Ministry of Energy of Mongolia
estimated that energy demand would double by the year 2030 due to the population growth and development of the mining industry in the southern region. Hence, it is critical to minimize the greenhouse gas emission by enhancing the use of rich renewable energy resources not only in urban areas but also in the rural areas of Mongolia.

Increasing the share of renewables in the energy mix has important unequivocal benefits. These include diversifying the country’s energy fuel portfolio, enhancing its energy security, contributing to sustainable economic growth as well as mitigating climate change by minimizing the amount of greenhouse gas emissions through increased access to clean energy service. Installation of high scale renewables with the aim of exporting electricity to neighboring countries can result in significant increase in job creation and new sources of revenue. Small-scale renewable systems are also well suitable for enhancing the degree of electrification particularly for herders living in rural areas. In remote areas, solar systems compete with diesel generators and extension of the electricity grid as a result of a need to supply small energy loads to nomadic families who move up to 10 times a year.

2.7.2. Renewable energy resources and their utilization in Mongolia

With wide geographic expanse and low population density, Mongolia has enormous opportunity to create values using its vast untapped renewable energy resources. With a potential to produce over 12,897 TWh of electricity per annum through wind and solar resources, particularly in Mongolia’s Gobi Desert areas (NREL, 2001), Mongolia can harness these resources to suit its economy. In addition to these resources, hydropower, biomass, and geothermal resources have the potential to be exploited for energy generation in Mongolia.
However, biomass and geothermal energy resources are currently not utilized in the utility applications and rural electrification process in Mongolia. Therefore, these types of renewable energy sources are not included in this section.

2.7.2.1. Solar energy resource and its utilization

Mongolia is known as “the Land of Blue Sky” because of its clear skies and the long periods of the sunshine with over 270 sunny days and 2250-3300 hours of daylight in a typical year. The Meteorological Organization of Mongolia (MOM) has been measuring solar radiation since 1960. Based on its measurement, MOM estimated that about 70% of the territory in the southern region has high solar resource accounting for 5.5-6.0 kWh/m² per day with 2900-3000 sunshine hours per annum while the remaining land area receives solar intensity in the range of 4.5-4.5 kWh/m² per day. The annual number of sunshine hours in Mongolia is higher than other countries on the same latitude. Figure 2.9 illustrates how the annual solar global radiation increases from the southern part of the country to the northern part ranging between 1163 kWh/m² to 1628 kWh/m².
The Mongolian national renewable energy center, in collaboration with NREL, evaluated the Mongolian solar energy resource in the entire territory in 2001. According to this evaluation, Mongolia can receive 4,774 TWh of solar power per annum. With the high-intensity solar radiation and the long periods of sunshine, the development of solar energy can be one of the useful energy sources in Mongolia despite, the utilization of the solar resource being quite low compared to its huge untapped solar resource. The total installed capacity of solar power plants has been estimated at 16,243 kW, as shown in Table 2.4.

Under the “100,000 solar ger” national program, 100,146 SHSs were distributed to herders between 2001 and 2012. Thus, solar energy is the most common type of renewable energy source in Mongolia as over 100,000 nomadic families use SHSs with an average capacity of 50 W throughout the country. Some off-grid small-scale solar power plants are in operation in
remote villages with a total installed capacity of 750 kW while there are three on-grid solar power plants with the capacity of 10,493 kW.

Table 2.4. Solar PV systems in Mongolia.

<table>
<thead>
<tr>
<th>№</th>
<th>Solar power plant’s name</th>
<th>Location</th>
<th>Installed capacity (kW)</th>
<th>Year of commissioning</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Altai</td>
<td>Altai soum, Gobi-Altai province</td>
<td>200</td>
<td>2010</td>
</tr>
<tr>
<td>2.</td>
<td>Bugat</td>
<td>Bugat soum, Gobi-Altai province</td>
<td>140</td>
<td>2007</td>
</tr>
<tr>
<td>3.</td>
<td>Buyant</td>
<td>Buyant soum, Bayan-Ulgii province</td>
<td>10</td>
<td>2010</td>
</tr>
<tr>
<td>4.</td>
<td>Durvuljin</td>
<td>Durviljin soum, Zavkhan province</td>
<td>150</td>
<td>2010</td>
</tr>
<tr>
<td>5.</td>
<td>Tsogt</td>
<td>Tsogt soum, Gobi-Altai province</td>
<td>100</td>
<td>2010</td>
</tr>
<tr>
<td>6.</td>
<td>Urgamal</td>
<td>Urgamal soum, Zavkhan province</td>
<td>150</td>
<td>2010</td>
</tr>
<tr>
<td>7.</td>
<td>SHSs for herders</td>
<td>All around Mongolia (100 146 SHSs)</td>
<td>5000</td>
<td>2001-2012</td>
</tr>
</tbody>
</table>

**On-grid PV systems**

<table>
<thead>
<tr>
<th>№</th>
<th>Solar power plant’s name</th>
<th>Location</th>
<th>Installed capacity (kW)</th>
<th>Year of commissioning</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.</td>
<td>Darkhan</td>
<td>Khongor soum, Darkhan province</td>
<td>10 000</td>
<td>2016</td>
</tr>
<tr>
<td>9.</td>
<td>Chinggis Airport</td>
<td>Khan-Uul district, Ulaanbaatar city</td>
<td>443</td>
<td>2011</td>
</tr>
<tr>
<td>10.</td>
<td>Jargalant</td>
<td>Jargalant soum, Khovd province</td>
<td>50</td>
<td>2012</td>
</tr>
</tbody>
</table>

**Total installed capacity of solar PV systems**

| Total installed capacity of solar PV systems | 16,243 kW |

The Gobi Desert region of Mongolia is ranked third on the list of the world’s desert areas with high solar energy resource. Large-scale grid-connected solar power plants can be built particularly in the sparsely populated Gobi Desert region based on its untapped solar resource and high clearness index. However to date, large-scale grid connected solar PV projects have been the subject of research but have not been implemented. Government policy on energy included high and medium-scale solar power plants with the total capacity of 100 MW, and some of them are under development.

**2.7.2.2. Wind energy resource and its utilization**

The circulation of the annual average wind resource in Mongolia is highly variable caused primarily by the westerly wind flow above several kilometers of the sea level and its interface with the topography. The Gobi Desert region is considered as the area with the highest wind resources due to its flat surface, whilst the mountainous regions have fewer wind resources. NREL assessed wind resource of Mongolia and produced wind resource atlas of Mongolia in 2001, shown in Figure 2.10.
According to the wind resource atlas of Mongolia prepared by NREL, Mongolia has enormous wind resource potential for both utility scale applications and small-scale rural electrification requirements. This is distributed largely in the southern and eastern parts of the country. Around 10% of the Mongolian territory has good to excellent wind resource and the country has the potential to build 1.1 TW of installed capacity of wind parks that can transfer more than 2.5 trillion kW of power per annum. Areas with moderate to excellent wind resource accounted for 40% of Mongolian territory. This has the potential to support over 4.3 TW of installed capacity and transfer around 8 trillion kWh of power per annum (NREL, 2001). Good-to-excellent and moderate-to-excellent wind resources at 30 meter above land are illustrated in Tables 2.5 and 2.6.

Figure 2.10. Wind Resource Atlas of Mongolia.

Table 2.5. Good-to-Excellent Wind Resource at 30 m above land.

<table>
<thead>
<tr>
<th>Wind Class</th>
<th>Wind Power (W/m²)</th>
<th>Wind Speed (m/s)</th>
<th>Total Area (km²)</th>
<th>Windy Land (%)</th>
<th>Installed Capacity (MW)</th>
<th>Total Power (GWh/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>300-400</td>
<td>6.4-7.1</td>
<td>130,665</td>
<td>81.3</td>
<td>905,500</td>
<td>1,975,500</td>
</tr>
<tr>
<td>4</td>
<td>400-600</td>
<td>7.1-8.1</td>
<td>27,165</td>
<td>16.9</td>
<td>188,300</td>
<td>511,000</td>
</tr>
<tr>
<td>5</td>
<td>600-800</td>
<td>8.1-8.9</td>
<td>2,669</td>
<td>1.7</td>
<td>18,500</td>
<td>60,200</td>
</tr>
<tr>
<td>6</td>
<td>800-1000</td>
<td>8.9-9.6</td>
<td>142</td>
<td>0.1</td>
<td>1,000</td>
<td>3,400</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>160,641</td>
<td>100.0</td>
<td>1,113,300</td>
<td>2,550,100</td>
</tr>
</tbody>
</table>


Table 2.6. Moderate-to-Excellent Wind Resource at 30 m above land.

<table>
<thead>
<tr>
<th>Wind Class</th>
<th>Wind Power (W/m²)</th>
<th>Wind Speed (m/s)</th>
<th>Total Area (km²)</th>
<th>Windy Land (%)</th>
<th>Installed Capacity (MW)</th>
<th>Total Power (GWh/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>200-300</td>
<td>5.6-6.4</td>
<td>461,791</td>
<td>74.2</td>
<td>3,200,200</td>
<td>5,572,900</td>
</tr>
<tr>
<td>3</td>
<td>300-400</td>
<td>6.4-7.1</td>
<td>130,665</td>
<td>21.0</td>
<td>905,500</td>
<td>1,975,500</td>
</tr>
<tr>
<td>4</td>
<td>400-600</td>
<td>7.1-8.1</td>
<td>27,165</td>
<td>4.4</td>
<td>188,300</td>
<td>511,000</td>
</tr>
<tr>
<td>5</td>
<td>600-800</td>
<td>8.1-8.9</td>
<td>2,669</td>
<td>0.4</td>
<td>18,500</td>
<td>60,200</td>
</tr>
<tr>
<td>6</td>
<td>800-1000</td>
<td>8.9-9.6</td>
<td>142</td>
<td>0.0</td>
<td>1,000</td>
<td>3,400</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>622,432</td>
<td>100.0</td>
<td>4,313,500</td>
<td>8,123,000</td>
</tr>
</tbody>
</table>


To date, 774 off-grid small scale wind systems have been used by nomadic families in remote areas (NSOM, 2017). In addition to these small wind systems, only one utility scale wind park with the capacity of 50 MW was built in 2013. Energy Regulatory Commission of Mongolia issued six licenses with the total capacity of 552MW to private companies that received approval from Ministry of Energy to implement large-scale wind projects. Two of them are under development, one in Tsetsii (50 MW) and the second in Sainshand (52 MW) and they are expected to be completed by the end of 2017.
1.7.2.3. Hydro energy resource and its utilization

Mongolia has a significant hydro energy potential for electricity generation. About 70% of the hydro energy resources are found in the mountainous sites of the northern and western regions as shown in figure 2.11. According to the evaluation of the Institute of Water Policy of Mongolia conducted in 1994, the hydropower electricity generation capacity was around 6,400 MW, capable of producing 56.2 billion kWh of electricity per annum included 3800 rivers with a flow of over one cubic meter.

![HYDRO ENERGY RESOURCE OF MONGOLIA](image)

Figure 2.11. Hydro Energy Resource of Mongolia.


According to the Water Management report-2013 published by the Ministry of Green Development of Mongolia, the total installed capacity of hydropower plants in Mongolia is 28 MW from 13 hydropower stations. This is less than one percent of the realistic potential of hydro energy resource (1200 MW – 3800 MW). Some details of the existing hydropower plants in Mongolia are illustrated in Table 2.7. Only two out of thirteen are grid-connected,
A critical review on solar home system program for Mongolian herders

large hydropower plants operating throughout the year while the others plants are off-grid, small-scale plants, operating to meet the energy needs of isolated villages during the warm months. Four small hydro power plants are not in operation due to equipment failure.

Table 2.7. Existing Hydropower Plants in Mongolia.

<table>
<thead>
<tr>
<th>№</th>
<th>Name of HPP</th>
<th>Year</th>
<th>Installed capacity (kW)</th>
<th>Annual Electricity Production (million kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Durgun</td>
<td>2008</td>
<td>12,000</td>
<td>38.7</td>
</tr>
<tr>
<td>2.</td>
<td>Taishir</td>
<td>2008</td>
<td>11,000</td>
<td>37.0</td>
</tr>
<tr>
<td>3.</td>
<td>Bogdiin gol</td>
<td>1997</td>
<td>2,000</td>
<td>6.0</td>
</tr>
<tr>
<td>4.</td>
<td>Uench</td>
<td>2006</td>
<td>960</td>
<td>1.5</td>
</tr>
<tr>
<td>5.</td>
<td>Kharkhorin</td>
<td>1959</td>
<td>528</td>
<td>1.1</td>
</tr>
<tr>
<td>6.</td>
<td>Guulin</td>
<td>1998</td>
<td>400</td>
<td>0.9</td>
</tr>
<tr>
<td>7.</td>
<td>Tosontsegel</td>
<td>2006</td>
<td>375</td>
<td>22.0</td>
</tr>
<tr>
<td>8.</td>
<td>Jigi</td>
<td>1989</td>
<td>200</td>
<td>0.4</td>
</tr>
<tr>
<td>9.</td>
<td>Erdenebulgan</td>
<td>2006</td>
<td>200</td>
<td>4.4</td>
</tr>
<tr>
<td>10.</td>
<td>Tsetsen Uul</td>
<td>2009</td>
<td>150</td>
<td>0.4</td>
</tr>
<tr>
<td>11.</td>
<td>Mankhan</td>
<td>1998</td>
<td>150</td>
<td>0.4</td>
</tr>
<tr>
<td>12.</td>
<td>Munkhkhairkhan</td>
<td>2003</td>
<td>150</td>
<td>0.4</td>
</tr>
<tr>
<td>13.</td>
<td>Zavkhan Mandal</td>
<td>2009</td>
<td>110</td>
<td>0.3</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td></td>
<td><strong>27'963</strong></td>
<td><strong>114</strong></td>
</tr>
</tbody>
</table>


Table 2.7 indicates that identified hydro energy potential is underutilized in Mongolia. The Mongolian government has focused mainly on large hydropower plants to regulate daily power generation in the Central Energy System and support variable renewable energy sources. Feasibility studies of high-scale hydropower plants with capacities of 315 MW at Egiin river, 220 MW at Selenge river, 100MW at Orkhon river and 60 MW at Khovd River To use hydro energy resource have been conducted.
Chapter 3 - Herders’ electrification in Mongolia and impact of the SHS program

3.1. Status of herders’ electrification in Mongolia

Mongolia has a vast land area of 1.5 million square kilometers where one-quarter of the Mongolian population is comprised of nomadic herders. These herders are adapted to their nomadic way of life and are geographically dispersed throughout the countryside in sparsely populated areas. Herders live in traditional portable tents known as “gers”, generally set up at least 5–15 km from each other. Providing electricity to these people plays an important role in enhancing basic human needs and improving the quality of living for the rural people.

The Mongolian government achieved remarkable success by implementing the solar home system (SHS) program with the aim of providing 100,000 SHSs to rural nomadic herders from 2000 and 2012. As a result of this program, 100,146 SHS with 50% subsidy from the Government were distributed to nomadic herders. Today 89% of the nomadic population in Mongolia representing 143,665 families have access to electricity by using SHSs and small scale wind turbines and diesel generators (Table 3.1).

Table 3.1. Electrification rate of herding households in rural areas of Mongolia

<table>
<thead>
<tr>
<th>№</th>
<th>Electricity sources</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
<th>2016</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Solar energy</td>
<td>117’410</td>
<td>120’012</td>
<td>129’704</td>
<td>130’452</td>
<td>134’038</td>
</tr>
<tr>
<td>2</td>
<td>Wind energy</td>
<td>2’290</td>
<td>1’499</td>
<td>1’002</td>
<td>1’338</td>
<td>774</td>
</tr>
<tr>
<td>3</td>
<td>Diesel generator</td>
<td>1’639</td>
<td>1’361</td>
<td>1’395</td>
<td>1’325</td>
<td>1’089</td>
</tr>
<tr>
<td>4</td>
<td>Central Power grid</td>
<td>5’863</td>
<td>4’119</td>
<td>7’435</td>
<td>7’076</td>
<td>7’583</td>
</tr>
<tr>
<td>5</td>
<td>Other</td>
<td>297</td>
<td>455</td>
<td>231</td>
<td>60</td>
<td>181</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>127’499</td>
<td>127’526</td>
<td>139’767</td>
<td>140’251</td>
<td>143’665</td>
</tr>
</tbody>
</table>

The total number of herder families | 145’982 | 145’311 | 145’311 | 149’735 | 160’650  |

The total number of herder families without electricity supply | 18’483  | 17’785  | 5’544   | 9’484   | 16’985   |

SHS is used more frequently by herders compared to wind turbines due to their ease of assembly on relocation, lower maintenance requirement, and more reliable solar resources compared to wind energy. In addition to these, SHS is environmentally friendly and does not emit greenhouse gas emissions that would otherwise result by using a diesel engine, kerosene or candle. As a result of reduced indoor smoke pollution, respiratory and other illnesses decreases among herder population. Therefore, SHS is the most common and suitable energy source for rural herders of Mongolia compared to other energy sources such as diesel generators and wind turbines. It is now common to see SHSs outside most herders’ tents in the Mongolian countryside, as shown in figure 3.1.

![Figure 3.1. A typical Mongolian tent with a solar home system.](image-url)

Other forms of electricity used by nomads include small-scale diesel generators (a total of 1,863) and wind turbines. Diesel fuel is imported from neighbouring countries and its price
increases year by year which makes it the most expensive energy source for herders. Diesel generators also result in noise and air pollution which impact the environment. Wind turbines, despite being a source of renewable energy, require constant maintenance and are also associated with noise. It is fairly difficult for herders to transport and assemble wind turbines when herders move from one place to other. Based on these difficulties, only 1% of the total herders utilise diesel generators and wind turbines for their electricity supply. The use of diesel generators and wind turbines as sources of electricity has decreased and are being replaced by SHSs.

Compared with the urban areas of Mongolia, business activities and commercial trade is minimal in rural areas. Sparse populations and the low electricity demand make it very expensive to reach these areas through the central power grid. Herder families also move from one place to another place up to 10 times a year except for some herders who live in urban areas. Therefore, it is not a feasible option to connect nomadic herders to the national grid. Only herder households living in urban areas (7,583) are connected to the central power grid.

3.2. Mongolian solar electrification program for herders

Since 2000, the Mongolia government has greatly emphasized increasing access to electricity for the country's large rural population. It is extremely difficult to connect nomadic herders to the national power grid. Instead, the Mongolian government approved the National “100,000 Solar Ger” national program in 1999. The aim of this program was to meet the basic electricity needs of herders living in rural areas through SHSs which were safe and of high quality. The overall purpose of the program was to increase access to electricity and reliability of this electricity among the herder population in Mongolia.
With bilateral grants and donations from The World Bank, Japanese and Chinese Governments, a total of 100,146 portable SHSs were delivered to nomadic households by 2012, enabling a half million herders to have modern electricity services. Based on the national statistics for 2010, the program reached 74% of the country’s herders in all twenty-one provinces and Ulaanbaatar, as shown in Figure 3.2.

Figure 3.2. Total distributed SHSs under the SHS program between 2000 and 2012.

Source: REAP, 2013.

3.3. Phases to the implementation of the SHS program

Phase-I (2000-2002): SHS with a capacity of 50W were distributed to 1,132 nomadic herders living in 43 soums of eight provinces. These SHSs were produced in Mongolia by the Mongolian Solar PV cell manufacturer under the Department of Post and Communication.
Phase II (2003-2005): The Mongolian government with the financial support from donor countries provided 31,790 portable SHSs to herder families in rural areas over the next three years. SHSs capacity was ranged from 20W to 75W.

Phase III (2007-2008): The Mongolian Government supplied funding from the state budget for the program and distributed 40,400 SHSs with the capacity of 50W to herders in all provinces through its local administration in all soums. Thereby, access to modern energy among the rural population was greatly expanded during these years due to the Government's efforts.

Phase IV (2009-2012): The initial success was then further accelerated and supported by international donors such as the World Bank, the International Development Association, the Global Environment Facility as well as the Government of the Netherlands who provided the necessary funds to expand the reach of the program. The World Bank distributed 26,816 SHSs to nomadic families through its Renewable Energy Access Project (REAP). REAP also helped redesign some core aspects of the Government's program based on experiences from the World Bank’s projects in other developing countries. Under the World Bank project, the SHSs were of high quality and met international standards through inspections which enabled herders to buy the SHSs with confidence. The project established 50 Sales and Service Centers (SSC) in every province of Mongolia where local people got advice on maintaining the SHSs. SSCs played an important role in selling SHSs to the widely dispersed nomadic population in Mongolia’s vast landscape and providing maintenance within reasonable proximity to nomadic people. If a defect was found after the sale, the PV system could be returned to one of the SSCs for a replacement. The availability of such services dispersed throughout the country is crucial for sustaining and maximizing the benefits of the SHS program. This not only helps anchor the program in the local community but also raises knowledge and awareness of the Solar Home Systems.
amongst the prospective customers. Among other things, the World Bank's REAP program contributed to the institutional capacity building to implement the program successfully through training courses. The project has trained roughly 400 people and thereby improved the capacity for implementing renewable energy projects and policies in Mongolia.

The program used a cost-sharing mechanism in which the Government and donors provided a subsidy to first-time purchasers of SHS by covering 50% of the cost of the PV systems. This subsidy made the SHSs more affordable to lower income herders and had a great impact on the number of sales. Table 3.2 shows the background information on financial sources and installed capacity of the PV systems. The average capacity of the PV system distributed to the herders was 50W. This system matches the herder’s basic electricity needs for lighting, watching television and charging mobile phones. In the first three phases, the distribution of SHSs relied on the existing network of 342 local village administrations enabling the SHSs to reach the most remote areas of Mongolia.

Table 3.2. Background information on distributed SHSs.

<table>
<thead>
<tr>
<th>№</th>
<th>Phases: Nominal installed capacity</th>
<th>Year</th>
<th>Number of SHSs</th>
<th>Subsidy</th>
<th>Financial source</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>I phase 50 W</td>
<td>2000</td>
<td>232</td>
<td></td>
<td>State budget</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2001</td>
<td>900</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>II phase 62 W</td>
<td>2003</td>
<td>11,170</td>
<td></td>
<td>Japanese Government donation</td>
</tr>
<tr>
<td>3</td>
<td>III phase 20, 50, 75 W</td>
<td>2004</td>
<td>6,520</td>
<td>50%</td>
<td>Chinese Government donation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2005</td>
<td>14,100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>IV phase 50 W</td>
<td>2007</td>
<td>26,500</td>
<td></td>
<td>State budget</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2008</td>
<td>13,900</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>2009</td>
<td>1,250</td>
<td></td>
<td>World Bank</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2010</td>
<td>3,750</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td>2011</td>
<td>11,743</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2012</td>
<td>8,257</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td></td>
<td>100,146 SHS</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2000-2012</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: REAP, 2013.
3.4. Current photovoltaic system business in Mongolia

After the implementation of the SHS program the subsidy for SHS was eliminated, and many new smaller companies have emerged that are dedicated to selling renewable energy systems on a commercial basis. These privately owned companies have entered the solar market focusing on the smaller systems that are more affordable to their customers. The emphasis on smaller systems and cutting costs is a common strategy employed by photovoltaic companies to make systems more affordable and marketable to a larger segment of the herder population. The photovoltaic market is increasingly competitive. Sales data collected from the National Statistic Office of Mongolia indicates that sales of photovoltaic systems have increased steadily and herders purchased over 30,000 SHSs between 2012 and 2016.

The companies selling photovoltaic systems typically involve two different types of operations. Some companies are distributors that procure PV components mostly from Chinese manufacturers and sell the systems directly to end users while two companies have their manufacturing facilities for key components including PV modules. These two companies sell PV systems mainly through their established channels in rural areas. The domestically manufactured photovoltaic modules are used for many applications including telecommunication, commercial and residential PV systems, pumping water, and street lighting.

Key companies involved in the PV industry in Mongolia include the Malchin Group and Sankou Solar Mongolia LLC. Malchin group, founded in 1994, is one of the leading distributor companies in the solar market. Malchin offers many different kinds of electrical products to herders based on their needs. These include solar home systems, solar
batteries, portable freezers, LED television, washing machines, smart hand washers, solar water pumps, satellite antennas and spare parts for SHSs.

Sankou Solar Mongolia LLC, which established in 2011, has a manufacturing capacity of 12 megawatts per year and exported most of their products to Japan due to the limited PV market in Mongolia. By 2016, Sankou Solar exported 40,000 solar panels to Japan and these panels were used in residential and commercial systems. Sankou Solar LLC offers four different capacities of PV systems to consumers including 75W, 150W, 210W and 270W.

The photovoltaic market is likely to remain competitive for reasons such as the reduction in the cost of the PV systems, the small start-up capital requirements and little investment required in equipment, buildings and vehicles. The technology required to put systems together is also relatively simple and widely available. Presently, there are no dominant brands, and the companies compete based on their product presentation and promises of quality, performance, and customer convenience.

3.5. Conclusion

The SHS program in Mongolia was implemented successfully and resulted in the distribution of 100,146 SHSs to around 70% of rural herders. It expanded electricity supply to herder families and herders in turn receive comfort, lighting and entertainment by doing away with polluting and expensive diesel generators. The program reached the most remote areas of Mongolia through its sale-service centres and the cooperation of village administrations. This improved the quality of the SHS. The distributed SHSs help to reduce over 40,000 tonnes of carbon dioxide emissions a year and minimise indoor air pollution, by eliminating the use of candles and kerosene. The high initial cost of SHS and relatively low-income of people living in remote areas were the main barriers in
providing electricity to the nomadic herders in rural areas. Therefore, SHSs were subsidized by 50% to make them affordable and to expand the electricity access to herders without electricity service.

The SHS served as an enduring reminder that centralized and capital-intensive energy systems. The SHS is the cheapest, most suitable and environmentally friendly energy source for nomadic herders in Mongolia, who reside every season with no fixed location. The Mongolian solar market has been competitive in recent years, typically dependent on imported Chinese PV systems. However, it has the potential to become a self-sustaining part of the local economy with the Government support. The Mongolian government is required to approve a standard for the PV system and take control on the standardization of PV systems to increase the confidence of consumers purchasing PV systems. The National Statistics Office of Mongolia revealed that around 20,000 nomadic herder families still lack electricity in rural areas and are not able to afford SHSs due to their financial difficulty. If the Mongolian Government makes commitments to expand the energy access to all nomadic families based on the previous SHS program, the new SHS program should ensure the participation of private sector companies to sustain the solar market in the long term. It should also consider bottom-up approach and get feedback from the end users to improve the program and match their electricity needs.
Chapter 4 Survey analysis

The Mongolian solar home system (SHS) program distributed 100,146 portable SHSs to the herders in remote areas. This chapter aimed to gain some measure of the factors behind the success of the program and barriers encountered during the implementation of the program through two surveys. One survey targeted the stakeholders and the second survey was aimed at the herders. Survey questionnaires were developed based on the literature review. Survey results were both qualitative and quantitative in nature. The two surveys were carried out through email and over the phone. The email survey was conducted with the stakeholders while the survey with the herders was carried out by a phone call. The herders selected for the phone survey were all SHS purchasers under the program.

4.1. Stakeholders’ survey analysis

A total of 15 participants were identified and chosen purposively based on their experience with the program using the author’s personal contacts. The survey involved the implementers of the SHS program, researchers and policy makers to gather their views on the outcomes and barriers of the program, and the future prospect of the program. Seven (47%) of the respondents worked for the private companies, five (33%) were employed by the Government agencies, and three (20%) by research institutes as shown in Figure 4.1.

![Figure 4.1. The number of participants from three different organizations.](image-url)
The email survey used two types of questions (Annex I), open ended and ranking. Open ended questions were used to obtain their views on the impact of the program, its success and shortcomings. Structured questions were used to rank the factors of the programs successes and issues. Evaluation scales ranging from “Strongly agree” (1) to “Strongly disagree” (5) were used to rate participants’ responses. The structured questionnaire included the following issues:

- The program output achieved.
- The main reasons behind the program’s success.
- The main issues encountered during the planning, implementation, and evaluation stages of the program.
- Participant opinion on the future Solar PV electrification program for the herders in Mongolia.
- Criteria seen to be important or critical to upgrade the existing solar PV electrification program or to develop a new program for the herders in Mongolia.

The analysis of the survey was focused on the degree of success and barriers of the program, and important criteria for upgrading the future SHS program in Mongolia.

4.1.1. Main success factors behind the program.

The first question of the survey asked the participants their opinion about the achievements of the program. About 87% of the respondents answered that the program was successfully implemented and reached its goal. The respondents highlighted the following important factors that helped contribute to the program’s success. Most of these factors were the goals of the program.

- Proper government policies and government collaboration.
- Good foundation for increasing renewable energy penetration.
- Greenhouse gas reduction through using clean energy source for electricity
- Affordable cost of the SHS through cross-subsidy.
- Matched capacity with herders’ electricity demands
- Increased awareness development of the SHS program

One respondent did not answer the first question. Another participant responded negatively as they felt that the program was not well planned and therefore was not a success. This participant explained that the Government had only a vision but did not have a clear plan on how to implement this program and the issues that were required be considered. The participant also felt that the program lacked proper operation and maintenance manuals for herders in the first phase. The last phase of the program implemented under REAP of WB changed the course of the implementation. The Mongolian Government finally accepted the principles offered by REAP which were based on experiences of implementing similar programs in other developing countries. As a result, the various problems encountered prior to the involvement of REAP were overcome and the outcome of the program was a success.

The second question of the survey examined the importance of success factors behind the program. Participants were asked to evaluate eight indicators from the list which were identified from the literature review (Tania et al. 2016). The success factors as reported by the respondents are summarized in the figure 4.2. The list included Government support policy, financial support, established sales networks in local areas, campaigning of the program, appropriate technology with superior quality, generating employment, regular evaluation of the program and training provided to the technicians.
Figure 4.2. The summary of survey result on the main success factors behind the program.

All respondents agreed that financial support was the most important factor in implementing the program successfully. There was also a strong level of support for Government policy (93%), awareness creation among herders (87%), superior quality of SHSs (67%), and establishing sales network in the local areas (60%). 47% of the participants agreed that both employment generation in rural areas and regular evaluation of the program were least critical factors in the success of the program. Only one third of the participants agreed with the statement that training provided to the users was the main success of the program.

According to the respondents, the most important factors were: financial support, Government policy, awareness creation among users, high quality of SHSs and establishing sales network in the local areas while the least important factors were...
training provided to the users, employment generation and regular evaluation of the program.

4.1.2. Main barriers of the program.

Respondents were also asked to answer an open-ended question based on their experience. However, one fourth of respondents answered this question and some respondents provided more than one answer. A total of seven types of barriers were defined in the questionnaire.

Table 4.1. Issues for the Mongolian SHS derived from the survey.

<table>
<thead>
<tr>
<th>Issues</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lack of sufficient funding</td>
<td>Economic</td>
</tr>
<tr>
<td>Improper management</td>
<td>Institutional</td>
</tr>
<tr>
<td>Quality of SHS</td>
<td>Technical</td>
</tr>
<tr>
<td>Lack of regular program evaluation</td>
<td>Institutional</td>
</tr>
<tr>
<td>Improper supply chain</td>
<td>Institutional</td>
</tr>
<tr>
<td>Poor program planning</td>
<td>Institutional</td>
</tr>
<tr>
<td>Spare parts availability</td>
<td>Institutional</td>
</tr>
<tr>
<td>Lack of training course for herders</td>
<td>Technical</td>
</tr>
</tbody>
</table>

34% of respondents considered the most significant barrier to the SHS program were the lack of sufficient funding and improper program management. Other issues identified by the participants included poor quality of SHS, lack of regular program evaluation, and improper supply chain. Other issues/barriers that appeared to be less important were poor program planning and spare parts availability after the implementation of the program.
However, according to the literature review, the availability of spare parts was very important for the success of the program (IEA, 2003).

Most participants agreed that the program did not provide sufficient training for the consumers of SHS i.e. the herders. As a result of this, some herders were not able to operate their SHSs properly and faced operational issues. Professional advice and guidance were required to fix this issue.

Survey participants reported main two operational issues with the SHS from the photos taken at the herders’ homes. In figure 4.3, pictures show that most PV panels were placed at different latitude angles. PV panels should be placed directly facing the sun in order to increase its output power. Therefore, it is essential for herders to be aware about placing their panels at the correct latitude angles.

![Figure 4.3. Cracked PV panel used in herder’s electrification.](image)

Secondly, the pictures show that most PV panels were not mounted on the mounting racks. Herders sometimes find that the PV panels crack due to strong winds when the panels are not mounted appropriately. The panels also fail during the relocation of herders. Most
herders pack their belongings on horses or camels which are not durable and safe modes of transportation for fragile products such as PV panels. In order to fix these issues, herders are required to use mounting racks to mount panels and durable safety boxes for keeping panels normal during regular relocation.

Figure 4.4. Improper connected batteries used in herders’ electrification.

Figure 4.4 shows batteries used with the SHSs which are directly connected to the electric appliances. Survey respondents noticed that herders were not aware of using batteries properly. Most nomadic people do not know the difference between a car battery and deep cycle battery for the SHS. Therefore, some herders use a car battery which is not suitable for the SHS and cannot provide sufficient energy to users. The improper use of batteries was a potential cause of fires, electric shocks and emission of toxic fumes into the air. Therefore, survey participants considered that training the consumers/herders in the proper use of the SHS should be an essential part of the future program to avoid further issues related to SHSs and increase the life time of the SHSs.
4.1.3. Stakeholders’ views on improvement of the Mongolian future SHS program.

Participants were asked to evaluate the importance of each indicator from the list which was developed from the literature review (Tania et al. 2016). The list includes availability of battery recycling, ease of operating SHS, users’ training, establishing after-sales service centres in local areas, high quality of SHS, enabling participation of private companies, involvement of users in the designing stage of the program, the role of stakeholders in the program, financial support, generating employment in rural areas, regular evaluation of the program, regular monitoring of customer satisfaction and developing standardisation. The important factors as ranked by the respondents are summarized in figure 4.5.

Figure 4.5. Summary of the important indicators for the future SHS program.
All participants agreed that high quality of SHS and enabling participation of private companies should be the most important factors for the future SHS program. About 93% of the respondents answered that the availability of battery recycling, financial support and developing a standardisation process are critical for purchasing a SHS program. The majority of the respondents (87%) indicated that it was crucial to establish after sales-sales services centres in rural areas. The most important factors are: ease operation of SHS (80%), the role of the stakeholder in the program (80%), regular monitoring of customer satisfaction (80%), generating employment (73%), and regular evaluation of the program (80%). Conversely, factors of less importance included in the survey questionnaire were related to users’ training on operation and maintenance of SHS (7% disagreed and 7% strongly disagree) and the involvement of users in the designing stage of the program (13% disagree and 7% neutral).

The majority of participants strongly agreed that the solar electrification program should be implemented again in Mongolia based on the previous experience. Only one participant disagreed with this statement. The participant explained that there were another issues for the herders in the countryside. Their opinion was that the government should focus on building the electricity supplement for pumping water in the local areas using solar power systems rather than distributing SHSs to herders. Pumping water from the ground would improve the pasture and water availability in the countryside.

Main suggestions made by the respondents and some issues to be considered in the future program in Mongolia:

- High electricity demand of herders
- High number of low income herders with lack of electricity service
- Enabling private company involvement in the program
• Battery recycling.
• Sustainability of the program in the long term.
• Subsidy for a superior quality SHS with a higher capacities and lower price.
• Solar market regulation (standardisation)

Most respondents indicated that a significant number of herders lack access to electricity in countryside due to their financial difficulty. The previous SHS program was aimed at distributing as many SHSs to herders as was possible, however, the SHS capacity was limited to 50W which was aimed at meeting herders’ the basic electricity needs of herders. Currently the aim is to increase the capacity of SHS, so that these SHS systems can power many electric appliances due to improved quality of life and living standards of herders. Most respondents agreed that it is essential to establish standardization for the PV system components in order to improve the quality of SHSs in the market. Domestic PV manufacturers produce high quality PV systems, but they cannot compete with cheaper, imported SHSs which are lower in quality.

4.2. SHS users’ survey

Phone interviews were carried out with 70 herders, who are current users of SHS. The herders were selected from the capital city, Ulaanbaatar, and from 17 out of the 21 provinces, as shown in Figure 4.6. The questionnaire was designed from the literature review. The survey was aimed to obtain the opinion of SHS users on the program’s impacts, barriers encountered during the operation of the SHS and also their opinion about future SHS program in Mongolia.
The participants were asked the following questions: (1) social, economic and environmental impacts of the program, (2) issues encountered during the operation of the PV systems, (3) herders’ opinion about purchasing a subsidized PV system with the higher capacity, and (4) important factors for improving the SHS program.

4.2.1. The impacts of SHSs on herder households

The portable SHS distributed to the herders under the program was equipped with a lamp. Following access to the SHSs, herder populations have been able to buy televisions and mobile phones. The impact of SHS on the rural life has been significant. The following figure summarizes the social, economic and environmental impacts on the herders’ daily lives.
Prior to the SHS program, herders needed to take a trip to the nearest village or listen to the radio in order to get the information they needed. Respondents (94%) reported that the availability of electricity helped them access information on weather forecast and livestock market price through watching television and using mobile phone. In addition, SHSs enabled nomadic herders stay connected to the wider world and reduced their isolation. The use of mobile phones within the herder communities allows rural people keep in contact with their children studying in the urban areas and also contact doctors for advice. Herders are able to access critical information such as weather forecasts easily. This information helps them to adapt to extremely harsh climatic conditions and keep their livestock safe. These systems also help their individual businesses and other income related activities. For example, herders now arrange business transactions for the sale of livestock and cashmere at the fair price level over the phone.
Access to more lumens and cleaner light

Prior to acquiring a SHS system, the herders interviewed were dependent on candles, kerosene and oil for lighting. These types of lightning cause indoor air pollution and may lead to a fire hazard. Following the distribution of SHSs candles are used only in emergency situations when electricity output is not sufficient. The SHSs have made it possible for herder families to increase the use of brighter electric lightning which can be utilized both outside and inside the tent. 94% of interviewers (73% strongly agreed and 21% agreed) are agreed in that advanced electric light bulbs provide cleaner and higher lumens of lighting compared to previous the generation lightning systems.

Reduction in use of traditional fuels

Herders’ main traditional fuels are coal, wood and livestock residue. These fuels are used for cooking and heating purposes. Almost half the interviewees (49%) disagreed with the statement that the use of traditional fuel was reduced. The SHS distributed under the program is capable of powering electric lamps, televisions, satellite dishes and phone chargers due to its limited capacity of 50W. Therefore, herders find that the SHS is incapable of powering an electric oven and a heater.

Increase in work and study hours

The majority of the participants (76%) responded that increased access to electricity allowed them to spend more time on studying and work diversification. Prior to the SHS, herders needed to postpone their daily work especially in winter when the sun set early as they could not work after dusk. Electric lighting made it possible for family members to finish their daily work without rushing and expanded their work time in the evening.
Figure 4.8. Social impact on the herder population using SHSs.

*Increased time spent on social activities*

Almost half of the respondents (47) agreed that they found more significant social changes with the use of the SHSs. However, some interviewees (19%) disagreed with this statement as they were unable to partake in social activities due to their isolation and high work load. It is evident from the survey interviews that, the greatest benefit of having mobile phones is that the herders are more connected with outside world and have closer relationships with their families and friends. Today, most herders own mobile phones and are able to make free phone calls once they pay a fixed low cost for mobile use on a monthly basis. Herders feel that they have increased communication with their relatives in urban areas and outer world with just a simple phone call. Prior to this they needed to go to the post office in the village to make a call which was time consuming.

*Increased time spent relaxing and watching TV*

The majority (89%) of respondents agreed with the statement that SHSs extended their evening activities to include listening to music and watching television. 57% of those
interviewed indicated that they spent increased time on relaxing and other common activities. Interviewees find themselves staying up one-two hours more in the evening due to the availability of bright lighting as well as watching television after the evening meal. After herders finish their work for the day, they usually watch movies and entertainment programs on the television. The time spent on relaxing and watching television made herders’ lives more enjoyable.

*Improvement in quality of life*

Based on the survey result, the living condition of the nomadic people’s has improved significantly, which is a direct result of the expanded electricity service. Among the interviewed herders, 60% (24% neutral and 16% disagree) noted that the SHS enabled improvement in the herders’ quality of lives. It was noticed from the survey results that the SHS had become the most useful equipment which made their lives more enjoyable in the countryside. Some examples provided were that the SHS made it possible for children to learn new concepts by watching educational programs on the television. Compared to the period prior to the SHS program, the herders’ living conditions improved significantly. In addition, the expanded electricity service in the countryside helps to decrease the difference in living standards between rural and urban areas and reduce migration from rural areas to urban areas.
Figure 4.9. Economic impact on the herder population using SHSs.

**Soft loan available for the users**

Only one third of respondents agreed with statement that soft loan was available for the users. Almost half of respondents said they did not remember that there was soft loan available. 27% of respondents disagreed with the statement because they found that there was no soft loan available for purchasing the SHS. Some herders reported that banks considered it is risky to give credit to herders as their income was not durable and that they did not own valuable property.

**Repayment amount (loan) is a burden**

About one third of respondents (42% neutral and 27% disagree) noted that they bought their system with cash so loan was not a burden for them. Only 3% found the loan repayment a burden as they had received credit for their SHSs where the interest fee was high (around 18% a year) and the duration of loan was short (2 years). In addition, their
income pattern was such that paying the loan on time was the main hurdle. The income of most of these herders is seasonal. Income is generated by selling their livestock in autumn and selling wool/cashmere in spring. However, the loan had to be paid every month. This problem could be solved with proper planning around the income pattern of the users.

Changes and improvement in the financial status of the users

Some herders (43%) indicated that their productivity improved as a result of increased time for evening activities. However, they were unsure about any increase in their income. 20% of respondents (neutral) reported that it was difficult for them to quantify their income increase with the help of SHSs. However, 37% of nomadic households agreed their income has increased after they gained access to lighting, television and mobile phones. Nomadic herders are able to check the current market price of livestock and cashmere easily prior to selling their products. Better access to reliable market price enables them to make transactions at higher price levels. Prior to the SHS, it was difficult to obtain market price so herders accepted the suggested price. Now transparency helps herders to sell their livestock product at higher prices which enables them to increase their income.

Reduction in monthly expenditure on energy use

Around two third (64%) of interviewees agreed that the SHS allowed them to minimize their monthly expenditure on energy use because candles were replaced by electric light bulbs. In addition, the use of dry batteries for radios and a flash lights has diminished significantly since televisions became common place. 20% of respondents (neutral) were not sure about the impact of SHS on the household budget. However, 26% of interviewees reported that the price of light bulbs price was higher than candles. Therefore, monthly expenditure on energy did not reduce significantly as the light bulbs need to be replaced frequently. After having access to electricity, herder households tend to purchase many
electric appliances such as light bulbs, televisions, satellite dishes and mobile phones. Therefore, it is difficult to define whether monthly household expenditure on energy use was reduced or not.

4.2.2. Difficulties faced by the herders during the operation of SHSs.

According to the phone interviews, herders experienced some difficulties during the operation of their SHSs. It is most likely that most of the problems are caused by the batteries and incorrect connection of the system. The following issues are illustrated from the past experience.

*PV system design issue*

Systems were not designed depending on the users’ electricity requirements because users were not involved in the system design. Therefore, the size of the PV system was limited. The average size of the PV system distributed to herders under the program was 50W. This was able to supply the basic electricity needs of the herders. Some of the herders had an unrealistic expectation about the SHS’s capacity of being able to power all electric appliances in the ger including a refrigerator, electric stove and television. Their overestimation led them to buy many electric appliances causing the PV system to fail.

The PV module mounting rack provided by the SHS program has a fixed angle at 60 degrees which significantly reduces the amount of electricity that can be generated during the summer months. Some herders mentioned that they sometimes find it hard to transport the SHSs during their relocation due to its big size. In addition, herders found that the PV panels cracked during regular relocation because there is no safety frame for the PV module.
Lack of operation maintenance knowledge about the SHS

Most herders do not have sufficient information regarding the operation and maintenance of the SHS. Training was not provided to SHS users under the program due to the isolation of the herders, the financial difficulties of the program and lack of human resources for providing training courses in rural areas. The herders were only provided with operation manuals. Therefore, a significant number of mistakes occurred due to insufficient training of the installers. It was common herders’ request that they required both the operational manuals and the maintenance manuals. When the system failed, they do not know what was wrong with the system and were not capable of maintaining their system by themselves requiring them to take a trip to urban cities to maintain their systems.

Battery related issue

Most of the SHSs have a battery bank capacity with an autonomy hour of few hours. Most herders are unaware of the ways to limit their energy consumption during overcast days. Some herders purchase inverters from the local market and try to use home appliances operating at 220 V AC. However, the battery of the SHS is discharged too deep and cannot be recharged by solar energy. These issues reduce the battery life. Today, the original batteries distributed under the program have been replaced by uncertified, low quality batteries from the local market. The performance of these batteries is not of high quality and is expensive for herders.

Reducing the performance of the SHS

Some herders try to build their own SHS by directly connecting the PV panel to the car battery and connecting electric appliances to the battery directly without using a power controller, thereby reducing the performance of the SHS. In addition, many herders install
the solar panel on the ger (tent) that leads to lack of cooling and thereby reducing the performance of the SHS by dropping the PV voltage. Herders do not clean the solar PV module regularly so the performance of the PV module is reduced due to dirt (dust and bird excrement) on the surface of PV module.

4.2.3. Herders attitude towards the future SHS program.

Based on the survey results, all herders are keen to be involved in future SHS programs. The majority of herders agreed that the following factors should be considered in the future SHS program (Figure 4.10). This list of supporting factors for the future SHS program was prepared based on literature review (Tania et al. 2016).

![Herders attitudes toward the future SHS program.](image)

Figure 4.10. Herders attitudes toward the future SHS program.

**Financial support (Subsidy)**

The average price of a PV system ranges from 1,650,000 tugrug ($690) for a 100W system to 2,400,000 tugrug ($1000) for a 200W system. In Mongolia these prices are not
affordable for most herders. The majority of survey participants (73% strongly agree and 10% agree) agreed that financial support is a critical factor for the next program. Just 15% of the survey participants answered neutral and only 1% is disagreed with this statement. The majority of respondents reported that the cost of SHS is the main factor for them get involved the program. Despite the financial support, they are not able to afford it.

*Improved quality of SHS*

Based on the survey, 86% of respondents (10% neutral and 4% disagree) considered that the quality of SHS was one of main supporting factors while developing a future program. Some herders said that the SHSs distributed under the program were of high quality. Nomadic herders just replaced batteries and light bulbs after few years. However, uneducated herders become victims of low quality systems. Nowadays, issues related to the batteries are a source of problem for the herders.

*Systems are designed to reflect users’ requirement and easy to operate*

The previous SHS program distributed PV systems with limited capacities. Therefore, herders have requested that in future, SHS systems of various capacities should be offered based on their affordability and electricity requirements. Some herders are keen to upgrade their previous SHS with the same capacity based on their financial situation while other herder households want to increase the capacity of SHSs to operate a freezer and a washing machine. Only one herder household among the interviewees had installed an additional PV system (150W) in order to accommodate a freezer. He finds the freezer helpful in his life as his family can keep their meat (food) fresh for almost one month. The survey found that all herders expressed their interest to upgrade their current SHSs and use larger electric appliances. After herders slaughter a sheep for cooking, they needed to consume the meat within 3 days in order to avoid spoilage. Therefore, herders slaughter
more livestock in summer rather than winter. If they had a freezer, they would spread out and balance their meat consumption over time. In addition, refrigerators enable herders to keep vegetables fresh and make their meal more nutritious. With the use of refrigerators, they can increase their income during summer through keeping their dairy products fresh and selling dairy products in the local market. A Washing machine is the second most wanted electric appliance which is useful for herders in improving their hygiene and also saving time on washing clothes by hands. The majority (86%) of survey participants agreed with the statement that SHSs should be designed to reflect users’ requirement while 5% is not agree with this statement. Also, 91% of interviewees (9% neutral) reported that the systems should be easy to operate.

*Users training and guidance book for operation and maintenance of the SHS.*

Herders noted that there were no training courses for herders during the implementation stage of the program. In fact, herders actually learned about the SHS systems from each other. Herders who had successfully used the SHSs actually provided a kind advice to other herders who did not know how to operate and maintain the SHS. Herders understood that they need not only guidance manual for operation, but also need maintenance manuals. Herders found that it is difficult to maintain their system in the capital city. There was a lack of experienced technicians in the rural areas and even in the province centers. 72% of survey participants (28% neutral) said they required training courses for the operation and maintenance of the systems.

*Availability of spare parts in local areas and distance to the closest local after-sale service center*

According to the survey, most herders serviced their SHSs in the capital city of Ulaanbaatar due to the lack of after-sale centers in the rural areas. Herders are scattered all over the country so they take long trips (longest distance around 1600 km away) from their
home to Ulaanbaatar. In some cases, the SHSs components were not maintained over long periods due to the high cost of transportation to the urban cities. The majority of respondents reported that local after-sale service centers and spare parts availability in local areas were important factors in improving the previous SHS program.

*Availability of battery recycling*

Lead acid battery is the most common battery used for the SHS in Mongolia. Its electrolyte is harmful for the environment and human health. Under the SHS program, over 100,000 lead acid batteries were distributed with the SHS and used for storing energy in rural household. Today, most of them have been replaced by new batteries. The old, replaced batteries cause big issues in the rural environment. 84% of respondents noted batteries should be collected and recycled properly. Only 13% of interviewees disagreed with this statement because battery replacement cost would increase the overall cost of the program.

4.3. The major findings and Lessons learned

4.3.1. The program output

The program was purely implemented to solve social issues of herders living in the countryside and improve their living conditions. The SHS program was launched by the Ministry of Energy of Mongolia with the support of donor countries and organizations. With the Government supportive policy, half million nomadic households gained access to electricity successfully through portable SHSs (Benjamin et Al, 2012). The SHS program provided many benefits and had significant strengths.

From the survey findings, the impacts of the program are summarised below:

- Access to more lumens and cleaner light by replacing candles and kerosene lamps;
- Easier access to information and communication;
- Increase in work and study hours;
- Improvement in quality of life;
- Increased time spent listening to the radio and watching TV;
- Increased time spent on social activities and relaxation;
- Reduction in monthly expenditure on energy use;
- Improvement in the financial status of the users;
- Reduction in greenhouse gas emissions.

According to the respondents (herders), the SHS program impacted positively on their livelihood and improved living conditions in the remote areas. The use of SHS created and a new market for electronic appliances and thereby spurred economic growth in the local economy. As a result, local shops offered consumers, electronic appliances such as satellite televisions, radios, light bulbs and cellular phones. Consequently, these appliances helped the herders enhance their income generating activities. Herders were able to use mobile phones to check the market prices of cashmere and wool easily which in turn enabled them to sell their livestock and dairy products at market prices.

Survey results were also supported by the study carried out by the National Statistics Office of Mongolia (NSOM, 2017). According to the report (NSOM, 2017), the majority of herders use mobile phones (96%), televisions (74%) and other electric appliances in their daily lives while 25% of the herder population use radios. With the help of these electric appliances, herders have experienced an improvement in their quality of life. In the evening the herders watch television or listen to the radio while children can read and study with the help of electric light. The electric bulb has displaced the use of candles and oil lanterns, which has helped improved the indoor climate as well. The herders could more easily manage their livestock by watching weather forecasts on the television.
throughout a year. The increased penetration of mobile phones among the nomadic people has reduced their isolation and enabling them to stay connected with the wider world. The following figure shows the number of electric appliances that are commonly used by herder families.

Figure 4.11. Common electric appliances used by the rural herders in Mongolia.

Prior to the SHS program, small-scale diesel generators were the main sources of electricity for the herders. SHSs replaced old, inefficient, polluting diesel generators. As a result, the greenhouse gas emissions were reduced in the rural areas. It is estimated that the SHS with a capacity of 50W would prevent 400 kg of CO$_2$ emission per year (GEF, 2006b). Therefore, it may be construed that the SHSs distributed under the program would help avoid approximately 40,000 metric tons of CO$_2$ emissions a year. The SHSs also improved indoor air quality by supplanting oil or kerosene lights sources.
4.3.2. Drivers of the program

A list of drivers behind the success of the program is determined from the email survey conducted with the program stakeholders and these are summarised below:

- Supportive Government policy
- Financial support (subsidy)
- Local after sale networks,
- Campaigning of the program or awareness creation,
- Appropriate technology with superior quality,
- Increasing income and also generating employment,
- Regular evaluation of the program.

The majority of participants reported that the Government support policy and financial support were the most important factors behind the success of the program. Another major reason for the success of the program was a cost sharing mechanism initially introduced by the Government of Mongolia and later prolonged by the World Bank and other international donors.

Local after-sale service, quality of the technology and regular evaluation were cited as being of critical importance for the success of the program. Prior to the program, SHSs typically were sold in urban areas. It was difficult for the herders to own a SHS due to the distance they had to travel to access the system and the high transportation cost. In addition, the market price of SHS was high, and SHSs were of low quality. The latter and generating employment and training received by users’ were commonly cited in the literature as important factors (Tania et al. 2016). However, survey participants (stakeholders) found these issues as neutral factors.
4.3.3. Limiting factors of the program

Despite the benefits of the program, the SHS market is confronted with issues. These include lack of adequate training provided to the users of the SHSs, limited after sales services in the local area, low quality of components especially the batteries, loan repayment and lack of spare parts in the local markets. The barriers classified as: financial, technical and institutional constraints.

Training was not provided during the implementation of the program as it was costly for implementers to organize training for the users’ due to the sparse and highly dispered herder population. However, majority of the herders perceived training on using and maintaining the system as an important criteria in reducing the maintenance cost of their systems. Herders are sparsely located in the countryside which makes it difficult to service their systems in the urban areas due to increased transportation costs. Awareness of the SHS among the herders is low which in turn leads to operational hurdles. Some herders use car batteries in the SHS thereby reducing the performance of the SHS. Some herders purchase inverters from the local market and try to use home appliances operating at 220 V AC. Many herders install the solar panel on the ger, due to lack of space between the roof of ger and solar PV panel. This leads to lack of cooling and thereby reducing the performance of the PV module. Herders do not clean the solar PV module often. As a result, performance of the PV module is also reduced due to dirt (dust and bird excrement) on the surface of PV module.

The previous program delivered SHSs through soum administrations. The Government then established 50 sale-service centers in all provinces by choosing local private companies. The selected local companies did not have the experience in running a business in the energy sector. Therefore, both delivery channels were incapable of providing advice
on the operation and the maintenance of the SHSs. After the completion of the program, these centers existed from the solar business as the market size of this business was small and not profitable. An appropriate regulation is required to solve this issue. Majority of the herders reported that spare parts are now not available in the local areas.

Standardization for SHS components has not existed in Mongolia. This results in some issues in the solar market. Some SHS components especially batteries that are sold in the local areas lack reliability. When the original battery fails, herder households often purchase low quality batteries for replacement. These batteries are discharged quickly and have to be changed every couple of years. Uncertified components led to higher operational costs, reduce the users’ confidence in the system and finally consumers advise others not to purchase such a system.

The users of the SHSs were not involved in the initial designing of the system. Therefore, the system designed was not based on the herders’ requirements. The average capacity of the distributed SHS was limited to the capacity of 50 W that was used to typically power the basic electricity needs of the herders. The design flaws of the SHS system included battery bank capacity with an autonomy hour of few hours. Secondly, the PV module has a fixed angle at 60 degrees which significantly reduces the amount of electricity that can be generated during the summer months.
4.4. Conclusion and lessons learned

Many lessons were learned from this research as the program implemented in Mongolia was unique due to its large territory and sparsely populated nomadic herders.

Mongolian SHS program financed by donor countries and institutions were aimed at disseminating as many SHSs as possible to rural herders, giving more priority to the number of distributed systems rather than to the sustainability of the SHS. Providing subsidies to the users removed the financial barriers and facilitated the widespread introduction of SHSs. In this way, the users benefitted from this financial support and obtained the SHS at lower prices. However, the donor funded program hindered the development of the solar market with the market distortion. Private companies were not involved in the program and could not develop their market structure depending on the donor program.

The second lesson was the lack of transparency of the distribution channel. In the first stages of the program, some SHSs were distributed for free during the parliament election campaign that led to lower cost recovery rate of the SHSs. SHSs were not delivered in a transparent way resulting in undefined responsibilities of the distributing channel. Therefore, funds were reduced and not recovered which resulted in the lack of funding for the distribution of the SHSs. In the fourth stage of the program, the World Bank was involved in the implementation of this program and provided the funding needed for subsidies and taking systematic actions such as establishing sales and service centers in each province, and implementing a continuous monitoring and evaluation procedure. The program was then successfully implemented with the support of the World Bank.
Rural herders were satisfied with the use of SHSs and considered the systems as the most suitable energy source for them. Many herders claimed that the SHS was more reliable than wind turbines which often break down due to strong wind or underperform when wind speed is low. Other herders saw the SHS as affordable and environmentally friendly compared to the diesel generators. It was revealed from the survey that consumers demand for electricity increased significantly. Some consumers had exceeded the capacity of the SHS due to changing their lifestyle to include the use of many electrical appliances. Herders are willing to increase the capacity of SHSs to accommodate freezers and washing machines as this can be interpreted as a step towards improving the living conditions of the rural households.

The SHS users have encountered two main issues including high initial cost of the SHS and low quality of SHS components when they purchase a SHS from the local market. Most herder households do not want to access commercial credit due to short loan payback period and high payment rate. On the other hand, some financial institutions do not offer commercial credit to herders as they lack collateral and have no durable income throughout the year. When the herders purchase the system with cash, they usually purchase the cheapest system from the local market resulting in higher maintenance and operational costs than expected. The lack of information regarding the quality of the systems and unavailability of spare parts are the other barriers faced by the users.

Based on the lessons learned from the surveys, it is recommended that the future SHS program should develop the solar market in a sustainable way by approving appropriate Government policies that support private companies, ensure the quality of the SHS and train the users of the SHS. In the long term, both herders and private companies would benefit from the program.
Chapter 5 - Summary and Conclusion

The purpose of this final chapter is to revisit the research questions and summarise the extent to which this study has been able to provide the answers for those questions. Recommendations are made regarding the implementation of future SHS program in Mongolia based on the findings from this research. This chapter also make suggestions to what future research is required or would be useful in this field.

5.1 Answering the research question

The first research question that led to this research was, ‘What is the current status of SHSs program in Mongolia?"

This research focused on the Mongolian SHS program and has attempted to collect information on the pros and cons of the program. The study also analysed the sustainability of the program based on the results of the surveys conducted.

The second research question that has underpinned this study was, ‘What is the current SHS market prospect in Mongolia? In order to answer this question, the drivers and barriers of the current program were analyse and a set of recommendations is provided. The question that now needs to be asked is to what extent these aims were achieved and to what extent the research questions have been answered.

5.2 Current status of SHSs in Mongolia

The Mongolian Government set high priority to the electrification of nomadic population in the rural areas of Mongolia and approved the National “100,000 Solar Ger” program in 1999 which was the main Government supportive policy paper of Mongolia. The Government’s target to electrify nomadic households in the rural areas of Mongolia was
stated in this policy paper and four phases to this achievement have been put into the program.

The program subsidized the purchase of SHSs so that low income rural households would only have to pay roughly half the price of the SHSs. It made the systems more affordable for the rural population and allowed a significant number of nomadic herders to participate in the program. As a result of this, the sales of SHSs significantly increased and leveraged additional funds to the program. This recovered funding was used further to purchase additional SHSs which helped in exceeding the program target of providing herders access to electricity.

According to the survey, the program brought some positive impacts on the livelihood of the herders living in remote areas such as: increasing quality of life, extend working hours, provide access to modern technology for communications, increased income, etc. Demand for new technology such as satellite televisions, radios, light bulbs and cellular phones was created as a result of using SHSs.

Prior to the SHS program, small-scale diesel generators were the main sources of electricity for the herders. SHSs replaced old, inefficient, polluting diesel generators used by some herders. The introduction of SHSs reduced greenhouse gas emissions in the rural areas and also reduced respiratory diseases amongst the herders. The benefits of the program were distributed and shared over the herder communities and it is very much a social improvement rather than a financial improvement.

One third of email survey respondents reported that improper management was seen as the most significant barrier to the SHS program. The “100,000 solar ger” program was actually implemented in four stages between 2000 and 2012. During the first three stages
of the program, SHSs were often distributed to herders for free with funds from bilateral donors through the Government channel of soum administrations. These were not considered as transparent implementation of the program. In this case, small costs were recovered and then absorbed into the Government budget. It also appeared that regular monitoring was inadequate during the implementation of the program in that it was impossible to recognize subsidized SHSs from the SHS that were selling in the market. Therefore, some sellers bought subsidized SHSs and sold them to herders at the market price in the rural areas.

The fourth stage of the program (2008-2012) involved the World Bank through its project REAP which changed the scenario significantly. The program was implemented smoothly in as the planning based on experience of implementing similar programs in other countries before. The Mongolian case was unique (SHS users were spread over a large territory) so special ways were considered. Prior to the program, it was difficult to reach sparsely populated nomadic herders more often. The involvement of the World Bank did not involve provided the funds needed for subsidies and taking systematic actions such as establishing sales and service centers in each province, organizing training and public awareness. Without the World Bank, the Government of Mongolia would have been unable to implement the program successfully. The sales service centers established in all provinces under the World Bank project reduced the distance involved in distributing the SHSs to the herders. Furthermore, the systems were inspected for the quality to make it reliable for herders to purchase. The improved quality of the SHSs meant that they lasted longer compared to poor quality systems and enabled herders to save money on the maintenance of SHSs.
Financing was the main issue of the program as pointed out by the herders. During the first three phases, a loan from the commercial banks was not available for herders because terms and conditions of the SHS program were suited to commercial loans. In terms of the SHS, the loan recovery time is long (7-8 years), and there were no guarantors for the herders. Another problem was natural calamity, which posed various risks the system. During the fourth phase of the program, loans were offered to the herders. Herders felt that paying off the loan was a difficult task for them as the interest rate was high and repayment period was short. Seasonal income was one of the reasons for this difficulty in repaying the loan. Herders’ income is dependent on seasons, and therefore, they were not able to pay every month. They also do not own valuable properties which can be kept as collateral by the banks.

There was no adequate training on the operation and maintenance of the SHSs. Mongolian herders are sparsely located in the rural areas. This makes it difficult to organize training courses for them. Moreover, after-sales and service centers lacked financial and human resource capacities. Following the implementation of the program, some issues existed related to operation of SHSs. Herders were unaware of the SHS and proper operational manuals were not available for the users. The SHS’s power producing capability was not explained to the herders so some of them overloaded the SHS or tried to use AC appliances on the SHS with DC appliances. Herders typically relied on other herders who had successfully used the SHSs.

Private sector participants reported that they did not benefit from the SHS program. The program subsidized 50% of the SHS and herders just paid half the cost of the system. It was tough for private companies to compete with the subsidized Government program and there wasn’t enough room to involve the private sector. After the commencement of the
A critical review on solar home system program for Mongolian herders

program, many renewable energy system distributors existed the solar market as these companies were not involved in the implementation of the program. Subsidized sales of SHSs existed for 12 years in the solar market until the program fulfilled its goal of distributing 100,000 SHSs to herders. As a result of this, the program led to failure in the long-term sustainability of the market.

Today, most SHSs are imported mainly from China and sold at low prices. However, these cheap SHSs and low in quality which is evident from the way the herders operate the systems.

To solve these barriers, it would be essential for all stakeholders involved in the program to work together and bring in changes to make the future SHS program more favourable and sustainable.

5.3. Current SHS market prospect in Mongolia

It was observed from both email and phone surveys that all participants strongly agreed with the statement that the SHS program for the herders should be implemented again in Mongolia based on the previous experience. Most respondents indicated that the previous program was aimed at distributing limited capacity SHSs to herders that only met basic electricity needs of the consumers.

Some users of the SHSs are keen to use additional electric appliances such as refrigerators and washing machines as their income grow from various income generating activities. Today, 16,985 nomadic families in Mongolia lack access to electricity in the countryside due to their financial difficulty (NSOM, 2017). Most financial institutions do not offer loans to the herders because their income is not durable and they have few assets. Livestock is the main income generating resource for herder families.
Herders tend to purchase imported PV systems due to their affordability and lack of knowledge. Currently there are two domestic Mongolian companies that manufacture quality PV panels. The cost of domestic SHS is higher than imported SHSs. As a result, the market share of the domestic manufacturers’ is low. Therefore, a standard is required in solar electricity devices including PV panels, deep cycle batteries, inverters and power conditioners. The program should be implemented involving the local solar panel manufacturers and solar system retailers. In addition, private companies compete with each other by selling high quality products in order to increase their market share. They have a vast knowledge about herders' lifestyle and culture and are able to offer insights on final product solutions. It is also important to design SHSs based on the users’ requirement and local solar resource. Various capacities of SHSs with higher quality should be available for the users. Availability of after-sale services and spare parts are essential during the life time of the system. If the government supports private companies by providing financial support, these companies would lower the cost of the SHSs which would make it affordable for herders. In this initiative, the government could achieve its goal to electrify all herders and, on the other hand, private companies would increase their sales and consumers would receive high quality SHS system at a lower price.

5.4 Recommendations

The majority of participants strongly agreed that the solar electrification program should be implemented again in Mongolia based on their previous experiences. Based on the survey findings and the literature review, the following factors should be considered in the future program in order to make it successful and sustainable.

In terms of program sustainability, the future SHS program should follow a bottom up approach by involving all stakeholders including users of the SHSs. It is crucial to provide
different sizes of SHSs based on the users’ electricity requirements and affordability that will help to sustain the future market. Users tend to purchase a SHS that meets their own particular electricity requirement and which matches their ability to pay for it. Today, herders’ ability to afford a system has increased and they desire to have a more powerful SHS which could power home appliances such as washing machines, computers, refrigerators, microwaves and cooling fans. Therefore, it is essential to offer systems with different capacities the users. Currently it is possible to use LED lights instead of fluorescent compact bulbs. This increases the quality of lighting significantly and also draws less energy from the SHS. So future SHSs should be furnished with LED lights.

Market assessment surveys should be undertaken on the herders’ affordability of the SHSs before commencing the future program. The majority of the herders are not able to buy the SHSs with cash. Therefore, the main issue of the future program could be the high upfront cost of the SHS. The program should be able to provide soft loan (loan term, low interest without collateral) to the herders for purchasing the SHSs. It should be take into consideration that the income of herders’ is seasonal and therefore it might difficult for the herders to pay the monthly instalments. Appropriate financial delivery mechanism should be developed by the Government or commercial bank in the Mongolian context in order to expand the program. If financial institutions do not offer loans with the long repayment period and low interest, it would be difficult for the herders especially the ones in the low income groups to acquire the systems.

Establishment of transparent distribution channels and audit systems must be included in the program and the results should be fed back to the stakeholders. This continuous monitoring and evaluation system will help check the fund recovery and subsidy management. Subsidy should be considered with caution and can be used for institution
building measures such as demonstration of viable business models, users’ training and developing operation manuals for the SHSs.

Efficient after sale service ensures the viability of the program by distributing high quality products and maintaining the systems in rural areas areas. The program implementers should choose professional companies as a local after-sale service centers or create opportunities for new businesses in local areas by training technicians and issuing operation licenses to them. In addition, supply chain for spare parts in rural areas is seen as important to run the program smoothly and reduce response time. When the consumers are satisfied with the service, they convince their neighbours and help create new costumers.

Proper awareness development helps the implementers of the program to expand the program and create demand amongst users. TV advertisements can be the best option in the Mongolian context to improve the awareness among the herders who are scattered over the country. The operation and maintenance manuals, strengthening the institutional framework, user’s training and the manufacturers’ warranties are essential in supporting the long term sustainable market development and deployment of PV services.

It is essential to improve the technical reliability of the PV systems by adopting international technical standards for the SHS components and enabling quality control measures. After the approval of the standard, SHSs should be tested and certified to meet the quality standards criteria. Appropriate standard define the quality of SHSs and help users choose better PV systems. It would reduce the potential for the system failure and reputational risks in the solar market.
The involvement of the private sector is one of the key factors for the sustainable solar market. It is essential to create favourable market structure for the private companies by developing supportive Government policies and providing financial assistance to sustain their businesses. These supports from the government attract and facilitate private enterprises to become more involved in the program and reduce their risks in this business. In this way, private companies would compete with each other to increase their market share resulting in improved the quality of the PV systems and thereby reducing the price of the systems.

It is essential to set up a proper battery recycling and disposal system. This would ensure sustainable use of SHSs in rural areas without damaging the environment and causing the harm to human health. Private companies are incapable of recycling batteries by themselves in an efficient way. The future program will need to ensure proper battery disposal for used batteries distributed under the program and introduce battery recycling facilities to avoid harming the environment. This battery recycling plant may bring external positive environmental impact through recycling batteries both for SHSs and automobiles.

5.5. Concluding remarks

The previous SHS program used donor funded approach which was designed to reach low income herders as the funding from the donor countries and organizations enabled the government to decrease the initial cost of the SHSs. However, the success of this approach has been minimized over the time resulting in issues such as lack of spare parts and after-sale services in the local areas. Market oriented approach (MOA) is considered more sustainable compared to the donor oriented approach. This funding relies mainly on the financial resources of private companies and the distribution channels established by
private companies in the local areas that provide spare parts and after-sale services (Nieuwenhout et al., 2001). Moreover, MOA program tends to design SHSs based on the users’ requirement and the affordability of consumers (Liebental et al., 1994). To achieve a sustainable and long-lasting solar market in Mongolia, both approaches should aim to coexist with one another. The future Government program should not obstruct the development of a direct sales market. However, it should strive to support direct sales by involving the private sector in the program.

5.6. Limitation of the study.

The surveys were conducted from Australia remotely via email and phone calls. Due to limited time and remoteness, it was not possible to conduct in-depth interviews with the stakeholders of the program and technical surveys on the SHSs distributed under the program.

It was difficult to investigate the SHS market under the broad condition including all provinces due to limited sources of data. Therefore, the solar market study was focused primarily on Ulaanbaatar, the capital city of Mongolia. Most consumers purchase their SHSs from Ulaanbaatar where the majority of SHS sellers operate. In this stage, market research was conducted to assess SHS price and its capacity as well as herders’ income. This required substantial amount of external resources and data from the statistics bureau and national companies that were involved in this market. In some cases, the study relied on discussions with some experts from NGOs, public and private entities rather than statistical data.
5.7 Future research recommendations

Based on the findings of this research some suggestions for useful future research in this area are:

- Assessing electricity needs of the herders and their ability to afford SHSs to match their needs.
- Mongolian herders are scattered throughout the country where solar resource is varied over the territory. The Southern part of Mongolia has 25% more solar intensity compared to the Northern part. Therefore, further study should be carried out on assessing the solar energy resources by regions over the country. This would help match the appropriate SHSs based on the solar resource of the region.
- Optimizing SHSs based on the herders’ electricity needs. It is necessary to calculate energy demand of a herder’s home and determine an appropriate capacity SHS with sufficient Ah battery bank.
- The design of effective stakeholder training programs and a method of evaluating the extent to which the training program affects the success of a project.
- A broader investigation involving a larger number of herder communities to obtain a more complete picture of the influence of all factors involved in SHSs project design, planning and implementation in remote areas.
A critical review on solar home system program for Mongolian herders

Reference list:


World Resources Institute. 2014. *Climate Data Explorer Washington*.

http://data.worldbank.org/country/mongolia
1. Social, economic and environmental impacts of the “100’000 Solar Ger (tent)” program in the Mongolian countryside.

*Please tick in the box for each answer.*

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<tr>
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<th>Evaluation</th>
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<td></td>
<td></td>
<td>Strongly agree</td>
</tr>
<tr>
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<td>Access to more lumens and cleaner light</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>Reduction in use of traditional fuels</td>
<td>□</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Easier access to information</td>
<td>□</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Increase in work and study hours</td>
<td>□</td>
</tr>
<tr>
<td>2.</td>
<td>Social impact</td>
<td>Improvement in quality of life</td>
<td>□</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Increased number of hours spent on relaxation</td>
<td>□</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Increased time spent in listening to the radio and watching TV</td>
<td>□</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Increased time spent on social activities</td>
<td>□</td>
</tr>
<tr>
<td>3.</td>
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<td>Reduction in monthly expenditure on energy use</td>
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<tr>
<td></td>
<td></td>
<td>Changes and improvement in the financial status of the users</td>
<td>□</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Repayment amount (loan) is a burden</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>New local businesses created</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>Soft loan available for the users</td>
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</tr>
<tr>
<td>4.</td>
<td>Environmental impact</td>
<td>Availability of battery recycling</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>Reduction in greenhouse gas emissions</td>
<td>□</td>
</tr>
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</table>

Participant comment:
2. What difficulties did you encounter during the operation of your solar home system?

3. If the Mongolian Government offers you subsidised higher capacity solar home systems through the upgraded “solar ger” program, would you consider purchasing a new solar home system?

4. In your opinion, which of the following should be taken into consideration or is essential in the upgraded solar home system program for the herders? *Please tick in the box for each answer.*

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
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</tr>
<tr>
<td>Availability of battery recycling</td>
<td>●●●●●</td>
</tr>
<tr>
<td>Systems are easy to operate</td>
<td>●●●●●</td>
</tr>
<tr>
<td>Consumer’s training on SHS operation, maintenance and monitoring, are available in the program</td>
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<tr>
<td>Distance to closest local after-sales service center</td>
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<tr>
<td>Availability of spare parts in the local area</td>
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<td>Systems are designed to reflect users’ requirement</td>
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<tr>
<td>Superior or improved quality of solar home system</td>
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</tr>
<tr>
<td>Financial support (subsidy)</td>
<td>●●●●●</td>
</tr>
</tbody>
</table>

Participant comment:
Annex II. Questionnaire for the email survey.

1. In your opinion, do you think 100,000 Solar Ger (tent)” program is successful? If yes, why?
2. What were the main reasons behind the “100,000 Solar Ger (tent)” program’s success?

*Please tick in the box for each answer.*

<table>
<thead>
<tr>
<th>Reason of success</th>
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<td>Government support policy</td>
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<tr>
<td></td>
<td>Agreed</td>
</tr>
<tr>
<td>Financial support (subsidy)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Neutral</td>
</tr>
<tr>
<td>Establishing sales networks in local areas</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Disagreed</td>
</tr>
<tr>
<td>Campaigning of the program or awareness creation</td>
<td></td>
</tr>
<tr>
<td>Appropriate technology with superior quality</td>
<td></td>
</tr>
<tr>
<td>Generating employment</td>
<td></td>
</tr>
<tr>
<td>Regular evaluation of the program</td>
<td></td>
</tr>
<tr>
<td>Training provided to the technicians</td>
<td></td>
</tr>
<tr>
<td>Your comment:</td>
<td></td>
</tr>
</tbody>
</table>

2. Is there any training program for the Herders about the use the SHS? If not why?
3. What were the main issues faced during the planning, implementation and evaluation stages of the “100,000 solar ger” program?
4. In your opinion, should the Solar PV electrification program for the herders in Mongolia be implemented again?
5. Please rate the following criteria which may be important or critical to upgrade the existing solar PV electrification program or to develop a new program for the herders in Mongolia. Please tick in the box for each answer.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Evaluation</th>
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<tr>
<td>Availability of battery recycling</td>
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</tr>
<tr>
<td>Systems are easy to operate</td>
<td>☐</td>
</tr>
<tr>
<td>Users training on SHS operation and maintenance</td>
<td>☐</td>
</tr>
<tr>
<td>Establishing after-sales service centers in local areas</td>
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</tr>
<tr>
<td>High quality of solar home system</td>
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</tr>
<tr>
<td>Enabling participation of private companies</td>
<td>☐</td>
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<tr>
<td>Involvement or inclusion of users in designing stage of the program</td>
<td>☐</td>
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<tr>
<td>The role of stakeholders in the program</td>
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<tr>
<td>Financial support (subsidy)</td>
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<tr>
<td>Generating employment in rural areas</td>
<td>☐</td>
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<tr>
<td>Regular social, economic and environmental assessment of the program</td>
<td>☐</td>
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<tr>
<td>Regular monitoring of customer satisfaction</td>
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<tr>
<td>Developing standardisation process</td>
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<td>Your comment:</td>
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## Annex III. The distribution of the SHSs to nomadic families by provinces.

<table>
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<th></th>
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<td>Gobi-Sumber</td>
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<td>7</td>
<td>Darkhan</td>
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<td>209</td>
<td>125</td>
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<td>8</td>
<td>Dornod</td>
<td></td>
<td>750</td>
<td>795</td>
<td>522</td>
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<td>9</td>
<td>Dornogovi</td>
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<td>73</td>
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<td>3266</td>
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<td>5392</td>
<td>4173</td>
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<td>Khentii</td>
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<td>705</td>
<td>1077</td>
<td>1835</td>
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<td>21</td>
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<td>1550</td>
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<td>352</td>
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<td>31’790</td>
<td>40’400</td>
<td>26’828</td>
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