A thesis submitted to the Department of Environmental Sciences and Policy of Central European University in part fulfilment of the

Degree of Master of Science

The growth of solar off-grid energy technology: a case study of Dharnai solar village in Bihar, India

Eqra Jawaid

July, 2018

Budapest, Hungary

Notes on copyright and the ownership of intellectual property rights:

(1) Copyright in text of this thesis rests with the Author. Copies (by any process) either in full, or of extracts, may be made only in accordance with instructions given by the Author and lodged in the Central European University Library. Details may be obtained from the Librarian. This page must form part of any such copies made. Further copies (by any process) of copies made in accordance with such instructions may not be made without the permission (in writing) of the Author.

(2) The ownership of any intellectual property rights which may be described in this thesis is vested in the Central European University, subject to any prior agreement to the contrary, and may not be made available for use by third parties without the written permission of the University, which will prescribe the terms and conditions of any such agreement.

(3) For bibliographic and reference purposes this thesis should be referred to as:

Jawaid, E. 2018. *The growth of solar off-grid energy technology: a case study of Dharnai solar village in Bihar, India.* Master of Science thesis, Central European University, Budapest.

Further information on the conditions under which disclosures and exploitation may take place is available from the Head of the Department of Environmental Sciences and Policy, Central European University.

Author's declaration

No portion of the work referred to in the thesis has been submitted in support of an application for another degree or qualification of this or any other university or other institute of learning.

Eqra Jawaid

CENTRAL EUROPEAN UNIVERSITY

ABSTRACT OF THESIS

Submitted by: Eqra JAWAID

for the degree of Master of Science and entitled: The growth of the off-grid energy technology: a case study of Dharnai solar village in Bihar, India.

Month and Year of submission: July, 2018.

Despite the efforts of rural electrification from both central and state governments, Bihar is the least electrified state in the country. It is found in the literature that decentralized solutions such as renewable off-grid systems can be a viable and more efficient option for rural electrification. Recently, a smart solar off-grid system has been developed in Dharnai village in Bihar with the assistance of Greenpeace India. The aim of the thesis was to investigate and identify drivers and barriers to the growth of the solar off-grid system in Dharnai, fill the knowledge gap about the solar off-grid sector, and provide recommendations to improve the sector in the state. Data collected from interviews and focus group discussion in Dharnai was analyzed using Painuly's (2001) framework. The findings suggested that significant drivers are unmet demands of consumers, policy ambitions, consumer's capacity and willingness to pay, benefits of solar perceived by consumers, an indicator of development, and uncertainty about the grid connection. Furthermore, significant barriers to the growth of solar off-grid systems are policy loopholes, unmet demands of consumers, consumer's affordability, and lack of financing options. The thesis recommends that the Bihar government should start awareness campaigns to improve consumer's lack of awareness about the benefits of solar off-grid systems; make grid expansion predictable so that consumers have clarity about its timeline; take appropriate measures to improve financing and overall affordability of the consumers.

Keywords: Renewable Energy, Solar, Micro-grid, Dharnai, Bihar, India

---

Acknowledgments

Foremost, I would like to share my deepest gratitude to my supervisor, Professor Alan Watt, for constant encouragement, invaluable feedbacks and keeping me on track. I would also like to thank Professor Aleh Cherp to deepen my research interest in this area throughout the masters' courses at CEU.

Additionally, I am grateful to numerous people for encouraging and assisting me during the research process. The thesis would have been incomplete without the helping hands of my dear sisters: Usra and Azra, during the field research in Dharnai. Mohini, my dearest friend, for keeping me motivated with her kind words, emotional support and quick fixes. And my friends for their constant support.

Most importantly, I am very thankful to the former village head, village electric committee and Santan for their constant assistance during the fieldwork; and the people of Dharnai for their hospitality. Moreover, I am also indebted to all the interviewees from Dharnai village and CEED who agreed to share their valuable time and contributed to this research.

Table of Contents

List of Tables

List of Figures

List of Acronyms

APL	Above Poverty Line
BPL	Below Poverty Line
BREDA	Bihar Renewable Energy Development Agency
CEED	Center for Environment and Energy Development
DDG	Decentralization Distributed Generation
DRE	Distributive Renewable Energy
EJ	Exajoules
GOI	Government of India
INDC	Intended Nationally Determined Contributions
IREDA	Indian Renewable Energy Development Agency
IRENA	International Renewable Energy Agency
MNRE	The Ministry of New and Renewable Energy
RET	Renewable Energy Technologies
SHS	Solar Home System
TFEC	Total Final Energy Consumption

Chapter 1: Introduction

1.1 Background

The history and development of mankind have been deeply linked with energy. Among all sources of energy, the connection between renewable energy and sustainable development are very important and need to be explored well. With the growth in India and other developing economies (Oda and Tsujita 2011), the per capita consumption and emissions from carbon are expected to soar exponentially. Overall energy demand is expected to increase by 80% in Southeast Asia by the year 2035 (IEA 2013). This has serious complications for global warming.

The Indian economy is projected to have growth rate of 8-9% over two decades to maintain its growth curve (Gupta and Blum 2018). According to World Development Indicators Database of the World Bank, India was the second most populous country in 2017 (World Bank 2018) but has very low energy consumption per capita. This also suggests the need to increase the supply of primary energy by a factor of three to four (Agrawal 2011). With the rapid economic development and urbanization, energy demands are growing exponentially, and India is forecast to have the world's largest energy demand in coming years (IRENA 2017).

According to the forecast by IRENA (2017), India's renewable energy consumption would account for 9% of the total global use, making it the third largest country to consume renewable energy. Planning Commission of the Government of India baseline's scenario projected that country's TEFC is likely to be more than double between 2010 and 2030 (GoI 2014). However, the understanding of the benefits of renewable energy was not able to increase share of renewable energy in the last decade. According to literature, numerous barriers have barred the penetration of renewable energy technologies such as cost-effectiveness, technological and

markets barriers. Some of the barriers includes institutional, political, environmental issues, such as inconsistent pricing systems for an example (Painuly 2001). Recently, both central and state governments have started programs to push and incentivize solar markets along with extending the electricity grid (IRENA 2017).

In India, around 300 million people are estimated to have limited or almost no access to energy in India (Chandran-Wadia et al 2015). It is also estimated that around 10 million people out of 300 million people who lack access to electricity live in villages or hamlets that are too remote to be reached by grid anytime soon (Chandran-Wadia et al 2015). Houses without electricity are mostly concentrated in the major states such as Assam, Bihar, Jharkhand, Odisha, Madhya Pradesh, Rajasthan and Uttar Pradesh (**Figure 1**). A study done by the Council on Energy, Environment and Water (CEEW) found that half of the electrified rural households in Bihar, Jharkhand, Odisha, Madhya Pradesh, Uttar Pradesh and West Bengal do not get 12 hours electricity in a day (D'Cunha 2018).

The penetration of subsidized LPG and kerosene is very low in rural areas and the subsidized kerosene is used for lighting and cooking purposes. There are numerous environmental and health impacts of using low or dim lighting systems and kerosene for cooking and lighting purposes (Climate Group 2015). IRENA (2017) estimates that nearly 400 million Indians, 90% of them are women, are susceptible to respiratory, pulmonary, vision and other chronic illness connected with indoor and outdoor air pollution from burning of coal, kerosene and traditional biofuels (Climate Group 2015). Therefore, there is a scope to reduce indoor and outdoor pollution through clean and sustainable rural energy systems and these can have wider positive social, environmental and economic impacts (Climate Group 2015; IRENA 2017).

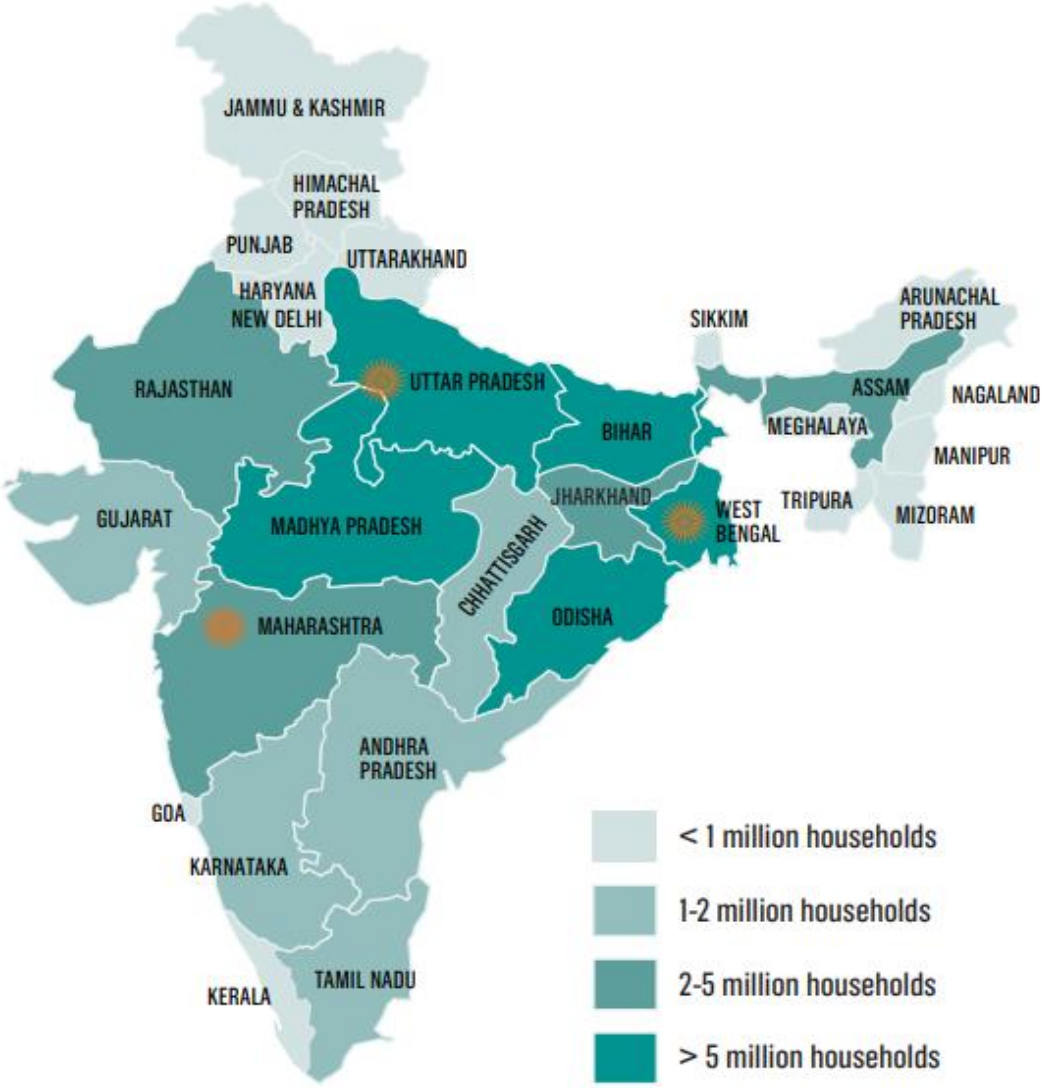

Figure 1. Distribution of underserved households in India. Sources: Population totals from India Census 2011; Electrification data (source of lighting) from India Census 2011; Climate Group 2015.

According to the Climate Group (2015), solar home systems (SHS) and distributed renewable energy (DRE) systems offer an extensive range of consumption at different prices. Solar home systems usually have solar panels fixed on building or nearby area that provide electricity to a nearby home or small business. On the other hand, DRE systems utilize any renewable energy source such as solar, wind, biomass etc. to generate electricity to numerous houses in the

locality of the utility (Climate Group 2015). However, most of these systems provide electricity to houses for basic lighting and mobile charging needs (Climate Group 2015). Moreover, the villages and hamlets should not take renewable energy solutions as the backup until the grid is extended to them. It can provide electricity for 24 hours for household and commercial purposes utilizing appropriate sized off-grids and micro-grids (Chandran-Wadia et al. 2015).

It is interesting to note that India is experiencing remarkable economic growth rate, but the pattern is not the same for all states. Particularly Bihar had lagged on most development indicators and considered one of the least developed states in the country (Rasul and Sharma 2014). Following indicators (**Table 1**) shows the contrast between Bihar and India on whole.

Table 1. Comparison of Bihar with Indian average

	Bihar	**India**
Population	Approx. 100 million (2011 data. Source: Census of India 2011)	Approx. 1.34 billion (2017 data. Source: World Bank 2017a)
Rural population (% of total population)	88.7% (2011 data. Source: Census Organisation of India 2011)	66% (2017 data. Source: World Bank 2017b)
Percentage of unelectrified households	89.6% (2011 data. Source: Census of India 2011)	44.76% (2011 data. Source: Census of India 2011)
GDP	Approx. 100 billion USD (2018 data. Source: PRS 2018)	Approx. 2.60 trillion USD (2017 data. Source: World Bank 2017c)
GDP per capita	Approx. 682 USD (2015 data. Source: Ministry of Statistics and Program Implementation 2016)	Approx. 1939.6 USD (2017 data. Source: World Bank 2017d)

According to Census 2011, only 10.4% of household have access to electricity in Bihar – a northern state of India. Moreover, 89.6% of rural and 33% of urban households in Bihar are not connected to the power grid (Census 2011), making the state ranks last among the Indian states. All these factors make Bihar an interesting state to investigate and identify the barriers and drivers of the development of solar off-grid renewable technologies in the state.

Recently, Dharnai – a village in the Jehanabad district of Bihar, set up an innovative and first of its kind smart off-grid based on solar energy. The project benefits 450 households in the village with a population of 2200 people by providing electricity for commercial and agricultural purposes (CEED 2016). The off-grid project focuses on creating an alternative system of access to electricity and be independent and take control of energy resources.

Figure 2. Solar PV on rooftop in Dharnai village, Bihar.

Because of the issues faced by the state, Bihar, Dharnai solar off-grid project is commendable. The thesis plans to study the case of Dharnai solar village and fill the knowledge gap in the solar off-grid sector in Bihar. The thesis intends to identify drivers and barriers to the diffusion of the off-grid technologies from the case study of Dharnai and provide recommendations that may improve the scenario.

1.2 Aims and objectives

The aim of the study is to explore how a small village of Dharnai in Bihar came up with a solar off-grid solution to meet their electricity needs. The present study limits its focus to the explanatory case study of solar off-grid and perceptions of the residents of the village regarding the off-grid installation. Therefore, considering potential limits, the study seeks to develop the primary understanding of the issues faced by the villagers from last 30-35 years in the absence of electricity and if the solar off-grid installation has improved their livelihood and living conditions. At the same time, the study also aims to explore if other small rural villages can come up with similar off-grid innovation.

1.3 Research questions

To achieve research objectives, the study will try to answer the following main research questions.

1. **How has Dharnai village managed to become the first solar village in Bihar and how the village is successful in doing so?**
    - What drivers of and barriers to the growth of the off-grid exists in Dharnai village, Bihar?

2. **Based on the findings from the Dharnai case study, what recommendations can be suggested to overcome barriers and promote off-grid solar technology in rural Bihar?**
    - What can be done to replicate similar smart off-grid projects in other rural villages of Bihar?
    - How state and central government policies be leveraged in achieving this goal?

1.4 Importance of the study

The Indian state of Bihar has not been able to improve its electricity scenario from last few decades. There is an absolute lack of scholarly works of literature and studies conducted in Bihar that describe the status quo of electricity and the ill-effects of unelectrified homes. Similarly, very few analyses have been done regarding the drivers and barriers to the growth of electricity in the state. Moreover, there is almost no literature available about renewable energy technologies such as off-grid, micro-grid solar technologies diffusion in the state and how these can be helpful in improving the overall electricity scenario.

The thesis seeks to fill the knowledge gap and come up with recommendations why the case study of Dharnai solar village is unique and how this village can serve as a role model for other villages to start thinking in this direction, develop and implement similar solar off-grid solutions to meet their energy needs. Overall, the thesis will help promote information about the Dharnai solar village and overall diffusion of similar off-grid solar technologies in rural villages of Bihar.

1.5 Structure of the thesis

The thesis is divided into six chapters to provide a full snapshot of the background, context, research questions, methodology, analysis and conclusion.

Chapter 1 elucidates the fundamental ideas about the research from an Indian perspective. It then goes on to explain the background and status quo of electricity and renewable energy technologies in Bihar and India. It also proposes the main research questions, aims and objectives of the present study.

Chapter 2 provides the detailed theoretical grounding of the research and research problems. It offers knowledge about the theoretical scholarship relevant to the study. It comprises of a comprehensive literature review of existing policies such as Jawaharlal Nehru National Solar Mission (JNNSM), National Renewable Energy (NRE) Act, etc. It is also accompanied by the review of applicable theories, theoretical and analytical frameworks.

Chapter 3 details the methodology employed in the data collection and data analysis.

It analyses how participants were chosen, data reliability issues, and limitations of the study.

Chapter 4 presents the result of the case study findings with the justification of exploratory case study research as an empirical method.

Chapter 5 provides the discussion of the findings along with answering the main research questions of the study. It is supplemented with recommendations to improve overall renewable energy and off-grid scenario in other rural villages of Bihar.

Chapter 6 provides a summary, concludes the thesis with recommendations.

Chapter 2: Review of Literature

The chapter consists of two sections. The first section provides overview of development of National Solar Mission and National Renewable Energy Act of India. This section will also elaborate on historical development of Indian policies and recent expansions happening in solar off-grid, micro-grid sphere in the country. The second section of this chapter elaborates analytical and theoretical frameworks applicable to this study.

2.1 Overview of literature

Around 80 million households which are nearly 50% of Indian rural population have little or no access to electricity from the grid and mostly rely on kerosene, biomass etc. as their source of lighting (Climate Group 2015). India has huge potential to add to its renewable energy technologies (RET) identified by IRENA in the REmap 2017. In recent years, both central and state governments have made efforts to increase grid connectivity, but progress has been slow (Climate Group 2015).

According to Press Information Bureau of the Government of India, the Ministry of New and Renewable Energy (MNRE) is eagerly taking measures to improve production of renewable energy devices by providing fiscal incentives. The incentives include "concessional customs and excise duties, provision of leans at concessional rates for renewable energy projects" by Indian Renewable Energy Development Agency (IREDA). MNRE also have policies to encourage transfer of foreign technologies, attract large scale investments for the renewable energy (GoI 2014). Indian energy policy is mostly focused on reducing the gaps of energy supply and demand. While bridging gap is the focus, Indian energy policy also understand the

importance of renewables and benefits of transitioning away from energy mix highly dependent on fossil fuels.

Therefore, it is important to overview major renewable energy policies of India and recent developments to fully understand the electricity scenario in the country. The paper outlined major Indian policies (**Table 2**) and discuss Jawaharlal Nehru National Solar Mission (JNNSM) and National Renewable Energy (NRE) Act in particular.

Table 2. Government of India (GoI) key initiatives for rural electrification; Source: Climate Group 2015; MNRE 2016 (with amendments).

Government of India initiatives	Responsible agency	Main features affecting off-grid systems
Electricity Act 2003	Ministry of Power (MoP)	▪ Removed licenses to generate and distribute power, only for the rural area ▪ Allowed off-grid enterprises to provide an alternative source of electricity
Remote Village Electrification Program (RVEP) 2005	Ministry of New and Renewable Energy (MNRE)	▪ Supported distribution of solar lanterns and home systems in remote villages ▪ Supporting installation of mini-grid in villages not connected to the grid ▪ Provides subsidies up to 90% for installation of off-grid systems
Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY) 2005	Ministry of Power (MoP)	▪ Outlined the scheme of decentralized distribution generation and the importance of off-grid systems for areas not connected to the grid ▪ Increased subsidies to encourage off-grid projects
Village Energy Security Program (VESP) 2005 -2012	Ministry of New and Renewable Energy (MNRE)	▪ Community partnership and ownership of assets were encouraged ▪ Capital subsidies up to 90% to start biomass-gasifier based off-grid systems in the rural area
Jawaharlal Nehru National Solar Mission (JNNSM) 2010	Ministry of New and Renewable Energy (MNRE)	▪ Created the Indian Renewable Energy Development Agency (IREDA) responsible for financing solar energy projects

		▪ Set the target of 20,000 MW for grid connected and 2,000 MW for off-grid solar PV systems ▪ Refinancing facilities available to banks who provide loans to off-grid energy systems

2.1.1 Jawaharlal Nehru National Solar Mission

The Jawaharlal Nehru National Solar Mission (JNNSM), popularly known as the National Solar Mission, is a combined initiative of Government of India and State Governments to encourage and ensure sustainable economic growth and solving the country's energy security issues was launched in January 2010 (MNRE 2012). The National Action Plan on Climate Change states that solar energy has a huge potential in India because of its geographical positioning with long and intense sunshine hours per day. On average, there are around 300 sunny days per year with solar radiation of 4-7 kWh per sq. According to MNRE data, India get abundant solar energy and capable of producing around 5000 trillion kilowatts of clean energy. There is a need to utilize the solar energy efficiently to reduce the energy deficits with the clean energy and no carbon emission (MNRE 2012).

The National Solar Mission targets 20,000 MW and 2,000 MW of grid and off-grid solar power respectively by the year 2022. The mission plans to reduce cost of power generation from solar to accomplish grid tariff parity. According to IRENA (2017), India can achieve the grid tariff parity by having long term solar power policy, investing in strong research and development and producing raw materials and products domestically in the country.

The mission follows a phased approach that permit government to update guidelines according to the experiences and lessons gained in earlier phases. Until now, the JNNSM has managed to drive investment in positive direction and total installed capacity of grids connected to solar

photovoltaic increased from 10 MW in 2010 to around 2500 MW in 2014 (MNRE 2012). The phase one of JNNSM mostly focused to achieve its target of 1000 MW of solar energy by splitting into solar thermal and solar PV project technology. The mission also managed to improve investments in solar energy to more than 2 billion USD in the year 2011(MNRE 2012).

The target of the Solar Mission has scaled up and India is planning to achieve 100 GW of solar capacity by the year 2022 (**Figure 3**). Within the 100 GW, 40 GW is targeted to come from rooftop solar projects while other 60 GW will come from utilities. Additionally, the annual target has increased from 2 GW in 2015 to 12 GW in 2016 and it is projected to reach 15 GW in 2017 and around 17.5 GW by the year 2021 (MNRE 2012).

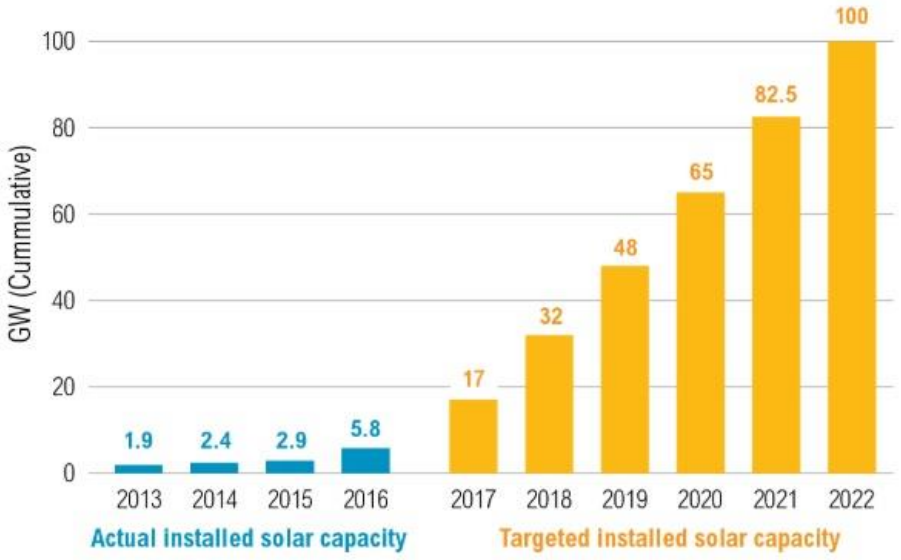

Figure 3. India's Solar PV Targets. Sources: IRENA 2017; World Resources Institute 2016

Indian industries have been supportive and responded positively to the Solar Mission but they are facing scaling up issues with the solar energy and this is one of the biggest hurdle in moving ahead. The central government with the assistance of state governments, financial institutions, research institutes, developers and communities need to come up with effective solutions for

increasing domestic manufacturing, creating and maintain strong financial structures, and ensuring reliable power transmission (MNRE 2012).

2.1.2 National Renewable Energy Act

According to the draft of National Renewable Energy (NRE) Act published by the Ministry of New and Renewable Energy (MNRE) in July 2015, there is a dire need to increase large scale consumption of renewables in the country. It is also identified in the draft that changes and upgradation of both state and central level energy policies are the prerequisite to increase its consumption.

Issues such as global and local environmental challenges and concerns over energy security were the main reasons that set up the new ministry for renewable energy in the first place. According to Singh (2015), there is a need to address above described challenges through different environmental policy and regulatory frameworks. India enters the new era of sustainable economic growth that need proper legislative frameworks. Presently, the development of renewable energy in India is mostly incentive driven and the absence of robust NRE Act frameworks have been useful in attracting consumers but it will hamper the growth curve in coming years. The absence of regulatory initiatives has not been effective in creating a compliance mechanism (Singh 2015).

Most countries have a range of motives that acts as drivers for renewable energy. For example, energy security and cost competitiveness were the main drivers in the US, while curbing air pollution and increasing local jobs were the drivers in China and phasing out nuclear powerplants was the main force in Germany (IRENA 2017). Similarly, Indian drivers for renewable energy are different and exclusive to India because of its unique socio-economic condition and maturity of energy markets. Therefore, the Indian government should work on the deployment of numerous forms of renewables such as solar, biomass, wind and geothermal

etc. varying from region to region and think beyond meeting its Intended Nationally Determined Contributions (INDC) commitments (IRENA 2017).

2.1.3 Recent developments

Most of the off-grids in India are powered by solar photovoltaic (PV) with an exception of some systems that run on hydropower and biomass. Until date, off-grid contributes to the tiny fraction of overall India's power needs. No official data is available about the number of micro-grids installed in the country, but a conservative count suggests that around 1,25,000 households are presently connected and using electricity from these off-grids (Ferris 2014). Micro-grid and mini-grid systems based on solar PV are easy to install and can be scaled up according to increasing needs with minimal intervention. Easy scaling up with least intervention make these renewable technologies suitable for the country like India and states of Bihar and Uttar Pradesh (Chandran-Wadia et al, 2015).

According to the mandate of the Ministry of Power (MoP) of the Government of India (GoI), a village is declared as electrified if 10% of its houses are connected to the grid. This is because, despite having electrification rate of 96%, around 44% of the rural households on average are not connected with the grid (Chandran-Wadia et al, 2015). Therefore, most of the electrified villages are still not 'energized' and have an insufficient supply of electricity. In this scenario, many households prefer not to get connected to the grid because of the erratic electricity supply and the hassles of getting connection and installation of meters for billing. Another issue that adds to houses being unelectrified is the large distance between groups of houses within the village (Chandran-Wadia et al, 2015).

Finance imposes a major challenge to the development of micro/mini-grids along with some technological and sociological barriers. The high one-time costs for the solar panels, cost of installation, service and maintenance charges (Chandran-Wadia et al, 2015) add up quite high

and impose a financial barrier for the diffusion of this technology in the rural area. Under the scheme of Jawaharlal Nehru National Solar Mission (JNNSM), 30% of the costs of systems is subsided by MNRE of the Government of India (GoI). The Decentralization Distributed Generation (DDG), another GoI's program from the MoP, provides around 90% of subsidy through the state governments. However, the generous looking subsidies have not encouraged enough entrepreneurs to start solar PV based mini-grids (Chandran-Wadia et al, 2015).

During the financial budget announcement for fiscal year 2015-16, the Government of India set a target of 175 GW of installed renewable power generation capacity by the year 2022. According to this target, solar power capacity would increase from 22 GW to 100 GW in 2022. To accelerate the installation, 400 million USD were allocated which will be used in increasing grid connection and distribution of renewable energy projects (Cleantechnica 2015). The set target also implies that around 20% of the country's total power consumption would come from the renewable energy sources (IRENA 2017).

Other measures for increasing finance for renewable energy projects, the government doubled the tax on coal imported and produced in the country. The revenue from the doubled tax goes to the National Clean Energy Fund (Cleantechnica 2015). The government plans to use new solar power capacity to electrify houses of 240 million people who lacks access to electricity, as the implementation of National Solar Mission (Cleantechnica 2014; Singh and Sundria 2017).

Although, there is a need to be critical about the official data regarding all villages being electrified because the official definition of "electrified" is little tricky (Andreas 2006). According to the government, a village is considered "electrified" if cables from the grid are connected to the transformer and 10% of households of that village are connected (D'Cunha

2018). Keeping the official definition of electrification in mind, it is certain that electrifying 100% villages are not enough, and India still has numerous villages to light up.

2.2 Applicable theories and frameworks

Regardless of technological development and economic feasibility, renewable energy technologies have been confined to very small niches. The concepts of drivers and barriers are frequently used in the field of renewable energy technologies to describe the hindrances and opportunities for the development (Ahlorg and Hammar 2012). This is mostly due to the presence of different types of barriers to the penetration of renewable energy technologies. The thesis reviewed studies about the potential of renewable energy technology and its diffusion in developing countries. However, there were not many studies that looked into the drivers of and barriers to the diffusion of off-grid, micro-grid systems in developing countries.

Ostrom (2007) recognizes the need to understand complexity, for the development of diagnostic methods to identify the actions of actors. To understand this, he suggests a nested framework for analyzing interactions and outcomes of the system. The nested system will be able to explain how all the factors jointly affect the users within the local systems and affect its outcomes over the time (Ostrom 2007). Painuly (2001) explains the barriers to the penetration of renewable energy technologies with a methodological approach. The framework can be useful in identifying barriers to the deployment of the off-grid solar technologies.

2.2.1 Painuly's (2001) analytical framework to identify barriers and drivers

According to Painuly's (2001) framework for identification of barriers, the first step is to identify renewable energy technologies with potential, such as solar micro and off-grid solar systems discussed in this paper. His framework defines potential for a renewable energy technology as *technological, techno-economic* and *economic potentials*. The *technological*

potential can be helpful in explaining the case when technically feasible technology is universally used without having any constraints of finance, reliability etc. that may delay its use. Moreover, *techno-economic potential* defines the situation when economically viable and technically feasible technologies are available in the competitive market and barriers such as finance, lack of infrastructure and other attributes do not exist. This development is essential to realize the goals of sustainable energy system. And lastly, *economic potential* tries to explain the situation in which the technology is used in the market without any failure (Painuly 2001).

He defines the current usage of technology as the *market potential* – a level existing with current barriers. As a result, the highest level of "theoretically possibly usage" is *technological potential*, followed by *techno-economic* and *economic potential* respectively. Therefore, renewable energy technology diffusion is the phenomenon by which market potential is improved to match the potential ladder defined by Painuly (2001). According to the framework provided by Painuly, drivers of and barriers to the penetration of energy can be analyzed in following steps.

The most important thing is to identify renewable energy technology having potential in certain country/area. The potential criteria may include adequate resources for RET, available technologies, market viability, environmental impacts and benefits etc. The identification process may also include qualitative or quantitative assessments. After this, the first step is to conduct a preliminary literature survey to identify potential drivers and barriers. Secondly, the potential area should be visited to closely study existing renewable energy projects. Lastly, a wide variety of stakeholders should be contacted for surveys, interviews or focus group discussions (Painuly 2001). An example of his framework is elucidated below, in **Figure 4.**

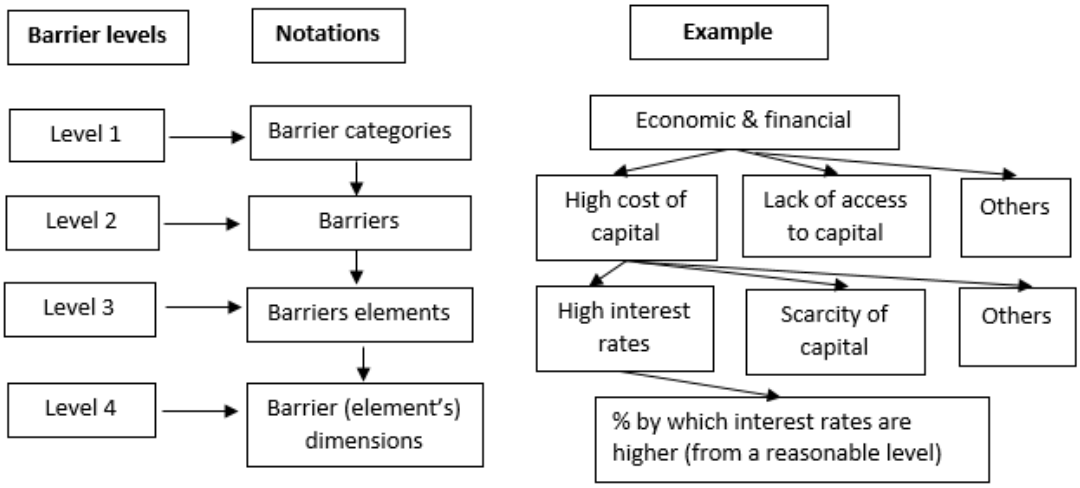

Figure 4. Level and identification of barriers. Source: Painuly (2001) (with amendments)

Painuly recommends using all three steps because all complement each other while identifying drivers and barriers of RET diffusion. His model and process has been followed with an exception of measurement of barrier element's dimension at level 4 due to cost and time constraints during the study. The "percentage by which interest rates are higher (from a reasonable level)" as mentioned in level 4, was not possible to study for this research, mostly due to the exploratory nature of the thesis. According to Painuly's (2001) framework, the present study analyzes barriers at every level and follow his methodological approach.

2.2.2 Women in development: autonomy, agency and decision-making

The World Plan of Action that appeared after the International Women's Conference in 1975 called for reconsideration and reevaluation of societal and family roles assigned to sexes and concentrated on women's roles so that women can contribute equally in economic production (Maguire 1984; Kabeer 1994). After this call, some consensus was reached to integrate women 'more productively' into the developmental process; and education and training emerged as the keys to achieve the equality of opportunity (Kabeer 1994).

The concept of female autonomy is important in understanding the social position of women in the family and their ability to take personal and household decisions. Safilios-Rothschild (1982) suggests that women of higher status have higher ability to control important events of their lives and have similar options in education, training, remuneration etc. as men of the same class and age group. Dyson and Moore (1983) define female autonomy as "the capacity to manipulate one's personal environment." It also shows the "technical, social and psychological" capability of decision making for themselves and their intimates. And the fairness of autonomy between sexes suggests alike decision-making ability (Dyson and Moore (1983).

According to Kabeer (1999), the ability to exercise choice is determined by three dimensions of resources, agency and achievement. She defines resources not only in an economic sense but also in numerous human and social forms that improve the capacity to exercise choice. At the broader level, resources can also include institutional domain such as family, community etc. and access to these resources will determine the rules and norms that govern institutions and provide authority to certain actors over another. For instance, heads of households and tribal chiefs have high decision-making authority primarily because of their position in households and community respectively (1999).

Kabeer's (1999) second dimension – agency – can be elaborated as one's goals and ability to act upon them. This also includes the meaning, enthusiasm and purpose that individuals bring with them. Although an agency is mostly confined to decision-making, it can have other forms such as bargaining, negotiation, subversion, resistance and other. Sen (1985) defined capabilities which are actually resources and agency together. Capability is the potential of the people to live their lives in their way (Kabeer 1999).

The third dimension of achievement indicator relates to the analytical clarity of choices. Achievement is about the differences in choices and include inequalities in the ability to make choices. It can relate to power, as long as what is chosen is adding to the welfare of people making choices (Kabeer 1999). However, achievement cannot fully accommodate gender inequalities especially when there seems to be chosen by women themselves. This phenomenon is explained in gender and well-being literature as the situation when women internalize themselves as the inferior, second class and accept the social conditioning (Kabeer 1999).

Alliance with such behaviors can have adverse effects not only on the well-being of the person but also on other female members of the family. Women acceptance to the claim of being second in the households, secondary in decision-making, willingness to bear and care about children at their own risk are some examples how women weaken their own welfare and have adverse effects. In the Indian context, a woman sees children, mostly sons, as a possible source of security in case of an uncertain future such as the death of her husband or other financial circumstances. Karve (1953) wrote "Only when she becomes a mother can she be a little freer … she rarely makes a positive impression except a mother" about the women of northern India.

Women's greater altruism towards their children, family or community is a proof of "women's internalization of their own subordinate status, their tendency to put the needs of others in the family before their own" (Kabeer 1999). Jackson (1996) argues that "it may well be true that women prioritize children's needs, but there is a sense in which one might wish women to be a little less selfless and self-sacrificing." According to Fierlbeck (1995), women will be more likely to increase their ability for decision-making if they see and consider themselves as an individual instead of a member of a social group or community. Despite the success of women in development for the years, women still continue to occupy a marginal place in the developmental thoughts and policies (Kabeer 1994).

Chapter 3: Methodology

This chapter also consists of three sections. The first section explains the research design and rationale for the choosing the method. The second one focuses on the methodology used during the data collection with specific information on sampling, focus group discussion and interview protocols, and limitations of the study. The third section will elucidate methods of data analysis to analyze collected data from the focus group discussions and interviews.

3.1 Research design

The study utilizes an exploratory case study research design to explore stakeholders' perspective and perception about the solar off-grid system installed in Dharnai village with the assistance from Greenpeace India and other partner institutions. This type of research design reflects the nature of the problem and enables researchers to examine a problem within a specific context. According to Yin (1984), a researcher can closely observe numerous phenomenon of the specific dataset while using the case study as a research method. The case study method focuses on a small area or limited numbers of subjects and observes data at the micro level as compared to quantitative analysis, which observes data at the macro level (Yin 1984).

Moreover, the Key Informant Interviews (KII) technique is followed to collect data from the key informants along with focus group discussion with the residents of the solar village. Britten and Fisher (1993) state that qualitative research approach offers a profound understanding of poorly understood topics. Using Dharnai solar village as a context for the case study research, the present study provides deeper insights into the drivers of and barriers to the diffusion of

solar off-grid technologies in Bihar. Thus, the exploratory case study method is well suited to explore the objectives and expected outcomes of the study.

3.2 Data collection

Most of the literatures were reviewed prior to the data collection and interviews were conducted. Literature review was done to understand the background of the electricity scenario in Bihar and dig into the information about Dharnai village. The literature review also influenced the stakeholders to be contacted and the kind of questions asked during the interviews. Moreover, newspaper articles and reports about Dharnai solar village have also been searched to better understand the socio-economic conditions of the village before leaving for the field research.

3.2.1 Study area

The area of case study was Dharnai village. Dharnai is a revenue village, in Makhdumpur block of Jehanabad district, in the eastern Indian state of Bihar (**Figure 5** and **Figure 6**). The village is located on the National Highway 83, close to State Capital – Patna and famous world pilgrimage city of Gaya (Roy 2014). It is a small village with around 2400 residents, 450 households and 50 commercial establishments.

Figure 5. A map of Dharnai village in Jehanabad district of Bihar. Source: Google map, retrieved on 26 July 2018.

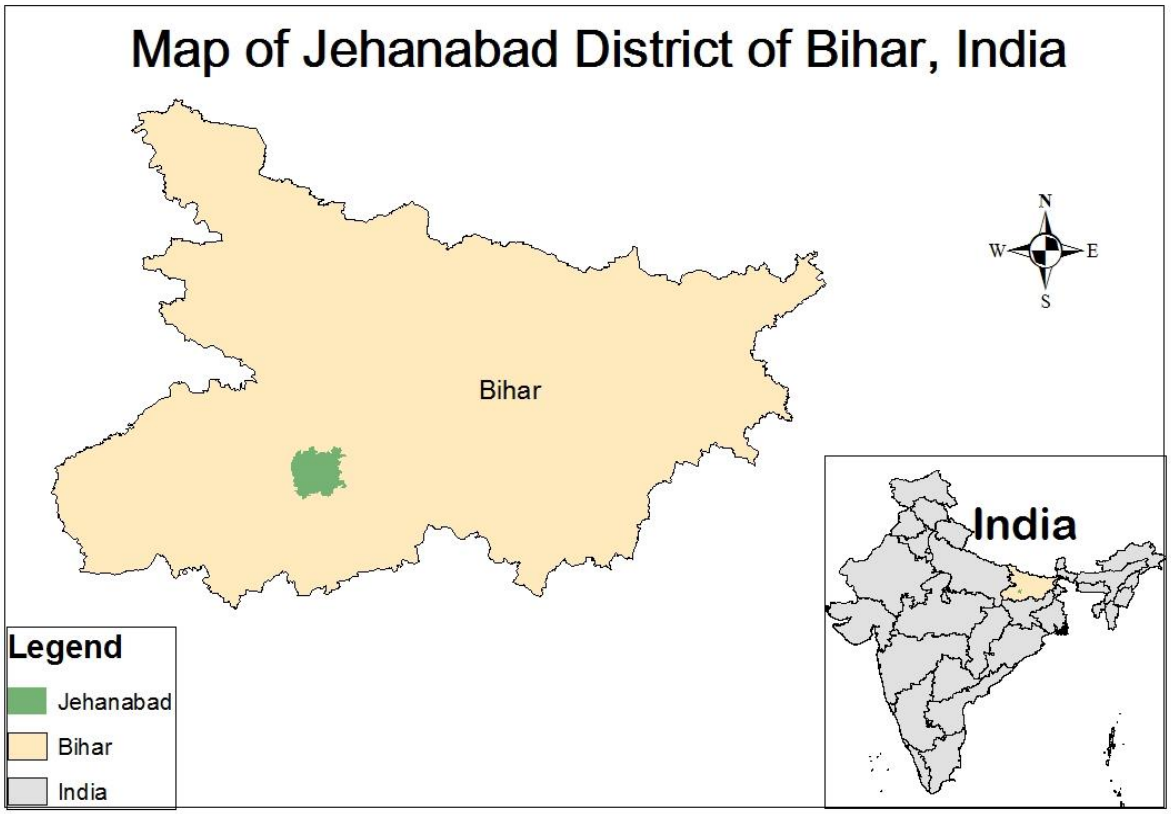

Figure 6. Map of Jehanabad district of Bihar, India. Data: ESRI GIS. Produced by the author.

3.2.2 Sampling

In total, eight Focus Group Discussions (FGD) and three semi-structured interviews were conducted about the off-grid project of Dharnai village. All eight focus group discussions were conducted with the residents of Dharnai village who were directly benefited by the electricity from solar off-grid installed in the village (**Figure 7** and **8**). Three semi-structured interviews were conducted with the Former *Sarpanch* (Village Head), Chairman of the Village Electric Committee (VEC) and an official from the Center for Environment and Energy Development (CEED) – one of the partner organizations in the off-grid installation.

Figure 7. Focus group discussion, Dharnai, Bihar.

All eight focus group discussions were conducted in the local language, Hindi. As already mentioned, Dharnai village comprises of four small *Tolas* (similar to hamlets) with people

belonging to different socio-economic background. As a result, eight focus group discussions were conducted to maintain gender mix and respondents from different socio-economic background. Two semi-structured interviews were conducted in Hindi in the village while one interview was conducted in English language in the CEED office in Patna, capital of the state Bihar. Moreover, all focus group discussions and interviews were conducted in person during the month of May 2018 in Bihar, India.

Figure 8. Focus group discussion, Dharnai, Bihar.

The focus group discussion (FGD) is a cautiously planned discussion with individuals having similar interests or background to gain information about an issue (Krueger and Casey 2000; Marczak and Sewell, 2007). The positive about FGD is that it relies on participants to agree and disagree among themselves and provides deep insights about the issue with various

opinions and ideas (ODI 2009). The researcher visited all four *Tolas* (a small settlement of a large village, similar to hamlets) to find participants for the FGD. Firstly, all participants were briefed that this small discussion is going to be about the solar off-grid of their village. The FGD started with general question such as "Can you share a little bit about the present and past electricity situation in your village?" and most participants were encouraged to share their experience. In between follow up questions were asked to continue the discussion. The following **Table 3** shows the number of participants.

Respondents for the semi-structured interviews were selected utilizing snowball sampling and quota sampling. For quota sampling, literature review was used to determine the stakeholders such as founding member and Village Electric Committee (VEC) chairperson that not only assisted in establishing the off-grid system but also users of its electricity. After connecting with the first stakeholder, researcher used snowball sampling to connect with next person and not to miss relevant stakeholders. The following **Table 4** shows the list of the interviewees.

Table 3. Focus group discussions

Focus group discussion	**Participants**
Residents	Subash Yadav, Male Anonymous, Male Anonymous, Male Anonymous, Male
Residents	Anonymous, Male Anonymous, Male Anonymous, Male
Residents	Anonymous, Female Anonymous, Female Anonymous, Female Anonymous, Female

Residents	Anonymous, Female Anonymous, Female Anonymous, Female Anonymous, Female
Residents	Kamal Kishore, Male Rajesh Kumar, Male Jaihind, Male
Residents	Anonymous, Female Anonymous, Female
Residents	Anonymous, Male Anonymous, Female
Residents	Anonymous, Female Anonymous, Female

Table 4. Personal interviews

Category	**Interviewee**
Energy expert	Ashwani Ashok, Business Analyst, Energy Division for Center for Environment and Energy Development (CEED)
Village Electric Committee (VEC)	Sunil Sharma, Chairperson of Village Electric Committee (VEC) of Dharnai
Founding member	Surendra Kumar, Former *Sarpanch* (Village Head)

3.2.3 Interview and focus group discussion protocols

Protocols were created and followed for both interview and focus group discussions. Both interview and focus group discussion started with an introduction where researcher explained the purpose and objectives of the research study, stated approximate time of interview (25-35 minutes) and focus group discussion (around 15-20 minutes). Researcher also briefed participants that they can share their names or be anonymous, asked their consent to record the discussion/interview and asked if they have any questions both prior and after the discussion and interviews.

The tentative questionnaire for interview and focus group discussion consisted of both open-ended and specific questions. Open-ended questions such as “do you think that there are scopes of improvement in electricity from solar micro-grid?” and specific ones such as “how exactly the system can be improved?” The researcher tried to maintain a proper mix of both open-ended and specific questions and only asked specific ones, if participants and interviewee missed touching those important points. On average, there were 5-7 broad questions for focus group discussion and around 10-12 questions for personal in-depth interviews. All focus group discussions and interviews conducted followed the already mentioned protocols. Researcher started discussions and interviews with general questions and asked specific ones if needed.

3.2.4 Limitations of the study

The main limitation of this study is the small number of focus group discussions and personal interviews conducted with the residents of Dharnai village. Depending on the available research logistics and time constraints, three *Tolas* (a small settlement of a large village, similar to hamlets) out of four, constituting Dharnai village were selected for the focus group discussions. The selection of *Tolas* was based on the socio-economic demographics of the village. It was found that the people from lower caste tend to have lower income were concentrated in one *Tola* as compared to the whole village. Therefore, focus group discussions were conducted in this *Tola* as well to make the data representative of the village, minimize discrepancies in perception and understand the general views of the people of Dharnai about the solar micro-grid. However, the findings of this study may not represent the perception of other residents of the village who was not part of these interviews.

Another limitation of this study is the language of the interview. All the focus group discussions and personal interviews were conducted in the local language, Hindi. The transcription of the interviews may not be the perfect translation of the content. However, to ensure the validity of

the transcribed interviews and avoid the problem of misinterpretation, cross-examination by another researcher – who is proficient and whose native language is Hindi – has been performed in a systematic basis. Furthermore, the field work was done in the month of May 2018 which is one of the hottest summer months in Dharnai. The summer month also affected the availability of participants for the focus group discussion. Most young residents were visiting other places during the summer and others were indoors due to the scorching heat of May. As a result, most of the participants in the focus group discussions are middle-aged women and men who were available during the interview days.

Additionally, not a single official from Bihar Renewable Energy Development Agency (BREDA) agreed to give an interview about the installation of solar micro-grid in Dharnai, mainly because it is the state-run agency which is supposed to promote the development of renewable energy schemes in the state. However, an international organization Greenpeace India was the lead organization assisting the development of solar off-grid in Dharnai and as a result, they did not want to comment on the project.

There are several aspects of the present study that need consideration regarding the validity and limitation of the results. The study was quantitative in nature and only covered Dharnai village, therefore the data gathered, and the area covered should not generalized and translated into other contexts. Moreover, the study was iterative in nature and interviews developed along the way. This means that some answers that were repeating in most FGD and interviews were also asked next interviewees to understand their thoughts. Therefore, it is very important to understand that result of this study cannot be generalized to other micro-grid projects of India but serve as a guideline for future studies.

Therefore, by examining a specific case of Dharnai, it is possible to develop an understanding about how support from organizations (Greenpeace India in this situation), willingness of the

local people and state policies (not much use in this case) can be helpful in changing status quo i.e. the installation of solar micro-grid, in a state such as Bihar. The findings of this study should be treated as a baseline evidence for further empirical studies that are beyond the scope of a master's thesis.

3.3 Data analysis

The recorded interviews and focus group discussions were transcribed. The researcher tried to maintain the originality of the content while transliterating from Hindi to English for analysis (except one). The content of the interviews and focus group discussions were divided into themes and it was analyzed accordingly.

3.3.1 Qualitative Analysis

To analyze the collected data, the study followed five general steps suggested by Taylor-Powell and Renner (2003). The recorded interviews and focus group discussions were first transcribed and then analyzed by categorizing information, identifying patterns and establishing connections between the categories as mentioned by Taylor-Powell and Renner (2003) in following **Figure 9**.

The study utilizes both inductive and deductive data analysis methods. The researcher studied the interview transcripts, categorized it into themes, coded the transcribed content for driver and barrier elements as mentioned by Painuly (2001) and Taylor-Powell and Renner (2003) in their frameworks.

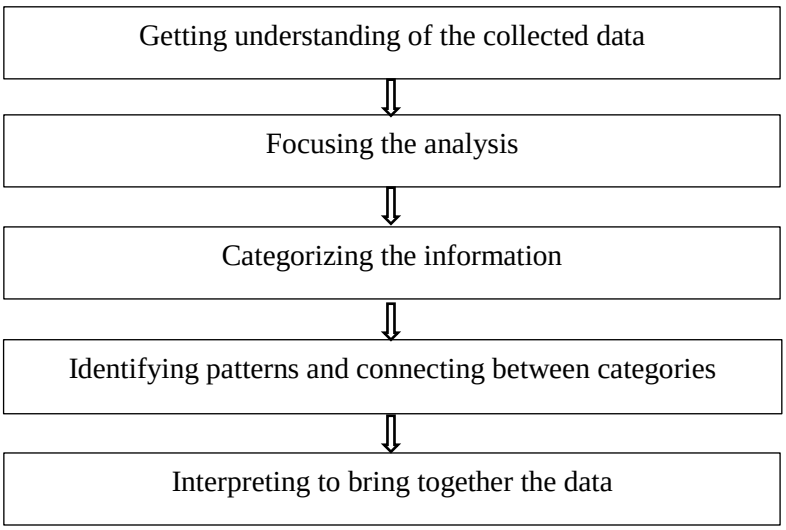

Figure 9. Steps of data analysis. Source: Taylor-Powell and Renner (2003) (with amendments).

Moreover, some new themes come up during the data collection that was not found in the literature review. Therefore, few themes have been added and analyzed in addition to drivers and barriers to solar off-grid technologies in Dharnai. The resultant themes of drivers and barriers are organized in the table and presented in the next chapter, followed by relevant discussions in Chapter 5.

Chapter 4: Result Analysis

The chapter describes the results collected from key informant interviews and focus group discussions conducted in Dharnai solar village and Patna, Bihar. Since the research design followed the case study method, the results presented in this section are solely from the interaction with residents of the solar village, key members of the village cooperative (famously known as VEC) and energy expert.

4.1 Results from interviews and focus group discussions

This section presents the results of eight (8) focus group discussions and three (3) in-depth key informant interviews conducted with different stakeholders in May 2018. The interviews helped address the significant knowledge gap existing about the historical and present electricity scenario of the village and how the solar off-grid system came into existence. All participants were asked to describe the electricity scenario before the installation of the solar off-grid system and how it impacted their lives, along with focusing on different drivers and barriers to the growth of the system. These interviews were crucial in explaining the plethora of problems faced by the residents, their frustration, and almost no expectation with the state electricity board and government in general, in absence of electricity from last 30-35 years. Moreover, the initial interviews were helpful in determining the *Tolas* that should be included because of its mix of socio-economic demographic.

4.1.1 Evolution of electricity in Dharnai village

Two interviewees out of three key informants and all participants of the focus group discussions provided information about the past and present electricity scenario of the village. According to most respondents, Dharnai village did not have electricity from last 30-35 years.

A person in the focus group discussion shared that some portion of their village was connected with electricity many years back, but it was ruined due to negligence and lack of maintenance from the electricity board of government. As a result, locals had to live in almost complete darkness from the last 30-35 years. Other respondents mentioned that they used to lit mud lamps with kerosene oil for lightening and household chores or try to complete their work during the day.

The former Sarpanch (village head) shared that he with other local people happen to meet officials from Greenpeace India and persuaded them to visit their village. During their visit, people explained that the village had more or less all other infrastructures except electricity and how it was hampering the socio-economic growth of the village.

Residents showed immense support, some volunteered the rooftops of their houses and lands for installing the solar off-grid system. Later, residents formed Village Electric Committee (VEC), a cooperative, for proper maintenance of the system and taking important decisions about the installation. A loose timeline is created about the evolution of electricity in Dharnai village based on interaction with different stakeholders, as mentioned in **Figure 10**.

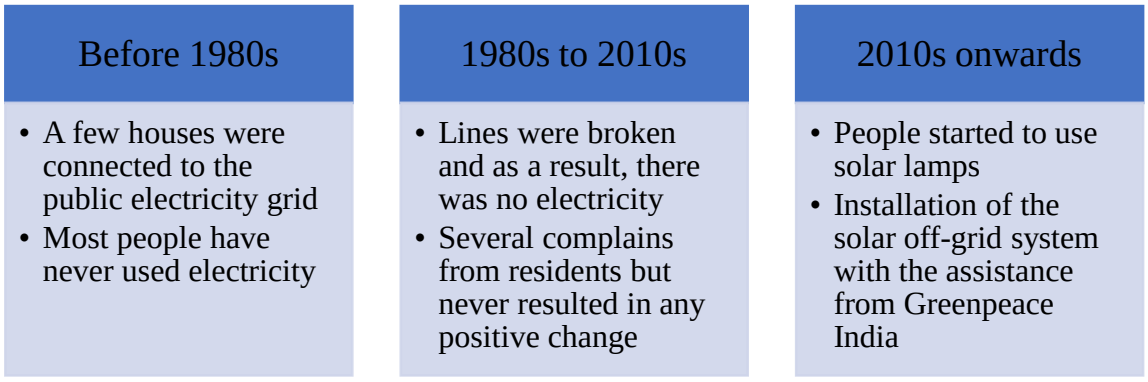

Figure 10. A timeline for electricity in Dharnai village, Bihar. Source: interviews.

4.2 Drivers and barriers derived from collected data

4.2.1 Significant drivers

During the analysis of the interviews and focus group discussion, six main drivers were found that accelerated the installation of solar off-grid in Dharnai. Moreover, there were few more drivers that were mentioned by a few respondents, but researcher categorizes these into themes. The main drivers are (1) policy ambitions of different organizations, (2) unmet demands of consumers, (3) consumer's capacity to pay, (4) benefits of solar perceived by consumers, (5) indicator of development and (6) uncertainty about the grid connection. Each driver has several driver elements as presented in **Table 5**.

Table 5. Drivers to the growth of solar off-grid in Dharnai village, Bihar

Drivers	Drivers in Detail	Total count	Key Informant Interviews			Focus Group Discussions							
			1	2	3	1	2	3	4	5	6	7	8
Policy ambitions	Support from NGOs such as Greenpeace India etc.	**10**	1	1	1	1		1	1	1	1	1	1
	Push from donors	**3**	1	1	1								
	Push from governmental policies	**1**	1										
Unmet electricity demands of consumers	Not connected to the grid	**11**	1	1	1	1	1	1	1	1	1	1	1
	Unavailability of electricity from last three decades	**11**	1	1	1	1	1	1	1	1	1	1	1
	Increasing household/business demands	**11**	1	1	1	1	1	1	1	1	1	1	1
	Electricity demands for agricultural purposes	**8**	1	1	1	1			1	1	1	1	1
Consumer's capacity to pay	Willingness to pay for the electricity	**9**	1	1	1		1	1	1	1	1		1
	Overall price reduction of solar off-grid systems	**2**	1										1

Benefits of solar perceived by consumers	Longer hours of electricity	**11**	1	1	1	1	1	1	1	1	1	1	1
	Use light bulbs, fans and charge mobile	**11**	1	1	1	1	1	1	1	1	1	1	1
	Longer study hours for children	**6**		1	1			1	1	1	1		
	Help women in household chores	**5**			1			1	1	1	1		
	Longer business hours	**5**		1	1				1		1		1
	Able to fix issues faster	**5**		1	1		1		1			1	
	Enhanced safety on streets	**3**		1	1				1				
Overall development	Basic pre-requisite for development	**8**	1	1	1	1				1	1	1	1
	Local initiative	**7**	1	1	1		1			1	1		1
Others	Uncertainty about connection to grid	**5**	1	1	1						1		1
	Awareness about solar power	**4**	1	1						1			1
	Faulty bills from electricity dept.	**2**							1	1			

4.2.2 Significant barriers

Similarly, the analysis of interviews suggested four main barriers to the growth of the solar off-grid system in Dharnai. All these also have driver elements and it includes (1) policy loopholes, (2) unmet demands of consumers, (3) consumer's affordability, (4) lack of financing options, as listed in **Table 6**.

Table 6. Barriers to the growth of solar off-grid in Dharnai village, Bihar

Barriers	Barriers in Detail	Total count	Key Informant Interviews			Focus Group Discussions							
			1	2	3	1	2	3	4	5	6	7	8
Policy loopholes	Uncertainty about reliable electricity from the grid	**8**		1	1		1	1	1		1	1	1
	No support from state electricity board	**6**	1	1	1				1	1		1	
	No push from governmental policies	**5**	1	1	1					1		1	
	Lack of awareness about govt. policies about solar	**1**		1									
Consumer's capacity to pay	Consumers are unable to pay per unit of electricity	**3**	1	1	1								
	Overall price of solar off-grid systems	**3**	1	1									1
	Lack of financing options for consumers	**3**	1	1	1								
	Unable to run machines/ motors	**6**		1			1	1	1		1	1	

Unmet demands of consumers	for agricultural purposes												
	Unavailability of water for all purposes	**3**						1	1		1		
Drawbacks perceived by customers	Less hours of solar battery capacity	**6**		1			1	1	1		1	1	
	Less hours of electricity	**6**		1			1	1	1		1	1	
	Scaling up issues	**4**		1			1		1			1	

Chapter 5: Discussion

The results generated from the interviews and focus group discussions provide insights about the growth of the solar off-grid system in Dharnai village, Bihar. The results fill the knowledge gap in the literature about the drivers and barriers to the solar decentralized systems in the state. It will also add to our understanding of the historical timeline of electricity and why the solar off-grid system has been successful and flourishing in the village. Moreover, the results will also elucidate how the installation of the solar off-grid system is impacting the overall development of Dharnai village from a developmental perspective.

The chapter is divided into two sections. The first section discusses the significant drivers to the growth of solar off-grid system identified during the interviews. The second section explains significant barriers inhibiting the growth of these systems. Lastly, the third section provides recommendations that can help overcome the barriers to the diffusion of solar off-grid systems in other villages or rural area in Bihar.

5.1 Significant drivers to the growth of the solar off-grid system

The section provides in-depth analysis of main drivers to the growth of the solar off-grid system in Dharnai. Altogether, six main drivers were found with numerous elements after thematic categorization of interviews. These driver elements were mentioned and emphasized by multiple respondents.

A total of 15 driver elements were discussed during the interview and all positively impacted the growth of the solar off-grid system. However, this section will only discuss the top six elements under different umbrella themes. Significant driver elements are mentioned below

along with the total number of times that particular element is raised during the key informant interviews and focus group discussions are mentioned in parentheses.

1) Unmet electricity demands of consumers (raised 11 times)
2) Need for long hours of electricity (raised 11 times)
3) Support from NGOs such as Greenpeace India etc. (raised 10 times)
4) Consumer's capacity and willingness to pay (raised 9 times)
5) Basic pre-requisite for development (raised 8 times)
6) Uncertainty about the grid connection (raised 5 times)

One of the significant drivers to the growth of the solar off-grid system is the **unmet electricity demands of consumers** not only in this village but in the state. Its significance can be understood in terms that this driver element was discussed and emphasized during all 11 interviews and focus group discussions. According to Census 2011, only 10.4% of household have access to electricity and around 89.6% of rural households are not connected to the power grid, in Bihar. One of the focus group discussion participant, Subash Yadav, shared his experience -

> *"from last 30-35 years, we lived in total darkness. They used to light mud lamps with kerosene oil which usually blow away in winds."*

The state's capacity generation is about 546 MW and has lowest per capita consumption of around 122 kWh (CEED 2015). Another participant during the FGD mentioned that most farmers of the village used diesel to run motors for irrigating their agricultural fields. Using diesel is a costly affair for small farmers and a majority of farmers cannot afford diesel for all year farming.

The state lacks reliable electricity transmission network causing peak demand deficit of around 28% and transmission and distribution (T&D) loss of around 38% due to lack of energy infrastructure (Oda and Tsujita 2011, CEED 2015). This suggests that around 400 MW of electricity is wasted out of every 1000 MW used in the state (CEED 2015). Due to long distribution lines, high transmission losses and low load factors, decentralized technologies (Sinha and Kandpal 1991; Andreas 2006) such as solar off-grid system can be a viable alternative to the extension of the grid.

Figure 11. Solar micro-grid power station in Dharnai.

Another important driver is the **need for long hours of electricity** for household, agricultural and business purposes. Ashwani Ashok, an energy expert presently working with the Center for Environment and Energy Development (CEED), shared that the state faces long hours of

power cuts. The power cuts are terribly bad in rural areas throughout the state. Not all areas get reasonable electricity supply. The availability of electricity varies from one village to another in near proximity with one to few hours of electricity one day and none another day (Oda and Tsujita 2011).

According to Kamal Kishor, an entrepreneur and resident of the village, it is easy to understand that we cannot work without electricity. These days, villages and cities do not have much difference, as our needs are very similar. We need electricity to charge mobiles, use coolers and fans and for kid's education. We also need electricity for irrigating our farms as farming with the diesel engine is very expensive and it makes the lives of poor farmers even harder. As a result, a demand-driven electrification is needed that can be customized according to local needs and can be scaled as per the requirements (CEED 2015).

The increased access to electricity from decentralized other off-grid systems also have significant social benefits such as increased study time for children, increased working hours of local businesses and farms, and overall increased economic hours especially retail in local communities (Climate Group 2015).

In Dharnai, the foremost factor was the **support from NGO – Greenpeace India** that made all the differences. Greenpeace along with its two affiliates, CEED – a non-profit institution working for the protection of the environment, and BASIX – a livelihood promotion institution, have put forward an example of alternative energy governance system by installing solar micro-grid project.

The significant high investment needed for the off-grid installation is a huge barrier for the locals, but Greenpeace removed the hurdle by financing the project. The project not only provides electricity to the people but also promote community control of energy resources by making them independent. In this way, organizations and developmental agencies can reduce

the resource gap such as the inability of the rural people to finance the project themselves and pay disproportionate prices for fuel-based energy services (Kruckenberg 2015).

The unmet demand, unreliable and nonexistence electricity paved the way for solar off-grid systems. The grim scenario of electricity encouraged **consumer's capacity and willingness to pay** for other alternative decentralized solutions. One of the participants in the FDG shared that he installed a small solar photovoltaic system, around 10 years back to run his small medical store in the village. He also added that it was and still an arduous job for small businessmen like him to be able to invest this huge amount in solar off-grid systems, therefore he took a loan and paid it gradually. He also emphasized that taking a loan from the bank was a lengthy process.

The awareness of renewables, micro and off-grid technologies has improved. It has increased due to the increasing electricity demands for household chores, charging mobile phones, education of kids and having livelihood options. These demands forced the villagers to think about the alternative of the central grid and that's how off-grid from the Greenpeace India came into existence in Dharnai village.

An energy expert working with CEED stated that the reduction of solar prices has a significant effect on the market. Some of the Chinese cheap products are available in the Indian market and positively impacted the poor. With the reduction in prices of solar PV, people started to analyze if they can afford or not. This not only strengthened affordability, but people are willing to pay a little more for a stable and constant source of electricity in their houses.

Furthermore, it was raised 8 times that electricity is the **basic pre-requisite for development**. This is self-evident that residents were connecting access to electricity to the overall development of their village. Electrification in rural areas is central for both social and economic benefits, as 88.7% of Bihar's population resides in rural areas (Census 2011; Oda

and Tsujita 2011). Kamal Kishor, an entrepreneur and resident of the village, stated following while discussing the importance of electricity on development.

> *"We cannot imagine the development of village and country without electricity. The arrival of electricity has made cooking and other household chores easier for women. The working hours have increased, and people can work smoothly even on farms until 10-11 pm. It is also easier and safer for people to move during the night because of solar street lights."*

The World Bank (2004) report about the impact of energy on women lives documented that electricity uses can have positive impacts on women in rural areas as using electricity for cooking, pumping water and other household chores can provide more free time for other activities. Electricity can improve socio-economic conditions; therefore, rural electrification is very important (Oda and Tsujita 2011). A middle-aged women participant during the focus group discussion emphasized the need for electricity for development by sharing her experience –

> *"The off-grid electricity has a very positive impact on my kids. It is easier for them to study in light bulbs as compared to the light of mud lamps. Moreover, electricity has made the lives of housewives easier. We can use fans for cooling during the summer months and even iron our clothes. Therefore, electricity overall positively impacted our lives."*

A report by the World Bank (2004) found that women in rural areas have a higher chance of reading during the day for homes having electricity. Even the level of literacy for women is higher if their homes are electrified, as compared to almost no reading happening in houses without electricity connections in rural areas. Therefore, electrification has positive effects on women such as continuation of education, taking less time in doing household chores, better

balance paid work and leisure as compared to women from homes not connected to electricity (World Bank 2004).

Additionally, decentralized systems such as off-grid are having significant positive effects on the livelihood of the residents of the Dharnai village. Electricity from the solar off-grid substantially increased the business hours for the local businesses. Now, basic amenities shops such as grocery, pharmaceuticals etc. have long opening hours that has positively impacted the residents in urgent needs. Moreover, farmers are using electric-motor that was installed under the off-grid project for irrigating their farms. Additionally, with solar street lights and personal home electricity connections, farmers are working longer hours in their fields. All these together really boosted the local businesses and over economic well-being of the residents.

The last driver element to be discussed in this section is the **uncertainty about the grid connection**. There is a major skepticism in the state due to lack of clarity about the grid extension plan of both central and state government. Therefore, this is an important driver in this context.

Power retailers in Bihar do not prefer extending the grid to supply electricity to rural homes and consider it as a less attractive business because of its small usage and low-cost tariffs. Moreover, farmers and households below the poverty line (BPL) get subsidies and pay less as compared to the market rates. Subsidies are mostly delayed by the state government, making it unattractive business for the electricity provider (Singh and Sundria 2017). As a result, many enterprises prefer remote locality for establishing their systems because of the low probability of grid expansion in the near future.

Remaining significant driver elements are: electricity demands for agricultural purposes (raised 8 times), local initiative (raised 7 times), longer study hours for children (raised 6 times), help women in household chores (raised 5 times), awareness about solar power (raised 4 times),

enhanced safety on streets (raised 3 times), push from donors (raised 3 times), faulty bills from electricity department (raised 2 times), and overall price reduction of solar off-grid systems (raised 2 times).

5.2 Significant barriers to the growth of solar off-grid system

The analysis of interviews suggested 4 main themes of barriers and 12 barrier elements to the growth of the solar off-grid system in Dharnai. All these barriers elements inhibited the growth and have been emphasized multiple times by the respondents during the interviews and focus group discussions. However, this section will only discuss the top four barrier elements under different umbrella themes. Significant barrier elements are mentioned below along with the total number of times that particular element is raised during the key informant interviews and focus group discussions are mentioned in parentheses.

1) Uncertainty about reliable electricity from the grid (raised 8 times)
2) No support from state electricity board (raised 6 times)
3) Unmet demands of consumers, such as unable to run machines for agricultural purposes (raised 6 times)
4) Lack of financing options (raised 3 times)

The **uncertainty about the reliable electricity from the grid** was mentioned and emphasized 8 times during the discussions. This particular barrier element tops the list because the uncertainty usually acts as the double-edged sword. This can assist residents in making a choice and installing decentralized systems because they are tired of waiting for the grid to be extended.

On the other hand, many respondents share that people are hopeful that the grid will be extended to their locality or village sooner or later. It is because if the grid is extended to their

village or home, they will get highly subsidized electricity. This is also because numerous people can only pay the subsidized prices as they are too poor to afford electricity without state subsidy. Moreover, some respondents suggested that extending the grid and providing electricity to rural areas became a political rhetoric to be used by the politicians to harness votes during the election. Unfortunately, people in need of assistance and subsidy on electricity bill fell prey to these kinds of false developmental rhetoric.

Electrification in India is a three-step process. The very first step is to build infrastructure, second is to extend infrastructure to the villages and household, and third is to ensure reliability and affordability of electricity supply (D'Cunha 2018). And the state is still very far from ensuring these three steps.

There is uncertainty about the long-term feasibility of off-grid systems because no one knows when the grid is going to be extended in the area. It is hard for enterprises because they cannot compete with the subsidized electricity rates provided by the public grid (Climate Group 2015). And it only adds frustrations and disappointments to the locals but also small enterprises of this sector.

Less almost **no support from state electricity board** is heavily prevalent in the state. This barrier element was discussed 6 times and have a lot to say about the present scenario of electricity and renewable energy policy of the state. During the 1990s and early 2000s, the electrification process was slow in the state, as the present government at that time did not put much priority on development. The electrification started to grow after 2005, as 41.7% of villages were electrified by the government standard (Oda and Tsujita 2011).

Not all rural houses can use kerosene or diesel to illuminate their house or to run machines in agricultural fields because these are costly and not afforded by the majority of the rural population (Chakrabarti and Chakrabarti 2002). State electricity board and other

developmental agencies can reduce resource gaps such as the inability of the rural people to pay disproportionate prices for fuel-based energy services. As a result, different business models such as direct sales, cash, (micro-) loans are mixed with financial models to run different projects in the state (Kruckenberg 2015).

Another issue with both central and state electricity boards is the implementation gap. This gap exists at multiple levels from national to local bodies. The multiplicity of actors make governance difficult and impacts evaluation tough (Jacobson 2007). Because of no support from state electricity board, small and medium enterprises face challenges of establishing suitable supply chains, developing the infrastructure of rural market and generating demand by promoting RETs (Jacobson 2007; Jacobsson and Johnson 2000; Kruckenberg 2015).

Another important barrier element shared by most respondents is the **unmet demands of consumers, such as unable to run machines for agricultural purposes**. This driver was mentioned 6 times mostly by farmers and women. These two categories of people are dependent on motors for water for household chores and agricultural purposes. One of the women respondents shared her problem regarding the unmet demand for electricity as following –

> *"We cannot use motors on the power from the solar off-grid system. Therefore, getting enough water for drinking, bathing and other household chores is hard using hand pumps as the water level goes down in summer."*

During the time of the green revolution in the 1960s, the government put a lot of focus on electrifying irrigation pumps to improve agricultural production (Bhattacharyya 2006; Oda and Tsujita 2011). However, it changed afterwards with rural electrification taking more social roles (Oda and Tsujita 2011). Bihar is an agrarian state and around 76% of its population is engaged in this sector (CEED 2015). Therefore, it is important for people to have enough

electricity from the grid or off-grid systems to run their agricultural machines and livelihood. One of the oldest farmer who was happy about getting electricity from the solar off-grid painfully shared the following –

> *"We are very happy with almost home-grown electricity [from off-grid] but we need to run motors for irrigating our farms as well. Farming is my only livelihood option. Having lights, fan and air condition in summer are great but these are not going to fill our tummy and pay our bills, unfortunately."*

His words are enough to remind us of the plight of the rural population who are mostly farmers. This is one of the areas where solar off-grid systems can play a vital role and save farmers from unpredictable oil market prices and make agricultural goods profitable.

Lastly, solar based off-grid renewable energy systems and enterprises need significantly high initial investment. For example, a solar off-grid system of around 10 kW cost more than 30,000 USD. And **lack of financing options** can have strong implication due on recovery timeline (Climate Group 2015). The huge initial investment is a key barrier element, mostly because it is harder for small enterprises to manage huge investment to start the project. Even non-governmental or developmental organizations such as Greenpeace can fund limited projects as such Dharnai.

Most business or community-based enterprises need long-term financing tenures due to high investment demands and difficulty in setting up operations of the off-grid systems. However, financial institutions such as banks rarely provide loans for this long tenure keeping in mind the vulnerability of the renewable sector, lack of adequate financial history of the enterprises of the early stages (Climate Group 2015). According to numerous enterprises, the cost of standard financing products available in the market (13-18%) is too high to be afforded by them (Climate Group 2015). Moreover, government subsidies mentioned in the National Solar

Mission and other governmental policies are hard to disburse on time that leads to the uncertain future of the enterprises but also the people needing the electricity supply.

One of the key challenges of the rural off-grid enterprises is to ensure affordability of the system by collecting regular payments from its consumers. Enterprises usually have low and narrow profit margins and off-grid systems run by community or NGOs only collect the maintenance cost, so that it can be afforded by the locals. Payment collection is labour intensive and time-consuming (Climate Group 2015). And high non-repayment can hamper operation and maintenance of system but also have ill-effects on cash flow and profit margins of the enterprises.

Other barrier elements are following: fewer hours of electricity (raised 6 times), no push from governmental policies (raised 5 times), scaling up issues (raised 4 times), overall price of solar off-grid systems (raised 3 times), consumers are unable to pay (raised 3 times), lack of awareness about governmental policies regarding solar power (raised 1 time).

Chapter 6: Conclusion

Rural electrification is important and usually focused on the centralized supply of power. However, in some areas, renewable off-grid energy technologies can be viable and more efficient in the electrification process. This is the first study about the solar off-grid system installed in Dharnai, Bihar. The aim of the study is to fill the knowledge gap about the Dharnai project, overall solar off-grid sector, and provide recommendations to improve the sector in the state. To accomplish the aims and objective, the research question was formulated which is answered in this thesis.

Since very less information was available regarding the diffusion of the off-grid systems in the state, the thesis utilized a few available academic articles about India. The thematic categorization of drivers and barriers from the interviews and focus group discussions were based on drivers and barriers to the growth of the off-grid sector in India and not from the state due to unavailability of previous researches. Painuly's (2001) framework was used during the data collection and data analysis to identify drivers and barriers to the growth of the off-grid system in Dharnai, Bihar.

Depending on the theoretical analysis in Chapter 2, result analysis in Chapter 4, and discussions in Chapter 5, the study found the significant drivers and barriers to the growth of the solar off-grid system in Dharnai village, Bihar. The main findings suggest that significant drivers are unmet demands of consumers, policy ambitions, consumer's capacity and willingness to pay, benefits of solar perceived by consumers, an indicator of development, and uncertainty about the grid connection. Furthermore, the study found that the significant barriers to the growth of solar off-grid systems are policy loopholes, unmet demands of consumers, consumer's affordability, and lack of financing options.

While analyzing the above-mentioned drivers and barriers, the thesis recommends that Bihar government should start awareness campaigns to improve consumer's lack of awareness about the benefits of solar off-grid technologies; make grid expansion predictable so that consumers have clarity and do not wait in a belief that grid will be extended sooner or later; take appropriate measures to improve financing and overall affordability of the consumers.

The research study brings new dimensions and understanding about off-grid technologies in Bihar. The findings will be beneficial for new research focusing on similar decentralized projects not only in Bihar but other states with similar socio-economic status quo such as West Bengal, Uttar Pradesh and others. Overall, findings will also be useful for non-governmental organizations, companies and organizations working in this sector.

However, the study only covered Dharnai village, therefore the data gathered, and the area covered should not generalized and translated into other contexts. There are several aspects of the present study that need consideration regarding the validity and limitation of the results.

References

Agrawal, A. 2011. *India's potential growth: a reality check.* STCI Primary Dealer Ltd. URL: http://www.stcipd.com/UserFiles/File/India's%20Potential%20Growth-%20A%20Reality%20Check.pdf

Ahlborg, H. and Hammar, L. 2014. Drivers and barriers to rural electrification in Tanzania and Mozambique – Grid-extension, off-grid, and renewable energy technologies. *Renewable Energy* 61: 117-124.

Andreas, K. 2006. *Regional disparities in electrification of India – do geographic factors matter?* Centre for Energy Policy and Economics (CEPE), ETH Zurich.

Ashok, Ashwani. Business Analyst, Energy Division for Center for Environment and Energy Development (CEED). Formal interview. Patna, 17 May 2018.

Bhattacharyya, S. 2006. Energy access problem of the poor in India: is rural electrification a remedy? *Energy Policy* 34 (18): 3387-3397.

Britten, N. and Fisher, B. 1993. Qualitative research and general practice. *The British Journal of General Practice* 43(372).

CEED. 2015. 100% renewable energy (RE) Bihar. Center for Environment and Energy Development (CEED). URL: http://ceedindia.org/wp content/uploads/2016/10/100BiharBriefingPaperEnglish.pdf

Census of India. 2011. *Source of lighting*. URL: http://www.censusindia.gov.in/2011census/hlo/Data_sheet/India/Source_Lighting.pdf

Census Organisation of India. 2011. *Bihar population census data*. URL: https://www.census2011.co.in/census/state/bihar.html

Chakrabarti, S., and Chakrabarti, S. 2002. Rural electrification programme with solar energy in remote region – a case study in an island. *Energy Policy* 30: 33-42.

Chandran-Wadia, L., Deorah, S., Nair, S., and Lath, A. 2015. Prospects for electricity access in rural India using solar photovoltaic based mini-grid systems. In *Decentralize solution for developing economies: Addressing energy poverty through innovation*, ed. Groh, S., et al. *Springer Proceedings in Energy*: 53-64.

Chaurey, A., Krithika, P., Palit, D., Rakesh, S., Sovacool, B. 2012. New partnerships and business models for facilitating energy access. *Energy Policy* 47: 48-55.

Cleantechnica. 2014. *Narendra Modi plans to bring solar to 400 million people, electrify rural India.* URL: https://cleantechnica.com/2014/05/26/narendra-modi-plans-bring-solar-400-million-people-electrify-rural-india/

Cleantechnica. 2015. *India allocates $400 million for Renewable Energy expansion in annual budget.* URL: http://cleantechnica.com/2015/03/04/ india-allocates-400-million-for-renewable-energyexpansion-in-annual-budget/

Climate Group. 2015. *The Business Case for Off-Grid Energy in India.* URL: http://www.goldmansachs.com/citizenship/environmental-stewardship-andsustainability/environmental-markets/cem-partners/gs-report.pdf

D'Cunha, S. 2018. *Modi ananounces '100% village electrification', but 31 million Indian homes are still in the dark.* Forbes. URL: https://www.forbes.com/sites/suparnadutt/2018/05/07/modi-announces-100-village-electrification-but-31-million-homes-are-still-in-the-dark/#629d175863ba

Dyson, T., and Moore, M. 1983. On kinship structure, female autonomy, and demographic behavior in India. *Population and Development Review* 9 (1): 35-60.

Ferris, D. 2014. *Indian microgrids aims to bring millions out of darkness.* Yale Environment 360. URL: https://e360.yale.edu/features/indian_microgrids_aim_to_bring_millions_out_of_darkness

Fierlbeck, K. 1995. Getting representation right for women in development: accountability, consent, and the articulation of women's interests. *IDS Bulletin* 26 (3): 23-30.

GOI. 2014. *Production of renewable energy.* Government of India. New Delhi. URL: www. pib.nic.in/newsite/erelease.aspx.

Gupta, P and Blum, F. 2018. *India's remarkably robust and resilient growth story. End Poverty in South Asia.* The World Bank Blog. URL: http://blogs.worldbank.org/endpovertyinsouthasia/india-s-remarkably-robust-and-resilient-growth-story

IEA. 2013. *Southeast Asia Energy Outlook: World Energy Outlook Special Report.* International Energy Agency, Paris.

IRENA. 2017. *Renewable Energy Prospects for India, a working paper based on Remap.* The International Renewable Energy Agency (IRENA). Abu Dhabi. URL: www.irena.org/remap

Jackson, C. 1996. Rescuing gender from the poverty trap. *World Development* 24 (3): 489-504.

Jacobson, A. 2007. Connective power: solar electrification and social change in Kenya. *World Development* 35 (1): 144-162.

Jacobsson, S, and Johnson, A. 2000. The diffusion of renewable energy technology: an analytical framework and key issues for research. *Energy Policy* 28 (9): 625-640.

Kabeer, N. 1994. *Reserved realities: gender hierarchies in development thought*. Verso, London.

Kabeer, N. 1999. Resources, agency, achievements: reflections on the measurement of women's empowerment. *Development and Change* 30: 435-464.

Karve, I. 1953. *Kingship organization in India*. Asia Publishing House, New Delhi.

Kishore, Kamal. Resident of Dharnai. Focus group discussion. Dharnai, 22 May 2018.

Kruckenberg, L. 2015. Renewable energy partnerships in development cooperation: towards a relational understanding of technical assistance. *Energy Policy* 77: 11-20.

Krueger, A. and Casey, A. 2000. Focus groups: A practical guide for applied research. 3rd ed. *Thousand Oaks:* Sage.

Kumar, Rajesh. Resident of Dharnai. Focus group discussion. Dharnai, 22 May 2018.

Kumar, Surendra. Former *Sarpanch* (Village Head) of Dharnai. Formal interview. Dharnai, 22 May 2018.

Liljefore, P. and Sahlin, J. 2014. *Drivers and barriers for solar home systems (SHS) in rural communities: a cast study in Kyerwa, Tanzania 2014.* Bachelor's thesis in cooperation with Vi Agroforestry, KTH Royal Institute of Technology, Stockholm.

Maguire, P. 1984. Women in development: an alternative analysis. *Centre for International Education*, Massachusetts University, Amherst.

Marczak, M. and Sewell, M. 2007. *Using focus groups for evaluation.* URL: http://ag.arizona.edu/fcs/cyfernet/cyfar/focus.htm

Ministry of Statistics and Program Implementation. 2016. *Indian states by GDP per capita*. URL: http://statisticstimes.com/economy/gdp-capita-of-indian-states.php

MNRE. 2012. *Jawaharlal Nehru National Solar Mission. Phase II – Policy Document*. URL: https://mnre.gov.in/file-manager/UserFiles/draft-jnnsmpd-2.pdf

Oda, H., and Tsujita, Y. 2011. The determinants of rural electrification: the case of Bihar, India. *Energy Policy* 39(6): 3086–3095.

ODI. 2009. *Research tools: focus group discussion.* URL: https://www.odi.org/publications/5695-focus-group-discussion

OECD. 2015. *Economic Outlook for Southeast Asia, China and India 2015 Special Supplement – March 2015.* URL: https://doi.org/10.1787/saeo-2015-en

Ostrom, E. 2007. A diagnostic approach for going beyond the panaceas. *Proceedings of the National Academy of Sciences of the United States of America* 104: 15181–15187.

Painuly, J.P. 2001. Barriers to renewable energy penetration; a framework for analysis. *Renewable Energy* 24: 73-89.

PRS Legislative Research. 2018. *Bihar Budget Analysis 2018-19*. URL: http://www.prsindia.org/administrator/uploads/general/1519878666_State%20Budget%20Analysis%20-%20Bihar%202018.pdf

Rasul. G., and Sharma, E. 2014. Understanding the poor economic performance of Bihar and Uttar Pradesh, India: a macro-perspective. *Regional Studies, Regional Science* 1 (1): 221-239.

Roy, A. 2014. *A village that harnessed the sun.* The Pioneer. URL: https://www.dailypioneer.com/columnists/oped/a-village-that-harnessed-the-sun.html

Safilios-Rothschild, C. 1982. Female power, autonomy and demographic change in the Third World. *In Women's roles and population trends in the Third World*, ed. Anker, R., Buvinic, M., and Youssef, NH. Routledge, London: 117-132.

Sen, A. 1985. *Commodities and capabilities.* Amsterdam: North-Holland.

Sharma, Sunil. Chairperson, Village Electric Committee (VEC) of Dharnai. Formal interview. Dharnai, 22 May 2018.

Singh, A. 2015. *Comments on "Draft National Renewable Energy Act," 2015*. URL: https://www.iitk.ac.in/ime/anoops/policypapers/Anoop%20Singh%20-

%20MNRE%20-%20Draft%20National%20RE%20Act%20-%202015%20%20A.pdf

Singh, R and Sundria, S. 2017. *Living in the dark: 240 million Indians have no electricity.* Bloomberg. URL: https://www.bloomberg.com/news/features/2017-01-24/living-in-the-dark-240-million-indians-have-no-electricitys

Sinha, C., and Kandpal, T. 1991. Decentralized v grid electricity for rural India: the economic factors. *Energy Policy* 19 (5): 441-448.

Taylor-Powell, E. and Renner, M. 2003. Analyzing qualitative data. *University of Wisconsin Extension: Program Development and Evaluation*.

World Bank. 2004. *The impact of energy on women's live in rural India*. Energy Sector Management Programme (ESMAP). World Bank, Washington.

World Bank. 2017a. *Population, total.* URL. http://data.worldbank.org/indicator/SP.POP.TOTL

World Bank. 2017b. *Rural population (% of rural population).* URL: http://data.worldbank.org/indicator/SP.RUR.TOTL.ZS

World Bank. 2017c. *GDP (Current UD$).* URL: http://data.worldbank.org/indicator/NY.GDP.MKTP.CD

World Bank. 2017d. *GDP per capita (current US$).* URL: https://data.worldbank.org/indicator/NY.GDP.PCAP.CD

World Bank. 2018. *Population 2017*. URL: http://databank.worldbank.org/data/download/POP.pdf

World Resources Institute (WRI). 2016. *India India Charts a Roadmap to Achieve Ambitious Solar Targets.* World Resources Institute. URL: http://www.wri.org/blog/2016/05/india-charts-roadmap-achieve-ambitious-solar-targets.

Yadav, Subash. Resident of Dharnai. Focus group discussion. Dharnai, 22 May 2018.

Yin, R. 1984. Case study research: design and methods. Beverly Hills, Calif: Sage Publications.