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The Sustainable Eradication of Energy Poverty

A study of micro hydropower in Murung Raya, Indonesia

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Abstract

The purpose of this thesis was to explore the sustainability of a renewable village grid micro hydropower project in the Murung Raya district of Central Kalimantan Province, Indonesia, according to indicators for five dimensions of sustainability: economic, environmental, social, technical, and institutional. The theoretical discussion and subsequent analytical framework are rooted in dimensions of sustainable development based on a paper from Ilskog and Kjellström (2008), where they aim to conceptualisation sustainable development for off-grid rural electrification. This framework, which uses quantitative indicators, supported by qualitative data, aims to remove what some have argued are the arbitrariness of sustainable development, and reinforce its action guiding power (Christen and Schmidt 2012). The thesis explores, firstly, the extent to which the micro hydropower project in Murung Raya is sustainable according to criteria from Ilskog and Kjellström (2008), and, secondly, based on findings from the case study, it proposes additional indicators that could be included in future research on the sustainability of rural electrification. Mixed methods fieldwork was conducted in the Murung Raya district, specifically the villages of Kolam and Saruhung. Data was also collected from a third village, Olung Soloi; however, since this village experienced de-electrification in 2012, the data from this village will be used purely to compliment the main findings from the other two villages. Based on the Ilskog and Kjellström (2008) indicators economic, environmental, and social sustainability are achieved, whereas technical and institutional sustainability are not, resulting in an overall unsustainable project. Additional indicators are proposed in the economic, environmental, and institutional dimensions to bring more depth to the categories identified in each dimension, whereas additional indicators in the social and technical dimensions aim to capture components not explored by the Ilskog and Kjellström (2008) indicators.

Key Words: rural electrification, micro hydropower, sustainable development, Indonesia.

Word Count: 14,998

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LIST OF ACRONYMS & ABBREVIATIONS

CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
GDP	Gross Domestic Product
GHG	Greenhouse Gas Emissions
GoI	Government of Indonesia
HDI	Human Development Index
IDR	Indonesian Rupiah
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
kW	Kilo Watt
kWh	Kilo Watt hour
MDGs	Millennium Development Goals
MP3EI	Masterplan for Acceleration and Expansion of Indonesia's Economic Development
PLN	*Perusahaan Listrik Negara* (State Electricity Company)
REDD+	Reducing Emissions from Deforestation and Forest Degradation
SE4ALL	Sustainable Energy for All
USD	United States Dollar

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Key Terminology

Sustainable development and sustainability

Robèrt (2000:243) defines sustainability as “/…/ a favourable outcome for a system /…/” and sustainable development as “/…/ principles for the process to reach this outcome.” For this thesis, I consider the sustainable development principles to be part and parcel of the sustainable outcome. Therefore, the terms ‘sustainable development’ and ‘sustainability’ will be used interchangeably. This decision was made to accommodate the lack of distinction between the two terms in much of the academic literature referenced, and to facilitate a discussion where the process and outcomes are viewed as having a circular rather than linear relationship.

Modern energy access; rural electrification

There is no universally agreed definition for the term ‘modern energy access’. I will adopt the definition used by the International Energy Agency (IEA): “/…/ a household having reliable and affordable access to clean cooking facilities, a first connection to electricity, and then an increasing level of electricity consumption over time to reach the regional average” (SE4ALL 2012:7). The term ‘rural electrification’ will often be used because it is commonly used in academic literature- yet it is not equivalent to ‘modern energy access’. Rural electrification does not necessarily include access to clean cooking facilities, nor does it stipulate reliable and affordable access. Rural electrification is simply when rural communities have access to electrical power or electricity.

Renewable energy based village grid (RVG)

Off-grid (decentralized) electricity grids are increasingly being viewed as a favourable option for providing power to isolated, rural communities (Pereira et al. 2010:1233). The term renewable energy based village grid (RVG) has recently been coined to describe off-grid rural electrification from a renewable energy source. This term will be used throughout my thesis, as renewable energy is examined in the case study. ‘Off-grid rural electrification’ will be used as a more general term in broader discussion when the energy is from either renewable or non-renewable sources. Since RVGs are a relatively recent development, most literature uses the term off-grid rural electrification.

1 SITUATING THE RESEARCH - ENERGY AND SUSTAINABLE DEVELOPMENT

Sustainable development is not possible in the presence of energy poverty. One in five people on the planet still lack access to electricity. Twice that number - a total of three billion people - relies on wood, coal, charcoal, or animal waste for cooking and heating (SE4ALL 2012). In today's economy, this contributes to inequity, a major barrier to eradicating poverty (Kaplinsky 2013). Access to modern energy services is generally viewed as one of the basic requirements for sustainable development as these services are central to improved welfare (Gómez and Silveira 2010:6251; Hasan et al. 2011:2316). Energy has been documented as influencing socio-economic conditions in developing countries and as a key strategy for promoting sustainable development in rural areas (Ilskog and Kjellström 2008; Kanagawa and Nakata 2008).

The World Summit for Sustainable Development held in 2002 led to the introduction of the link between energy and development into the international development agenda, highlighting the need for new efforts and policies to promote electrification in developing countries. This relationship was not wholly new, however. Five decades ago the United Nations described the provision of electrification as a means of 'development first', to improve development of rural communities by supporting an increase in the productivity of human capacity and promoting reductions in inequity between rural and urban areas (Ahlborg and Hammar 2014:117; Bastakoti 2006:33). Energy access in rural areas is especially important as energy poverty in these areas can exacerbate national poverty (Javadi et al. 2013). Much progress in rural electrification has been made in the past half century, yet energy access disparity continues in many countries. To this end, the United Nations declared 2012 the 'International Year of Sustainable Energy for All' and has furthered the initiative by launching the decade for 'Sustainable Energy for All' (SE4ALL) from 2014-2024, aimed to create a coordinated global response to energy poverty and access challenges. The SE4ALL 'Framework for Action' states a world with sustainable energy for all is achievable:

> *"Access to modern energy services is fundamental to human development and an investment in our collective future. Be it for health, education, the empowerment of women, food production, security, the mitigation of climate change, the creation of new jobs, or the expansion of markets, access to sustainable energy for all is essential for strengthening economies, eliminating poverty, protecting ecosystems, and achieving a more equitable society. Energy lies at the heart of all countries' and businesses' core interests"* (SE4ALL 2012:7).

The purpose of this thesis is to explore the impacts modern energy has on a rural population and to build on existing theory and analytical frameworks linking the topics of sustainable development, energy poverty, and rural electrification. In the context of the renewed international focus on sustainable eradication of energy poverty, it is appropriate to ask what steps are required for improved energy access to lead to the development benefits commonly associated with the provision of electricity, and to investigate whether or not these benefits – if achieved – are sustainable. In this thesis, the topic of the sustainable development of rural electrification is discussed and exemplified through a case study of a micro hydropower project in the Murung Raya district of the Central Kalimantan Province of Indonesia, installed in 2011 with funding from the Government of Indonesia (GoI). The micro hydropower is transmitted to a decentralised grid for potential distribution of the electricity to three rural villages in the district. This single case warrants an in-depth investigation for two reasons: examples of the intervention are uncommon across Indonesia relative to the number of people lacking access to safe and reliable forms of modern energy, and the implementation of similar projects in different locations is likely - throughout Central Kalimantan and across Indonesia hydropower potential is considerable (Hasan et al. 2011:2316). A paper by Ilskog and Kjellström (2008) titled ‘And then they lived sustainably ever after?- Assessment of rural electrification by means of indicators’ presents a five dimension framework for analysing sustainability, a framework that is adopted, with some modifications, in this thesis. Ilskog and Kjellström (2008) combined an extensive literature review on off-grid electrification sustainability with experiences from fieldwork for seven different off-grid projects, to develop a comprehensive framework on the topic. The Murung Raya case study makes a unique contribution to literature because the size of the target population for the micro hydropower is much smaller than that available in literature, and the access to electricity is universal, whereas previous studies looked at areas with energy access disparities.

A mixed methods case study in the villages impacted by the hydropower project forms the empirical foundation of this thesis. Considering the renewed focus on the sustainable eradication of energy poverty for rural populations in the international development agenda, this study aims to make a contribution to existing literature on the sustainable development of rural electrification, giving rise to the following research questions:

> [RQ1] In what ways is the off-grid rural electrification hydropower project in Murung Raya, Indonesia sustainable, according to the indicators presented by Ilskog and Kjellström (2008)?

[RQ2] How can the indicators of sustainability presented by Ilskog and Kjellström (2008) be modified - or what indicators could be added - based on findings from the Murung Raya hydropower project?

The research questions are explored in this thesis using empirical data collected from the field, and secondary literature sources on energy poverty, sustainable development, and rural electrification. The findings of the mixed methods case study are presented according to environmental, social, economic, technical, and institutional dimensions for sustainability; the five dimensions of sustainability outlined by Ilskog and Kjellström (2008). Within each dimension, a set of quantitative indicators is used to guide a discussion on the sustainability of the micro hydropower. These indicators are adopted from Ilskog and Kjellström (2008) [RQ1]; however at times, the Ilskog and Kjellström (2008) criterion is expanded to include additional indicators, as supported by other literature on off-grid rural electricity [RQ2]. In my mixed methods study, qualitative data supports quantitative indicators, adding to the depth of the discussion and triangulating the findings.

Thesis Outline

A justification of the research methods employed, and ethical considerations and project limitations are presented in Chapter 2. The case study is introduced in Chapter 3, along with background information on the context giving rise to the electricity project and motivating the research. A theoretical discussion is contained in Chapter 4 to conceptualise sustainable development for rural electrification. This chapter also includes the framework for analysis adopted from Ilskog and Kjellström (2008). Accordingly, the findings of the study are presented in Chapter 5, followed by a discussion on the most interesting findings from each dimensions. The final two paragraphs in Chapter 5 summarise the discussion to specifically answer each research question, including suggestions for how future projects could be improved, and how the research agenda might be furthered. Chapter 6 is a brief conclusion.

2 METHODOLOGY

Embedded case study research

A case study can be considered a research strategy or a choice of what is to be studied (Kohlbacher 2006); however, for this thesis, a case study is used as the research method (Yin 2009; Creswell 2012) that aims to explain present circumstances in a real-life situation (Yin 2009). The evidence collected through several data collection strategies is likely to be wide in breadth. The empirical material on which this thesis was based was mostly obtained during a one-week period of fieldwork in Indonesia in January 2014 (see ‘Ethical considerations and project limitations’ for more on this short fieldwork duration). The field of study is a single, real-life case bounded by geography and time – the intervention of study was implemented for a known time in a fixed location (Creswell 2012:98). Since I as the researcher have little control over the events and more variables interact than available data points to explain them, data triangulation is critical (Yin 2009:2). To achieve this, an embedded mixed-methods research strategy was used.

The research methods involved deduction, based on a literature review prior to entering the field; and induction, as the general ideas were reformulated to include new evidence acquired in the field with existing knowledge (Ragin and Amoroso 2010:15). The theoretical framework expanded from the three commonly accepted dimensions of sustainable development – social, economic, and environmental – to five components with the addition of institutional and technical sustainability (Ilskog and Kjellström 2008). The choice of framework was based on initial findings from the case study, as salient themes emerged from the data coding that aligned with the five dimensions. Some qualitative information was translated into quantitative data and presented in the form of indictors based on the set of indicators adopted from Ilskog and Kjellström (2008), whereas other qualitative and quantitative data is used to add depth to the discussions. In this way, the theory, methods, and analysis sections are circular rather than linear, allowing for a more dynamic study, open to the particular situation encountered. The fluid process lends itself well to a mixed methods approach.

Mixed methods

The mixed-methods approach adds rigor to the case study methodology (Yin 2009:14). Questionnaires were used to collect quantitative data; focus groups, semi-structured interviews, informal focus group discussion, and participant observation were the methods used to gather qualitative and quantitative data (Appendix II). The focused and insightful research questions in the questionnaire were based of the ASEAN Guideline for Sustainable Rural Electrification (Tran 2013); whereas the choice to use the Ilskog and Kjellstróm (2008) framework was made after the completion of data collection. However, since my data collection protocol was based on a thorough literature review, I had data for all except two of

Ilskog and Kjellstróm (2008)'s indicators[1]. The literature review also situates the research in a broader discourse reducing the risk that critical issues will be overlooked, and increasing the overall impact of the research. The findings, however, cannot be generalised to other rural electrification projects because each project is a unique function of myriad interacting variables (Silverman 2013:144); the study can only hope to add to the existing body of literature in a way that furthers future research agendas on the topic by gaining a thorough understanding of a single case (Creswell 2012:97).

Using mixed methods

A need for measureable results has been emphasised in development studies in recent years due to the belief in 'what gets measured gets done' and to track progress on reaching desired outcomes (Davis and Benedict 2011). Some metrics are inherently more difficult to quantify, such as social impacts, and the time period for change to be realised may be well beyond the project implementation phase, reducing the ability to measure results. Such challenges cannot be eliminated but they also present opportunity to improve the way projects are designed and implemented. Similarly mixed methods research, if well formulated, can increase the reliability and validity of results because many phenomena that cannot be addressed with questionnaires can be addressed with qualitative data collection and vice versa (Ragin and Amoroso 2010:66). I used an embedded mixed methods approach where the qualitative and quantitative data are mixed, and take form within the theoretical perspective, which is the Ilskog and Kjellström (2008) framework. The embedding of the data occurred during the data analysis with the purpose being that a single type of experimental data is insufficient to answer the research questions, however, when embedded the mixed data can be used for a thorough analysis (Creswell 2012:91).

Sampling strategies and data collection

Participant observation began the day I entered the village and continued throughout the week, as I observed and partook in the daily activities, rituals, events, and interactions of the villagers, and recorded these observations multiple times per day. Effective participant observation requires diligent documentation of events as frequently as possible (Mack et al. 2005:13). My interview protocol guide evolved as new knowledge was discovered, and as my

[1] The first missing indicator was 'share of population with primary school education'. However since the access to the electricity was universal in Kolam and Saruhung villages, this indicator was no longer applicable. The second missing indicator was 'satisfaction with energy services'. Although this specific question was not asked, other data can be used to investigate satisfaction with energy services.

cultural understanding improved I was able to pick up on subtleties in the participant's responses otherwise missed (Mack et al. 2005:16).

To select participants, snowball sampling - a form of purposive sampling - was used starting with the Head of Kolam village and Secretary of Saruhung village. All participants had experience with the phenomenon being studied – the impact of electrification on their village – because the access to electricity was universal, thus a narrow range sampling strategy was not necessary (Creswell 2012:155). There was no information to suggest that studying a specific group such as youth or women would be beneficial, nor does a gap in literature necessitate narrowing down the study population. Therefore, to broadly appreciate the impacts, I attempted to gather multiple perspectives from a heterogeneous sample in order to best represent the population of the villages (Creswell 2012:156). The breadth of variability allowed me to generalise results - as best as possible - to the villages as a whole (Creswell 2012:99). To facilitate efficient data collection, participants gathered in the village Head and Secretary's homes, in Kolam and Saruhung villages respectively, to complete the questionnaire. The Head and Secretary - with guidelines from the researcher to have equitable representation based on gender, household income, and age - invited villagers to participate in the quantitative data collection. These guidelines were adhered to (see Appendix II: Record of Informants – quantitative data collection for univariate statistics on sample). From this first point of contact villagers volunteered and were selected to participate in the focus group discussions. A summary of the data collection is in Table 1. Fifty-nine 20-question questionnaires were completed, 33 by Kolam residents and 26 by Saruhung residents. Three focus groups were held in each village lasting from 30 minutes to one hour, in addition to one semi-structured interview in both Kolam and Saruhung villages lasting one hour. Informal focus group discussion took place in the evening, once in Kolam village and twice in Saruhung village. Data from Olung Soloi was collected during three focus group interviews, but was only used to supplement discussions because they are not receiving access to the electricity.

Table 1: Type of data collected from Kolam, Saruhung, and Olung Soloi villages

Type of Data	Village		
	Kolam	Saruhung	Olung Soloi
Questionnaire	33	26	-
Focus Group	3 (18 people total)	3 (22 people total)	3 (18 people total)
Semi-structured Interview	1	1	-
Informal focus group	1	2	-

With the consent of participants, all focus group and semi-structured interviews were recorded, and then translated immediately after returning from the field. The semi-structured form was intended to encourage respondents to provide information on the aspects of the hydropower they found most relevant. I translated voice recordings and transcribed notes, combined them with notes from my research assistant, and coded according to the triple-bottom line of sustainability (economic growth, social inclusion, and environmental protection) for the first round of coding. Semi-structured interviews and informal focus group discussions were not voice reordered, instead notes were taken and a reflection was written afterwards, including a summary of the discussion with my research assistant to confirm themes in the responses.

Use of a research assistant

I was fortunate to locate a highly skilled research assistant, from Puruk Cahu, the capital city in the northern Central Kalimantan, fluent in Bahasa Indonesia and English and the local Dayak language. His ability to speak the local language was an asset: some village elders only spoke Dayak, so avoiding the need for multiple translators allowed the village elder to comfortably share their experiences, and reduced any potential altered content associated with multiple translations. His cultural familiarity ensured we respected village traditions to evoke a sense of trust in the villagers. Furthermore, I had the benefit of collaborating with my assistant during his work with the International Labour Organisation (ILO) in rural villages in the south of the Central Kalimantan Province, and therefore knew we worked well together. My research assistant was especially skilled at interacting with our host families and the villagers who regularly gathered at our hosts' homes in the evenings. His experience with rural development and his keen interest in improving the lives of those in his home province, allowed him to engage villagers in very insightful casual conversation, which he either translated or summarised for me. The villagers were extremely willing to share information, especially regarding the electricity because of the constant challenges they face, in this causal setting.

Data analysis

This thesis adopts the framework designed by Ilskog and Kjellstöm (2008) to answer the research questions regarding the sustainability of the RVG. It does, however, differ in two important ways: Ilskog and Kjellström's (2008) work was purely quantitative; they base their evaluation on a set of indicators they devised through the iterative process of literature review and fieldwork experience. I will present these quantitative indictors, but the discussion also includes qualitative data to further support findings. Secondly, Ilskog and Kjellström's (2008) study is comparative; they look at seven different rural electrification projects and compare the sustainability indicators. Thus their findings are substantiated based on the value of the indicators relative to each other (ie. relative ranked from one to seven based on an indicators value) and the absolute value. Since my case study if for a single RVG project, the indicators have absolute value only. Data triangulation between quantitative data, qualitative date, existing literature, and theory, gives meaning to the indicators.

I prepared questionnaires before entering the field, based on the ASEAN Guideline for Sustainable Rural Electrification (Tran 2013), which focused on economic, environmental and social sustainability indicators. Villagers were mainly asked questions on ordinal scales comparing their present situation to that prior to electrification. Although this information is indicative of the current situation, and reveals areas for improvement, data from a single evaluation is not sufficient for a complete assessment of sustainability, which is a matter of progression over time. With no baseline data available, the comparative style of questioning was the optimal alternative to capture changes. In the discussion, the indicators are supplemented with qualitative data, providing a richer description of the case study than the indicator alone can provide. An interview protocol guide, which evolved over time was used to guide focus group and semi-structured interview discussions (Appendix III).

Positionality as a researcher

As a white female researcher from Canada studying in Sweden, my position was that of an outsider (Sultana 2007), which impacted the data I was able to collect. Further impacting my positionality was my association with my gatekeeper, the Head of the Provincial REDD+[2] Agency of the Central Kalimantan Province, a well-respected agency in the village. REDD+ Agency representatives had visited Kolam village one month prior to my data collection as part of an investigation of the potential for future projects in the district. In numerous conversations with the Head of Kolam village and Secretary of Saruhung village, they expressed the desire to attract more support from international organisations to their village, and were thus very accepting of outsiders to the village. Additionally, my research topic struck a chord to the villagers because they have been dealing with challenges in regards to the electricity since its installation. Their attempts to communicate their frustrations have often been met with mute responses. They saw me as an individual in a position of power, as

[2] Reducing Emissions from Deforestation and Forest Degradation (REDD+)

a potential outlet to communicate their concerns with institutions able to support them in improving the electricity and other services in the villages. This was advantageous to my data collection because the villagers were enthusiastic to share information and willing to dedicate their time to discussions on the topic. Throughout the data collection I was cognisant, however, of the fact villagers wanted the information they shared with me to be passed to a broader audience, which could have altered, either positively or negatively, their responses to questions.

Ethical considerations and project limitations

Using coded responses throughout the thesis ensures animosity of the respondents. In accordance with local culture, permission to carry out the study was sought from the Head of Kolam village via text message. Upon entry to Kolam, I travelled to Saruhung to seek similar permission from their leader, the village Secretary. Leadership and institutional organisation in Olung Soloi is lacking; it was unclear whom to approach for permission to carry out data collection. To facilitate entry, a villager from Saruhung acted as my gatekeeper.

The one-week period of data collection appears short. However, it was sufficient time to collect data that corresponded to all but two of the indicators presented by Ilskog and Kjellström (2008), in addition to collecting a wide breadth of qualitative data. My research assistant and I were hosted in the villages allowing for constant engagement throughout the seven days, so data collection in its many forms was happening constantly providing rich data. Furthermore, prior to the intensive data collection, I spent six months in Indonesia, four of those in the Central Kalimantan Province. As an intern with a coordination body (United Nations Office for REDD+ Coordination in Indonesia), I had frequent engagement with multiple stakeholders, one of which lead to the discovery of the hydropower installation. Although not explicitly contributing to the data, this time had a signification indirect contribution to my contextual knowledge on rural communities in the Central Kalimantan Province. Potential researcher bias is actively addressed through the adoption of an analytical framework for data analysis, and data triangulation between theory, literature, and multiple forms of fieldwork data.

Using a sustainable development theoretical discussion to underpin the framework and subsequent analysis presented challenges and opportunities. The topic of sustainable development is vast, covering a broad range of social, economic and environment criterion and, for this thesis, technical and institutional sustainability criterion. The wide breadth of the study was intentional – the aim is to provide a multi-faceted analysis –

however, this approach comes with a trade-off in the depth of the analysis. Important criteria are discussed in each of the sustainability dimensions, yet the discussion for any single dimension is not exhaustive. The indictors adopted from Ilskog and Kjellström (2008) aim to remove some arbitrariness from sustainable development theory, amalgamate findings from previous literature, and capture key components of sustainability as they pertain specifically to off-grid rural electrification, while theoretically grounding the thesis and countering the challenges associated with the vast scope (Christen and Schmidt 2012).

3 BACKGROUND

This section situates the research within the regional context to exemplify why research on off-grid rural electrification in Indonesia is important. In contrast to other countries in the region, Indonesia has failed to achieve universal access to modern energy services. The need to prioritise rural electrification in addition to the potential for development of energy from renewable sources, gives hope that many more RVG projects will be implemented in Indonesia in the coming years, and, as such, more research on the topic may help improve project success rates.

Regional context[3]

Indonesia is the world's fourth most populous country, Southeast Asia's largest economy, and the country's strong economic demand has created an even faster increase demand for energy (Mujiyanto and Tiess 2013:31). However, energy poverty has been persisting in rural Indonesia, leading to prolonged economic poverty (Javadi et al. 2013:402). The electrification rate in Indonesia remains lower than many surrounding countries, according to data from the IEA (2013). From the most recent available data in 2011, the electrification rate for Indonesia stood at 73 percent, which is higher than that of the Philippines (70 percent) and Pakistan (69 percent), but lags far behind that of Vietnam (96 percent) or Sri Lanka (85 percent), all classified - similar to Indonesia - as lower-middle-income economies (IEA 2013). Access to electricity in the region as of 2011 is shown in Figure 1. The bars on the graph indicate the total number of people without access, and the lines provide data on the percentage of the urban, rural, and total population with access to electricity.

[3] For additional information on the Indonesian context see Appendix 1.

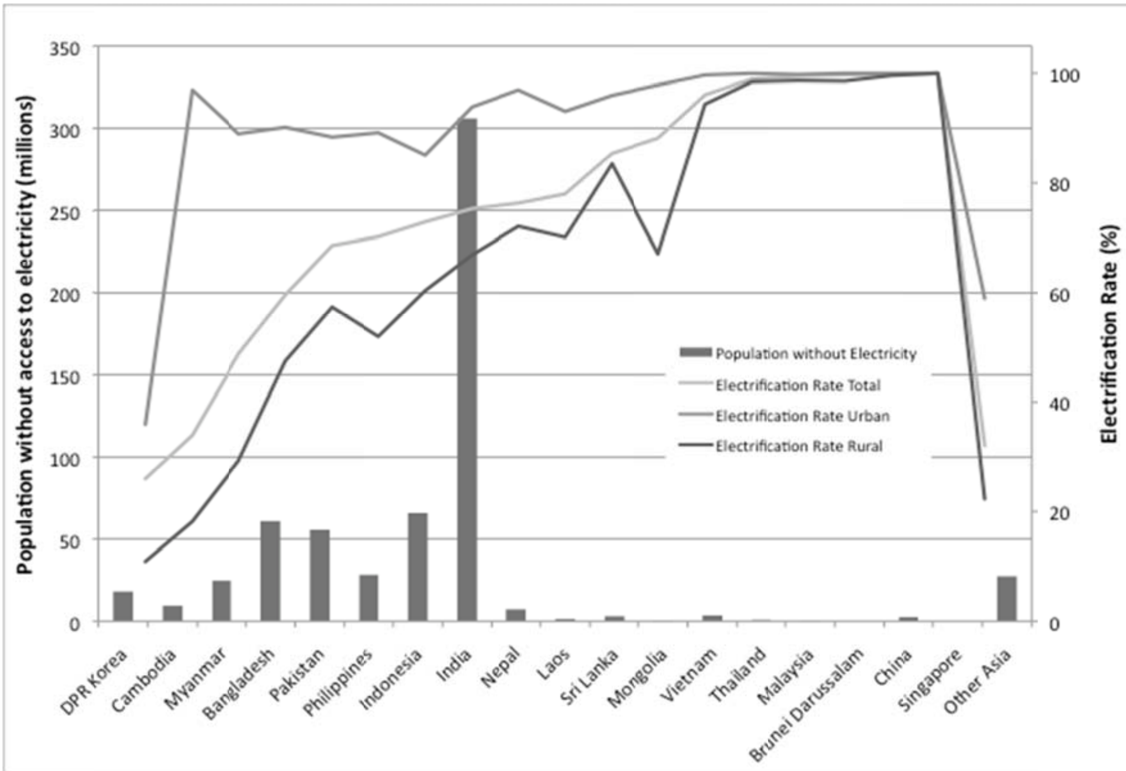

Figure 1: Access to electricity in 2011 for select countries in Asia (IEA 2013)

It is estimated that only 60 percent of the rural population in Indonesia has reliable access to electricity, compared to 85 percent for the urban population (IEA 2013). There are 66 million Indonesians who have never used electricity in their homes. The country's total electricity generation capacity of 31,656 MW at the end of 2010 is one of the largest in Southeast Asia, yet low on a per capita basis considering the total population is 237.6 million (BPS 2013). Indonesia aims to improve access to electricity to 95 percent by 2025 (Javadi et al. 2013:404), a target that requires the diversification of energy generation to include energy renewable sources, such as micro hydropower and other sources (Hasan et al. 2011:2316). An example of a renewable energy project, that marries the challenges of inequitable rural access with the solution of renewable energy generation, can be found in the Murung Raya district of Indonesia's Central Kalimantan Province.

The Murung Raya district of Central Kalimantan, Indonesia

Central Kalimantan is one of four provinces on Indonesia's side of Borneo Island. Murung Raya is the province's northern most district, located in the geographic centre of Borneo or the so-called "Heart of Borneo", straddling the equator. The district, with a population of almost 100,000 people, is rich in natural resources, such as gold, coal, tin, and timber, and the large intact forest (Holland 2012:18). In a country with large-scale deforestation, Murung Raya has among the highest primary forest cover in Indonesia and is home to an exceptional diversity of flora and fauna (ibid.). Much of the population resides in rural locations practicing traditional, forest-dependent ways of life (Holland 2012:28). The rural population relies on rubber, fishing, small-scale farming, and collecting *gaharu* - a rare, high value export timber product used in perfumes – for subsistence living (ibid.).

In recent years there has been improvement in the Murung Raya district with regards to electricity production, and corresponding improvements in social welfare. Gómez and Silveira (2010:6251) show that electricity availability, as a driver for development, has led to welfare improvements, as measured by the Human Development Index (HDI). The positive correlation between HDI and electricity production holds true for Murung Raya between the years of 2008-2011, as evident in the Figure 2. As of December 2012, 34 percent of households in the district had access to electricity provided by the *Perusahaan Listrik Negara* (PLN, in English: State Electricity Company), an improvement from previous years, but still well below the national average of 73 percent (BPS 2013). This graph supports the conclusion that electricity availability and social development are linked; however, it does not provide the direction of the correlation. Academic literature suggests the causation that electricity availability is a pre-requisite to social development (Nautiyal et al. 2011:2021).

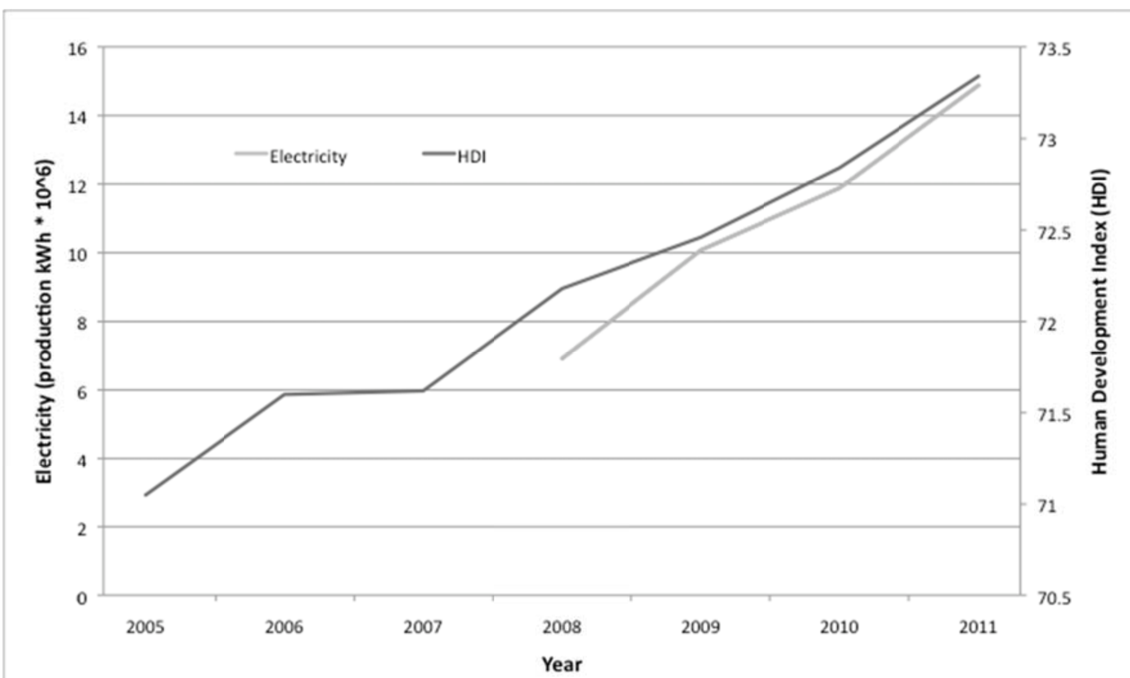

Figure 2: Electricity production and HDI for Murung Raya from 2005-2012 (BPS 2013)

The socio-economic conditions in Murung Raya has improved over the past eight years: the percentage (absolute number) of the population living below the poverty line has decreased from 10.24 percent (9800 people) in 2005 to 5.78 percent (5870 people) in 2012, while, over the same time period, the poverty line income has increased from 136,661 IDR (11.89 USD) to 311,328 IDR (27.09 USD)[4] per month (BPS 2013). The majority of the economic growth can be attributed to the mining and quarrying sector, which has experienced an average growth in gross regional domestic product of 21 percent between 2009 and 2012 (ibid.). While the economic condition of the district as a whole has improved, these figures fail to capture the inequitable distribution of benefits. Limited electricity access, especially in rural areas, exemplifies this. Grid extension for electricity transmission and distribution in Murung Raya is costly due to the hilly topography and low population density. The district does, however, have large potential for small-scale hydropower production. The case study presented is harnessing "run-of-the-river" hydropower to provide rural villages with a renewable source of electricity.

The hydropower project

The case study takes place in the villages of Kolam, Saruhung, and Olung Soloi with official populations of 326 (116), 194 (97), and 120 (23) people (households) respectively (BPS 2013). A logging road connects the villages to the Murung Raya district capital of Puruk Cahu and the Tanah Siang sub-district capital of Saripoi. From the logging road turnoff, a smaller road leads to the villages: 7.5km to Kolam, 4.5km past Kolam to Saruhung, and 3km past Saruhung to Olung Soloi. The hilly terrain and lack of infrastructure makes travelling to - and between - the villages difficult. The low population density does not qualify the area for network coverage, as it is viewed as economically nonviable, further isolating the communities. Outside support to the villages has been limited with the exception of a hydropower turbine that was installed by the Mining and Energy Department of the Murung Raya district government, providing off-grid electrification to Saruhung and Olung Soloi villages in 2011.

The micro-hydropower turbine is installed adjacent to a river approximately 2km from Saruhung village. The hydropower originates at a river basin, where a dam and sluice gate system control the flow of water through the dam/river and into a diversion canal. Once in the

[4] The conversion to USD dollars is a simplified calculation using the 2014 exchange rate and does not account for inflation.

diversion canal, water travels through a catch box to filter out floating debris, and into a pipeline that carries the water to the powerhouse building containing the turbine and generator. The powerhouse is located beside a waterfall. The flow and pressure of the water are converted into mechanical energy, as the water travels through the turbine; and then into electrical energy, as the turbine turns the generator. The water emerges from the turbine to join the waterfall, returning to its natural watercourse. The turbine is capable of producing 40kW[5] of electricity when running at full capacity. Two transmission lines originate from the powerhouse; one goes in the direction of Saruhung (and beyond that Kolam) and the other to Olung Soloi. The network is off-grid, meaning that it is not connected to the provincial transmission and distribution network. Kolam village petitioned the district's Mining and Energy Department to extend services to their village, and - for a brief period in 2012 - all three villages were electrified, until Olung Soloi lost electricity later that same year. They have yet to re-establish connection (as of January 2014). Due to the de-electrification of Olung Soloi, data from that village is not relevant to studying the impacts of rural electrification on the villagers; however, the village does provide supporting evidence, and will be used in the discussion to highlight the weakness of the technical-client relations in the technical sustainability dimension.

4 SUSTAINABILE RURAL ELECTRIFICATION

Sustainable development

The idea of sustainability has emerged as one of the leading normative models for how society ought to develop (Christen and Schmidt 2012:400). From the 1987 the World Commission on Environment and Development definition of sustainability as "development that meets the needs of the present without compromising the ability of future generations to meet needs of their own" (Brundtland 1987) to the 2012 Rio+20 conferences' broad stance that sustainable progress must cover all three of the dimensions that affect life changes (Heap and Kent 2000), sustainable development has emerged to often be referred to by so-called triple-bottom line of sustainable development: economic development, environmental

[5] Hydropower systems are classified based production capacity ranges: mini-hydropower, 100kW to 1000kW; micro-hydropower, 5kW to 100kW; and pico-hydropower less than 5kW are all examples of small-scale hydropower (Kaundinya et al. 2009). Large-scale hydropower projects are distinctly different from the power generation discussed here: they are connected to the national grid, they have a greater impact on the environment, and they produce far larger quantities of energy (ibid.).

sustainability, and social inclusion (Sachs 2012:2206). This is a more widely adopted definition; however, there is no single agreement on the synergies and trade-offs between the three components (Sachs 2012:2206). Many consider the social dimension of sustainable development to be the most neglected, partly due to the fact that it is arguably the broadest in scope and most difficult to quantify (Lehtonen 2004:199). In addition to unequal emphasis given to each dimension of sustainability, the discourse on sustainable development has been criticised for lacking a unified theoretical underpinning. Christen and Smith (2012:407) state sustainable development discussions, within scientific and political spheres, are disharmonious; "/…/ there is an urgent need to gain a better understanding of the idea of sustainability and its components to surmount arbitrariness and reinforce its action-guiding power." Without clear conceptualisation of sustainability it can be used in myriad ways to justify actions, which, when accounting for the arbitrariness in the concept, does not serve to validate any actions at all (Christen and Schmidt 2012). Simply put, sustainable development theoretical discourse is vast; multiple positions could be justified depending on the conceptualisation of the term negating the usefulness of the concept both in theory and practice. The arbitrariness of sustainable development may be partly attributed to the term evolving in a variety of ways depending on the context in which it is employed, and the parallel but distinct discourses around sustainable development from superficial consensus (Redclift 2005:213). As such, in an attempt to overcome arbitrariness and reinforce its action-guiding power of the term, it is helpful to conceptualise sustainable development as it pertains specifically to rural electrification (Christen and Smith 2012). While trade-offs and synergies between economic development, environmental sustainability, and social inclusion will still exist, challenges with subjectivity will be reduced through a context-specific discussion on sustainable development.

Sustainable development and rural electrification

The work of Ilskog and Kjellström (2008) is an example of an effort to conceptualise sustainable development as it pertains to rural electrification. In their academic paper comparing seven different rural electrification projects, they attempt to assess the sustainability of the projects by means of multiple indicators. Each indicator belongs to one of the five 'dimensions of sustainability'. They adopt the first three dimensions from the triple bottom line (economic, social, and environmental), and add two more dimensions – institutional and technical sustainability - based on their findings and an intensive review of academic literature. The inclusion of the technical dimension makes their attempt to evaluate sustainability of rural electrification unique (Ilskog and Kjellström 2008:2675). The indicators are selected through an iterative process, starting from indicators used previously by researchers and consultants, and modified or changed based on their field experiences (Ilskog and Kjellström 2008:2675). Their work is an important step forward in the discourse on sustainability of rural electrification because it aggregates findings from previous research on each dimension of sustainability, and focuses on the five aforementioned dimensions of sustainability concurrently. Much of the existing academic literature on the topic considers on only one or two dimensions, such as economic impacts (Birol 2007; Mainali and Silveira 2011; Schmidt et al. 2013) or socio-economic benefits (Bastakoti 2006; Kanagawa and Nakata 2008), or, alternatively, does not use sustainable development as a point of departure for the study (Ahlborg and Hammar 2014; Bhattacharyya 2012; Palit and Chaurey 2011). The following sub-sections conceptualise sustainable development of rural electrification, highlighting the most important considerations for economic, environmental, social, technical, and institutional sustainability.

Economic Sustainability

Many authors have explored the importance of access of electricity to economic development and poverty eradication (Ahlborg and Hammar 2014; Birol 2007; Cook 2011; Hasan et al. 2012; Ilskog and Kjellström 2008; Javadi et al. 2013; Kaundinya et al. 2009; Palit and Chaurey 2011; Pereira et al. 2010; Rogelj et al. 2013). Eliminating energy poverty is accepted as one of the driving forces of economic development for both developed and developing countries (Kaundinya et al. 2009; Nautiyal et al. 2011:2021). Electricity may not bring development in its own right, but it is a highly desired commodity and a pre-requisite to economic development in the long term (Ahlborg and Hammar 2014). Yet, less well understood are the mechanisms through which (sustainable) energy access leads to economic growth and financial viability. For this, both the direct overhead and operational costs, and the indirect job creation and income generation resulting from the RVG, are important considerations. External support to fund initial installation is almost always required as off-grid rural electrification projects are often capital intensive (Ahlborg and Hammar 2014; Ilskog and Kjellström 2008), and financial un-viability is often a cause for de-electrification (Palit and Chaurey 2011). Development of productive uses of energy is the main link between the induction of rural electrification and the increases in income (Cook 2011:304). Rural electrification can support income-generating activities for individual households or it may benefit existing, or encourage the establishment of new, small-businesses within the community. However, access to electricity does not necessarily translate into productive energy use unless rural electrification is integrated with - and complimented by - other investments, such as education or business training (Ahlborg and Hammar 2014; Palit and Chaurey 2011; Peters et al. 2009). The most successful off-grid electricity projects are those that support job creation and have a direct effect on the income of the local community (Javadi et al. 2013).

Environmental Sustainability

Global experience indicates that, on average, as energy production increases, carbon emissions also tend to rise, especially for low-middle income countries (Saboori and Saluiman 2013). If the electricity is generated from a renewable source, however, instead of from traditional fossil fuels, greenhouse gas (GHG) emission and energy production could be decoupled (Saboori and Sulaiman 2013:892; Sovacool 2013). Thus, renewable energy can have a positive global environmental impact. Moving from global emissions impacts to the local level, the energy transition theory suggests that as the welfare of communities improves they transition from traditional fuels, such as wood and biomass, to electricity, to meet their energy needs (Campbell et al. 2003; Martins 2005). Yet this transition is more complex than theory would suggest (Ilskog and Kjellström 2008; Martins 2005:37), as households are often slow to change from traditional cooking methods to electric stoves, among other reasons. The benefits of completing this transition include reduced environmental degradation due to fuelwood consumption (Birol 2007; Kanagawa and Nakata 2008:2017; Sovacool 2013:403) in addition to health benefits from a reduction in indoor air pollution (Martins 2005:381). At present, however, much of the debate on energy remains entangled in the issue of rising consumptions and associated emissions. Discussions tackle likely trade-offs between emissions and growth, with less recognition of the levels of 'under-consumption' and the centrality of access to energy services in boosting human development, building resilience, and diversifying and securing livelihoods. Extending cleaner energy to the poor supports better emissions management in the process of eradicating energy poverty while tackling the aforementioned challenges (Birol 2007). A lack of livelihood diversification options for rural communities may result in an over-reliance on natural resources for development (Bastokoti 2006), arguably contributing to environmental degradation at a scale greater than that of an electrified village.

Social Sustainability

The social dimension of the most complex of the five, because not only is it vast in scope, it is also dependent on, and influenced by, factors beyond the electricity service being evaluated (Ilskog and Kjellström 2008). Based on their experiences with off-grid rural electrification in Southeast Asia, Palit and Chaurey (2011) state electrification is highly desired by all communities and does have development benefits. It is a catalyst to wider social by enabling education, health, and sustainable agriculture, and creating jobs (Nautiyal et al. 2011:2021), resulting in overall increases in quality of life (Javadi et al. 2013). Even when there is the potential for a household electricity connection, financial constraints or the perception that the quality and/or quantity of the electricity will be inadequate, retard universal access (Palit and Chaurey 2011:267), which can result in increased inequity within the community (Ilskog and Kjellström 2008). This inequitable access can hinder development benefits, or even result in a net negative impact from the electrification (Murni et al. 2012). Research suggests energy poverty or inequitable energy access can manifest in many forms including increased poverty, lack of opportunity for development, migratory flow to large cities, and a society's own disbelief regarding its own future (Pereira et al. 2010:1229). Universal access is one telling parameter of social sustainability that is relatively easy to quantify. When some, but not all, households in a community have access to electricity the potential development benefits can be undermined, as the universalisation of access to electricity is of fundamental importance to poverty eradication, a reduction of social inequality and long-term sustainability (Pereira et al. 2010:1230). Although most literature associates electricity with social, education, and health benefits, there have also been instances where access to electricity has resulted in negative impacts, including a reduction of social cohesion of communities (Murni et al. 2012:193), giving rise to the importance of investigating the social impacts of rural electrification.

Technical Sustainability

For a rural electrification project, or infrastructure projects more generally, to be sustainable the solution must be appropriate for the given context. Low population densities, geographic isolation, and difficult terrain favour off-grid energy solutions, regardless of the reliability drawbacks of these decentralised grids when compared with well-functioning national girds (Ahlborg and Hammar 2014:117; Javadi et al. 2013; Schmidt et al. 2013:581). Shortcomings of decentralised grids include a limited production capacity, increased barriers for external technical support, and a lack of ability for the network to respond to changes in demand (Ahlborg and Hammar 2014:117; Ilskog and Kjellström 2008; Murni et al. 2012:191; Palit and Chaurey 2011:272). Despite this, research indicates that renewable energy sources may be particularly useful for off-grid systems, especially in areas far from grid connections (Ahlborg and Hammar 2012:117; Javadi et al. 2013). The technical sustainability includes maintaining the energy for the economic lifetime of the initial investment (Ilskog and Kjellström 2008:2675), provided the design is adequate. A poorly designed distribution system can undermine the success of the entire project (Murni et al. 2012). Operation and maintenance, and technical client relations, are arguably the two most important factors for technical sustainability. Research indicates that for community owned off-grid electricity systems, it is challenging to keep smooth operations and appropriate maintenance of the generation, transmission, and distribution of the system (Poudel 2013:292).

Institutional Sustainability

Institutional sustainability can be defined as "survival of the organisation and its ability to maintain adequate performance with respect to other dimensions of sustainability" (Ilskog and Kjellström 2008). Projects may be owned and operated by the government, a third party, or the local community (among other ownership and operation options) each having an impact on the success of the project (Tran 2013). While the most successful programmes for rural electrification focus on capacity building on local institutions and encourage community participation and feedback, in addition to selecting the appropriate technology for the circumstance (Sovacool 2013), there has also been negative fallout from community centred projects (Palit and Chaurey 2011:272). Furthermore, for community centred off-grid rural electrification to be sustainable in the long term, the local population needs to receive adequate training (Ilskog and Kjellström 2008), and there must be assurance from the local contractor/government about the continued technical and other support to maintain the supply of the electricity (Poudel 2013:295). User satisfaction with energy services is an important component to long-term sustainability. Literature suggests that a yearly 4000kWh/capita corresponds to an HDI of 0.90 or greater (Gómez and Silveira 2010:6256), a household capacity of 250kWh/year covers basic rural household usage (OECD/IEA 2010), and annual electric consumption needs to be above a threshold value of 1000kWh/capita before improvements in the social condition of the population are fully realised (Javadi et al. 2013:405; Pereira et al. 2010:1231). Qualitative assessment of the satisfaction of the energy services is important given the lack of general consensus minimum required capacity.

5 PRESENTATION OF FINDINGS AND DISCUSSION

This section has five sub-sections, one for each dimension of sustainability. The sub-sections discuss the Ilskog and Kjellström (2008) indicators and the findings for this case study, in addition to introducing additional indicators and/or qualitative data.

Economic sustainability

Economic sustainability indicators cover both the financial aspect of establishing and maintaining the energy source, as well as the economic growth catalysed by energy availability. The financial perspective considers profitability, operational and maintenance costs, costs for capital and installation, share of profit set aside for reinvestment in electricity service business, and tariff lag. Due to the costly initial investment to establish an off-grid electricity source, access to capital is expected to be a necessary prerequisite. Findings from Ilskog and Kjellström (2008:2677) suggest that profitability is necessary for the survival of the energy source unless external donor support covers the profit deficit. Tariff lag, an issue caused by difficulties to adjust electricity tariffs to compensate for inflation, is expected to be proportional to operating costs and national inflation rates. For development of productive uses of energy, the share of electricity consumed by businesses and the share of households using electricity for income-generating activities are indicators. Only a small number of income-generating activities result from energy availability according to the findings of Ilskog and Kjellström (2008:2678), a comparable finding is expected for my case study. Similar to the seven off-grid sites investigated by Ilskog and Kjellström (2008), the hydropower has no competition; it is the only electricity service organisation in the area.

Table 2: Presentation of economic sustainability indicators (Ilskog and Kjellstöm 2008)

Indicator	Result
Financial Perspective	
Profitability, USD/kWh	0.013
Operational and maintenance costs, USD/kWh	0.005
Costs for Capital and Installation, USD/kWh	0
Share of profit set aside for re-investment in electricity service business, %	60
Tariff lag, USD/kWh	0
Development of productive uses	
Share of electricity consumed by businesses, %	0
Share of households using electricity for income-generating activities, %	16
Competition	
Number of electricity service organisations in the area, no.	1

The GoI funded the initial installation costs entirely, including distribution of the energy to all households in Kolam and Saruhung villages. The community is not required to pay back the initial capital investment, thus costs for capital and installation are zero (Male, SS1K; male

SS2S). The operation and maintenance costs are more difficult to determine. The only direct operation and maintenance costs are salaries for the members of the ‘management and maintenance team’, three people responsible for collecting the monthly electricity payments and an additional two people responsible for performing routine daily maintenance. Each member is paid a monthly salary of 300,000 IDR (26.10 USD) in addition to up to 200,000 IDR (17.40 USD) per month for materials (Male, FG2K), for a total monthly operation and maintenance cost of 0.005 USD/kWh[6]. The money remaining after the management and maintenance team salaries have been paid is profit (60 percent of revenue or 226.20 USD/month), which the villages set aside for future hopes of building a second micro hydropower turbine at a site adjacent to Kolam village (Male, FG2K; male, SS1S). Tariff lag, in this case study, is negligible. In a village meeting, the villagers came to a consensus to pay 20,000 IDR/month (1.74 USD/month) for electricity services, regardless of electricity consumed. This price was decided based on the affordability of the service to all villagers, and thus it is not a market driven price, and will not fluctuate based on changes in operating costs or national inflation rates.

> *“For the monthly payment of the electricity, at the beginning, they held a meeting between the two villages – Kolam and Saruhung – they meet and they came up to a decision for 50,000 IDR [4.35 USD]. But because a lot of old people in this village they cannot afford to pay that amount, that is too much, so again they met and made an agreement of 20,000 IDR [1.74 USD] and everyone agrees with that.” (Male, FG2K)*

From a financial perspective, according to the Ilskog and Kjellström (2008) criteria, the Murung Raya micro hydropower installation appears economically sustainable. It is profitable due to low management and maintenance costs and the non-repayable upfront capital costs covered by the GoI, and money is being set aside for re-investment. However, the inability of the management and maintenance to perform their duties – as will be discussed in the institutional and technical sustainability sections – strongly undermines the potential economic sustainability demonstrated by this set of indicators.

The second category of economic sustainability indicators from Ilskog and Kjellström (2008) explores productive uses of energy. Economic development can be linked with productive uses for energy and poverty reduction by exploring economic issues underlying development of rural electrification, and the impact of electrification on rural communities’ ability to generate income (Cook 2011). Economic sustainability that supports job creation has a direct effect on the income of the local people and is paramount in the most

[6] Calculation based on continuous energy production at the maximum rate of 40kW. See Appendix V for calculation.

successful rural electrification projects (Javadi et al. 2013:415). For the five villagers employed as a direct result of the micro hydropower project, this additional income is significant; however, it is concentrated in the hands of a small percentage of the villagers. Furthermore, 16 percent of those who completed the questionnaire answered 'yes' when asked if they have set up a home business (ie. households using electricity for income-generating activities) since receiving electricity. However, qualitative data did not support this finding. Many villagers discussed ideas of using the electricity for income-generating activities, none of which were actually underway:

> *"They want to establish a garage and a business for home furniture. They also expect they can do home businesses, for housewives, such as weaving." (Male, FG1K)*
>
> *"She would like to open a warung* [restaurant] *but first she would need a fridge to store the leftovers." (Female, FG2K)*
>
> *"They would like to establish a photocopy or printing shop and also a garage to fix motorbikes. It would help with small business opportunities." (Male, FG3K)*

Contrary to expectations from pervious literature (Cook 2011:304; Javadi et al. 2013) but aligned with the findings from Ilskog and Kjellström (2008:2678), the share of electricity used for productive activities is low. No electricity is currently being used for by businesses, and, according to questionnaire date, but not supported by qualitative findings, 16 percent of households are using electricity to support income-generating activities. The discrepancy between the qualitative and quantitative findings may be attributed to differing interpretation of 'productive use of energy' between the villagers and the researcher. Specifically, the time it took to complete tasks was altered (ie. shorter cooking times) (Male, FG1K; female, FG6S) which could equate to an increase in productive hours in the day, and thus translate into income generating opportunities, namely time in the evening for women to weave (female, FG6S). However, I did not include this example as a productive use of energy because it did not contribute to the household income, as weaved products were used by the household exclusively (Female, IG1K). The remaining discussion will move beyond the indicators used by Ilskog and Kjellström (2008) to further explore economic sustainability based on productive use of energy.

A more significant direct economic benefit may be cost savings due to the low monthly cost of the electricity.

> *"[Villagers] are now paying less because they are no longer in need generators to get the light. /…/ They used to spend 700,000 IDR [60.90 USD] per month but now they only need to spend 20,000 IDR [1.74 USD] per month." (Male, FG2K)*

An estimated 15 households in each village owned generators (FG1S, SS1K) and are thus experiencing direct costs savings. For households without generators, kerosene was previously used to provide light at a cost higher than the current monthly electricity fee.

> *"In addition to reducing the costs that the households needs to pay, and now they have lights for that, they can actually save up more money that they can allocate to other things instead of buying fuel and other things." (Female, FG3K)*

> *"When they are cooking rice they no longer need to use the kerosene or wood, they can use a rice cooker and they save money with that." (Female, FG6S)*

In addition to direct income saving benefits, indirect benefits occur from changes in daily routines; the electrification has resulted in more productive hours in the day.

> *"It actually has contributed to more income for some people in the village by having the electricity. At least they can be motivated more to do different activities with the assistance of the electricity." (Male, FG1K)*

Women specifically have benefited from preparing food in the evening hours, and using electric rice cookers and water boilers to reduce total cooking time.

> *"They can do it [cooking] more efficiently. Say once they are back from the forest, they can go directly back to their home and cook with a very short time." (Female, FG6S)*

Despite direct employment for five villagers, and costs saving reported related to fuel use change, the electricity is not being utilised by the majority of households in Saruhung or Kolam villages for productive means. The direct and indirect income and employment benefits culminate in overall changes in income after the electrification, as compared to before the RVG connection. Questionnaire data indicates the economic benefits associated with the electricity are marginal, with a net ten percent of respondent reporting increased income after electrification (Figure 3). However, questionnaire respondents were not asked about monthly cost savings or changes in disposable income, which, based on qualitative data, may have shown positive results. This was the case for Murni et al.'s (2012:194) study, where 38 percent of households reported increases in income, and 59 percent increases in disposable income, corresponding to micro hydropower. In addition to the two indictors Ilskog and Kjellström (2008) propose for discussing development of productive uses of energy, including a figure on the net numbers of households with increased household income would provide information on the actual increases in income. Beyond this, future studies could consider collecting data on disposable income before and after access to electricity.

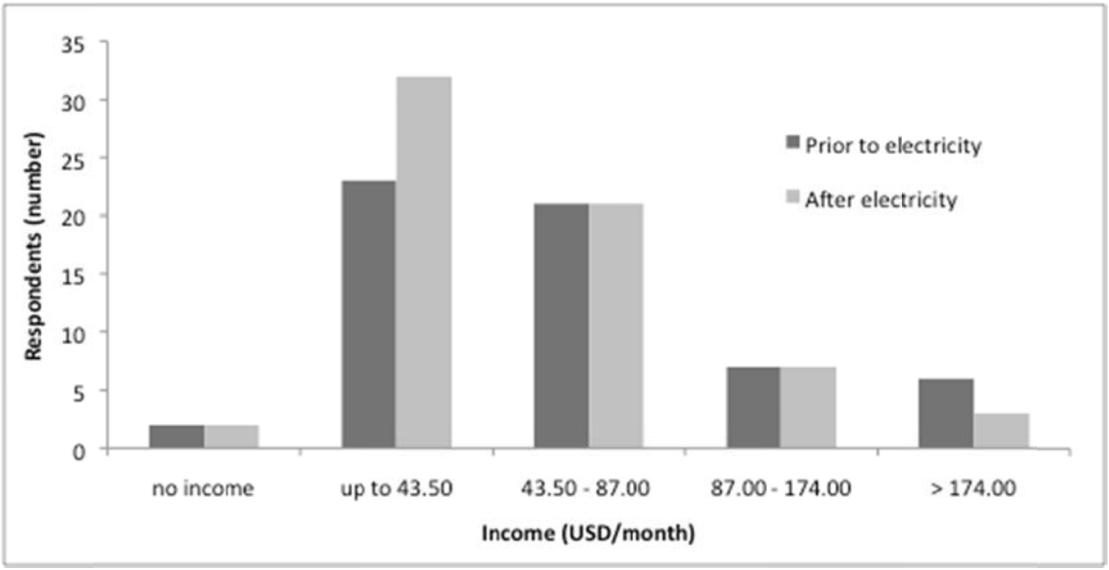

Figure 3: Changes in monthly household income before and after electrification for Kolam and Saruhung villages

Environmental sustainability: local and global impacts

To examine the relationship between environmentally sustainability and off-grid rural electricity generation, Ilskog and Kjellström (2008:2678) include global and local impacts in their assessment. For the global impact they consider two indictors: the share of renewable energy in total energy production, and the emissions of carbon dioxide (CO_2) in production. Together these give an estimate of the intensity of carbon dioxide production per kilo Watt-hour (CO_2/kWh) of energy production. However, since not all cases Ilskog and Kjellström (2008) examine source renewable energy, their indicators do not include decreased fossil fuel consumption, a quantifiable environmental benefit from renewable energy generation (Campbell et al. 2003; Martins 2005). My thesis includes an estimated avoided carbon dioxide emission figure associated with decreased fossil fuel consumption. For direct impacts on the local environment, Ilskog and Kjellström (2009:2679) consider indicators for changes in charcoal and/or firewood consumption for cooking, and changes in kerosene and/or candles for lighting, and the identification of any serious local environmental impacts. The expected findings would suggest a positive global environmental impact through reduced emissions and a decrease in traditional fuel consumption. However, for cooking, it is expected that only a small number of households will have shifted to from traditional biomass to electricity (Ilskog and Kjellström 2008:2678).

Table 3: Presentation of environmental sustainability indicators (Ilskog and Kjellström 2008)

Indicator	Result
Global impact	
Share of renewable energy in production, %	100
Emissions of carbon dioxide from production (calculated on input energy), kg CO2/kWh	0
Local impact	
Share of electrified households where other energy source for lighting (mainly kerosene and candles) has been replaced, %	100
Share of electrified households where other energy sources for cooking main meals (most charcoal and firewood) has been replaced, %	2
Any serious local environmental impact identified, yes/no	no

Forest destruction and land degradation – not energy production - currently account for the large majority of Indonesia's emissions (Hartono and Resosudarmo 2008). Nevertheless, the heavy reliance on diesel and the increased reliance of coal for energy production, and steady energy demand increases, mean that GHG emissions from the electricity sector are likely to rise substantially, increasing threefold by 2030 (ibid.) and ultimately becoming the dominant source of emissions in the country. Thus, renewable energy production is important for sustainable development with an emphasis on environmental considerations. Micro hydropower can be considered environmentally benign because it is a carbon neutral source of energy, and flooding or displacement issues commonly associated with large-scale hydropower projects are eliminated with the so-called 'run of the river' technology (Kaundinya et al. 2009). Since 100 percent of the energy is from a renewable source, associated emissions from carbon dioxide are zero. The case of avoided emissions is difficult to make when a community goes for having no electricity to having electricity from a renewable source, because emissions in the un-electrified state are minimal. However, if the alternative to renewable energy production were fossil fuel based production, avoided emissions can be calculated. Using Intergovernmental Panel on Climate Change (IPCC) standard value for the calculations, the avoided emissions associated with sourcing energy from a carbon neutral, renewable source instead of a fossil fuel source is 300g CO_2/kWh[7], based on a 100 percent replacement rate (Sims et al. 2007). Extrapolating that figure for equivalency to the maximum production capacity of the hydropower turbine, 105 tonnes of CO_2e are avoided annually as the result of the micro hydropower project. To put that number in perspective, the average CO_2 emissions for a person living in Sweden is 5.6 metric tonnes per annum (WB 2014). However, this is not a true emission avoidance number for the villages because prior to the hydropower only some households (approximately 15 per village) were able to afford a generator, most used kerosene for lighting, and this figure is based on 24-hour

[7] See Appendix V for the calculation.

consumption at the maximum turbine capacity of 40kW. Regardless, the calculation is indicative of the environmental benefit of using renewable sources for energy production versus equivalent production from a fossil fuel source. The second environmental sustainability category focuses on the local impact.

The access to electricity in Saruhung and Kolam villages is universal, and of those surveyed, 100 percent of respondents have light bulbs and are using electricity as their main source of lighting, replacing traditional kerosene fuel. The transition from firewood to electricity for cooking has been much slower, however. Only one respondent indicated his/her household switched to an electric stove to prepare meals (Respondent 13, quantitative data). Water boilers and rice cookers have entered the kitchen offsetting some, but not all, fuelwood use:

> *"[When] cooking rice they no longer need to use the kerosene or wood, they can use a rice cooker." (Female, FG3K)*
>
> *"It depends on the condition of the electricity itself. If it is working, then prefer to cook with rice cooker and electric appliances." (Male, FG1K)*

These quotations indicate fuel consumption patterns are changing. However, quantifying households based on the switch to electrical energy (ie. electric stoves) fails to capture the changes in fuelwood consumption resulting from rice cooker and water boiler use. Information on the amount of time villages spend collecting wood from the forest is indicative of the reduced consumption of wood for meal preparation:

> *"They don't usually go for collecting firewood to the jungle since the electricity has come – only a few of them still go. So at least the number of days they usually need for collection of the firewood, it has been much less." (Male, FG1K)*
>
> *"We can significantly see the positive impacts on the environment due to the electrification, even in its insufficient capacity. We can see fewer people collecting firewood in the jungle." (Male, FG4S)*

A reduction in the time spent collecting wood would suggest that electric kitchen appliance use has offset a significant amount of fuelwood consumption. The question remains if the scale of reductions has a noteworthy environmental impact. Some academic literature concludes forest protection is not a valid justification for rural electrification (Ilskog and Kjellström 2009:2681; Madubansi and Shackleton 2007:416), and although no studies were found to conclusively demonstrate a reduction is forest degradation as being an important consideration for RVG projects, other literature suggest positive impacts are possible (Birol 2007; Kanagawa and Nakata 2008:2017; Sovacool 2013:403).

Environmental protection is one of the three core pillars of the common sustainable development discussion. Renewable energy can decouple the traditional correlation between energy production and emissions rates (Saboori and Sulaiman 2013:892; Sovacool 2013), thus RVG projects in their very nature support environmental protection. For Murung Raya, carbon dioxide emissions are zero (and emissions associated with fossil fuel consumption are avoided), no serious environment impact was identified, households have transitioned to electricity as a source of lighting, and electrical appliance use in the kitchen has reduced fuelwood consumption. Thus, the RVG is environmentally sustainable according to Ilskog and Kjellström (2008) indicators and the additional indicator for avoided emissions. It is important to remember, however, that arguably the environmental sustainability dimension may be of lesser importance than the primary objective of eradicating energy poverty (Birol 2007:1).

Social sustainability

Part A: The Ilskog and Kjellström (2008) social sustainability indicators

Social sustainability is arguably the most complex of the dimensions; its scope is broad and it is challenging to isolate social inclusion variables as resulting directly from the electrification. Ilskog and Kjellström's (2008:2678) social sustainability indictors measure improved availability of social electricity services, credit facilities, and equal distribution. The availability of social electricity services is measured by the number of street lights in the area; credit facilities are measured by micro-credit possibilities for electricity services connection; and equal distribution is measured by four indicators: share of population with primary school education, share of population with access to electricity, distribution of electricity client households in income groups, and subsidies offered for electricity services. Ilskog and Kjellström (2008:2678) found for the seven projects they evaluated, electricity clients are a small fraction of the total population, and are mainly found in the higher income groups. It is expected that if there is a high number of streetlights, access to micro-credit possibilities, and equal distribution, the RVG can be considered socially sustainable.

Table 4: Presentation of social sustainability indicators (Ilskog and Kjellström 2008)

Indicator	Result
Improved availability of social electricity services	
Number of streetlights in the area, number/1000 population	0
Credit facilities	
Micro-credit possibilities for electricity services connection, yes/no	no
Equal distribution	
Share of population with primary school education, %	N/A
Share of population with access to electricity, %	100
Distribution of electricity client households in income groups, % in higher income categories	universal access
Subsidies offered for electricity services, yes/no	yes

The initial proposal from the government was to have each house pay a connection fee, which is common practice for RVG projects, but often results in increased inequity within the village because only wealthier households are able to afford the fee (Ilskog and Kjellström 2008:2678). However, the village leaders recognised this would exclude households from the benefits of electricity:

> *"First of all when they proposed this connections /…/ the contractor asked them to pay 400,000 IDR for the instalment in each house. In this village there are around 97 households, and because of that reason and that the cost was high they proposed for money to the Department of Mining and Energy of the district. And finally they got some funding from this department to install electricity to 97 houses, all of the houses." (Male, FG2K)*

All households in Kolam and Saruhung villages were connected free of charge, thus there is no need for access to micro-credit for electricity services connections. Equitable distribution indictors aim to capture differences in the population with access to electricity. With universal access, data on education rates and income earnings is no longer important. When villagers were asked about their perceptions of the cost of the electricity, 100 percent of respondents answered moderate (25 percent), (28 percent), or very cheap (5 percent). Since villagers view electricity as affordable, a discussion on subsidies is also not required. There are zero streetlights installed in either village; however, *"now they are no longer lazy to go to people's houses because they have some light so they can go easily to their neighbours house." (Female, FG3K).* The goal of streetlights – to reduce the feeling of insecurity when walking the streets after dark, especially for women (Cecelski 2000:19) – has been achieved with lights on the exterior of homes. Distribution is equal; credit facilities are not available, but the affordability of the electricity, and free households connections, negate the importance of this indicator to social sustainability; and exterior home lights reduce the insecurity of walking at night, fulfilling Ilskog and Kjellström's (2008) criteria for social sustainability. Their criteria are, however, built on the assumption that access to electricity has positive development benefits. As other studies have found, this is not necessarily true (Murni et al. 2012). For my case study, a more nuanced view will be considered to provide information on the improved availability of social electricity services, and, more generally, the contribution of electricity to social development.

Part B: Can social benefits be black-boxed?

In contrast to Ilskog and Kjellström (2008), this section questions the impact of the electricity, and does not take social benefits to be 'black-boxed' or assumed to be exclusively positive. Since it is difficult to definitively measure impacts in this dimension, and to attribute the changes in the social condition as arising as a result of the electrification, qualitative and quantitative data, and supporting literature are triangulated in the discussion. A review of rural electrification literature suggest expanded criteria to capture social sustainability, including an especially relevant investigation by Murni et al. (2012) on the role micro hydropower systems in remote rural electrification on Borneo Island. Murni et al. (2012:193) concludes not all social impacts are positive: they reported a perceived reduction in social cohesion and reduced frequency of visits to neighbours' homes, with access to electricity. The ASEAN Guideline on Off-Grid Rural Electrification (Tran 2013) suggests health benefits, education benefits, and social benefits are indicative of social development, culminating in an overall impact on quality of life (Martins 2005). Based on indicators suggested in these two literature sources, additional indicators considered in my case study are changes in: health due to cleaner air, study time for children at home, access to information through TV or radio, time spent on community activities, social cohesion, and visits to neighbours' homes.

As discussed in the environmental sustainability section, use of traditional fuels, namely kerosene and fuelwood, has decreased. An advantage of electrification is decreasing harmful effects of burning fuels for cooking and lighting on the household's health (Javadi et al. 2013:405). Seventy-four percent of respondents said their health was either 'better' or 'much better' than before the electricity; a finding supported by interviews:

> *"Because they are not using kerosene there is not the black smoke which is unhealthy and now they do not have any problem with that, and second of all for the cleanliness of they houses this traditional lamp can cause dirt on they ceiling and now it is much cleaner." (Female, FG6S)*

Education benefits are measured based on a perceived increase in children's time spent on homework after the electrification. Of the respondents with children, 70 percent reported an increase in time spent on homework. The principal of the school in Saruhung village, a resident of Kolam village, commented on the impact of electricity on education, and students and adults alike, have sourced new information from watching television:

> *"A lot of her students allocate more time to work on their homework or schoolwork since the electricity exists in their village because in the past when they did not have electricity it was hard for them to work on their homework in the evening /…/ now she is seeing the difference in how students can allocate more time for studying in the evening." (Female, FG2K)*
>
> *"From television for the education sector they can improve very much because they can be in the know of the current news and also the development in the education sector – so at least they can be updated in many things.."(Male, FG5S)*

Three survey questions provide insight on social benefits: 69 percent of respondents have experienced an increase in time spent on community activities; 66 percent reported improvement in community cohesion; and 59 percent visit neighbours' homes more frequently, since electrification.

> *"[T]hey have more spare time after the electrification. He mentioned several things: they have the light for all households in this village, and the second of all the cohesion among the community is bound even stronger than before, they can visit neighbours houses at night and they can allocate more time, and it is much easier for them, to hold community meeting or gathering in the evening." (Male, FG5S)*

Electrical appliance ownership varied greatly; only seven percent of respondents use energy for lighting alone, the rest own at least one other, and up to nine, appliances. The most commonly owned appliance is a rice cooker (80 percent ownership for households surveyed) followed by televisions and cell phones (both at 66 percent ownership), in addition to lights, which were used by 100 percent of respondents. Other appliances owned include a water boiler, electric fan, water pump, and computer/laptop.

Health, education, and social benefits are realised, based on the conclusion from both qualitative and quantitative data. This is in contrast to the findings of Murni et al. (2012) where social development impacts are mixed, but does support the work of Ilskog and Kjellström (2008) who consider social benefits as 'black-boxed'. The overall positive social development benefits may be partly attributable to the universality of access.

Technical sustainability

Past experiences show that a large number of off-grid electrification projects fail because focus is generally given in technical installation without paying sufficient attention to long-term sustainability of projects (Kumar et al. 2009:1946). From Ilskog and Kjellström (2008:2677) technical sustainability involves maintaining the energy service during the economic lifetime of the initial investment, using indicators for operation and maintenance and technical client-relations, to capture the long-term technical sustainability. Operation and maintenance is measured by conformance with national standards for the transmission/distribution system and technical client losses, whereas technical client-relation issues are gauged by daily operation service and availability of services (ibid.). It is expected that strong client-relations and conformance with national standards for transmission/distribution will result in technical sustainability. For any decentralised RVG system, a significant share of the electricity generated is expected to be lost in transmission/distribution (Ilskog and Kjellström 2008:2677; Palit and Chaurey 2011:268).

Table 5: Presentation of technical sustainability indicators (Ilskog and Kjellstöm 2008)

Indicator	Result
Operation and maintenance	
Conformance with national standards for transmission/distribution systems and client installations, yes/no	yes
Technical losses (also referred to as un-paid electricity generation), yes/no	yes
Technical client-relation issues	
Daily operation service, %	0
Availability of services, %	0

It is not possible to determine a percentage of technical losses from production to consumption because electricity meters are not present. For situations where the cost of electricity is based on the amount consumed, meters would be common, but for the flat monthly rate used in Kolam and Saruhung villages electricity meters not necessary. It is possible, however, to identity conditions that would likely lead to technical losses. All electricity transmission and distribution systems experiences losses as electricity travels for the point of production to consumption. The losses are a function of both the distance travelled and the width of the cable through which the electricity travels: the longer the distance and the smaller the width of the cable, the higher the technical losses. The decentralised grid system was designed to transmit energy from the powerhouse to the all the households in the villages. These permanent connections initially established by a skilled individual would likely have some, but minimal, technical losses, and they conformed to national standards for transmission/distribution networks. The villagers have extended connections to other locations such as the community centres or local water source to pump water to their homes. They call these ‘temporary connections’ because they have simply cut the line in their homes, added additional cable, and connected the appliance (light, water pump). These connections that use thin wires to span long distances would introduce a great amount of resistance into the system, increasing the already present technical losses. Overall, for the operation and maintenance category, technical losses are high and initial connections conformed to national standards but the ‘temporary connections’ installed by the villagers did not.

In addition to operation and maintenance challenges, the weak technical client-relations put the sustainability of the energy at risk. There are many cracks in the dam and the foundation of the structure house the turbine and generation. Corrosion was visible on the outside of the piping, not necessarily indicative of failure, but evidently a problem that will persist and worsen without proper maintenance such as regular painting of the pipes to protect the metal from environment factors leading to corrosion and eventual leakage. According to Murni et al. (2012:195) most renewable energy projects in developing counties that have not been sustainable in the long term, have failed because of poor maintenance and monitoring. The two individuals trained to perform the operation services have not been performing any daily maintenance such as turning off the turbine once every three days (as suggested by the Mining and Energy Department) or clearing out the intake channel to prevent debris from reach the turbine (Male, SS2S). Daily operation services of the RVG system are non-existent. Furthermore, technical client relations are weak because there is no availability of services from outside the village. Evidence of this, is persisting de-electrification of Olung Soloi village since 2012. Attempts made to contact the government for assistance to repair the connection have proved unsuccessful and the last visit of a technical expert to the villages was to install connections to Kolam in 2012 (Male SS1K). Outside expertise is not available in the region: *“[T]he electricity was distributed by the central government and all the technicians are from Bandung [located on Java Island, a full day of travel away from the villages]” (Male, FG1K).* The community centred model for RVG development still requires strong support from technical experts (Palit and Chaurey 2011:270), which is not present in Murung Raya leading to technical unsustainability.

Other academic literature suggests technical sustainability begins with the appropriateness of the solution and design for the given context (Murni et al. 2012). I have added a category called ‘technical solution’ with three indicators – including ease of future central grid connection, which was suggested by Ilskog and Kjellström (2008:2677) in the conclusion of their study, and battery storage abilities and appropriateness of the technical solution (Murni et al. 2012) – to facilitate a discussion on the extent to which the technology design in adequate. Off-grid systems are not connected to the national grid and as a result electricity produced during off-peak demand periods (overnight and during days light hours) has no central network to feed in to. Unused power is lost without battery storage (Kaundinya et al. 2009), as is the case in Murung Raya. The efficiency of the system could be improved if power produced during off-peak hours power was stored, and fed back into the network during times demand is high, such as in the evening (Palit and Chaurey 2011:269). Furthermore, decentralised systems are often designed to be a precursor to central grid connectivity creating a customer based and making services available years in advance of a grid connection (Ahlborg and Hammar 2014:117). Off-grid serviced communities continue to aspire to a grid connection because of the limited supply from off-grid projects (Palit and Chaurey 2011:269). Once connected to a central network, they can either draw from the central grid when demand exceeds off-grid production capacity, or sell to the gird if they are producing unused energy, or, most likely, a combination of both based on the variable load factor[8]. This system is relatively well prepared for central grid connection because it has a decentralised transmission/distribution grid. Other renewable off-grid systems, such as solar home systems, do not have transmission/distribution networks and are thus far less well prepared for future central grid connection (Ilskog and Kjellström 2008:2677). The geography of the region, including the distance of the villages from the central electricity grid and the abundance of hydropower sources, make the choice to install micro hydropower appropriate; however, shortcoming in the design itself - as discussed in the institutional sustainability section - threaten sustainability.

The initial transmission and distribution network conforms to national standards, but the 'temporary connections' installed by the villages are both dangerous and increases the technical losses in the system. There is no daily operation being performed by the villagers (specifically the operation and maintenance team), and there is a very limited availability of services from outside the village to support technical challenges, as illustrated by the de-electrification of Olung Soloi village. The lack of capacity of the villages to perform routine maintenance and absence of technical experts from outside the village threatens the technical sustainability of the RVG.

Institutional sustainability

Studies highlight the importance of strong leadership in running the project long after installation (Kamalapur and Udaykumar 2012; Sovacool 2013) with key elements to institutional sustainability being local capacity strengthening, client-relations, and stakeholder participation (Ilskog and Kjellström 2008). From Ilskog and Kjellström (2008:2679) capacity

[8] The load factor is calculated as average demand divided by maximum demand. (Kamalapur and Udaykumar 2011:211)

strengthening includes the share of management and maintenance team with appropriate education, degree of local ownership, share of women on management and maintenance team, and number of years in business; for client relations indicators are the share of non-technical losses and level of satisfaction with the energy services; and stakeholder participation based on yearly report auditing. These quantitative indicators are all presented, yet for capacity strengthening it is the complementary qualitative data that provides a rich description of the situation. Respondents were not asked surveyed on their ‘level of satisfaction with the energy services’; instead quantitative data on frequency of blackouts, and qualitative and quantitative data on the capacity of the system will be used to answer this question. Palit and Chaurey (2011:272) conclude community participation in rural electrification has been relatively successful, but it is not without negative examples, showing that institutional sustainability alone is not enough to gauge project success. Thus, it is expected that strong local-level capacity building and adequate client-relations are required to achieve institutional sustainability, whereas community participation does not necessarily correspond to institutional sustainability. Lastly, for institutional sustainability criteria to be fulfilled there must be a high level of satisfaction with the energy services.

Table 6: Presentation of institutional sustainability indicators (Ilskog and Kjellström 2008)

Indicator	Result
Capacity strengthening	
Share of staff and management with appropriate education, %	0
Degree of local ownership, %	100
Number of shareholders, no.	213
Share of women in staff and management, %	0
Number of years in business, no.	2
Client-relations	
Share of non-technical losses (also referred to as unpaid electricity services), %	yes
Level of satisification with energy serivces, high/medium/low	low
Stakeholder participation	
Auditing of reports on yearly basis, yes/no	no

The management and maintenance of the system is the responsibility of two-member team from Saruhung village, which received skills training but at a level viewed as insufficient to deal with technical and operation challenges that may arise.

> *“[T]hey have not actually received intensive training for instalment of the hydropower. But they only just [the management and maintenance team] see them how they [the skilled technicians] are working, something like that, not receiving technical training for how to install /…/ So basically if there are problems regarding maintenance or loss of electricity happen, they do not do something directly because they have no complete idea on how to work on that, on how to solve the problem.” (Male, FG4S)*

No members of the management and maintenance team are women. Stakeholder participation is weak to non-existent; the technicians have not been to maintain the system since the connection was extended to Kolam village, and there is no auditing of yearly reports. Non-technical losses, losses resulting from missed payments, are low. In Murung Raya, the villages view the price as fair, as discussed in the social sustainability section, and do not experience difficulties making monthly payments.

Moving on to the satisfaction with the energy services, most villagers are dissatisfied with the total capacity of the system. There is no general consensus on the minimum amount of energy necessary to eliminate energy poverty (Pereira et al. 2010:1235). Research has shown that once access has been established, annual electric consumption needs to be above a threshold value of 1000kWh/capita before improvements in the social condition of the population are fully realised (Javadi et al. 2013:405; Pereira et al. 2010:1231). Since energy consumption data was not available due to a lack of electricity meters, the production rate can be calculated as an alternative to estimate kWh/capita of available energy. Based on a total population of 520 people for the two villages and 24-hour, year around generation of the electricity at the maximum capacity of the turbine (40kW), the per capita annual production rate is 674kWh[9]. Taking into account the reduced generation during the dry season, and the variable load factor on the system (ie. not all the produced energy would be consumed in the night time hours, and no system is in place to store this energy), this estimate is likely to be very high. Regardless, even using the most optimistic estimate, the production value is 326kWh below the minimum threshold value for social benefits to be fully realised (Javadi et al. 2013:405). Qualitative data supports this finding. On many accounts villagers noted dissatisfaction with the energy service and a lack of electrical capacity as being a hindrance to use.

> *"There have been a lot of challenges that have emerged, mainly because of the lack of capacity /…/ he observed, there was not enough capacity from the beginning." (Male, FG2K)*

> *"If the capacity stays like the current conditions they cannot do lots of activities as they want /…/ At least when they are having enough capacity they can do a lot of things they are planning before and have motivation to do even more things." (Female, FG2K)*

Another indicator of service satisfaction is frequency of blackouts – a temporary loss of energy that occurs when the demand (load) is greater than the amount of power produced (Murni et al. 2012:191). Quantitative data concludes 88 percent of respondents experience

[9] See Appendix V for the calculation.

blackouts either sometimes (60 percent), often (14 percent), or very often (14 percent). Only 12 percent suggested blackouts are rare, and zero people reported never having experienced a blackout. During qualitative data collection, every person I spoke with was concerned with the capacity of the electricity. Capacity issues are exacerbated in the dry season, which indicates planning and design shortcomings.

> *"Commonly in the dry season they have lots of problems. In the dry season the electricity is not working really well. When it is the rainy season it works normally. /…/ If it is a very long dry season, it could be a week or even more than a week without electricity, waiting for the river to get deeper." (Male, FG5S)*

The design of the hydropower system should be based on long term river flow data (Murni et al. 2012:191), which evidently was done for this case study. During the rainy season the river basin, created by the dam, where the diversion channel originates, is full. With a high water level in the river basin enough water passes through the controlled sluice gate to fill the pipes to capacity, and thus have the turbine run at capacity and generate the maximum amount of power. However, during the dry season the river basin water level decreases to a point where only a small amount of water can be diverted into the channel. The villagers have attempted to install some above ground piping to bring water from the river to the diversion channel but, even with the innovative attempts, minimal amounts of water make it to the diversion channel during the dry season. Thus, the turbine runs well below capacity, supplying a reduced amount of power to the already overstretched grid. Seasonal drought is a barrier to the ultimate sustainability of the energy, a problem not exclusive to this project (Ahlborg and Hammar 2014:122; Murni et al. 2012:191). The limited capacity of the electricity and high frequency of blackouts equates to a low level of satisfaction with the energy service. Limited local capacity building, weak client-relations, low stakeholder participation, and dissatisfaction with the capacity of the electricity all contribute to a failure in institutional sustainably for the Murung Raya RVG, which undermines the sustainability of the electricity according to the other four dimensions.

RQ1 Summary

In what ways is the off-grid rural electrification hydropower project in Murung Raya, Indonesia sustainable, according to the indicators presented by Ilskog and Kjellström (2008)?

The Murung Raya RVG satisfied economic sustainability criteria for financial sustainability due mainly to the upfront costs being covered by the GoI and the profitability of the electricity, but failed to fulfil all criteria for development of productive uses of energy, namely the establishment of small businesses and households using electricity for income generating activities. The RVG is environmentally sustainable: the carbon neutral source of energy limited any negative global environmental impacts, and a significant portion of traditional fuel consumption has been replaced by electricity. Indictors including universal access to energy, household connections fees paid by the GoI, and an affordable monthly electricity fee result in social sustainability. Technical sustainability criteria, as measured by operation and maintenance, and technical client-relation issues, are not met. There is an absence of external technical support to maintain the RVG, and local level capacity is insufficient. This lack of local capacity to address operational and maintenance – and non-technical issues – with the RVG, in addition to dissatisfaction with the energy service, mainly due to a perceived and real lack of capacity, result in failed institutional sustainability. Three sustainability dimensions – economic, environmental and social – are fulfilled, and two sustainability dimensions – technical and institutional – are not. Thus, overall, according to the indicators presented by Ilskog and Kjellström (2008) the RVG in Murung Raya is not sustainable.

RQ2 Summary

How can the indicators of sustainability presented by Ilskog and Kjellström (2008) be modified - or what indicators could be added - based on findings from the Murung Raya hydropower project?

In terms of economic criteria, productive use of energy is one of most important factors to ensure sustainable development (Javadi et al. 2013). Indicators for the net change in household income would illustrate if the share of electricity used by businesses or households for productive means translated into economic gains. Furthermore, the household economic situation may improve with a reduction of expenses, most notably savings on fuel costs. An indicator for changes in disposable incomes would capture these potential economic benefits.

Ilskog and Kjellström (2008) consider the production of carbon dioxide emissions associated with electricity production; however, they do not consider the avoided emissions when carbon-neutral renewable energy is used instead of traditional fossil fuels. An avoided emission indictor should be included, calculated based on the IPCC values, and considering 100 percent production replacement rates. Literature suggested the energy transition from traditional biomass to electricity is complex; a complexity that is not captured by the Ilskog and Kjellström (2008) indicators for the share of lighting and cooking fuel replacement alone. Quantifying the time saved on fuelwood collection, and considering electric appliance use such as rice cookers and water boilers, are indicators that could be added to capture the complexity of the transition from traditional biomass fuels to electricity.

The indicators from Ilskog and Kjellström (2008) assume social benefits to be exclusively positive. My findings support this conclusion, yet the positive benefits may be partially attributed to the universality of access, which is unique for this study. Considering this, and accounting for literature on the topic that supports negative development impacts are possible, a set of social development indictors could be added to gauge social sustainability. I propose ordinal variables for social cohesion, visits to neighbours' homes, time spent on community activities, children's time spent on homework, and changes in health be included in future studies.

Technical sustainability indicators could go beyond the operation and maintenance, and technical client-relations to consider the appropriateness of the technical solution for the given context and design of the system, including battery storage and technical preparation for future grid expansions, two factors that impact the capacity of the system. In this vein, the capacity of the system is also of important consideration for institutional sustainability as satisfaction with the energy services is necessary for sustainability. A quantitative indicator on the available household electricity capacity[10] and frequency of blackouts would help to gauge the level of satisfaction with the energy service, in addition to qualitative data on the satisfaction with the services. Lastly, information on seasonal variability of the capacity would be relevant to the long-term sustainability of the project.

[10] Ideally capacity would be calculated based on energy consumption but as this case study showed, that is not possible, and in such cases production capacity can be used to estimate total capacity available.

7 CONCLUSION

Indonesia struggles to extend modern energy services to its population, especially rural communities far from central distribution networks. The island geography and challenging terrain present obstacles to grid extension; however, Indonesia has great potential to generate energy from renewable sources, especially useful for off-grid electrification. This case study of a micro hydropower turbine in the Murung Raya district contributes to existing literature on the topic the sustainable development of rural electrification with the aim to potentially improve the success of future off-grid electrification efforts.

The results of the case study, uncovered through an embedded mixed methods design, draw on qualitative and quantitative data. Key failures occurred in the technical and institutional dimensions, specifically an absence of local capacity building, inadequate capacity of the energy, and a lack of external support for operation and maintenance. Even within the dimensions that had mainly positive results areas for improvement were identified. Rural electrification needs to be integrated with and complemented by other investments in infrastructure, social services, local finance institutions and education (Ahlborg and Hammar 2014) in order to achieve productive uses for energy; arguably one of the strongest determinants of long-term sustainability and project success (Javadi et al. 2013). Indicators showing positive results include: profitability, positive social development benefits, universal access, and environmental benefits. However, since sustainable development is rooted in trade-offs and synergies between the different dimensions of sustainability, the failure in any one single dimension, undermines successes in other dimensions, ultimately culminating in the conclusion that the RVG in Murung Raya is not sustainable.

The implications of this research suggest it is important to consider the five dimensions of sustainable development when assessing an off-grid electrification projects, because positive results in a single category are not necessarily indicative of long-term sustainability if indicators in another dimension are not fulfilled. Furthermore, when using sustainable development theory it is necessary to conceptualise the term for the rural electrification specifically, as was done by Ilskog and Kjellström (2008). Finally, this thesis makes a modest attempt to build on their work by suggesting additional indicators to include in future studies.

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Appendices

Appendix I: The Indonesian context

From the early 1980s to the late 1990s the power industry in Indonesia expanded rapidly. Even with a period of significantly weakened progress due to the Asian Financial Crisis in 2008, from 1987 to 2009 the power industry production increased by 620 percent (Hasan et al. 2012:2307). Production is struggling to keep up with demand, however. Despite an average 6.1 percent growth per year of electricity consumption between 2000-2006, there has been insufficient supply in recent years, mainly during peak hours (WB Pumped Storage Project). The majority of tangible progress made in the past decades has improved urban electrification ratios; further expansion of the national power grid into vast rural areas has been limited. The archipelago geography of Indonesia, in addition to population distribution, development policy, and economic activities, are the main drivers- and challenges- of power generation, transmission, and distribution.

Nearly two thirds of the total installed capacity services the Java-Bali region. Small power grids service other major islands, and isolated mini-grids provide electricity to select rural areas (WB 2nd Power Transmission). Indonesia's transmission and distribution grid is overextended: some areas connected to the grid receive electricity for only a few hours a day and blackouts are common, even in Java-Bali (Gunningham 2012:185). The mandate to provide Indonesia with electricity rests largely in the hands of a single state-owned entity, *Persuhaan Listrik Negara* (PLN), the sole transmission and distribution services provider, and the single authorised buyer at the wholesale level in the power market. The PLN accounts for 85 percent of the power generation, with the remaining 15 percent split between 24 Independent Power Producers (IPP) (WB 2013).

The World Bank has financed two large power transmission projects in Indonesia, one in 2010 and the second in 2013 with a combined budget of US$579 million. The 2013 project objective was to "…accelerate infrastructure and energy development to meet the country's economic growth targets and to improve equity and poverty reduction" (WB 2013). To support the World Bank financed transmission projects generation needs to be increased. The Indonesian government implemented two strategic "Crash Programs" in its domestic energy policy. The first programme in 2008, charged the PLN to build coal-fired power plants with a total capacity of 10,000 MW. The second phase, implemented between 2009-2018, continues to be dominated by coal power plants despite plans for renewable energy-based power plants (Gunningham 2012:186). Indonesia has large volumes coal, oil, and gas reserves. Unlike oil and gas, coal-mining rights have not been sold to international companies with export rights. Thus, coal is readily available and seen as an economically viable source of energy. With the total energy demand in 2025 predicted to be three times higher than 2010, Indonesia is feeling pressure to increase its production from secure and diversified sources to meet their target of increasing electricity access to 95 percent by 2025 (Gunningham 2012; Javadi et al. 2013).

The heavy reliance on crude oil, natural gas, and coal for power generation in is not necessary since Indonesia is rich in renewable energy sources, especially geothermal, hydropower, solar, wind, and biomass (Hasan et al. 2011:2316; WB 2013). A lack of incentives and regulatory certainty of major national and local institutions, as well as weak and low coverage of transmission networks has hindered the rapid development of these indigenous and clean resources. Currently, the share of renewable energy is the total energy mix is only about three to four percent (Hasan et al. 2011:2316; Mujiyanto and Tiess 2013:31).

In addition to slow growth of renewable energy, there is a lack of policy framework and national planning to electrify rural Indonesia. Neither WB project makes mention of the disparity between rural and urban access to modern energy sources; nor does it have component targeting rural areas, despite its overall aim to improve equity and reduce poverty. The network expansion is focused on serving Indonesia's main economic corridors. Indonesia's does, however, aim for equitable growth, which must include both urban and rural populations, and arguably cannot be achieved without universal access to modern energy.

Indonesia's development objectives: Equitable growth

Indonesia has made rapid advancements in recent years. But the growth has not come without challenges, most notably increased inequity between rich and poor, and serious concerns about the environment. Indonesia is an example that economic growth alone does not necessarily translate into human development progress. The number of people living below the poverty line is Indonesia has decreased substantially in recent years as the country moved for low to middle income status. Yet this figure can be misleading. If the poverty head count for the entire country at the national poverty line was 12.5 percent in 2011 (WB 2014); however, if the poverty line is increased to USD2.00 ($1.25) per day, the poverty headcount ratio jumps to 43.4 (16.2) percent of the total population, according to 2011 figures (WB 2014). This represents a large portion of the population vulnerable and without capacity to deal with unexpected events.

In 2009, the President of Indonesia, Mr. Susilo Bambang Yudhoyono, voluntarily committed to reducing Indonesia's greenhouse gas emissions by 26 percent from business as usual (BAU) using national resources, and by 41 percent with the support of the international community, by 2020. In tandem with this commitment, Indonesia set a target of 7 percent annual economic growth. Both targets are to be achieved in the pro-poor, pro-growth, pro-development, pro-environment framework outlined in the Masterplan for Acceleration and Expansion of Indonesia's Economic Development (MP3EI 2011). Decoupling emissions production from economic growth will be central to meeting these twin objectives.

Currently, forest destruction and land degradation generally - not electricity generation - accounts for the large majority of Indonesia's emissions. Nevertheless, the heavy reliance on diesel and the increased reliance of coal as the national grids expands and energy demands increase, mean that GHG emissions from the electricity sector are likely to rise substantially, increasing threefold by 2030 (Resosudarmo et al. 2010) and ultimately becoming the dominant source of emissions. In terms of climate change mitigation, there are arguments for an increased emphasis on developing renewable energy. The challenge will be to prioritize the climate change migration agenda while considering energy security and energy poverty mitigation, and continue to promote strong economic growth on the domestic stage (Gunningham 2012:186). Reducing dependence on fossil fuels has proved difficult.

As a result of high international energy prices, subsidies for oil products and electricity in Indonesia peaked in 2008 at 3.5 percent of the GDP or 20 percent of the total national budget. In the Medium Term Plan (RPJM) of 2010, the government has set a goal of reducing subsidies by 40 percent by 2013, and eliminating fuel subsidies entirely by 2014 (IEA, 2010), a goal that was not achieved. Attempts to raise fuel prices have sparked riots and created political division with the country (Mujiyanto and Tiess 2013:39). Increasing energy capacity through renewable options may be an alternative to the current path of development. Indonesia represents a particularly interesting case in terms of renewable energy potential, given the size of its population, its economy, its resource sector, and the country's ambitious GHG emission targets. Among all renewable sources, small hydropower is one of the promising sources for sustainable energy development (Nautiyal et al. 2011:2021), and one that can target rural locations.

Given the current disparity between urban and rural electrification rates; the twin goals of GHG emission reduction and economic growth; and the pro-poor, pro-growth, pro-development, and pro-environment national framework, it is apparent Indonesia aims for a trajectory of sustainable development, in which energy plays a key role in socio-economic factors and environmental considerations. Bearing in mind these broad links to the alignment of national objectives, this case study in an in-depth look at the path required for the provision of energy to achieve development benefits. The remainder of this thesis will focus specially on the case study, with a short discussion paragraph situating the results of the case study back into the broader country context.

Appendix II: Record of informants

Qualitative data collection

Table 6: Record of informants for qualitative data collection for Kolam, Saruhung, and Olung Soloi villages

Code	Type of Data	Number of Respondents	Village	Gender	Date
FG1K	Focus group	6	Kolam	Male	13-01-2014
FG2K	Focus group	5	Kolam	Mixed	14-01-2014
FG3K	Focus group	7	Kolam	Mixed	14-01-2014
SS1K	Semi-structured interview	2	Kolam	Male	15-01-2014
IG1K	Informal focus group	8	Kolam	Mixed	15-01-2014
FG4S	Focus group	6	Saruhung	Male	17-01-2014
FG5S	Focus group	7	Saruhung	Male	17-01-2014
FG6S	Focus group	9	Saruhung	Female	17-01-2014
SS2S	Semi-structured interview	1	Saruhung	Male	18-01-2014
IG2S	Informal focus group	4	Saruhung	Mixed	17-01-2014
IG3S	Informal focus group	8	Saruhung	Mixed	18-01-2014
FG7O	Focus group	6	Olung Soloi	Mixed	19-01-2014
FG7O	Focus group	8	Olung Soloi	Mixed	19-01-2014
FG7O	Focus group	4	Olung Soloi	Mixed	19-01-2014

Quantitative data collection

Respondent	Age	Village	Gender	Date	Household income today (IDR)	Household income today (USD)
1	59	Kolam	Male	14-01-2014	IDR 1,000,000	$87
2	38	Kolam	Female	14-01-2014	IDR 1,000,000	$87
3	21	Kolam	Female	14-01-2014	IDR 1,000,000	$87
4	51	Kolam	Male	14-01-2014	IDR 1,000,000	$87
5	25	Kolam	Male	14-01-2014	IDR 500,000	$44
6	37	Kolam	Male	14-01-2014	IDR 1,000,000	$87
7	30	Kolam	Male	14-01-2014	IDR 500,000	$44
8	70	Kolam	Female	14-01-2014	IDR 600,000	$52
9	50	Kolam	Male	14-01-2014	IDR 500,000	$44
10	39	Kolam	Female	14-01-2014	IDR 600,000	$52
11	55	Kolam	Female	14-01-2014	IDR 1,000,000	$87
12	51	Kolam	Male	14-01-2014	IDR 1,000,000	$87
13	26	Kolam	Female	14-01-2014	IDR 3,500,000	$305
14	32	Kolam	Male	14-01-2014	IDR 2,000,000	$174
15	45	Kolam	Male	14-01-2014	IDR 4,500,000	$392
16	63	Kolam	Male	14-01-2014	IDR 500,000	$44
17	31	Kolam	Male	14-01-2014	IDR 500,000	$44
18	16	Kolam	Male	14-01-2014	IDR 300,000	$26

19	37	Kolam	Male	14-01-2014	IDR 600,000	$52
20	28	Kolam	Female	14-01-2014	IDR 2,000,000	$174
21	35	Kolam	Male	14-01-2014	IDR 2,500,000	$218
22	32	Kolam	Female	14-01-2014	IDR 300,000	$26
23	62	Kolam	Male	14-01-2014	IDR 1,000,000	$87
24	45	Kolam	Male	14-01-2014	IDR 500,000	$44
25	46	Kolam	Male	14-01-2014	IDR 1,000,000	$87
26	35	Kolam	Female	14-01-2014	IDR 500,000	$44
27	35	Kolam	Female	14-01-2014	IDR 1,000,000	$87
28	35	Kolam	Male	14-01-2014	IDR 200,000	$17
29	50	Kolam	Male	14-01-2014	IDR 500,000	$44
30	23	Kolam	Male	14-01-2014	IDR 200,000	$17
31	21	Kolam	Male	14-01-2014	IDR 500,000	$44
32	32	Kolam	Female	14-01-2014	IDR 2,000,000	$174
33	50	Kolam	Female	14-01-2014	IDR 500,000	$44
34	26	Saruhung	Male	16-01-2014	IDR 3,000,000	$261
35	38	Saruhung	Male	16-01-2014	IDR 2,000,000	$174
36	30	Saruhung	Male	16-01-2014	IDR 500,000	$44
37	65	Saruhung	Male	16-01-2014	IDR 500,000	$44
38	70	Saruhung	Male	16-01-2014	IDR 500,000	$44
39	42	Saruhung	Male	16-01-2014	IDR 1,000,000	$87
40	37	Saruhung	Male	16-01-2014	IDR 1,000,000	$87
41	22	Saruhung	Male	16-01-2014	IDR 1,000,000	$87
42	17	Saruhung	Male	16-01-2014	IDR 500,000	$44
43	53	Saruhung	Male	16-01-2014	IDR 2,450,000	$213
44	57	Saruhung	Male	16-01-2014	IDR 1,500,000	$131
45	37	Saruhung	Female	16-01-2014	IDR 1,500,000	$131
46	36	Saruhung	Male	16-01-2014	IDR 500,000	$44
47	58	Saruhung	Male	16-01-2014	IDR 500,000	$44
48	14	Saruhung	Male	16-01-2014	IDR 0	$0
49	12	Saruhung	Male	16-01-2014	IDR 0	$0
50	47	Saruhung	Female	16-01-2014	IDR 1,500,000	$131
51	25	Saruhung	Female	16-01-2014	IDR 3,000,000	$261
52	41	Saruhung	Female	16-01-2014	IDR 1,000,000	$87
53	50	Saruhung	Female	16-01-2014	IDR 300,000	$26
54	60	Saruhung	Female	16-01-2014	IDR 500,000	$44
55	40	Saruhung	Female	16-01-2014	IDR 1,000,000	$87
56	49	Saruhung	Female	16-01-2014	IDR 500,000	$44
57	70	Saruhung	Female	16-01-2014	IDR 600,000	$52
58	30	Saruhung	Female	16-01-2014	IDR 1,000,000	$87
59	25	Saruhung	Female	16-01-2014	IDR 1,000,000	$87

Univariate Statistics:

Age: Average, 40 years; maximum, 70 years; minimum, 12 years
Gender: 36 male and 23 female respondents
Income: Average (excluding no income), USD 93; maximum, USD 391.50; minimum (excluding no income), USD 17.40

Appendix III: Interview guide for semi-structured interviews

Time of interview (+duration: 60 minutes, max.):
Date:
Place (village + location):
Interviewee:

** Be sure the interviewee has also filled out the questionnaire **

Project Description: Off-grid electrification has advantages over grid connectivity for places where the population is spread out. Indonesia also has great opportunity to use renewable energy sources for electricity, such as the hydropower dam in Saruhung. It is my aim to better understand the impacts of electrification on you, your family, and your community. I hope better knowledge will lead to more successful off-grid, renewable energy electrification in Indonesia.

Questions:

1. What have been the main differences in your daily activities since receiving electricity?

2. What have been some changes you have noticed in your neighbours or your community since electrification?

3. Has having electricity allowed you to increase your family income? If so, how?

4. Have you noticed changes in relations within the community since electrification, such as more time spent alone or together, or changes in equality?

5. How do you spend your time in the evenings? Do you spend time watching TV or listening to the radio? Do you visit the homes of others?

6. I noticed you cook with __________. Have or any neighbours considered using an electric stove? (If they have an electric stove, discuss this purchase instead.)

7. Before being connected to the hydropower dam, what fuel sources did you use?

8. I understand each household pays the same for electricity. Is this correct? If so, does this system work well?

9. Who should I turn to, to learn more about the impacts of electrification?

Appendix IV: 20-questions questionnaire

1. Which of the following electrical appliances do you own (circle as many as apply)?
   - TV
   - Radio
   - Refrigerator
   - Electric stove
   - Computer
   - Washing machine
   - Water boiler
   - Rice cooker
   - Electric fan
   - Water pump
   - Cell phone
   - AC
   - Other (please list): ______________________

2. Do you use wood fuel for cooking? Yes or No.
   a. If no, what do you use for cooking fuel? _______________
   b. If no, how much money do you spend cooking fuel? IDR _________ / month
   c. If yes, how much time does your household spend collecting firewood? _____ hours / month
   d. If yes, how much money does your household spend on firewood? IDR _______ / month

3. Compared to before electricity, how much fuelwood do you use?
   Much less   Less   Same   More   Much more

4. How often do you experience a blackout (loss of electricity)?
   Never   Rarely   Sometimes   Often   Very Often

5. Compared to your neighbors, how much electricity to you use?
   Much less   Less   Same   More   Much more

6. Compared to before electricity, how much leisure time do you have?
   Much less   Less   Same   More   Much more

7. Compared to before electricity, how much time do you spend on community activities?
   Much less   Less   Same   More   Much more

8. Compared to before electricity, how do you view the cohesion of the community?
   Much weaker   Weaker   Same   Stronger   Much stronger

9. Compared to before electricity, how much time do you spend visiting neighbors homes?
   Much less   Less   Same   More   Much more

10. Compared to before electricity, how is the health of you and your family?
    Much worse   Worse   Same   Better   Much better

11. Compared to before electricity, how much time do your children spend on homework?

Much less Less Same More Much more No children

12. Do you or anyone in your housework directly related to the hydropower dam (ie. maintenance, management)? Yes or No.

13. Are you or anyone in your house employed outside the home as a result of the electricity provided by the hydropower dam? Yes or No.

14. Have you set up a home business since receiving electricity? Yes or No.

15. What year did you receive electricity? 20____

16. How much money do you spend on electricity? IDR _________________ / month

17. What is your household income today? IDR ________________ / month

18. What was your household income before electrification? IDR _______________ / month

19. How many people live in your house? _________ people

20. How do you view the cost of electricity?
Very cheap Cheap Moderate Expensive Very Expensive

Name: ____

Age: ____

Village: ____

Gender: Male or Female.

Thank you very much for taking the time to complete this questionnaire. It makes a large contribution to my research, and I hopefully further village electricity projects.

Note: By filling out the questionnaire you agree to be included in my research. If you do not want to be included in the research please indicate that on the questionnaire.

Appendix V: Calculations

Operation and maintenance calculation

Monthly costs for five salaries and money set aside for materials:
Monthly costs = salaries + materials = 5(26.10USD) + 17.40 USD = 147.90 USD

34-hour electricity generation at the turbine's maximum capacity, for 30 days per month:
Monthly production = (24hours/day) (30days/month) (40kW) = 28800 kWh

Operational and maintenance costs, USD/kWh = (147.90 USD) / (28800 kWh)
= **0.005 USD / kWh**

The total monthly operation and maintenance cost is **0.005 USD/kWh.**

Avoided emissions calculation

Avoided emissions associated with carbon-neutral, renewable energy for each kWh of production = **300g CO_2e/kWh**

Using a 100% replacement rate (ie. considering that the entire production capacity of the micro hydropower turbine were replaced with traditional fuels), the total avoided annual emissions are:

$\text{Emissions}_{\text{avoided}}$ = yearly production capacity * avoided emissions per kWh
= (40kW)(24h/day)(365days/year) * 300g CO_2/kWh
= **105 tonnes of CO_2e / year**

The total avoided emissions assuming a 100% replacement rate and year-round maximum generation of the hydropower turbine are **105 tonnes of CO_2e / year.**

Electricity capacity calculation

Total combined population of Saruhung and Kolam villages:
$\text{Population}_{\text{total}} = P_{\text{Kolam}} + PS_{\text{aruhung}}$ = 326 + 194 = 520 people

24-hour, year-round electricity generation at the turbine's maximum capacity:
Production = (24 hours/day) (365 day/year) (40kW) = 350 400 kWh / year

Annual per capita production:
Production = Production / $\text{Population}_{\text{total}}$ = (350 400 kWh / year)/520 people
= **674 kWh/capita/year**

The total annual per capita production generation of the hydropower turbine is **674 kWh.**